FWS/OBS-78/9

Biological Services Program

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August 1979

An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas

VOLUME I

NARRATIVE REPORT

Interagency Energy-Environment Research and Development Program

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

AND

Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

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AN ECOLOGICAL CHARACTERIZATION STUDY OF THE CHENIER PLAIN COASTAL ECOSYSTEM OF LOUISIANA AND TEXAS

VOLUME I

NARRATIVE REPORT

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(CEO-234)

Dear Colleague:

The attached three volume report, "An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas," is the result of a contract funded by the Environmental Protection Agency. This study was conducted to provide an information synthesis for use by coastal resource planners. The report emphasizes the functional relationships between resources and the environment within the Chenier Plain Region, and identifies linkages between socioeconomic and ecological systems.

Any comments about the contents, or usefulness of this report will be appreciated.

Sincerely yours,

Robert E. Stewart, Jr.
Team Leader

PREFACE

The purpose of this ecological characterization was to compile existing information about the biological, physical, and social sciences for the Chenier Plain of Louisiana and Texas. Decisionmakers, among others, may use this report for coastal planning and management. This is the first in a series of characterizations of coastal ecosystems that will be produced by the U.S. Fish and Wildlife Service. Future studies will include the sea islands of Georgia and South Carolina, the rocky coast of Maine, the coast of northern and central California, the Pacific Northwest (Oregon and Washington), the Mississippi deltaic plain, and the Texas barrier islands.

Funding for this study was provided through the Interagency Energy/Environment Research and Development Program, which is planned and coordinated by the Environmental Protection Agency Office of Energy, Minerals, and Industry. Inaugurated in FY75, this program serves to coordinate the efforts of 77 Federal agencies and departments to provide environmental data and technology for the protection of natural resources which may be threatened by the development of domestic energy sources.

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CONVERSION FACTORS

ENGLISH

LENGTH

1 inch (in)	= 2.540 centimeters
1 inch (in)	= 25.400 millimeters
1 foot (ft)	= 0.305 meter
1 yard (yd)	= 0.914 meter
1 mile (mi)	= 1.609 kilometers
1 mile (mi)	= 1,609.344 meters
1 mile (mi)	= 5,280 feet
1 nautical mile (naut. mi)	= 1,852 meters
1 nautical mile (naut. mi)	= 6,076 feet

AREA

1 square foot (ft^2)	= 0.093 square meter
1 square yard (yd^2)	= 0.836 square meter
1 square mile (mi^2)	= 2.590 square kilometers
1 acre (a)	= 0.404 hectare

VOLUME AND CAPACITY

1 cubic foot (ft^3)	= 0.0283 cubic meter
1 cubic foot (ft^3)	= 0.0000230 acre-feet
1 gallon (gal)	= 3.785 liters

VELOCITY

1 foot/second (ft/sec)	= 0.682 mile/hour
1 foot/second (ft/sec)	= 1.097 kilometers/hour
1 cubic foot/second (ft^3/sec)	= 0.0283 cubic meter/second
1 mile/hour (mi/hr)	= 1.467 feet/second
1 mile/hour (mi/hr)	= 0.447 meter/second
1 knot (kn)	= 1 nautical mile/hour

TEMPERATURE

degrees Fahrenheit (°F) = 9/5 (°C) + 32

MASS AND ENERGY

1 ounce (oz)	= 28,350 milligrams
1 ounce (oz)	= 28.350 grams
1 pound (lb)	= 0.454 kilograms
1 short ton (ton)	= 0.907 tonne
1 Btu	= 0.252 kilocalories

METRIC

LENGTH

1 centimeter (cm)	= 0.394 inch
1 millimeter (mm)	= 0.0394 inch
1 meter (m)	= 3.281 feet
1 meter (m)	= 1.094 yards
1 meter (m)	= 39.370 inches
1 meter (m)	= 100 centimeters
1 kilometer (km)	= 0.621 mile
1 kilometer (km)	= 1000 meters
1 kilometer (km)	= 3,280.840 feet

AREA

1 square meter (m^2)	= 10.764 square feet
1 square meter (m^2)	= 1.196 square yards
1 square kilometer (km^2)	= 0.386 square mile
1 hectare (ha)	= 2.471 acres

VOLUME AND CAPACITY

1 cubic meter (m^3)	= 35.315 cubic feet
1 cubic meter (m^3)	= 264.172 gallons (U.S.)
1 liter (l)	= 0.264 gallon (U.S.)

VELOCITY

1 meter/second (m/sec)	= 3.600 kilometers/hour
1 meter/second (m/sec)	= 2.237 miles/hour
1 cubic meter/second (m^3/sec)	= 35.315 cubic feet/second
1 kilometer/hour (km/hr)	= 0.911 foot/second
1 kilometer/hour (km/hr)	= 0.278 meter/second

TEMPERATURE

degrees Celsius (°C) = 5/9 (°F - 32)

MASS AND ENERGY

1 milligram (mg)	= 0.0000353 ounces
1 gram (g)	= 0.0353 ounces
1 kilogram (kg)	= 2.205 pounds
1 tonne (t)	= 2,205 pounds
1 tonne (t)	= 1.102 short tons
1 kilocalorie (kcal)	= 3.968 Btu

GLOSSARY

A

a	Acre
accretion	Build up of land by deposition of sediments
advection	The horizontal movement of water or air masses.
aggradation	See accretion.
aggregate	Formed by the collection of particles into a mass; combined.
aliphatic	Of, relating to, or derived from fat; belonging to a group of organic compounds having an open-chain structure and consisting of the paraffin, olefin, and acetylene hydrocarbons and their derivatives.
alkaloid	One of a group of nitrogenous bases of plant origin; many are toxic or of pharmaceutical value.
alluvial	Deposits formed by finely divided material laid down by running water.
ambient	Surrounding conditions.
anastomosing	Uniting or interconnecting of branched systems in either two or three dimensions.
anoxia	A condition resulting from the inadequate oxygenation of the blood.
anticyclonic	Referring to a rotation that is clockwise in the Northern Hemisphere, counterclockwise in the Southern Hemisphere, and undefined at the Equator.
areal	Pertaining to the area of something.
attenuation	The reduction in level of quantity, such as the intensity of a wave.
autecology	The study of the biological relations between a single species and its environment; ecology of an individual organism.

B

barrel (bbl)	42 U.S. gallons.
bathymetric	Pertaining to the measurement of ocean floor depths to determine the sea floor topography.
benthic	Of, pertaining to, or living on the bottom or at the greatest depths of a large body of water; refers to species attached to the substrate, e.g., oysters, mollusks.
berm	A slightly elevated area along man-made and natural waterways and beaches having an abrupt fall and formed by deposition of materials by wave action.
biomass	The dry weight of living matter, including stored food, present in an area or volume, usually expressed in terms of a given area or volume of the habitat.
bivariate	Varying in two directions; characterized as having two variables.
brine	Water containing a higher concentration of dissolved salt than that of the ordinary ocean.
buildout	Progradation.

C

carrying capacity — The maximum biomass or number of individuals of a single species that can be supported by a given habitat.

catchment area or drainage basin — An area in which surface runoff collects and from which it is carried by a drainage system such as a river and its tributaries.

chenier — A continuous ridge of beach material built upon swampy deposits; often supports trees such as pines or evergreen oaks.

chlorinity — The cloride and other halogen content, by mass, of water.

colloidal system — An intimate mixture of two substances, one of which called the discontinuous or dispersed phase is uniformly distributed in a finely divided state through the second substance called the continuous or dispersion phase; e.g., oil droplets (discontinuous phase) in water (continuous phase).

creel census — An enumeration of sport fishermen and their catch.

crustal downwarping — A downward motion or movement of the earth's crust.

cultch — Mass of broken shells, pebbles, and debris placed in estuaries to serve as a substrate for oyster growth.

D

demersal — Living at or near the bottom of the sea or another water body; refers to necktonic, or free swimming, aquatic animals that are essentially independent of water movement, e.g., shrimp, fish.

diurnal — Of, relating to, or occurring in the daytime.

drawdown — The magnitude of the change in water surface level in a well, reservoir, or natural body of water resulting from the withdrawal of water.

E

ecotone — Transition zone between two different habitat types.

edaphic — Part of or influenced by conditions of soil or substrate.

eustatic — Pertaining to worldwide fluctuations of sea level due to changing capacity of the ocean basins or the volume of ocean water.

eutrophication — The natural or artificial addition of nutrients to bodies of water and the effects of added nutrients, often accompanied by oxygen deficiencies.

evapotranspiration — The loss of water from the soil both by evaporation and by transpiration from plants growing thereon.

exploitation pressure — The rate of utilization or removal of a natural resource.

F

facies — In geology, any observable attribute of a rock or stratigraphic unit, such as overall appearance or composition.

faulting — A fracture in rock along which the adjacent rock surfaces are differentially displaced.

fetch — The distance traversed by waves without obstruction.

flocculate — To cause to aggregate, coalesce, or precipitate into a noncrystalline mass.

fluvial — Pertaining to or produced by the action of a stream or river; or existing, growing, or living in or near a river or stream.

freshets — A rise and flood of a stream as a result of rain or melting snow.

gene pool — The genetic material possessed by a local interbreeding population.

geomorphic — Of, or relating to, the form of the earth; topographic features carved by erosion of the substrate and buildup from erosional debris.

geosyncline — A part of the crust of the earth that sank deeply through time.

GIWW — Gulf Intracoastal Waterway.

groin or jetty — A barrier built out from a seashore or riverbank to protect the land from erosion and sand movements, among other functions.

H

h — Hour.

ha — One hectare (ha) = 2.47 acres (a).

hibernacula — Shelters occupied during the winter by dormant animals.

hinterland — The region behind the coastal district.

hydroclimate — That part of the climate that pertains to water; i.e., rainfall, evaporation, water budgets, etc.

hydrographics — The physical features of the oceans, lakes, rivers, and their adjoining coastal areas, with particular reference to their control and utilization.

hydrophyte — A plant which grows in water or in water-logged soil.

I

insolation — Solar energy received, often expressed as a rate of energy per unit horizontal surface.

isohalines — A line or surface drawn on a map or chart that connects adjacent points of equal salinity in the ocean or other water body.

K

kn — Knot – a speed unit of one nautical mile per hour. It is equivalent to a speed of 1.688 feet per second or 51.4 centimeters per second.

L

landfall — The first sighting of land when approaching from seaward.

langley — A unit of solar radiation equal to 1 gram-calorie per square centimeter of irradiated surface.

leachate — That which is separated or dissolved out of the soluble constituents of a rock or ore body by percolation of water.

lek — An assembly area where animals carry on display and courtship behavior.

lenses — Geologic deposits that are thick in the middle and converge toward the edges, resembling a convex lens.

lentic — Of, relating to, or living in still waters such as lakes, ponds or swamps.

lenticular — Having the shape of a lentil or double convex lens.

limiting factors — Any condition which approaches or exceeds the limits of tolerance for species.

limnetic — Pertaining to open waters of lakes, especially to areas too deep to support rooted aquatic plants.

lithologic — The physical character of a rock as determined by eye or with a low power magnifier, and based on color, structure, mineralogic components, and grain size.

littoral — Of, or pertaining to, the zone between high and low water marks.

lotic — Of, relating to, or living in running waters such as rivers or streams.

M

macroinvertebrates — Those invertebrates that are large enough to be seen by the unaided eye.

mcf — Thousand cubic feet.

meiobenthos — Microscopic and small macroscopic animals inhabiting the sediments of water bodies.

MHW — Mean high water.

MLW — Mean low water.

MSL — Mean sea level.

MWL — Mean water level.

N

nekton — Free swimming aquatic animals, essentially independent of water movements.

niche — The functional role served by an organism in its habitat or community.

NRR — Natural renewable resources.

nutrient — An element or inorganic compound essential to life.

O

onlapping — A type of overlap characterized by regular and progressive pinching out of strata toward the margins of a depositional basin; each unit transgresses and extends beyond the point of reference of the underlying unit.

ontogenetic — Of, relating to, or appearing in the course of development of an individual organism.

P

pelagic — Of, relating to, or living in the open sea.

perturbation — Any effect that makes a small modification in a physical or biological system.

physiography — The topographic features of a region, as shown in the character arrangement and interrelations of elements such as climate, relief, soil, or land use.

Pleistocene — Epoch of geologic time of the Quaternary period, immediately proceding the recent epoch. Also known as Ice Age:Oiluvium.

ppt (°/oo) — Parts per thousand.

prism (tidal)	The volume defined by the difference between ebb and flood tides.
productivity (production rate)	The rate at which energy is stored in the form of organic matter by green plants (primary productivity) and by animals (secondary productivity).
progradation	Seaward buildup of a beach, delta, or fen by nearshore deposition of sediments transported by a river, by accumulation of material thrown up by waves, or by material moved by longshore drifting.

Q

qs	Areal water load.

R

Recent	Epoch of geologic time within which modern man appeared, starting about 11,000 years ago.
relict	A persistent, isolated remnant of a once-abundant species or geomorphic feature.
riparian	Relating to, or living, on the bank of a natural watercourse or sometimes of a lake or tidewater.
riverine	Of, or pertaining to, a river.
rookery	Bird nesting site.
Rp	Phosphorus retention.

S

sedge	A member of the grass family that provides a food source for waterfowl and furbearers.
shoal	A submerged elevation rising from the bed of a shallow body of water and consisting of, or covered by, unconsolidated material. May be exposed at low water.
species richness	The number of different kinds of species in a habitat.
standing stock	The numbers or biomass of a population available for exploitation at any given time.
strandline	The level at which a body of standing water meets the land.
subaerial	Pertaining to conditions and processes occuring on or adjacent to the earth's surface.
subsidence	A sinking down of a part of the earth's crust.
sustained yield	The maximum rate of harvest of a living resource that can be maintained without diminishing the supply of the resource.
synergistically (adv)	Pertaining to the interaction of two or more processes so that the response of the whole is greater than the sum of the individual processes; or so that the response of the whole is not predictable by summation of the individual processes.
synoptic	Meteorological data obtained simultaneously and presented so as to give a comprehensive picture of the state of the atmosphere.
system	A method of organizing entities into a larger aggregate.

T

tectonic	Dealing with regional structural and deformational features of the earth's crust including the mutual relations, origin, and historical evolution of the features.

tidal wrack — Vegetation and debris deposited along the shoreline during high tide.

tide — Periodic rising and falling of the oceans resulting from lunar and solar tide-producing forces acting upon the rotating earth.

trophic — Pertaining to the feeding hierarchy, or food web, of a biotic community.

turbidity — Condition of water having reduced transparency due to suspended materials.

W

watershed — The land area providing drainage to a stream.

weir — A dam in a waterway over which water flows that serves to regulate water level or to measure flow.

wetlands — Lands or areas containing much soil moisture, such as tidal flats or swamps.

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[2] LWFC—Louisiana Wildlife and Fisheries Commission
[3] ERCO Energy Resources Corporation
[4] LSU-FWM Louisiana State University - School of Forestry and Wildlife Management
[5] FWS U.S. Fish and Wildlife Service
[6] BLM Bureau of Land Management
[7] NMFS—National Marine Fisheries Service
[8] TGLO Texas General Land Office
[9] TPWD - Texas Parks and Wildlife Department
[10] LDTD Louisiana Department of Transportation and Development

An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas

1.0 The Ecological Characterization Process

1.1 INTRODUCTION

An ecological system, or ecosystem, is composed of plants and animals which interact with one another and with their habitat or physical environment. Man is part of the ecosystem and his actions influence or respond to the various components and processes of the system. Only when man understands how ecosystems function will he be able to effectively manage his natural resources and prudently guide developments generated by social and economic demands.

An ecological characterization study describes the important components and processes of an ecosystem and provides an understanding of their interrelationships by synthesizing and integrating existing physical, biological, and socioeconomic information. The main purpose is to provide an information base to aid in evaluating human impacts on the ecosystem and to provide an ecological framework for guiding resource management and coastal planning.

1.2 CHENIER PLAIN ECOLOGICAL CHARACTERIZATION

The Chenier Plain (fig. 1-1) in southwestern Louisiana and southeastern Texas is a relatively large coastal ecosystem created by 5,000 years of sediment deposition from the Mississippi River. This ecosystem was selected for study because of its biological diversity, valuable fish and wildlife resources, and its proximity to actual and proposed oil and gas production activities.

1.2.1 APPROACH OF THE STUDY

In this study the Chenier Plain is modeled and described at four levels of ecological organization (fig. 1-2). Major processes which operate at each level are identified (fig. 1-3). This facilitates an understanding of their relationships by minimizing problems associated with differences in scale and duration between physical and biological events.

Discussions about components and processes and their interrelationships are often supplemented by the use of graphic models and symbols (fig. 1-4). A circle represents an external driving force, such as solar energy. A dashed line encloses a system of interest (A). Arrows represent a flow of energy in the direction indicated. The energy may take many forms; between biotic compartments it is usually a flow of organic matter (food), such as when a predator eats its prey (B).

Often energy transfer is much more subtle. For instance, tides or inorganic nutrients are energy sources that do work or allow work to be done on the recipient. This energy flow is also shown by arrows.

A consumer, pictured as a hexagon (B), is an organism or system that consumes more organic matter than it produces. According to the second law of thermodynamics, because no process is totally efficient, some of the energy involved in any process is changed into a nonusable form (the Law of Energy Degradation). Respiration of living organisms demonstrates this; part of the organic energy they metabolize is converted to waste heat. Symbolically this is represented by a heat sink such as that shown for the consumer (C). This energy "loss" is universal and is implied for every process occurring in an ecosystem, but for simplicity's sake it is not shown in the system diagrams in this study.

A common symbol of general utility is the storage bin (D), which symbolizes the storage or standing stock of a commodity. It is implied in the producer and consumer modules and is generally used for nonliving materials. Thus when plants die, the dead tissue accumulates in a litter compartment.

Three other common symbols are used to denote functional groups. The bullet (E) is the symbol for producers of organic matter, plants such as emergent grasses, trees, or phytoplankton. Producers convert the sun's energy to organic matter (F).

Production is controlled by availability of nutrients, shading (e.g., turbidity for phytoplankton) or by other limiting factors. A "work gate" (G) shows this as in the control of phytosynthesis by nutrients and turbidity (H). Interactions that control the flow of energy are shown by (I).

The litter/microbial consumer relationship is often shown by a combination of consumer and storage module (J) that symbolizes the inseparability of the living and nonliving components.

A diagrammatic system model (fig. 1-5) often contains a feedback loop. Loops for nutrient regeneration and for self-shading are important control mechanisms of all ecosystems and they contribute to system stability. In this example, growth of phytoplankton increases the turbidity (suspended load) of the water. This reduces light penetration by shading, which leads to a lower rate of phytosynthesis, which in turn reduces growth. This process stabilizes the system at some optimum level of phytoplankton for a given light intensity.

1.2.2 ORGANIZATION OF CONTENTS

The contents of this study are organized into three volumes (fig. 1-6). Volume I (Narrative Report) contains five parts. Part 1.0 briefly describes the characterization process. Part 2.0 is a description and analysis of climatic, geomorphic, and functional processes that formed or are changing the Chenier Plain ecosystem. Part 3.0 focuses on drainage basins. Part 4.0 describes the Chenier Plain habitats, and part 5.0 gives biological accounts of some of the most important animal species.

Volume II (Appendixes), in five parts, generally is a continuation of the elements of Volume I. Part 6.0 provides an introduction. Part 6.1 contains geological, hydrological, meterological, chemical, biological, and socioeconomic data sources. Part 6.2 describes socioeconomics, oil and gas production, agricultural values, sport and commercial fisheries, fur trapping, and waterborne transportation. Part 6.3 gives biological information about primary production, waterfowl, fishes, and a habitat/species list. Part 6.4 contains data about water discharges, phosphorus levels, and habitat changes. Literature sources for the appendixes are listed in part 6.5.

Volume III (Atlas) consists of the following eleven plates (maps):

1. Plates 1A and 1B Index Maps
2. Plate 2–The Pleistocene Erosional Surface
3. Plates 3A and 3B Chenier Plain Habitat Groups
4. Plates 4A and 4B Chenier Plain Wetland Habitats
5. Plates 5A and 5B–Canals and Point Source Discharges
6. Plates 6A and 6B Special Features (bird nesting colonies, archeological sites, refuges and oyster reefs)

The letter "A" denotes the western portion of the Chenier Plain, and "B" denotes the eastern portion.

1.2.3 AUDIENCE

The Chenier Plain Characterization is intended for users having a moderate understanding of socioeconomic and ecological principles, and a concern about resource management or coastal planning problems.

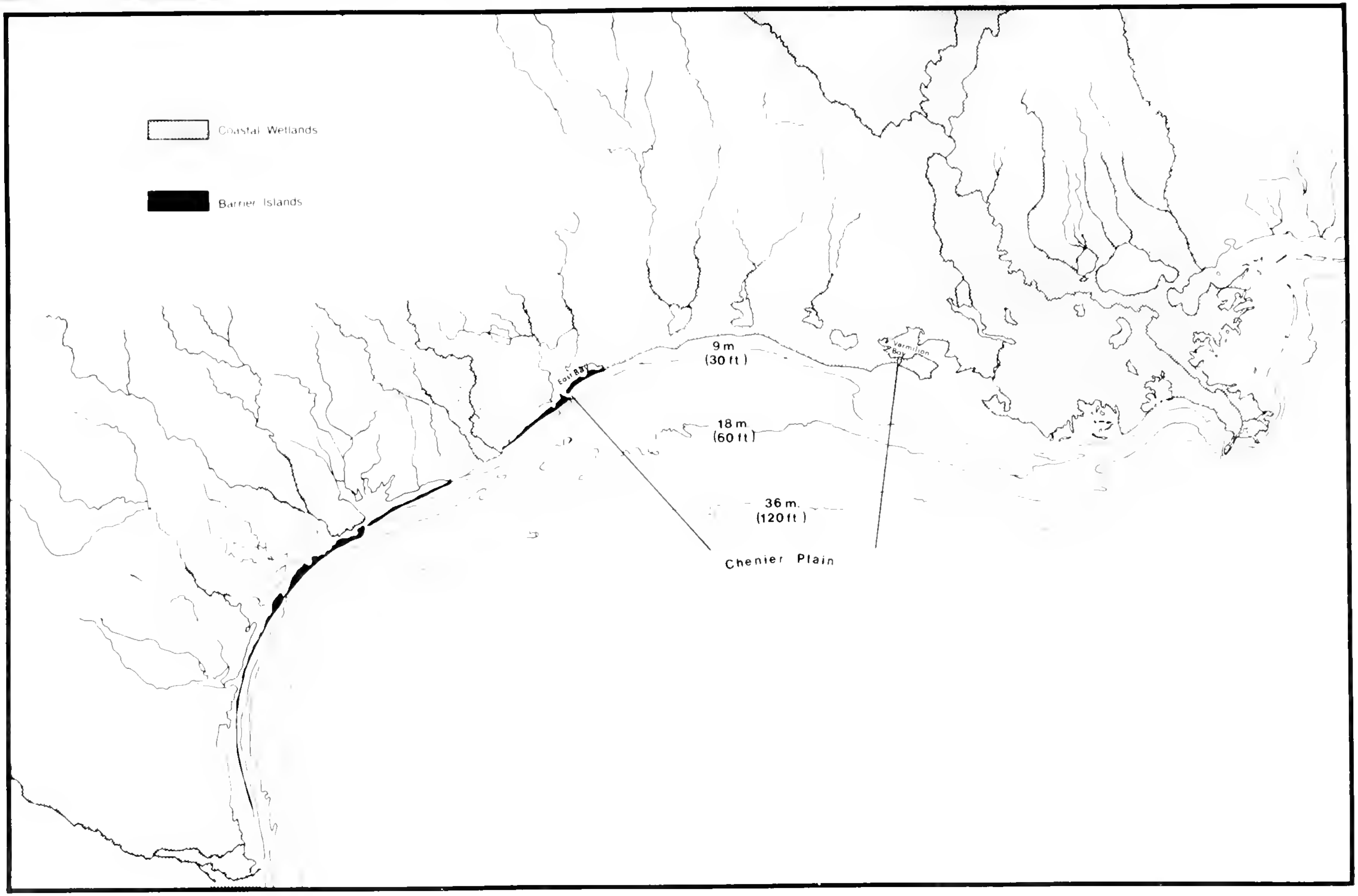

Figure 1-1. The Chenier Plain coastal ecosystem of Louisiana and Texas.

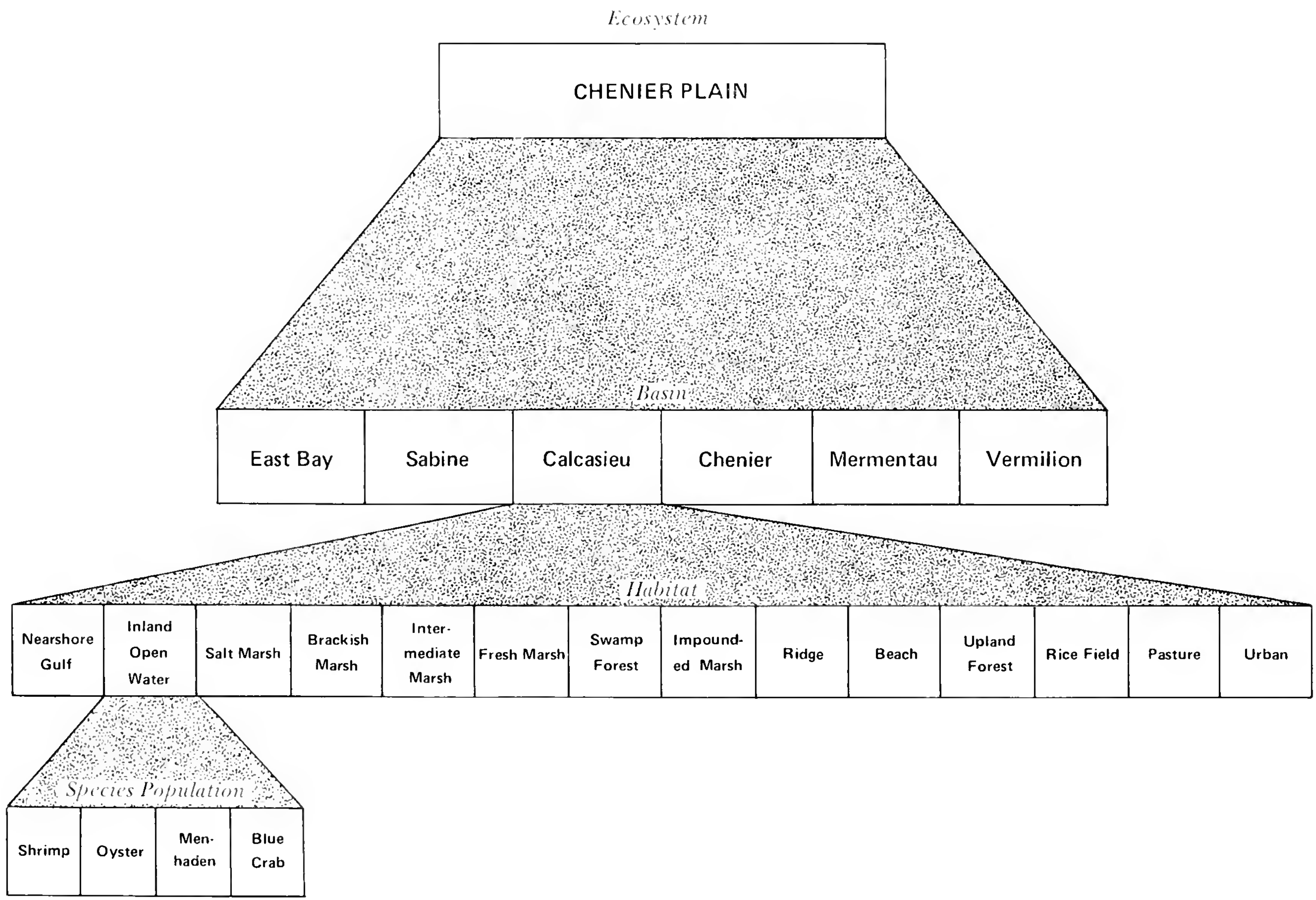

Figure 1-2. An illustration oi the Chenier Plain ecosystem hierarchy.

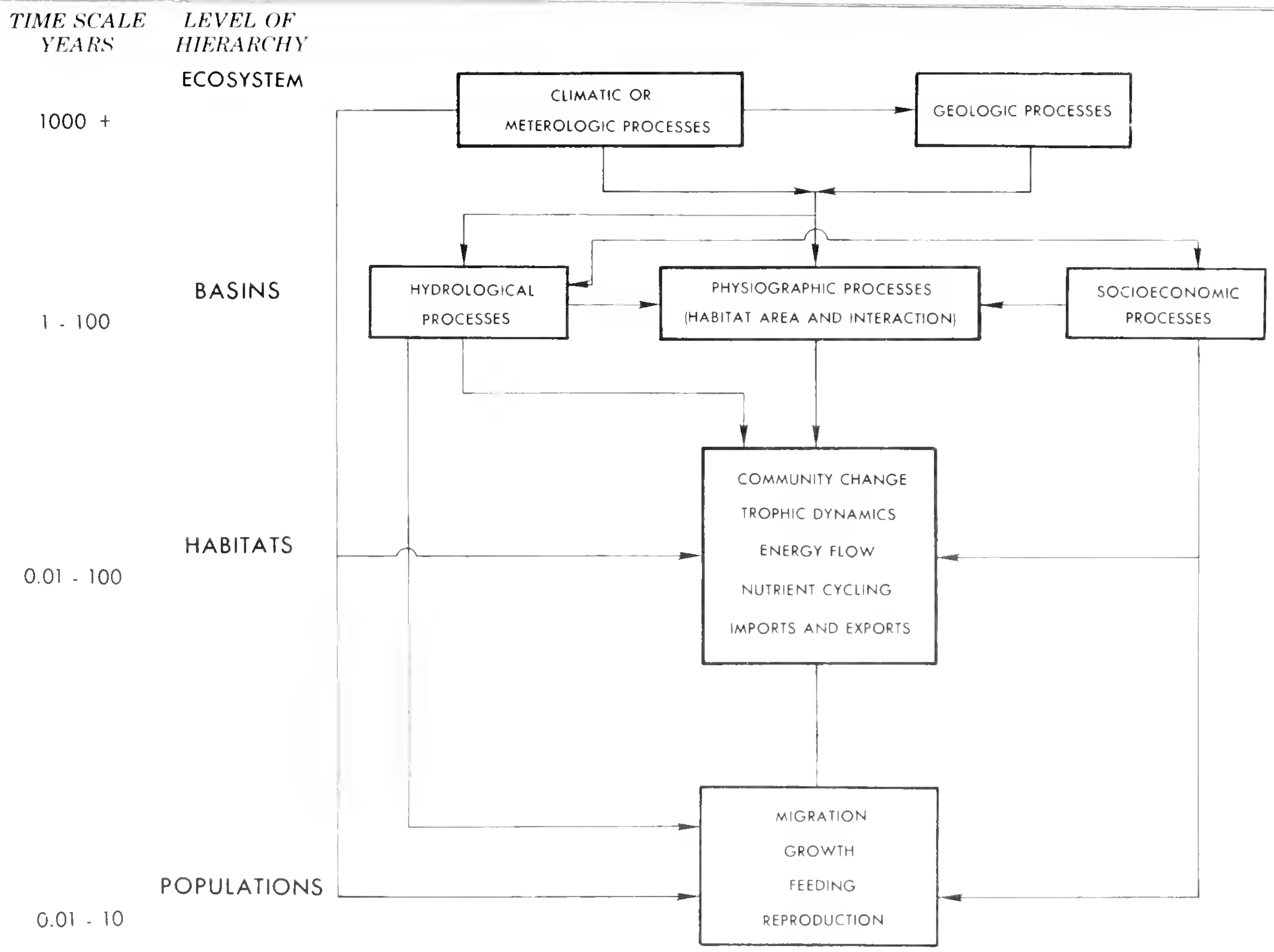

Figure 1-3. The interaction of major ecological and physical processes in the Chenier Plain ecosystem.

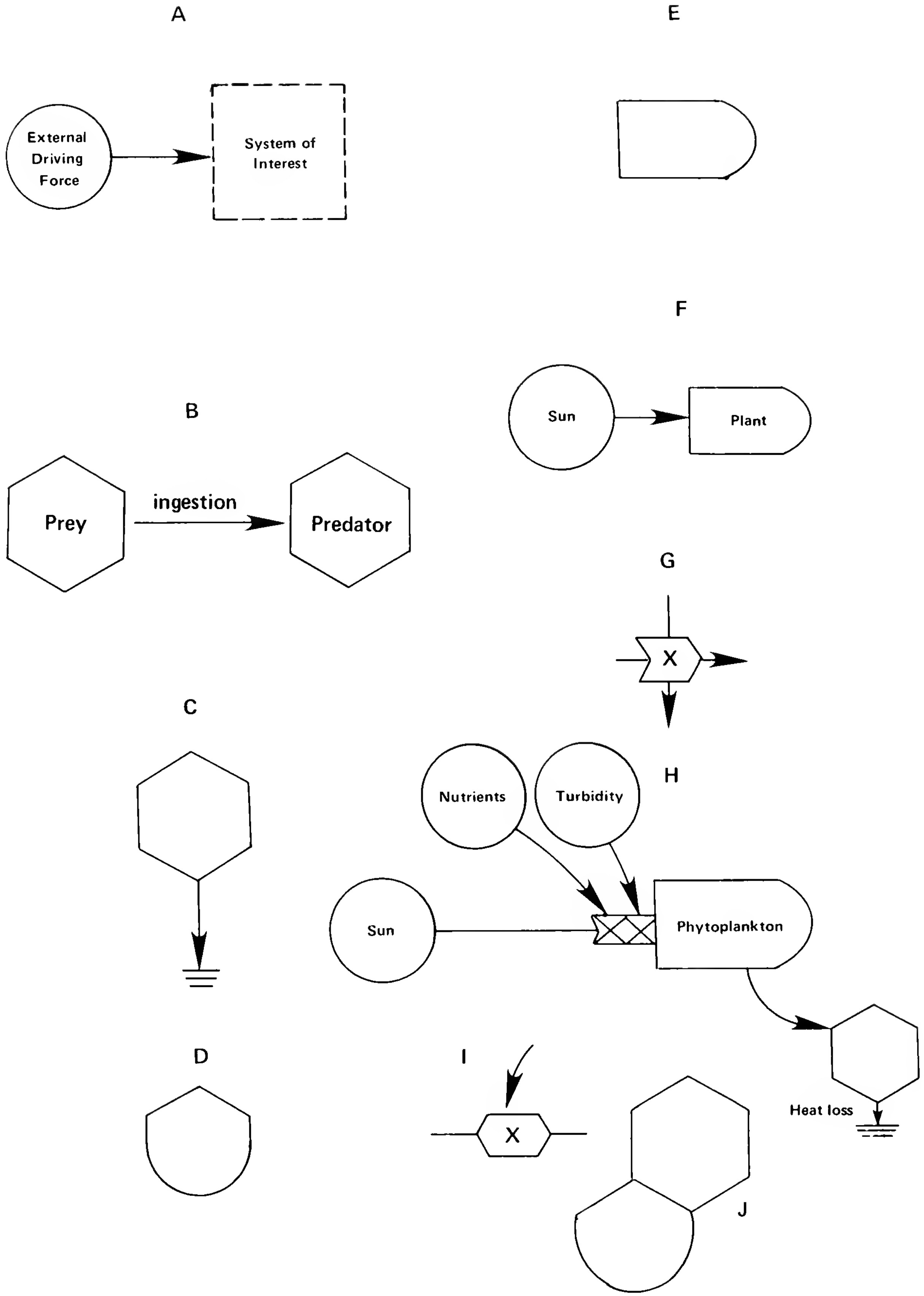

Figure 1-4. Graphic symbols used in ecological modeling (Odum 1967).

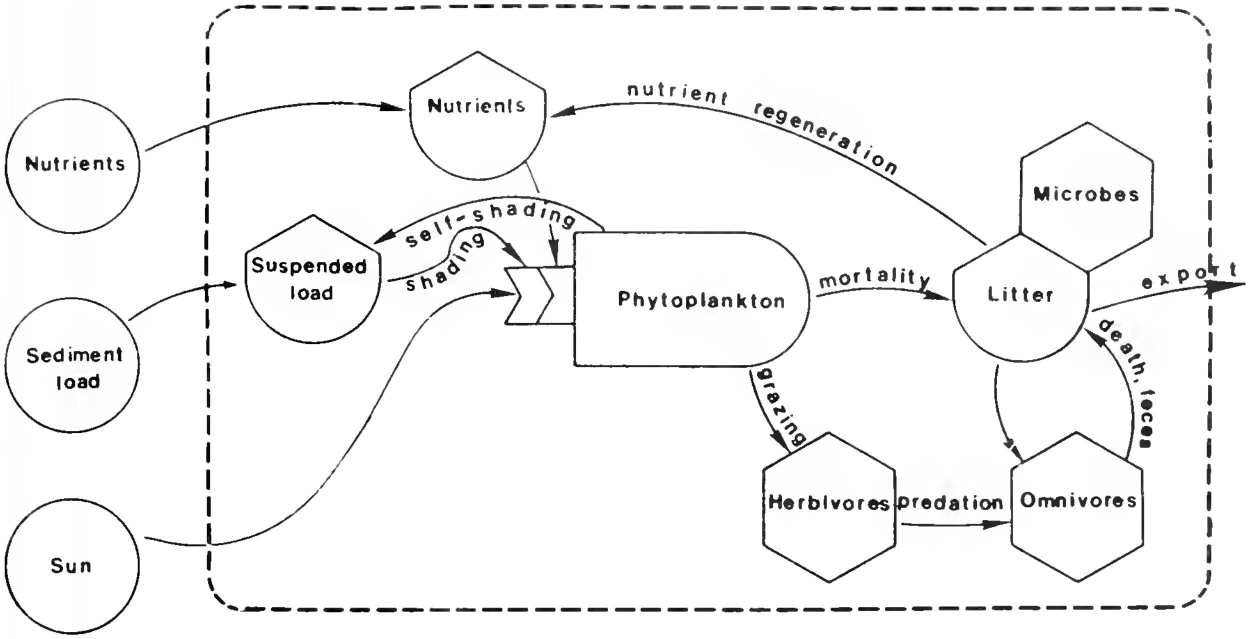

Figure 1-5. A diagrammatic systems model of an aquatic habitat.

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Narrative Report

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Figure 1-6. Contents of the Chenier Plain Ecological Characterization Study.

2.0 The Chenier Plain Ecosystem

2.1 INTRODUCTION

The Chenier Plain ecosystem is a rich and complex mixture of wetlands, uplands, and open water that extends about 322 km (200 mi) from Vermilion Bay, Louisiana to East Bay, Texas (fig. 2-1). The lengthwise boundaries cf the ecosystem are the 9 m (30 ft) depth contour along the shore of the Gulf of Mexico and the 1.5 m (4.9 ft) land elevation contour. These boundaries are separated by distances ranging from 16 km (10 mi) to 64 km (40 mi) and encompass a total area of over 1,295 km^2 (5,000 mi^2). Several systems of rivers and lakes cross the Chenier Plain from north to south and divide it into six fairly distinct drainage basins.

Pleistocene-age deposits, which form the geologic substrate of the Chenier Plain region, are found at the surface a few kilometers inland from the coast and dip gently seaward to include the slope of the Continental Shelf which is delineated by the 10 m (33 ft) bathymetric line that lies about 8 km (5 mi) offshore and by the 20 m (66 ft) line lying some 45 km (28 mi) offshore. These Pleistocene deposits are overlain at the coast by geologically Recent sequences of inland stranded beaches that align the topographic grain parallel with the coast. Near sea level marshes interlaced with tidal channels lie between successive ridges. The coastline is breached by inlets that connect estuaries extending inland up river basins. The exception is the East Bay Basin in Texas, whose long axis parallels the coast. Although geographically part of the Chenier Plain, the topography of this basin is similar to that found in basins of the Strand Plain ecosystem to the west.

Water–riverine, Gulf, and subsurface–is the single most important medium for transporting and mixing sediment, and nutrients. Rivers function as arteries transporting sediments and nutrients from inland catchment basins to the mixing and receiving basins of estuaries, marshlands, and the Gulf of Mexico.

Meteorological forces interact with tides and waves to generate currents along the coast and in estuaries. Although highly variable from year to year, climate exerts a long-term influence sustaining major repetitive water movement patterns. Onshore winds associated with summer sea breezes and offshore winds that accompany the passage of winter cold fronts raise or lower water levels, and drive surface water.

Landforms and accompanying habitats result from the complex interaction, through time, of geological, hydrological, and meteorological processes. Parts 2.2 through 2.5 focus on these processes which are relevant to understanding the development, variability, and interaction of habitats. The basins that compose the ecosystem function as discrete units but are also subject to similar regional forces. These basins, as the primary functioning units of this study, are discussed in part 3.0.

2.2 GEOLOGICAL PROCESSES

This section discusses the sedimentary and erosional processes associated with land gain or loss, and habitat development. Changes that have occurred since the sea reached its present level, approximately 3,000 to 4,000 years ago are of primary concern. The relation between events that occurred during the last few decades and those presently underway are also of significance. However, this record is framed against coastal plain development processes (e.g., alluvial, deltaic, and marine sedimentary processes) that occurred during the last ice age when the sea level was dramatically lower, as well as during the time when the sea was rising to its present level.

2.2.1 SEA LEVEL CHANGES

The last continental glacial advance lowered the sea level approximately 135 m (443 ft) below its present level (Fisk and McFarlan 1955, Gould 1970), and the shoreline was at a point approximately 200 km (124 mi) seaward of its present position (Russell 1936). Receding seas exposed the Pleistocene surface (known as "Prairie" in Louisiana and "Beaumont" in Texas) to erosion and weathering. With lowered base levels, coastal streams along the Chenier Plain cut valleys into the Pleistocene deposits (plate 2). Subsequently during sea level rise with glacial retreat, sequences of sediments were deposited on the eroded Pleistocene surface (Saucier 1974). These sediments consisted of sequences of open Gulf, bay, lake, marsh, and swamp deposits. Each habitat can be described from borings by the composition of flora and fauna and the quantities and bedding characteristics of sands, silts, and clays contained in the deposits (Byrne et al. 1959). The depositional phase ceased when the sea reached its approximate present level. At that time the shoreline was landward of its present position, as evidenced by the inland location of former beach ridges of Recent age (fig. 2-2a and b). Subsequently the shoreline advanced, by sediment accretion, some distance seaward of its present location. At present much of it is retreating again. The entrenched valleys that were drowned during sea level rise have not been filled with sediments but form shallow inland lakes.

2.2.2 LAND SUBSIDENCE

When combined with wave attack, loss of sediment supply, and sea level fluctuations, land subsidence occurs. This process is highly complex and includes regional crustal downwarping of the Gulf coast geosyncline, tectonic processes of folding and faulting, and compaction of sediment through dewatering. Compaction, which is the major cause of land subsidence, includes: differential consolidation because of sediment textural variability; consolidation of underlying sediments from weight of levees (natural and artificial), beaches, buildings, piles, and fills; lowering of the water table through extraction of ground water, salt, sulfur, oil, or gas, or reclamation practices; and extended droughts and marsh burning that cause surface dehydration and shrinkage in highly organic soils.

In comparison with other causes of subsidence, crustal downwarping has a minor effect on the Chenier Plain region. The Pleistocene surface lies only about 10 m (33 ft) below the Recent surface at the present shoreline (plate 2). Below the Mississippi River delta the depth of the Pleistocene surface is over 300 m (984 ft) (Fisk and McFarlan 1955, Gould 1970). Land subsidence caused from dewatering processes is usually less dramatic in the Chenier Plain than farther east because of the relatively thin section of Recent deposits that overlie the Pleistocene surface. Nevertheless, the overall net rate of subsidence (or sea level rise) is significant and averages about 1.75 cm (0.69 in) per year on the Chenier Plain.

2.2.3 RECENT SEDIMENTARY ENVIRONMENTS

During the geologic formation of the Chenier Plain, the Mississippi River occasionally constructed deltas close to its eastern flank, just as the Atchafalaya River, located between the Mississippi River and the Chenier Plain, is presently doing. The westward movement of reworked former delta sediments combined with sediments from adjacent active Mississippi River distributaries are thought to be the main source of sediments for the Chenier Plain. It is also evident that the rivers within the region contributed sediments to the coast (Howe et al. 1935, Van Lopik and McIntire 1957).

Deposits of marine origin are represented in the lower part of the Recent sedimentary wedge. Although not delineated in every core examined, they exist in theory based on an understanding of processes that must have been operating during sea level rise. Thus, they may only be distinguishable from overlying nearshore, marsh, bay, or beach deposits by their relationship to the erosional Pleistocene surface (Byrne et al. 1959, Gould and McFarlan 1959). Gulf bottom, marsh, lake, and bay deposits cap the marine deposits and comprise sequences of sand, silt, clay, and organic deposits representing open Gulf, bay, lake, . and marsh or swamp habitats (Byrne et al. 1959, Kane 1959, Coleman 1966).

The open Gulf marine deposits are highly variable depending on their proximity to the sediment source and to the offshore energy conditions. They interfinger with marsh, bay, or lake deposits close to the shoreline where erosion or accretion has occurred. The open Gulf deposits are distinguished by the marine fauna, distinctive sedimentary structures, and absence of accumulations of organic detritus.

Bay, lake, and marsh deposits are closely connected both vertically and laterally. As a result of small changes in rates of sea level rise and subsidence, and in current patterns, what was a coastal marsh became a lake or bay within a relatively short time. Types of marsh habitat also changed in this dynamic setting. Marsh deposits formed organic layers that can be dated by their radiocarbon content to reconstruct the depositional history of the area (Byrne et al. 1959, Gould and McFarlan 1959, and Coleman 1966). Swamp deposits are confined to river valleys and do not represent a major depositional element in the Chenier Plain.

Bay and lake deposits differ from each other chiefly in their exposure to varying degrees of river and tidal influence. They can be recognized in the subsurface by their lithologic, faunal, and sedimentary properties. Virtually every water body in the Chenier Plain is subject to some tidal influence except where engineering projects disrupt the natural process. The inland water bodies resulted from the drowning of relict Pleistocene entrenched valleys, as was the case for East Bay, Sabine Lake, and Calcasieu Lake along the coast, and for White Lake and Grand Lake, located inland from major Gulf connections (Fisk 1944). Many small lakes originated as marsh ponds that enlarged when salinity changes or other stresses interrupted the marsh building processes. Many irregularly shaped lakes represent old river or tidal stream courses that were abandoned.

2.2.4 CHENIER RIDGES

The Chenier Plain is characterized by sand and shell fragment ridges that parallel the shoreline (fig. 2-2a and b). These ridges are of three basic origins: barrier islands, river mouth accretions, and recessional beach ridges. The cross sections of sediment facies in figure 2-3 were constructed from unpublished data in the Louisiana State University Coastal Studies Institute files.

Barrier islands or spits are progradational features produced by longshore transport of sand-size or larger particles. Barrier islands represent accumulation of sediments that develop seaward of embayments that are usually connected with the Gulf by inlets. They are usually connected with the Gulf by inlets. Barrier islands are nourished by sediments from physiographic structure while undergoing erosion and retreat. Growth usually occurs downdrift and landward by spit and accretion ridge formation. Bolivar Peninsula (fig. 2-3, cross sections A and B) is the single example within the study area. However, barrier islands probably existed along other coastal sections of the Chenier Plain during sea level rise.

River mouth accretion ridges are another feature of the Chenier Plain created by progradation. These multiple bars form concavely seaward where the excess of sand-size particles deposited at river mouths are reworked by waves and currents into complex accretionary patterns (fig. 2-3, outlet of Sabine Lake). Multiple rivermouth ridges converge to form a single recessional ridge extending between the river inlets. The fanning pattern at river mouths differ from barrier spits that form broad single ridges or multiple ridges with less seaward concavity. River-mouth ridges are well-developed at the mouth of the Sabine River, with less extensive development occurring at the mouth of the Calcasieu River (fig. 2-2a). A series of these accretion ridges, representing older shorelines occur as far north as Little Pecan Island and

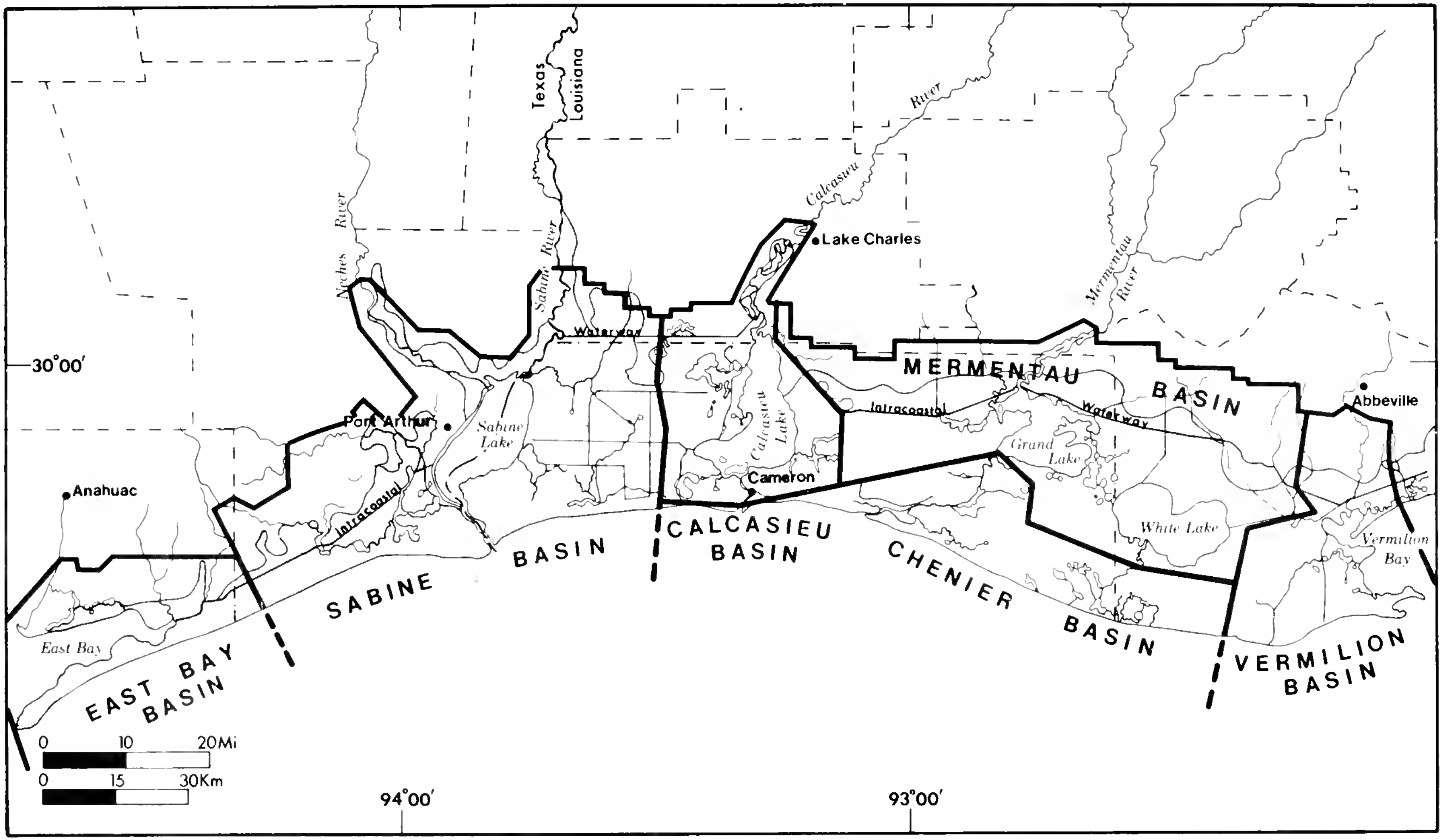


Figure 2-1. The six basins of the Chenier Plain ecosystem.

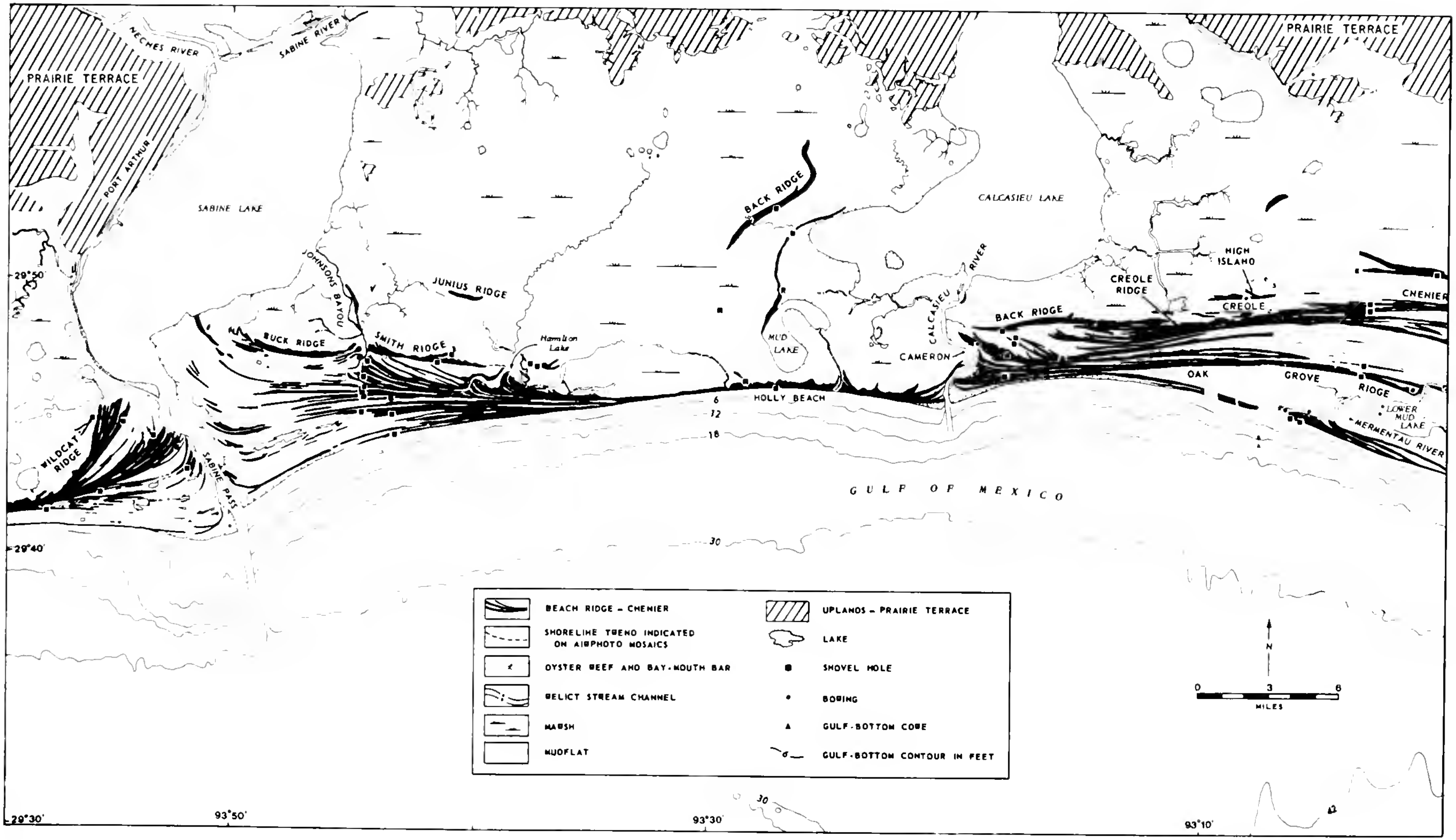


Figure 2-2a. Physiography of the western Chenier Plain showing chenier ridges (in black), from photomosaics and published maps.

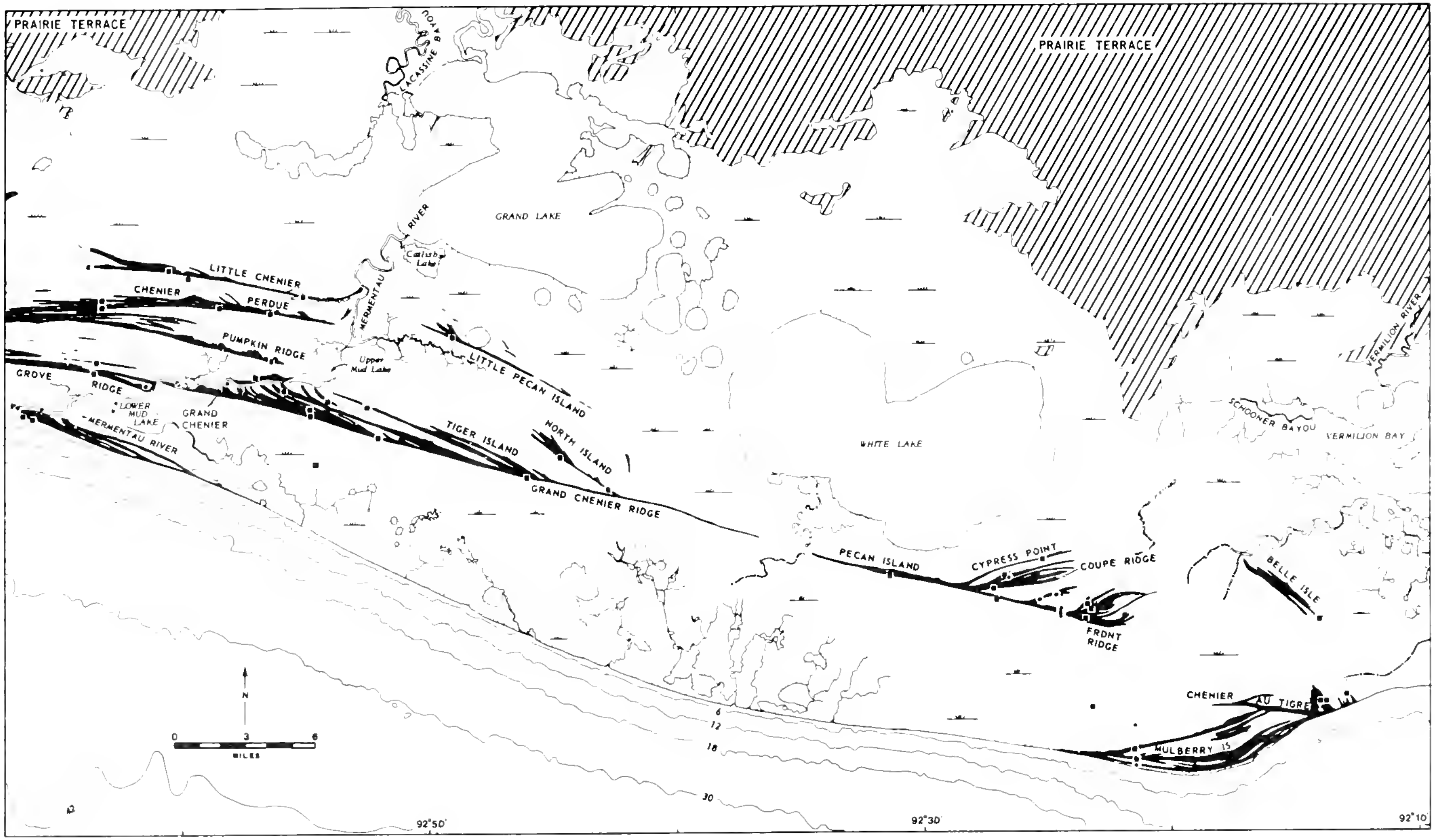


Figure 2-2b. Physiography of the eastern Chenier Plain showing chenier ridges (in black), from photomosaics and published maps.

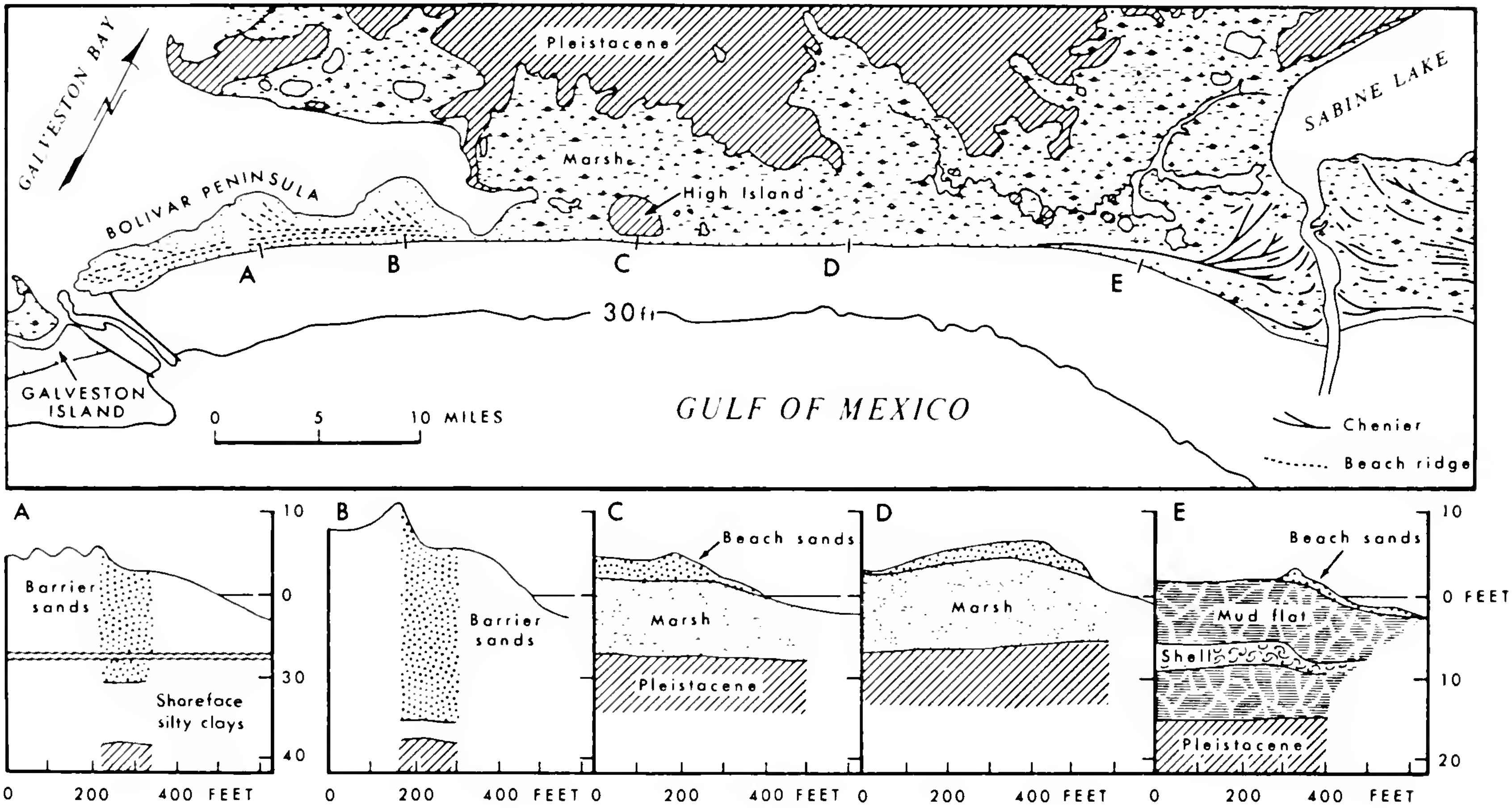


Figure 2-3. Bolivar Peninsula and the adjacent coast with cross sections of sediment facies across beaches. (Louisiana State University, Coastal Studies Institute, unpublished data). Borings were made during the summer of 1955 by McIntire, Saucier, and Gagliano.

Little Chenier. There has been a progressive westward shift of river mouths through time in response to the dominant littoral drift to the west. The sediment buildup at Hackberry Beach was shifting the Mermentau River mouth westward until construction of the navigation channel (through lower Mud Lake) and the jetty system at the coastline interrupted normal riverine and littoral processes.

Recessional beach ridges, the most common sand ridges, are the characteristic type in the Chenier Plain (fig. 2-2a and b). These ridges were constructed by erosional processes but may be laterally continuous with progradational ridges at bay or river mouths. The ridges were formed along sections of the coast undergoing coastal retreat, and their development coincides with Mississippi River shifts eastward and the resulting lack of sediments to maintain coastal buildout. As a consequence, existing beach front and nearshore deposits are eroded and are deposited landward over marsh or bay deposits. Storm conditions accelerate this process. Most of the present shoreline in the Chenier Plain is experiencing retreat; the existing beaches are pushing back over marshes. As evidence of this process, exhumed peat and marsh plant remains are exposed along the strandline. It is likely that sediments being transported westward from the Atchafalaya delta will reverse the erosional trend along the coast in the eastern section of the Chenier Plain. The present coastline contains many examples of seaward buildup of progradational ridges at river mouths over nearshore deposits that grade laterally into recessional ridges overlying marsh deposits.

2.2.5 NEARSHORE TOPOGRAPHY

Turbidity is high along the nearshore zone when waves are breaking, and each breaking wave injects plumes of fine-grained sediment into the water column. On long stretches of the coast, water energies are essentially working against shoal mud bottoms. Coarse-grained sediments are deficient except at locations where the strandline is either holding its own or experiencing slight buildout. Coarse-grained sediments are winnowed westward and accumulate at inlets or river mouths. Thus, progradation is occurring on the shores fronting Chenier au Tigre, at river mouths, and along the Bolivar Peninsula. The remainder of the coast is experiencing retreat over marshlands and bay bottoms that provide the source of fine-grained sediments and much of the broken shell that makes up the beach. The Atchafalaya Bay is becoming an increasingly important source of fine-grained material, which drifts westward and enhances the sediment supply. Evidence indicates that Atchafalaya suspended sediments extend westward to the Sabine River (Wells 1977).

Deficiencies of course-grained sediments are also reflected in the general absence of extensive dune fields along the coast and of well-developed offshore bars. Hackberry Beach and Bolivar Peninsula constitute the only areas of important dune activity. Offshore bars that constitute conspicuous features along most coasts are only subtly developed along the Chenier Plain. Where sand is more plentiful, such as along the Bolivar coast, offshore bars are well-developed. Depending on offshore conditions, there may be two or more sequences of bars seaward paralleling the shore.

2.3 HYDROCLIMATE

Climate combines with the biological and physical components of the ecosystem to determine the character of the physical environment. At the regional level, emphasis is placed on the dynamic aspects of climate that interact with water and water movement. Climate is highly variable and exerts both short- and long-term influences on the region.

Time scale is important when considering variability and climatic trends such as the long-term variability of global temperature (fig. 2-4). The Chenier Plain's development has spanned approximately the last 3,000 to 4,000 years, and the climatic variability associated with that time period has influenced conditions in the study area. Sea level rise to its approximate present position resulted from long-term climatic influences. Note that the global temperatures of the mid-1970's were warmer than the mean when one views temperatures over both the last 1,000 or 10,000 years; during the last 100 years the temperatures have not shown as large a variance.

The most important aspects of climate in the study area are precipitation, temperature, and wind. A generalized hydrologic cycle across the Chenier Plain is depicted in figure 2-5. The parameters illustrated are in a constant state of flux and the movement of water between the ground-water aquifers and the overlying marshes is known to occur but has not been quantified.

Winds are of primary importance in water movement. Several of the basins in the area align in a north-to-south direction that gives maximum exposure to southerly and northerly winds. Southerly winds drive Gulf waters shoreward into the estuaries, resulting in raised water levels. The magnitude of rise in water levels depends on the strength and duration of the winds, on tidal conditions, and on the amount and duration of rainfall. Southeasterly winds are dominant throughout the study area (Atturio et al. 1976, Murray 1976). The frequency of southeasterly winds are higher in the spring, when they occur approximately 30% of the time, and decrease in winter to a low of 17% (fig. 2-6). These winds cause the dominant westerly longshore drift. Coastal landforms in this area indicate that winds from the southerly and easterly quadrants were prevalent during the past 3,000 to 4,000 years.

North winds occur, on the average, 16% of the time from October through March, and decrease to less than 5% of the time during the summer months. Winds are usually strongest during the winter, coinciding with the high frequency of north and northeasterly winds. These winds, which are associated with the passage of cold fronts, lower

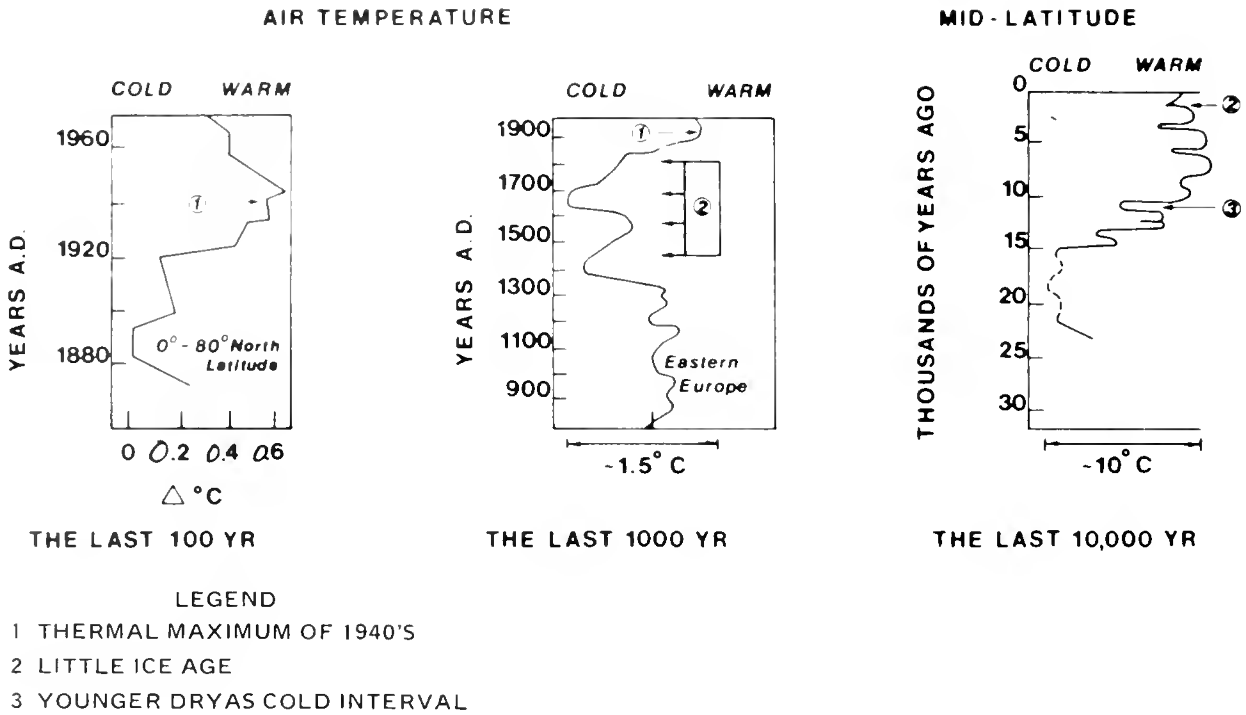


Figure 2-4. Major trends in global climate during the past 10,000 years (National Academy of Sciences 1975).

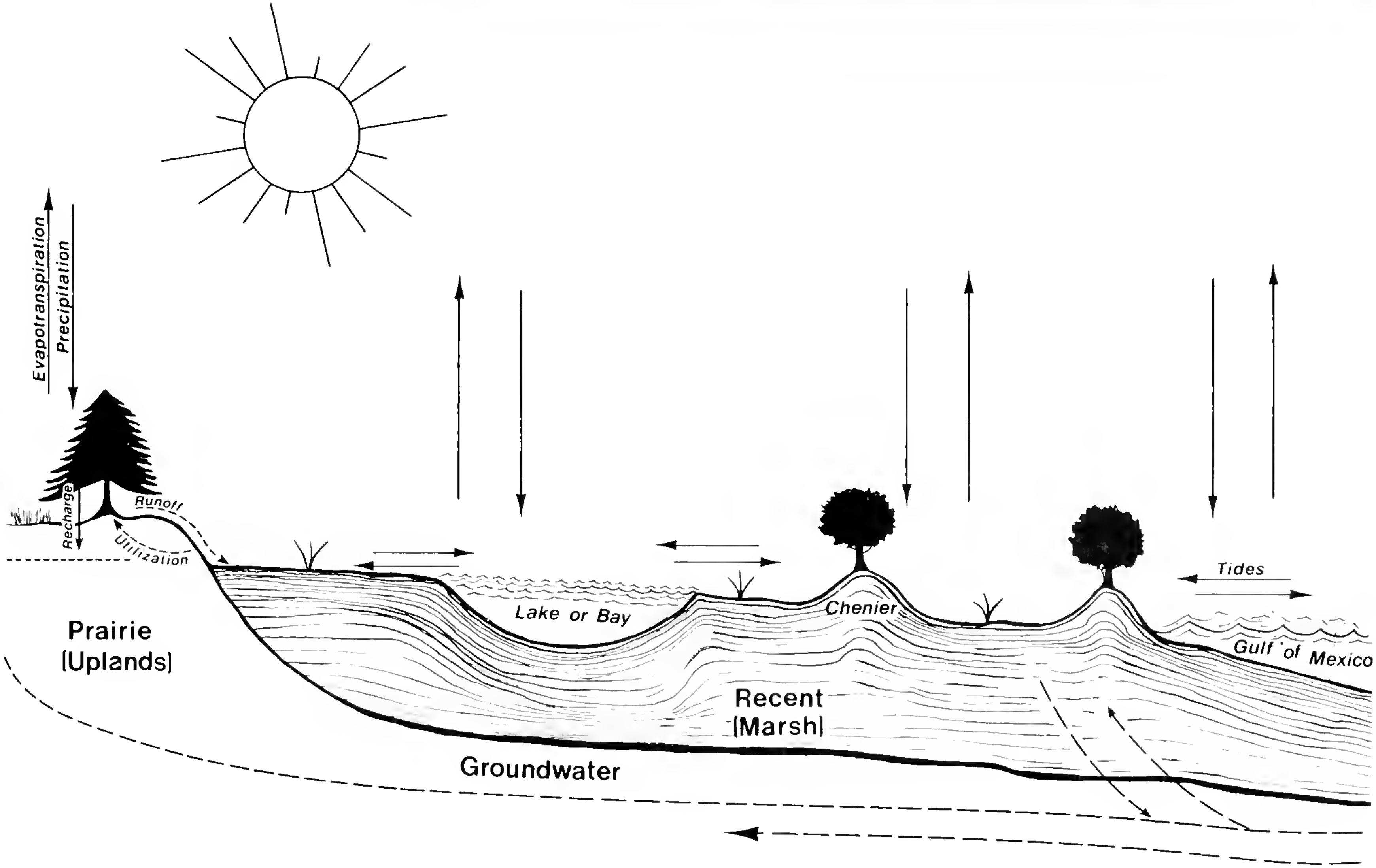


Figure 2-5. Generalized hydrologic cycle of the Chenier Plain.

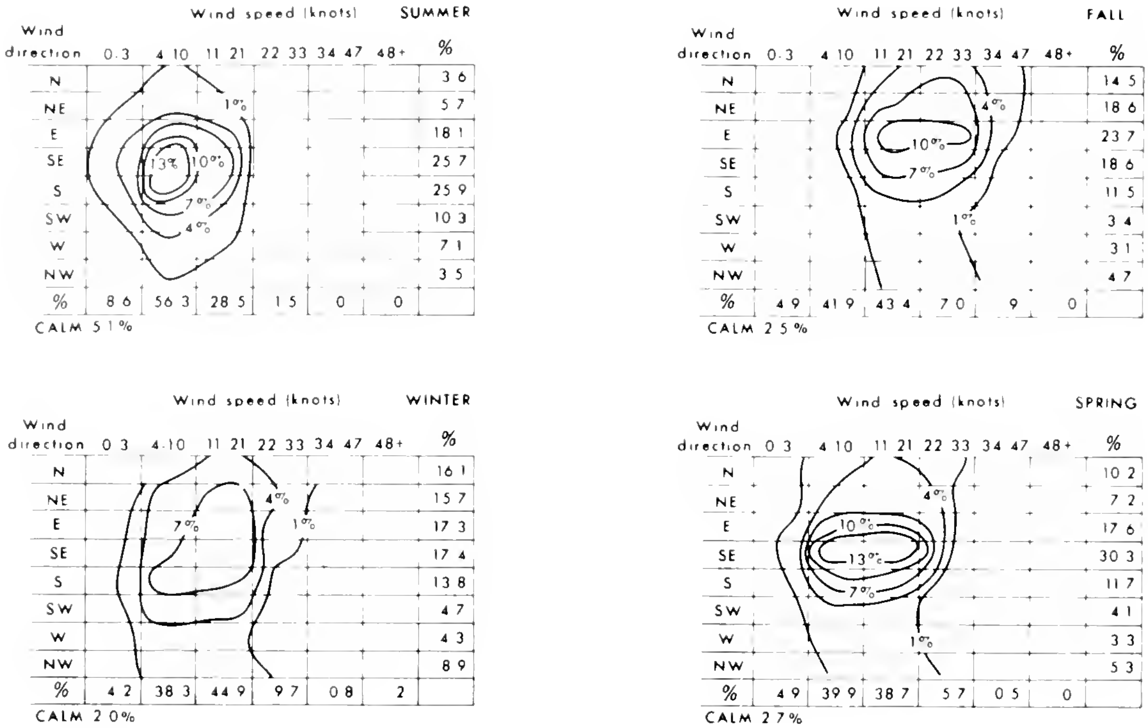


Figure 2-6. Bivariate frequency distribution of wind speed and wind direction offshore of Sabine Pass by season. Percentages of occurrence are given in the margin.

inland water levels. The response is strongest over lakes, bays, and surrounding marshes and is weakest in or near the uplands in constricted river basins (Wax 1977). If the same weather pattern continues for an extended period, the response weakens as steady-state conditions are approached (Part 3.3).

The prominence of north-to-northeast and south-to southeast winds coupled with the lack of westerly components cause unequal erosion along the shorelines receiving the impact of wind-driven waves. Generally southern shorelines experience the highest rate of erosion, reflecting the strength of the northerly winds. Northern shorelines somewhat less erosion, reflecting the high frequency but low intensity of southerly winds. Eastern and western shorelines experience the least amount of erosion (Adams et al. n.d.).

The Chenier Plain has a warm, humid climate. The seasonal precipitation based on a 30-year average (fig. 2-7) is fairly uniform, with the months of October, November, and March being somewhat drier than other months; July typically receives the greatest amount of precipitation. Precipitation, almost always in the form of rainfall, supplies water for groundwater recharge, soil moisture recharge, and surface water runoff. Runoff differs considerably from the precipitation distribution because of the seasonality of solar radiation and temperature (fig. 2-7). Changes in temperature lag behind changes in solar radiation by approximately one month.

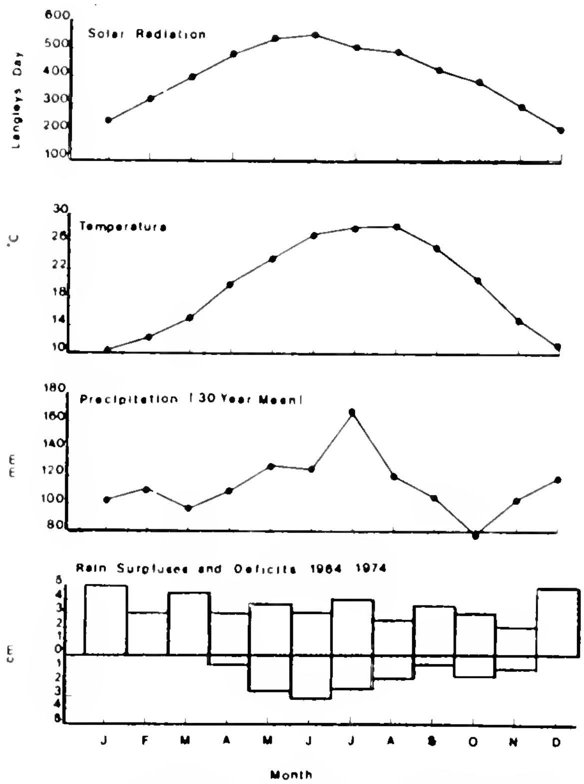


Figure 2-7. Seasonal fluctuations in solar radiation, air temperature, precipitation, and rain surplus at Lake Charles, from National Weather Service records.

Gulf tropical disturbances are important erosion factors; approximately one-half of the shoreline erosion on lakes in the Calcasieu area over the past 25 years, as deduced from maps and photos, was the result of Hurricane Audrey (Adams et al. n.d.). Tropical disturbances cause both wind and water erosion. Storm surges and heavy rains produce an abnormally large volume of water that must exit to the Gulf through restricted passes.

Tropical disturbances are low frequency events; however, Muller (1977) included them as one of eight synoptic weather events that, when combined, represent the climate of the northern Gulf coast. The probability that a tropical disturbance will cross the Chenier Plain in any given year is 0.5% based on data reported by Cry (1965). However, tropical disturbances centered outside the Chenier Plain may also cause dramatic changes in the area.

Annual precipitation decreases from east to west in the study area from a mean of 144 cm (57 in)/yr in Vermilion Basin to 113 cm (44 in)/yr in the East Bay Basin.

The temperature pattern is not as evident; however, it may be slightly warmer in the western portions of the Chenier Plain. On a seasonal basis a strong temperature gradient is found in a south-to-north (coast-to-inland) direction. Sea and land breezes tend to moderate the climate, cooling it in summer and warming it in winter. Table 2.1 shows the inter-regional differences that can be expected in the average number of freeze days between Rustin and Hackberry, Louisiana. Rustin is about 261 km (162 mi) north of Hackberry. Freezes in the coastal environment are more moderate, occuring later in the fall and earlier in the spring.

Table 2.1. Average number of freeze days annually at various places in Louisiana (U.S. Department of Commerce, Weather Bureau 1964, 1965).

Station	Area	Freeze days
Hackberry	Chenier Plain	13
Alexandria	Central Louisiana	27
Rustin	Northeast Louisiana	46

2.3.1 WATER BUDGET

The climatic water budget originally developed by Thornthwaite (1948) combines the effects of precipitation and temperature into an accounting system for water. Although it was devised for upland agricultural areas, the model has been modified for wetland situations (Wax et al. 1978). The water budget of wetlands differs from that of the uplands in the following ways:

1. Since soils are always saturated, a soil moisture storage term is not necessary in the wetlands; more water is available to the plants. Thus, the model predicts that plants in the wetlands will have higher transpiration rates.

2. In the uplands, water surplus in the form of runoff flows away from the area through constricted streams, whereas the same runoff in coastal areas flows into the wetlands and provides an additional source of water.

Rain surplus is the amount of water available for surface runoff and ground-water recharge. Evaporation and transpiration rates are low during the winter, thus a high percentage of the precipitation is surplus. Throughout the Chenier Plain, average conditions show that the surplus period extends from December through April. The effect of this surplus on the streams and eventually on the marshes varies with the size, slope, watershed area, and substrate of the individual streams. Small streams will respond almost immediately to rain surplus; however, in rivers such as the Calcasieu, it may take several months before all of the surplus generated from rainfall has drained into the marshes. Rain deficits occur when evaporation and transpiration exceed precipitation; this is common during May, June and July (fig. 2-7).

2.3.2 SYNOPTIC WEATHER TYPES

Synoptic climatology classifies all observed weather in a region into designated types. Muller (1977) devised a synoptic climatology for the northern Gulf of Mexico based on data from the New Orleans weather station. Muller and Wax (1977) extended this synoptic analysis to Lake Charles, Louisiana. Table 2.2 lists the weather types, and enumerates and contrasts the averages for several parameters for four Januaries during 1971 through 1974.

A strong seasonal pattern for many of the weather types is apparent (table 2.3). Cold fronts occur frequently on the Chenier Plain during winter. The weather type sequences associated with these fronts begin with the Frontal Gulf Return, when the cold front is still several hundred miles to the west or north but is affecting the weather by lifting the warm Gulf air. Rain is common at this time. Frontal Gulf Return accounts for 31% of the average annual precipitation although it occurs only 11% of the time. As a cold front passes through, it often stalls out in the northern Gulf (Frontal Overrunning), bringing on precipitation from the western Gulf. This weather type accounts for 32% of the average annual precipitation. After the front has passed, clearing skies, cool temperatures, and northerly winds dominate (Continental High). With this sequence, water levels and salinity generally fall. As the cold front continues to move east to northeast, the Coastal Return situation is initiated, and winds shift from northeast to southeast. Continued movement of the front away from the basin brings about a stronger flow of maritime tropical air (Gulf Return), with an accompanying increase in water level and salinity. As another cold front approaches from the northwest, Gulf Return changes to Frontal Gulf Return, and the series of events is repeated.

In contrast, summer weather is dominated by a southerly flow of air. The frequent occurrence of the Gulf High is the result of the displacement of a Bermuda High pressure cell south and west over the Gulf of Mexico but still east of the Chenier Plain. The relatively weak clockwise circulation accompanying the Gulf High causes gentle winds in the Chenier Plain to come from the south to southwest. The Gulf Return has a somewhat stronger circulation with winds coming from the southeast. The

Table 2.2. Mean values of parameters of synoptic weather types at Lake Charles during each January from 1971 to 1974; number of observations in parenthesis.

Parameter[a]	Synoptic weather type							
	Pacific high (8)	Continental high (25)	Frontal overunning (43)	Coastal return (10)	Gulf return (24)	Frontal gulf return (12)	Gulf tropical disturbance (0)	Gulf high (1)
Air temperature (°C)	8.3	8.3	7.2	10.0	17.2	17.2		12.8
Dew-point temperature (°C)	7.2	0.6	4.4	10.0	16.7	17.2		12.8
Relative humidity (%)	92	85	87	98	97	99		100
Wind direction (azimuth)[b]	06	02	01	12	17	17		15
Wind speed (kn)	7	7	11	6	9	8		5
Cloud cover (%)	80	30	90	70	100	100		100

[a]Parameters recorded at 0600 CST.

[b]Where 0 = North, 9 = East, 18 = South, 27 = West.

Table 2.3. Synoptic weather types and percent of hours recorded at Lake Charles, 1971 through 1974.

Synoptic weather types	Percent of hours, by month											
	J	F	M	A	M	J	J	A	S	O	N	D
Pacific high	8	15	9	9	9	0	0	0	4	10	6	9
Continental high	18	22	18	21	28	19	10	21	16	40	27	25
Frontal overrunning	31	19	19	13	11	11	5	7	14	13	29	30
Coastal return	9	13	11	13	7	5	7	21	16	19	10	9
Gulf return	20	16	24	29	26	25	29	18	18	11	15	10
Frontal Gulf return	13	15	19	15	14	10	2	2	6	8	13	19
Gulf tropical disturbance	0	0	0	0	1	2	5	6	24	0	0	0
Gulf high	1	0	0	0	4	28	44	28	3	2	0	0

Continental High occurs fairly regularly. Its characteristics during the summer are not as noticeable as in the winter; however, it generally brings cooler, somewhat drier air with fair skies.

The Gulf Tropical Disturbance, which includes hurricanes, occurs infrequently from late spring through early fall. Winds can be extremely strong and can approach from any direction except northwest through northeast. This weather type is associated with the most dramatic environmental responses.

2.4 NEARSHORE HYDROLOGIC PROCESSES

The coastal waters of the Chenier Plain area are kept in constant motion by the driving forces of wind, waves, tide, atmospheric pressure gradients, and semipermanent currents. Wave-driven currents control the circulation patterns in the immediate nearshore zone. Rainfall and freshwater inflows from rivers, such as the Atchafalaya, mix with Gulf waters to bring about density gradients and buoyancy effects that are important in the circulation at tidal passes and estuary mouths. Nearshore waters are very turbid during high discharge periods of the Atchafalaya River and when waves are breaking along the coast.

Wind direction and intensity are the primary factors controlling orientation and size of wave trains approaching the coastline and consequently the overall circulation pattern. Winds along the Louisiana and eastern Texas coast generally come out of the east and southeast, at velocities of 4 to 10 kn (8 to 19 km/hr) (5 to 12 mi/hr) in summer, and at slightly higher velocities in winter (fig. 2-6, Murray 1976). These winds drive longshore currents toward the west.

Prevailing southeasterly winds often develop swells that contact the bottom of the smooth, gently sloping shallow shelf and shoreface, causing wave trains and currents that control deposition and erosion along the coast. Investigations along muddy coasts indicate that highly turbid waters have a dampening effect on waves (Wells 1977).

Approximately 92% of the waves along coastal Louisiana are 1 to 2 m (3.3 to 6.6 ft) in height and have a period of 4.5 to 6 sec when wind speeds are greater than 10 km/hr (6.2 mi/hr) (Louisiana Superport Studies 1972). Waves greater than 2.5 m (8.2 ft) in height occur approximately 30% of the time during winter but only 2% of the time in mid summer. Thus, the Chenier Plain coast is a relatively low-to-moderate energy coastline in terms of offshore waves. The shallow slope of the Continental Shelf apparently attenuates the offshore wave power sufficiently to yield the low energy environment of the coast.

Winds associated with winter frontal passages or hurricanes produce large and sustained waves offshore. Hurricanes usually have a net drift toward the northwest. They can cause considerable modification to the shelf waters and generally drive oceanic waters onto the shore and into estuaries. The intense wave action associated with hurricanes reworks the shelf sediments and can transport large quantities of sediments shoreward.

The significant inflow of fresh turbid water from the Atchafalaya River reduces nearshore salinities. During the flood season, the salinity levels along the entire open coast of the Chenier Plain are similar to salinity levels in the estuaries, i.e., 10‰ to 20‰ (part 3.3).

Tides along the western section of the Chenier Plain, especially in the vicinity of Sabine and Calcasieu lakes, are as high as 0.7 m (2.3 ft) and are capable of producing significant tidal currents. Currents of 3.3 kn (6.1 km/hr, 3.8 mi/hr) flood and 4.3 kn (8.0 km/hr, 4.9 mi/hr) ebb develop in restricted passes in the Galveston Bay area, particularly between Galveston and West Bay and between Christmas Bay, Bastrop Bay, and West Bay (Murray 1976).

Mudflats result from the net effect of sedimentary input from local rivers, the Atchafalaya River and its general westward drift, and the erosional forces of the coastal waves and longshore currents. When sedimentation exceeds erosion, mudflats may develop offshore of the beach. During severe storms the mud, along with whatever beach material is present, may be driven landward over the adjacent marshes.

2.5 GROUND WATER

Rain surplus coupled with favorable geologic conditions have enabled extensive ground-water aquifers to develop in the Chenier Plain. These aquifers are part of a regional ground-water area that extends throughout most of the northern coast of the Gulf of Mexico.

Sands and gravels with over- and under-lying clays have been deposited through geologic time along the northern coast of the Gulf of Mexico. The tremendous weight of these sediments has caused the downwarping known as the Gulf Coast Geosyncline. Two favorable conditions for ground-water development are associated with this downwarping. First, the resultant slope allows for a gravity flow of water from the outcropping areas in the north (the principal recharge areas) to the Chenier Plain. Second, faults associated with the downwarping generally parallel the coast and therefore transect all major surface flows. This allows for additional ground-water recharge from surface streams during periods of high surface flows and a discharge of ground water to surface streams during periods of low flow. This discharge maintains a minimum baseflow in surface streams and acts as a buffer against drought conditions for riparian vegetation.

A third major source of ground-water recharge is by downward seepage through the large surface area of the wetlands. According to Zack (1973), maximum seepage occurs when surface water levels are highest, i.e., during the spring, and late summer to early fall. Less important recharge sources are through fractures associated with faulting from salt domes, and inter-aquifer exchange in localized areas where separating clay layers become thin or nonexistent.

The most important ground-water aquifer in the Chenier Plain is the Chicot Aquifer, which was formed during the Pleistocene age. This aquiter suppties more than 90% of all ground water pumped in the Chenier Plain (Guevara-Sanchez 1974). In the hydraulic center of this aquifer, Calcasieu Parish and vicinity, extensive clays separate the Chicot Aquifer into three distinct layers: 60 m (197 ft), 150 m (492 ft), 210 m (689 ft) sands. Massive beds of sand and gravel ranging from 15 to 250 m (49 to 820 ft) in total thickness are overlain by extensive, impermeable clay beds. Alternating, interfingering lenses of sand and mud are found in the shallow subsurface of southeastern Texas. The vertical and lateral distribution of sand in this region suggests that the Chicot Aquifer may comprise several local aquifers separated by mud intervals that are locally well-developed (Guevara-Sanchez 1974). The deposits slope gently gulfward 1 to 3 m/km (2 to 6 ft/mi) and increase in thickness from less than 30 m (98 ft) in northern Louisiana to more than 2,150 m (7,054 ft) beneath the Gulf of Mexico. Thickness increases from Lake Calcasieu east to White Lake and then decreases to the Atchafalaya Basin. To the west the beds become thinner, although localized variability is much greater than to the east of Lake Calcasieu. Aquifers of the Chicot reservoir have been tapped by offshore wells and contain freshwater beneath the Gulf of Mexico near the shoreline between Cameron and the Atchafalaya river.

Older Miocene and Pliocene aquifers, although large, are used only indirectly. The Pliocene aquifers are directly connected to the Chicot reservoir in many areas; therefore, an indirect withdrawal is taking place. Due to the numerous interconnections in southeast Texas, the Pliocene and Pleistocene aquifers are collectively known as the Gulf Coast Aquifer.

2.5.1 USAGE OF GROUND WATER

Cyclical, and continuous ground-water pumping takes place in the Chenier Plain. Irrigation requirements are cyclical (spring and summer); municipal and industrial needs are continuous. Ground-water withdrawal volumes by activity are presented in parts 3.2.3 and 3.2.6. In the Chenier Plain and immediate vicinity, the total withdrawal is $2 \times 10^9 m^3$ ($7.06 \times 10^{10} ft^3$) per yr, with irrigation accounting for 74% of the usage, industry 17%, and municipalities and rural areas 9% (Louisiana Department Public Works 1971, Baker and Wall 1976). Pumping has been increasing annually; in the Lake Charles area the rate of increase is about $2.8 \times 10^6 m^3$ ($9.89 \times 10^7 ft^3$) per yr (Harder et al. 1967, fig. 2-8). Based on the estimated freshwater recharge rate for aquifers currently being pumped in southwestern Louisiana (Jones et al. 1956) and extending this rate to the Texas area of recharge, use exceeds recharge by $1 \times 10^9 m^3$ ($3.53 \times 10^7 ft^3$) per yr.

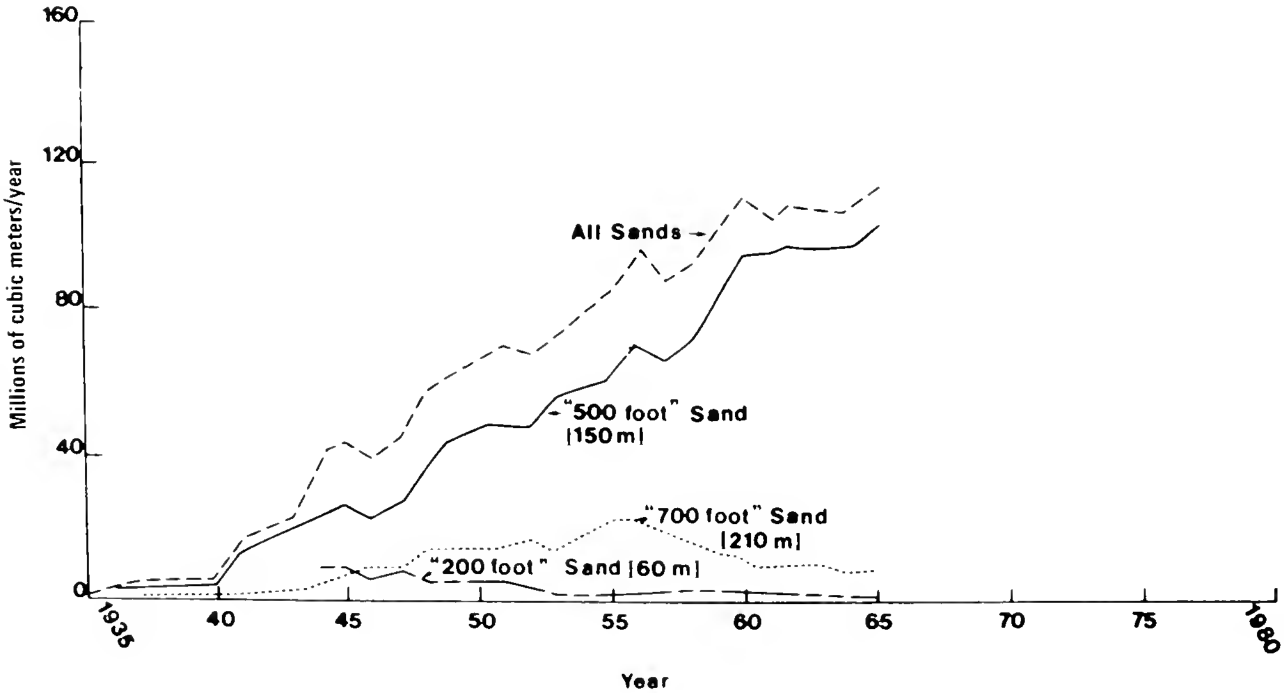


Figure 2-8. Volume of water pumped from different sand strata in the Lake Charles area from 1935-65 (Harder et al. 1967).

2.5.2 EFFECTS OF WITHDRAWALS

Large-scale and unregulated ground-water pumping results in hydrologic problems such as declining water levels, stream flow depletion, saltwater intrusion, and land surface subsidence.

When pumping is started in a well, the water table is drawn down around the well to form a cone of depression. The cone expands and the water table is progressively lowered until a balance is achieved between the rate of flow of water to the well and the amount pumped. If pumping rates continue to increase, the size of the cone also increases. The creation of this depression around a well or group of wells has led to at least two documented effects in the Chenier Plain and vicinity: saltwater intrusion and land subsidence.

In the 210 m (689 ft) sands of the Chicot Aquifer in Calcasieu Parish most of the ground water moved gulfward prior to large-scale pumping operations. Because of the large freshwater head, saltwater was flushed from the landward portions of the aquifers. Because ground-water levels have declined in the last few decades, the direction of the hydraulic gradient has been reversed, the density balance has been disturbed, and recharge with saltwater from the Gulf has begun. The 210 m (689 ft) sands in central Calcasieu Parish now contain salty water as far north as Lake Charles, and saltwater intrusion has caused many industries to discontinue pumping operations from this aquifer (Zack 1973). Decline in ground water in the Gulf Coast Aquifer near Houston has also occurred (fig. 2-9).

The removal of water from the pore space of the sands creates a void. Water from adjacent clay layers moves into the interbedded sands. The dewatered clays are highly compressible and become compacted. In turn, the compaction is translated to the land surface as subsidence. Ground-water and mineral extraction has led to a maximum of 2.5 m (8.2 ft) of subsidence in northern Galveston Bay (Kreitler 1977).

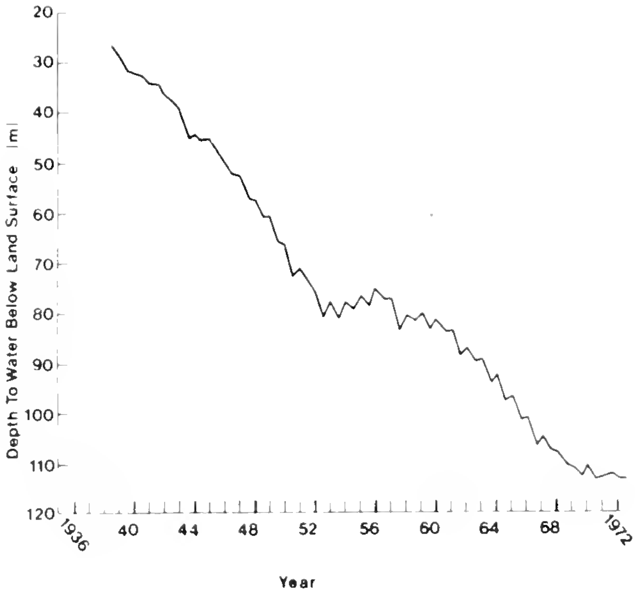


Figure 2-9. Depth to the water table in the Gulf Coast Aquifer at Houston, Texas, 1939-72 (Kreitler 1977).

3.0 Chenier Plain Basins

3.1 INTRODUCTION–GENERALIZED BASIN DESCRIPTION

A basin, the result of long-term geologic processes, can be described as a set of interacting habitats constrained by climate and physiography, and integrated by the flow of water through it. Each habitat type has characteristic species and productivities. Man is a major factor in a basin; his activities influence nearly all natural processes. The objectives of the basin-level analysis are to describe the natural functions of Chenier Plain basins and the modifications caused by human activities.

A conceptual model of basin-level processes and interactions places in perspective the detailed analysis that follows. The model (fig. 3-1) includes only the most critical components and processes, and shows interactions of water, wetlands, uplands, wildlife and fish, and man. At this level of analysis, hydrological and land-modifying processes are emphasized because they determine the capacity of a basin to support renewable resources such as waterfowl and fishes. Thus, the basin-level discussion of living resources emphasizes factors that change habitat area rather than habitat quality. The latter is discussed in part 4. Differences among basins result from differences in the relative areas of habitats, the degree of interaction among them, and in basin inputs and outputs.

A drainage basin can be envisioned as four linked submodels driven by a set of forces external to the basin (fig. 3-1). Each submodel represents a different group of processes interacting within the basin. They are: (A) basin hydrologic processes, which represent water storage and flow through a basin; (B) land-modifying processes, which result in the exchange of area among different habitats and especially in the loss of natural wetland; (C) the renewable resource productivity of a basin, or its capacity to support wildlife and fish species, to purify water, and to perform other services for men; and (D) basin-level socioeconomic processes, those human activities and management decisions that impinge directly on natural processes in a basin.

3.1.1 HYDROLOGIC PROCESSES IN A BASIN

Hydrology (part 2.4) has already been identified as a major factor in the development of the entire Chenier Plain region and is largely responsible for the unique characteristics of each basin. Further, the hydrologic regime at any specific site within a basin determines the kind of habitat that develops at the site (Bahr et al. 1977). Basin hydrology results from: the interactions among water stored and flowing in a basin (A_1); upstream riverine and rainfall inputs of water, sediment, and nutrients (A_2); and downstream tidal water with accompanying salts, sediments, and nutrients (A_3) (fig. 3-1).

Hydrology determines habitat type by water levels, flows, and salinity gradients. Water levels are controlled by the pressure head between water level at a given site and upstream and downstream water levels; consequently they are modified by rainfall, tidal stage, and wind direction and intensity. The pressure differentials and resultant water flows contribute to the potential natural resource productivity of a basin by facilitating the movement of organisms, nutrients, organic matter, and wastes from one part of the basin to another. For instance, the export of organic detritus and the flushing of wastes and toxins are important to the maintenance of biological production in open water areas. In this context, man-made impoundments or canals modify water flow, thus changing these hydrologic processes.

Mean salinity and salinity range at any given site in the basin are determined by the relative volume, timing, and duration of upstream (fresh) and downstream (saline) inputs. Sediments and nutrients are distributed among various basin habitats by freshwater inflows and by currents produced by density gradients (salinity).

In summary, the hydrologic submodel symbolizes the physiographic configuration of a basin that, together with upstream and downstream water sources, determines the water level and water flow regimes and the salinity and turbidity regimes at any point in the basin. These parameters in turn control the type of habitat that can develop at that site and directly influence the productivity of those habitats.

3.1.2 LAND-MODIFYING PROCESSES

Over the past several thousand years the dominant trend in the Chenier Plain has been an increase in wetlands, concurrent with the formation of new chenier ridges, at the expense of aquatic habitats. In contrast, during the past 50 years, the major change has been loss of wetlands (fig. 3-1). Subsidence and erosion that lead to wetland degradation and its conversion to open water are natural geologic processes. But these natural processes have been accelerated by modifications, such as canals and control structures, which have changed basin hydrology. Also, impoundment of wetlands for waterfowl, or drainage for agriculture, industry, and urban use result in wetland degradation. These changes may result from activities outside the basin. For example, maintenance of the present Mississippi River course on the eastern side of the Mississippi Delta during the 20th century has meant that, until the recent growth of the Atchafalaya River, very little new sediment reached the Chenier Plain. Modification of ridge and upland areas is not depicted in figure 3-1, but changes in these habitats have also occurred through residential and urban development.

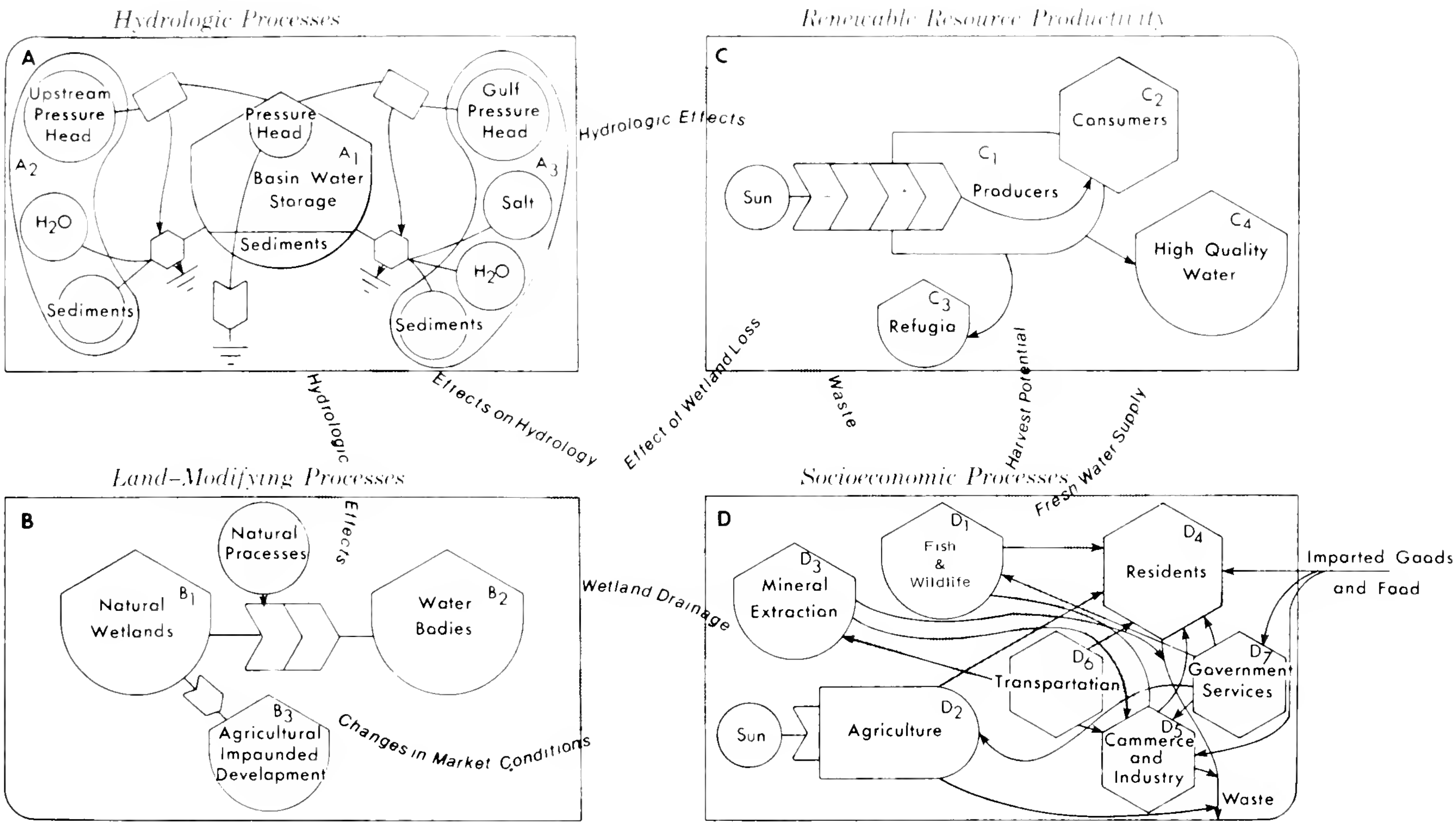


Figure 3-1. Generalized model of major ecological processes of the Chenier Plain basins.

3.1.3 BASIN RENEWABLE RESOURCE PRODUCTIVITY (RRP)

A basin's RRP is determined by the kinds of habitats it contains, their areal extent, and their juxtaposition (since many species require access to two or more habitats during their life cycle). The RRP submodel (fig. 3-1) consists of four main components: producers (C_1), consumers (C_2), refugia (C_3), and storage (C_4). Components C_1 (producers) and C_2 (consumers) reflect the "quality of the basin," which is related to the kinds of renewable resources that a basin can support. For example, the inland open water habitat can be in a balanced state with respect to nutrient input and use, and support many species, or it can be degraded by excessive nutrient loading into a dangerous eutrophic state and support few species. If environmental changes (such as modified flooding regimes or eutrophication) occur, the quality of a given habitat will be modified. Changed quality leads to such changes in community structure as the increase of undesirable fish species in waters of a dangerous eutrophic state.

As some habitat types decrease in size, it is important to preserve natural areas. These serve as refugia (C_3) that are important in maintaining a diverse gene pool.

Freshwater wetlands and water bodies (C_4) are especially valuable for storing surface water, which is used by man for many purposes. For example, much of the irrigation water for rice in Louisiana and Texas is stored in fresh marshes. In the Chenier Plain this freshwater supply is in contact with groundwater aquifers. Ground-water aquifers often extend beyond basin boundaries, thereby becoming a regional resource.

As water flows over wetlands, many chemical transformations occur. Inorganic nutrients, that could cause dangerous eutrophic states, undergo important changes. The nutrients may be taken up during plant growth or by bacteria. Some of these nutrients may be exported later as organic detritus. Phosphorus may physically bind with sediments, and nitrogen compounds may be denitrified. These processes are important in determining the load of nutrients a basin can assimilate and the resulting quality of water within the basin (Hutchinson 1969).

3.1.4 SOCIOECONOMIC PROCESSES

Basin-level socioeconomic processes (fig. 3-1) have been organized into seven components: (D_1) fish and wildlife resources harvested by man both commercially and for sport; (D_2) agricultural activities; (D_3) mineral extraction, primarily petroleum and natural gas; (D_4) the total human population, its energy and material requirements, and its waste production; (D_5) all commerce and industry such as manufacturing, refining, and retail sales, along with the concomitant waste release; (D_6) transportation activities that facilitate mineral extraction and other industries but also may disrupt natural ecosystems by such alterations as dredging and leveeing; and (D_7) government services, including government subsidies for transportation, flood control projects, refuge acquisition, and sewage treatment plants. In general, all these socioeconomic processes require large quantities of freshwater for irrigation, human consumption, and industrial processing.

Human activities are a major influence on basin level processes. For this reason, the socioeconomic sectors are described in part 3.2, and the effects of their activities are identified and quantified where possible. In part 3.3 through 3.5, basin level processes are elaborated and the influence of human activities on these processes is considered. The dynamics of individual basins of the Chenier Plain are summarized in part 3.6.

3.2 SOCIOECONOMICS

3.2.1 INTRODUCTION

Techniques. Analysis of the economics of the Chenier Plain region has required extensive modification of existing data. The boundaries of the Chenier Plain region and basins were drawn along lines dictated by the natural physiography of the region. Socioeconomic data, on the other hand, are collected by political unit. Therefore, the primary data are usually from the parishes (counties) of the region (volume 2, appendix 6.2). In the text, socioeconomic data are displayed by basin. The assumptions made in converting parish-based to basin figures are stated either in the figure legends or in the accompanying appendixes.

The second problem, inherent in studies of this kind, is that of comparing diverse materials in common terms. A comparison of shrimp and Gulf menhaden is a good example, because they are harvested for different purposes. The annual harvest of menhaden in pounds far exceeds the harvest of shrimp, but the dollar value of the shrimp fishery exceeds that of menhaden. Menhaden are processed into fish meal or oil, while shrimp are processed for human consumption. The immense harvest of menhaden could have much more severe environmental repercussions than the harvest of shrimp; yet from an economic viewpoint, shrimp is the more important commodity. This problem pervades the analysis of the socioeconomic sectors. We have, in general, relied on dollar values as an index of the magnitude of different man-related activities in the Chenier Plain, but it should be remembered that this does not necessarily signify the relative environmental impact of those activities.

The various socioeconomic sectors, e.g., transportation and mineral extraction, can influence natural basin processes through activities they generate. Since several different sectors may generate the same kind of activity, the environmental impact of one sector may be difficult to distinguish. Because canal dredging and spoil is an impact that results from eight different economic sectors (table 3.1), it is difficult to establish each sector's relative impact on the environment.

Table 3.1. Socioeconomic components and ecologically sensitive activities generated by them. The matrix identifies major activities associated with each sector of the economy.

	Ecologically sensitive activities											
	Waste generation			Habitat modification					Natural resource exploitation			
Economic sectors	Point source	Agriculture runoff	Urban runoff	Filling & draining	Controlled H_2O level impoundment	Upland construction Urban & Agriculture	Canal dredge & spoil	Water-based construction	Wildlife harvest	Surface Water use	Ground water use	refuge creation
Commercial fishing & trapping	●						●	●	●			
Recreational fishing & hunting								●	●			●
Agriculture		●		●		●	●			●	●	
Mineral extraction	●				●	●	●	●		●		
Resident population			●	●		●	●					
Commerce & industry	●			●		●	●			●	●	
Port & navigation				●			●	●				
Highways, rails, airports			●	●	●	●	●					
Government services	●				●		●	●		●	●	●

The primary ways in which socioeconomic sectors interact with natural processes are in (1) waste generation, when industrial or domestic pollutants are discharged into the basin; (2) habitat modification, when spoil banks are created, wetlands impounded, or upland forests cleared for agriculture; and (3) natural resource exploitation, including water use and refuge creation.

Overview. The Chenier Plain region is predominatly a rural and agrarian area, and the population density is low because the extensive wetlands are unsuitable for urban development (table 3.2). The western edge of Sabine Lake in the Sabine Basin is, in contrast, heavily industrialized. In addition, major urban areas occur just north of the Chenier Plain boundaries, and these have a major impact on the Chenier Plain. North of the Vermilion Basin lies the city of Lafayette. Several farming communities–Crowley, Rayne, and Jennings are north of the Mermentau and Chenier basins. Lake Charles is the major industrial metropolitan area that lies along the northern border of the Calcasieu Basin; the entire Texas coast north and west of the Sabine and East Bay basins is heavily industrialized

Given the population distribution, it is to be expected that the impact of human, industrial, and urban development on all basins of the Chenier Plain except Sabine Basin would come from adjacent inland areas, whereas commercial exploitation of the natural renewable resources through agriculture, trapping, and fishing is by the resident population. However, the major pressure on noncommercial sportfish and wildlife is from individuals who live outside the Chenier Plain boundary.

The four sectors that directly harvest the region's resources are (1) mineral extraction, (2) agriculture, (3) commercial trapping and fishing, and (4) recreational fishing and hunting. This section will discuss the ecological impacts of these sectors; of the resident population; of transportation development, particularly for navigation; and of the local, State, and Federal governments.

Table 3.2. Human population distribution in the Chenier Plain basins and adjacent northern parishes (counties).

Basin	Chenier Plain			Chenier Plain plus adjacent northern parishes (counties)	
	Population[a] (number)	Land area[b] (ha)	Density (persons per ha)	Population (number)	Density (persons per ha)
Vermilion	804	56,335	0.014	112,547	2.00
Mermentau	7,974	206,567	0.039	90,857[c]	0.31
Chenier	1,220	89,151	0.014		
Calcasieu	9,790	94,428	0.104	127,483	1.35
Sabine	130,636	244,543	0.534	337,730	1.38
East Bay	4,824	54,821	0.088	250,000[d]	4.56

[a]Calculated from 1970 Census (U.S. Department of Commerce 1973), by summing the population of all cities with population 1000, then prorating the rural population of individual wards (divisions in Texas) by the areal proportion within a basin boundary.

[b]Inland area exclusive of open water.

[c]Includes population north of the Chenier Plain boundary.

[d]East Bay plus about one-fifth of Harris County, Texas.

Approach. Typically, each sector has an economical and ecological impact on the Chenier Plain region. Each important activity is identified and its magnitude in relationship to the economic sector is discussed. The sectors and resulting activities are summarized in matrix form in table 3.1. The effect of each activity on the ecosystem is discussed in sections dealing with hydrology, land-modifying processes, and natural resource productivity.

3.2.2 MINERALS

Production. Mineral extraction particularly oil and gas, is the major industry on the Chenier Plain. The dollar value of minerals extracted in 1974 was six times greater than the total value of the renewable resources (table 3.3). On a statewide basis, more than 96% of the mineral production value is derived from the mineral fuels, natural gas and crude oil (Jones and Hough 1974). Although the dollar value is still increasing, the volume of production peaked in 1970 and has been declining since 1971 (fig. 3-2). A second trend is the depletion of inland (coastal) production and the development of new wells farther and farther offshore in Federal waters of the Gulf of Mexico. Within the Chenier Plain, the total value of minerals extracted in 1974 was $438 million. Most of this production was within the "intermediate" zone defined by the Louisiana Department of Conservation (Melancon 1977). This zone includes most of the coastal marshland. Production in the nearshore Gulf is, with the exception of the Vermilion Basin, a rather small proportion of total production. (Details of 1974 production and cumulative production by field in the Chenier Plain are in appendix 6.2).

Table 3.3. Annual value of major resources of the Chenier Plain.

Resource	Value Millions of Dollars
Oil and gas[a]	438
Agriculture[b]	28
Commercial fishing and trapping[c]	12
Recreational fishing and hunting[d]	21

[a]1974 production (Melancon 1977).

[b]1974 production (U.S. Department of Agriculture 1975).

[c]Based on 1963-1973 commercial production (U.S. Department of Commerce 1976), see table 3.29.

[d]Based on calculations shown in tables 3.32 and 3.33.

The oil and gas production and value in 1974 was highest in the Mermentau Basin (60×10^{12} kcal, $114 million), followed by the Chenier and East Bay basins (table 3.4). The Chenier and Mermentau basins sustain the most intense mineral extraction per unit of area.

Human Activities that Affect the Environment. Pollutants: Mineral extraction results in discharges of brine into coastal and estuarine waters, and also in oil spills. The latter include chronic low level spills, and major spills.

Brine water is discharged into wells, pits, and nonpotable water bodies in the Louisiana portion of the Chenier Plain (table 3.5 and appendix 6.2). For areas close to the coast, disposal into saline waters is the most economical practice. The environmental effects of surface disposal are much more adverse in freshwater areas. Because of the lack of saline waters, the large volume of brine generated in the Mermentau Basin is returned to disposal wells. Part 3.5.3 discusses the environmental effects of brine. In addition, large amounts of drill fluids containing biocides are disposed of into reserve pits (inland) or discharged into the Gulf. Little is known about the environmental effects of these fluids.

Large volumes of freshwater are an additional requirement for well leaching. As an example, the freshwater demand for the LOOP storage facility in the Clovelly salt dome (in Barataria Bay, east of the Chenier Plain) is estimated at up to 8.8×10^4 m^3 (3.1×10^6 ft^3) per day. The maximum 12-month withdrawal has been estimated at 30.56×10^6 m^3 (1.08×10^9 ft^3). The impact of this withdrawal rate would depend on the size of the watershed area and the flow of water through it. In Barataria Bay with an upstream watershed area of 3,400 km^2 (1,313 mi^2) and a mean annual rain surplus of 42 cm (16.5 in), this withdrawal rate would be 1.7 to 3.4% of the freshwater input (Gosselink et al. 1976). The impacts of brine disposal are discussed in part 3.5.3.

Table 3.4. The 1974 production of oil and gas in the Chenier Plain (Melancon 1977).

Basin	Crude oil (bbls)	Natural gas (mcf)	Kcal equivalent[a] (kcal x 10^{12})	Value[b] \$1,000
Vermilion	2,833,930	112,943,923	32.6	53,151
Mermentau	8,543,329	189,940,493	60.4	114,011
Chenier	2,485,233	193,579,634	52.4	75,633
Calcasieu	6,003,821	43,191,467	19.7	52,405
Sabine (La.)	3,832,609	39,269,853	15.5	37,045
(Tex.)	1,900,025	6,105,777	4.3	14,235
Sabine total	5,732,634	45,285,630	19.8	51,280
East Bay	8,163,375	123,346,093	43.0	91,092
Total	33,762,322	708,287,240	227.9	437,572

[a]Assuming one million Btu/mcf natural gas and 5.8 million Btu/bbl crude oil.

[b]Calculated at the rate of \$0.307/mcf for natural gas, and \$6.52/bbl for crude oil.

Table 3.5. Louisiana brine disposal by basin, in mbbl (Louisiana Department of Conservation 1977).

Basin	To disposal wells	To pits	To nonpotable water bodies
Vermilion	1,648.7		3,601.8
Mermentau	32,415.2	34.1	1,388.9
Chenier	2,657.8	42.1	4,461.7
Calcasieu	3,308.6	50.0	4,134.6
Sabine (La.)	675.2	10.3	6,446.3

Two potential developments related to energy production on the northern Gulf coast may increase the impact of brine. Both the Department of Energy (DOE) and private corporations [e.g., Louisiana Offshore Oil Port, Inc. (LOOP)] are leaching salt from salt domes to create chambers for crude oil storage. One such site is the Hackberry salt dome in the Calcasieu Basin. Other sites are east of the Chenier Plain in the Weeks' Island and Choctaw dome areas. In addition, development of geothermal/geopressure energy sources would require disposal of enormous quantities of brine. Many potential brine disposal locations are within the Chenier Plain (fig. 3-3; see appendix 6.2 for well description). The possibility of significant environmental modification by discharge of this brine into the Gulf is currently under investigation by the Division of Geothermal Energy (DGE).

The probability of major oil spills from transportation has been evaluated by Bryant (1974) from U.S. Coast Guard data. He estimated a probability of 6.7 tons (6.1 tonnes) of crude oil spillage per vessel-year of operation in the superport region east of the Chenier Plain (table 3.6). This type of spill would be expected only in the navigation channels and approaches of the Calcasieu and Sabine waterways.

The probability of pipeline spillage is extremely small (table 3.7). Nearly all incidents are associated with structural failure, ruptures, or leaks. Bryant (1974) used an estimate of 320,000 km (198,839 mi) of pipeline in existence during 1971 and 1972 to calculate an expected spillage of 16.3 l/km/yr(6.9 gal/mi/yr) or 0.008 incidents/km/yr (0.013 /mi/yr). Extrapolating for the estimated 7,549 km (4,691 mi) of pipelines in the Chenier Plain, an average annual spillage of about 770 bbl/yr of crude oil is predicted. Although this is small, the possibility of single large accidents exists.

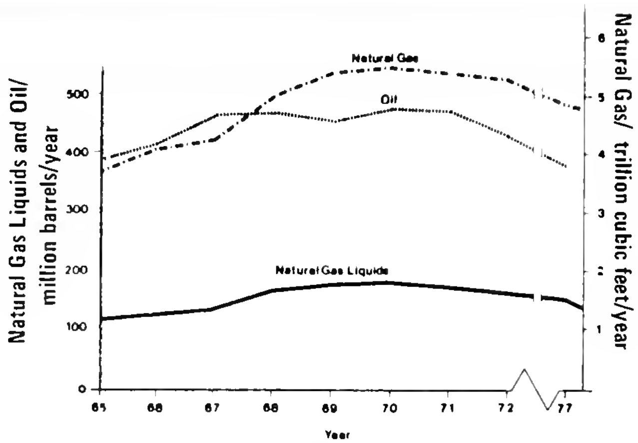


Figure 3-2a. Annual production (millions of barrels) of gas and oil in Louisiana 1965-72, and 1977 (Jones and Hough 1974).

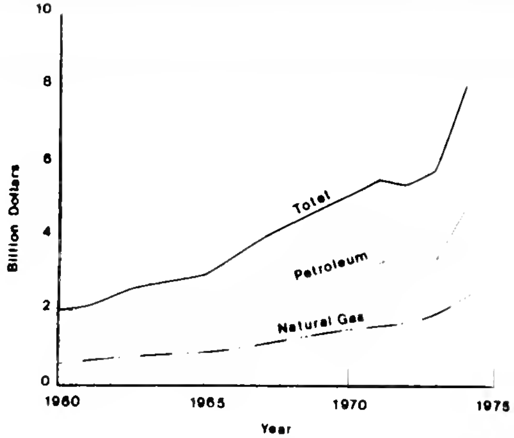


Figure 3-2b. Annual value (millions of dollars) of oil and gas in Louisiana, 1960-75 (Jones and Hough 1974).

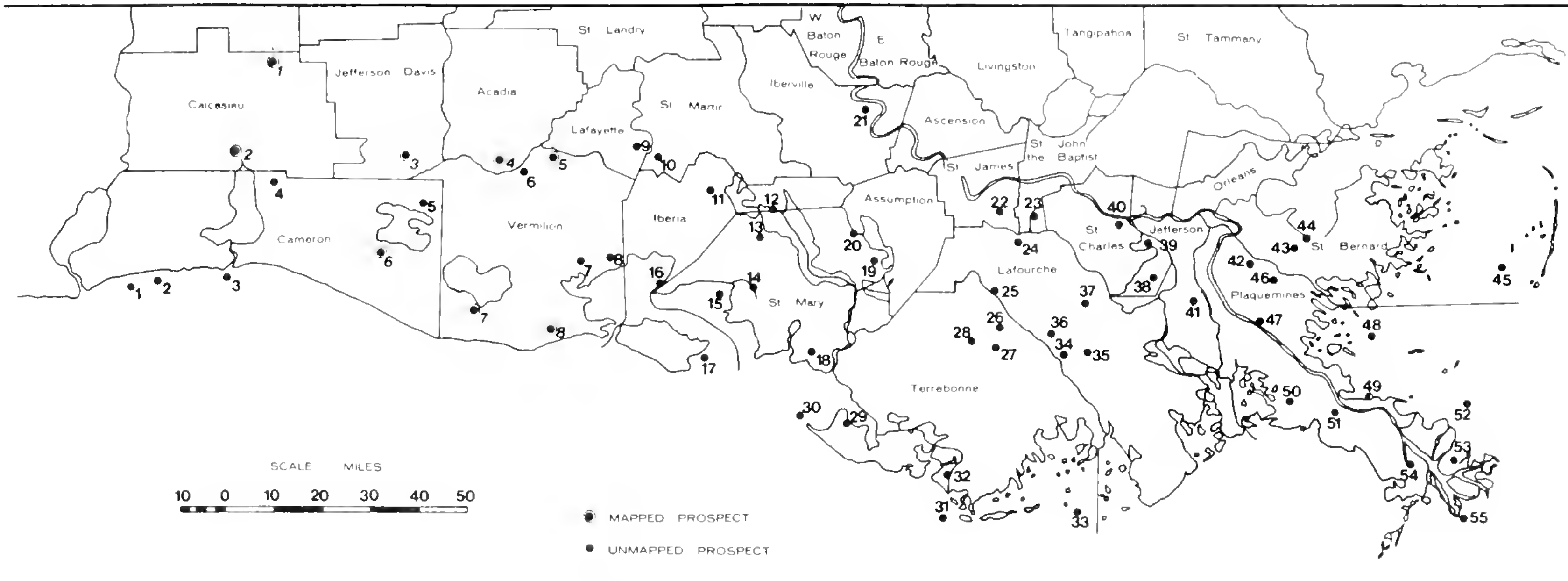


Figure 3-3. Numbered geopressure/geothermal prospect locations in southern Louisiana (Hawkins 1977).

Table 3.6. Expected oil spillage due to non-catastrophic incidents (vessel not sunk) involving seagoing vessels in superport region (Bryant 1974).

Type of incident	Probability of polluting incident per vessel-year in region	Average spillage per polluting incident, in tons	Expected spillage (tons)	
			Per vessel-year	Per vessel-day
Breakdown	0.000615	25	0.015	0.000042
Capsizing	0.000307	213	0.065	0.000178
Collision	0.0177	225	3.98	0.0109
Explosion	0.00153	72	0.11	0.0003
Fire	0.00397	360	1.43	0.00392
Ramming	0.00641	158	1.01	0.00277
Structural failure	0.00244	40	0.098	0.00027
Total			6.708	0.018380

Table 3.7. Pipeline spillage incidents and volume for the United States and its territories during 1971 and 1972 (Bryant 1974).

Incidents	Number of incidents	Spillage (bbl)	Spillage per incident (bbl)
Casualty	12	211.9	17.7
Rupture, leak or structural failure	2,266	63,367.2	28.0
Equipment failure	223	902.5	4.0
Personnel failure	40	290.4	7.3
Deliberate discharges	4	48.1	12.0
Natural phenomena	11	611.7	55.6
Unknown	26	319.9	12.3
Total	2,582	65,751.7	
Overall Average			25.5

Perhaps a more serious long-term hazard of mineral production within the inland wetlands is the chronic spilling of small quantities of oil over a period of many years. Some of this oil finds its way into the sediments of the surrounding wetlands, as shown by hydrocarbon analyses (Bishop et al. 1976). The sediments appear to act as a sink for the hydrocarbons, releasing them slowly to the bottom waters in oil field canals (Milan and Whelan 1978).

Impoundments: Leveed pits are created for confinement of brine associated with mineral extraction. The volume of brine disposed of in this fashion in the Chenier Plain is small relative to other disposal means (table 3.5). The number of these leveed pits is small and total area is insignificant, although the local impact may be important.

Probably a more important activity is the inadvertent creation of impoundments as a result of canal dredging. Spoil banks from crisscrossing canals or from canals along natural ridges may effectively cut off an area from normal water flow. The number and area of impoundments due to mineral extraction activities alone are difficult to quantify. Impoundments are discussed further in parts 3.3 and 3.4. The effect of impoundments on biota is discussed in part 4.0.

Water Based Construction: The Chenier Plain has an overall density of about 0.33 well/km^2 (0.85 well/mi^2) (Louisiana Department of Conservation 1977); the Calcasieu Basin has the highest density—0.72 well/km^2 (1.86 wells/mi^2). Probably the major impacts of well construction are disturbances of the site. Construction of pipelines is another activity associated with mineral extraction. The direct construction effects are small compared to the major impact of the resulting canals.

Canal Dredge and Spoil. The major long-term impact of mineral production on basins is the construction of canals and their associated spoil banks through shallow water bodies and wetlands. Table 3.8 shows the length and area of these canals (plates 5A and 5B). The majority of canals provide access for navigation, although road embankment canals become increasingly important toward the west end of the Chenier Plain. Most pipeline canals are back-filled, but many later become shallow-water linear features because of compaction and erosion. (See part 3.3 for a discussion of impacts of canals.) Oil field activity canals cover about 6,700 ha (6,556 a) of the Chenier Plain. Associated spoil banks cover anywhere from two to three times as much area as the canals (Craig et al. 1979). Using a conservative factor of twice the canal area for spoil banks, the total land permanently impacted by canals and spoil banks is about 20,000 ha (49,421 a). This type of modification is discussed in part 3.4.

Table 3.8. Lengths and areas of oil production related canals for each basin and the total for the Chenier Plain.

Basin	Navigation canals Length (km)	Navigation canals Area (ha)	Canals for road embankments Length (km)	Canals for road embankments Area (ha)	Open pipeline canals Length (km)	Open pipeline canals Area (ha)	Total Length (km)	Total Area (ha)
Vermilion	137.3	824	15.5	11	25.3	13	178.1	848
Mermentau	310.4	1,863	56.5	40	84.7	42	451.7	1,945
Chenier	150.3	902	109.3	76	75.1	38	334.7	1,016
Calcasieu	122.7	736	115.2	81	41.3	31	279.2	848
Sabin, La.	120.2	721	76.2	53	13.3	7	209.7	781
Sabine, Tex.	41.3	248	1.7	1	0.6	1	43.6	250
Sabine Total	161.5	969	77.9	54	13.9	8	253.3	1,031
East Bay	5.5	33	0	1	0	0	5.5	33
Total	887.7	5,327	374.5	263	240.3	132	1,499.5	5,721

3.2.3 AGRICULTURE

Production. The magnitude of the agricultural industry in the Chenier Plain is indicated by the total farm acreage, the acreage of rice and other cultivated crops, and the total number of farms (fig. 3-4). About 147,000 ha (363,492 a) were being farmed in 1975. Forty percent of this was cropland; the rest was pasture. Of the cropland, 87% was rice. In 1974, rice area was 48,600 ha (120,093 a) and the average yield was 3.9 t/ha (1.75 tons/a) (Fielder and Guy 1975). The Mermentau and Sabine basins are the major agricultural producing areas (plate 3B).

The total market value of the region's agricultural products in 1974 was about $28 million. About $20 million of this was derived from crop production, chiefly rice (table 3.9). These figures are estimates for individual basins, calculated from parish (county) production figures. An average value per hectare of farmland was calculated from the parish (county) information. This value was used with the farm area (determined from 1975 U.S. Geological Survey orthophotoquads) to estimate the total value of agricultural products. The data (U.S. Department of Agriculture 1975) indicate there is a wide discrepancy across the Chenier Plain in the market value of agricultural products per hectare of farmland. This value varied in 1974 from a low of about $126/ha ($51/a) in the Sabine Basin to a high of $370/ha ($150/a) in Vermilion Basin. The reason for variation is unclear but is probably related to the proportion of the total farm area in rice production and the proportion which was fallow in 1974. For instance, Cameron Parish, Orange, and Galveston counties, all had low ratios of harvested cropland to total cropland [0.35, 0.32, and 0.42 respectively; (U.S. Department of Agriculture)], and low ratios were associated with low market values per hectare. The Mermentau and Sabine basins produce the highest total values of farm products because of the large areas involved, in spite of the relatively low

Table 3.9. Estimated farm area and value of all agricultural products and of crops by basin in 1974.

Basin	Market[a] value of all agricultural products: Farm area (ha)	Value/ha ($)	Total value ($ x 1,000)	Estimated value of crops: Crop area (ha)	Value/ha[b] ($)	Total value ($ x 1,000)
Vermilion	5,374	370	1,988	2,056	448	917
Chenier	3,421	193	660	670	314	210
Mermentau	59,435	240	14,264	36,366	348	12,655
Calcasieu	13,238	168	2,224	7,268	326	2,369
Sabine, La.	5,944	126		1,221	282	
			6,242			2,222
Sabine, Tex.	43,590	126		8,941	210	
East Bay	19,420	136	2,641	3,765	322	1,212
Total	150,422		$28,107	60,282		$19,586

[a]U.S. Department Agriculture 1975. See appendix 6.2 for details of data conversion from parish-based (county-based) basin.
[b]Calculated as in a) using parish values for value per acre of total cropland (Orange $61; Galveston $79.7; Jefferson $205.1; Chambers $181.6; Calcasieu $145.6; Cameron $90.8; Jefferson Davis $201.4; Vermilion $180.4).

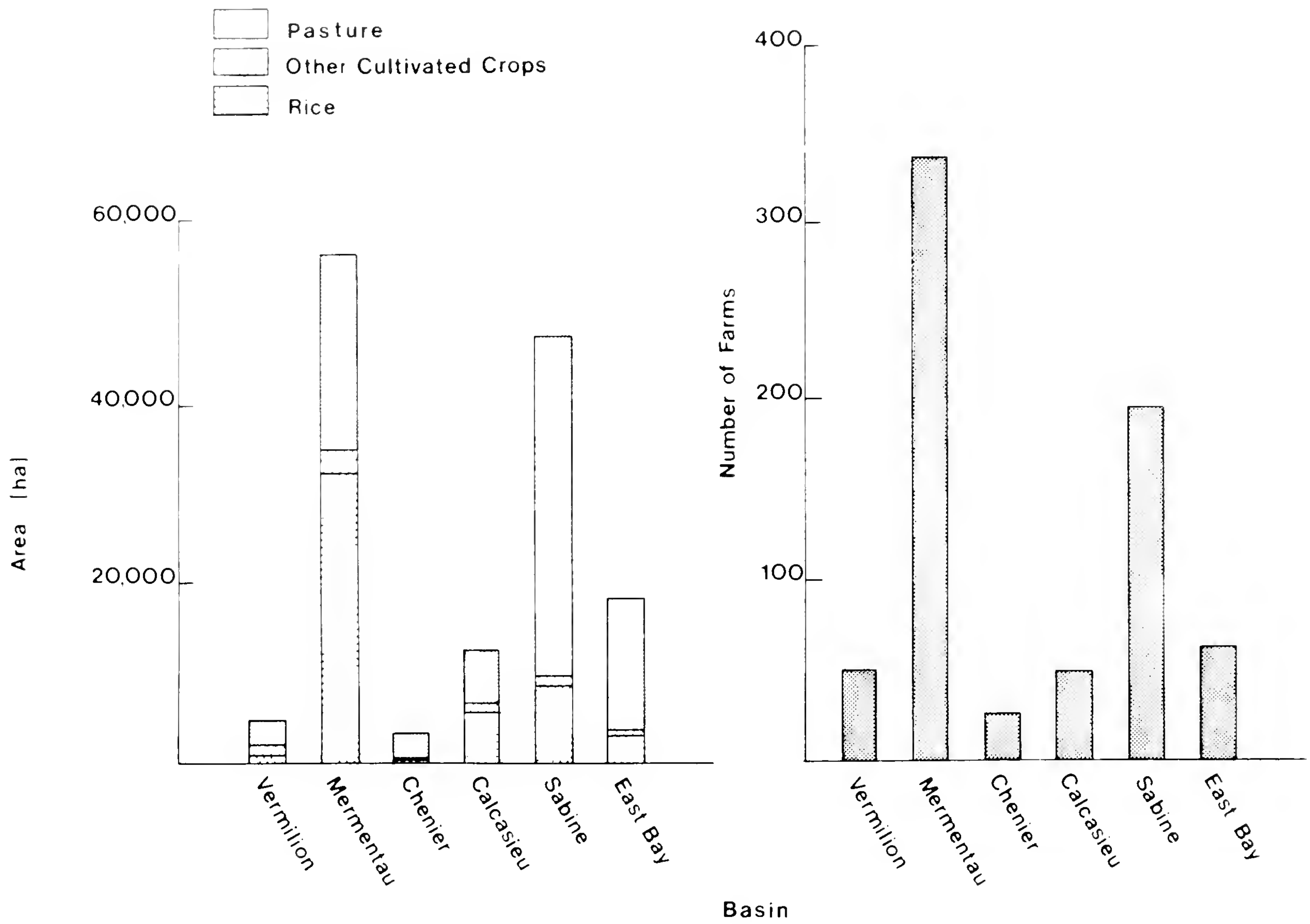


Figure 3-4. Area and number of farms in each basin of the Chenier Plain (U.S. Department of Agriculture 1975).

values per unit area in the Sabine Basin. In contrast to the total agricultural value, the crop value per hectare of cropland in 1974 varied much less [from about $250/ha ($101/a) in Sabine Basin to $445/ha ($180/a) in Vermilion Basin].

Since the early 1900s, the total area of cropland on the Louisiana coast has been declining slowly (fig. 3-5), although the production per hectare for rice has increased in a spectacular manner (Fielder and Guy 1975). In the Chenier Plain, agricultural habitat has increased 4% since 1952 (table 3.10). This small increase generally reflects a substantial (9 to 45%) increase in the eastern part of the Chenier Plain with a net loss in Sabine and East Bay basins.

Agricultural Activities that Affect the Environment. Loss of natural habitats to agriculture: Agricultural activities take place in areas that were formerly wetland, ridge, or upland forest. Over 80% (7,285 ha) (1,800 a) of the increased agricultural area since 1952 has resulted from draining natural and impounded wetlands. Another 1,500 ha (3,707 a) have been "reclaimed" from natural ridges and forested land. As figure 3-5 shows, most of the land currently in agriculture was being farmed many years before 1952. These old sites developed first on the fertile prairies of the Chenier Plain and later on cleared upland forests of the region. The normal sequence is to use high, well-drained grasslands first, then to clear upland forests, and finally to drain wetlands. At the same time, urban expansion takes over agricultural land, as shown for the Sabine Basin in table 3.11. Between 1952 and 1974 there was no reversal of this process in the Chenier Plain. That is, no agricultural land reverted to natural wetlands or uplands, although in the Sabine Basin, 204 ha (504 a) of pasture were converted to open water habitat.

Table 3.10. Areal changes in agriculture habitats from 1952 through 1974.

	Areal changes[a] in land usage							
	Rice		Non-rice crops		Pasture		Total	
Basin	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Vermilion	+551	+30.8	+451	+51.5	+676	+25.6	+1,678	+45.4
Mermentau	+2,238	+ 7.3	+877	+34.9	+1,893	+ 8.9	+5,008	+ 9.2
Chenier	+29	+76	+196	+48.2	+120	+ 4.6	+ 345	+11.3
Calcasieu	+1,300	+30	+214	+16.0	-352	- 5.6	+1,162	+ 9.6
Sabine	- 945	- 9.4	+20	+ 1.9	-1,277	- 3.1	-2,202	- 4.3
East Bay[b]	- 386	- 9.8	+68	+51.9	+121	+ 0.8	- 197	- 1.0
						Total	+5,794	+ 4.0

[a]Increase (+) or decrease (-) from 1952 area.

[b]For East Bay from 1954 to 1974.

Table 3.11. Hectares of natural habitat converted to agriculture, and agricultural habitat converted to urban use in the Chenier Plain from 1952 to 1974.

	Basin						
Habitat converted to agriculture	Vermilion	Mermentau	Chenier	Calcasieu	Sabine	East Bay	Total[a]
Natural marsh	619	2,466	none	1,049	321	none	4,455
Impounded marsh	800	2,030	none	none	none	none	2,830
Natural ridge	104	145	376	62	20	none	707
Spoil	none	none	none	140	none	none	140
Upland forest	177	289	---[b]	199	none	---	665
Swamp forest	none	118	---	none	none	---	118
Total	1,700	5,048	376	1,450	341	none	8,915
Agricultural habitats converted to urban use	22	40	31	272	2,339	197	2,901

[a]The totals do not agree with the total habitat changes in table 3.10 because some minor conversions are not shown.

[b]Broken line indicates that habitat does not exist in the basin.

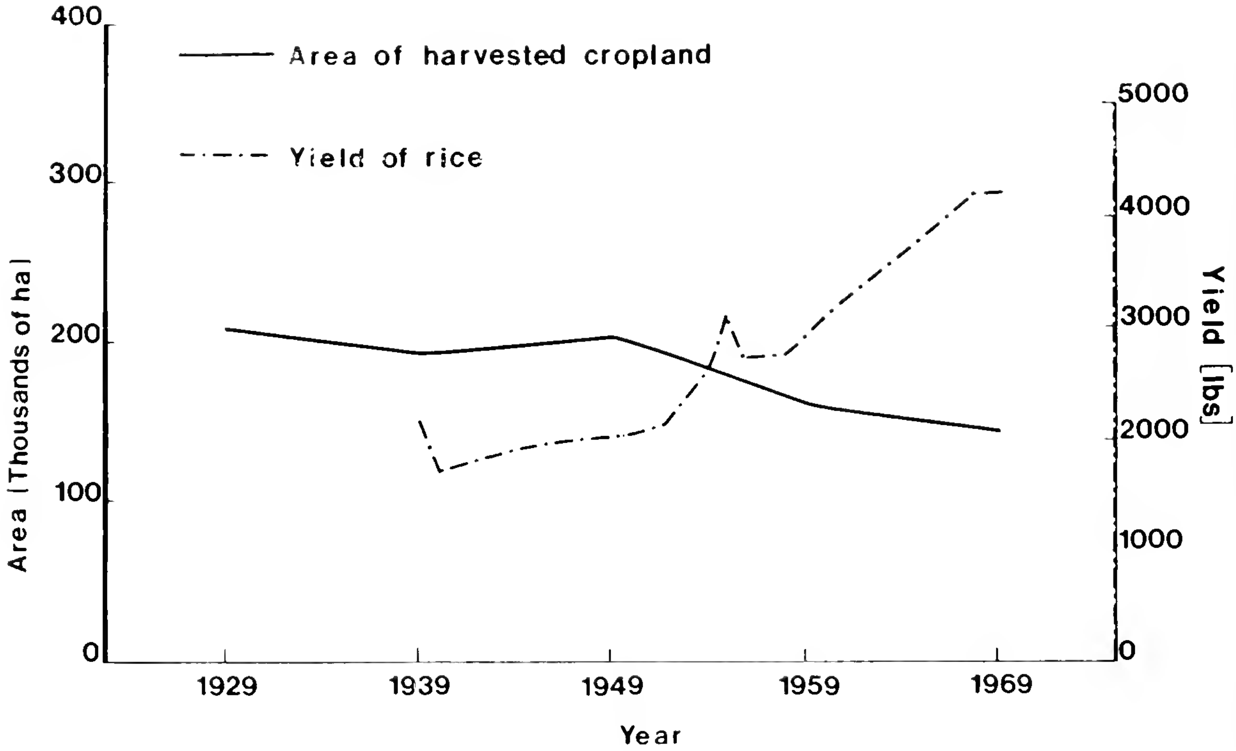


Figure 3-5. Change in area of harvested cropland and yield of rice in coastal Louisiana (Corty 1972, Fielder and Guy 1975).

Agricultural Drainage Canals. About 3,450 km (2,144 mi) of agricultural canals (40% of the total length of all canals in the Chenier Plain) were dredged primarily for agricultural drainage or access (table 3.12). Canal density in individual basins varies from 0.37 to 0.56 km/km^2 (average of 0.46 km/km^2). About half of these canals drain upland areas. The rest flow through wetlands adjacent to the uplands (plates 5A and 5B). The agricultural drainage canals form a gridlike network along the northern parts of the Chenier Plain. The impacts of these canals on the natural system are discussed in parts 3.3, 3.4, and 3.5.

Agricultural Runoff. Canals are dredged in the low-lying agricultural lands of the Chenier Plain primarily to drain the land and not for irrigation, since much of the water for flooding rice land comes from wells (see the following section about Surface- and Ground-water Use). The accelerated runoff increases erosion and the leaching of fertilizers and manure from the soil. The U.S. Department of Agriculture (1975) reports that an average of 0.38 ±0.04 tonnes fertilizer is used on each fertilized acre in the Chenier Plain parishes. This amount and the

Table 3.12. Length and density of agricultural drainage and access canals in the Cheneir Plain basins[a].

Basin	Upland (km)	Wetland (km)	Total (km)	Density[b] (km/km^2)
Vermilion	66.2	167.4	233.6	0.41
Mermentau	668.2	488.3	1,156.5	0.56
Chenier	0	329.2	329.2	0.37
Calcasieu	217.5	300.0	517.5	0.55
Sabine, La.	58.5	83.9	142.4	
Sabine, Tex.	553.5	212.2	765.7	
Sabine Total	612.0	296.1	908.1	0.37
East Bay	197.2	108.1	305.3	0.56
Total	1,761.1	1,689.1	3,450.2	0.46

[a]Wetland drainage plus canals associated with access roads.

[b]Total canal length (km) ÷ area (km^2) of wetlands and uplands in basin.

proportion of acres fertilized were used to estimate the total fertilizer use in the Chenier Plain (table 3.13). Probably the major use is in rice cultivation where the fertilizer blend of 18-18-9 (percent N-P_2O_5-K_2O) is commonly applied at planting time. The resultant nutrient load (expressed as phosphorus) to basin waters and its contribution to eutrophication are discussed later.

Use of agricultural areas by wildlife: Although the creation of agricultural land destroys natural habitat (for instance, the loss of the grassland habitat of the Attwater prairie chicken), it also provides an important concentrated food source that is available to some wildlife, particularly migratory birds. The use of rice fields and pastures by waterfowl is discussed in part 5.0. The agricultural areas appear to be especially valuable when conditions are unfavorable in adjacent wetlands.

Surface- and Ground-water Use. Rice irrigation puts severe seasonal demands on the freshwater supply in the Chenier Plain. Since over 95% of the water used for agriculture (fig. 3-6) in Louisiana is for rice production (98% in the southwest portion of the state, including the Louisiana portion of the Chenier Plain (Louisiana Department Public Works 1971), other agricultural uses will be ignored. Considering the rice area in the Chenier Plain basins, the freshwater usage for rice ranges from 0.7 million m^3 (24.7 million ft^3) in the Chenier Basin to 320 million m^3 (11,301 million ft^3) in the Mermentau Basin (fig. 3-7) for an estimated total of 571 million m^3 (20,165 ft^3) (based on 3.11 acre-feet per acre, Louisiana Department Public Works 1970). The timing of this withdrawal is ecologically important since it corresponds with the hottest months of the year when water demand by natural vegetation is also at its peak (fig. 3-8).

In the southwestern part of Louisiana (including Vernon, Beauregard, Allen, Evangeline, St. Landry, and Acadia parishes as well as the Chenier Plain parishes), 38% of the required water is purchased from commercial suppliers, 28% is self-supplied from surface water, and the rest is pumped from groundwater by the rice growers (table 3.14). Overall, about 66% of the water is drawn from the surface, the rest from wells. The Vermilion River and the Gulf Intercoastal Waterway (GIWW) supply about 26% of the total irrigation surface water used in southwestern Louisiana. Other principal water sources for surface water in the Chenier Plain region are tabulated by the Louisiana Department of Public Works (1970).

The use of surface and ground water for agricultural irrigation is only one demand on this renewable resource. The total demand and environmental implications are discussed in part 3.5.3.

Table 3.13. Area of agricultural lands, fertilized lands, and tons of fertilizer used for each Chenier Plain basin.[a]

Basin	Agricultural land (ha)	Fertilized land[b]		Quantity used[c] (t)
		Percent of agricultural land	Area (ha)	
Vermilion	5,374	0.45	2,418	917
Mermentau	59,435	0.24	14,264	5,411
Chenier	3,421	0.29	992	376
Calcasieu	13,238	0.25	3,310	1,256
Sabine, Total	49,534	0.15	7,430	2,818
East Bay	19,420	0.14	2,719	1,030
Total	150,422		31,133	11,809

[a]Fertilizer ratio not stated in U.S. Department of Agriculture (1975), but the common ratio for rice is 18-18-9 (N-P_2O_5-K_2O).

[b]Calculated from the parish percentage of fertilized land (U.S. Department of Agriculture 1975) converted to basin values using agriculture factors developed from the rural population figures (appendix 6.2).

[c]At a rate of 0.173 ± .019 short tons/a (0.379 metric tonnes/ha) (U.S. Department of Agriculture 1975).

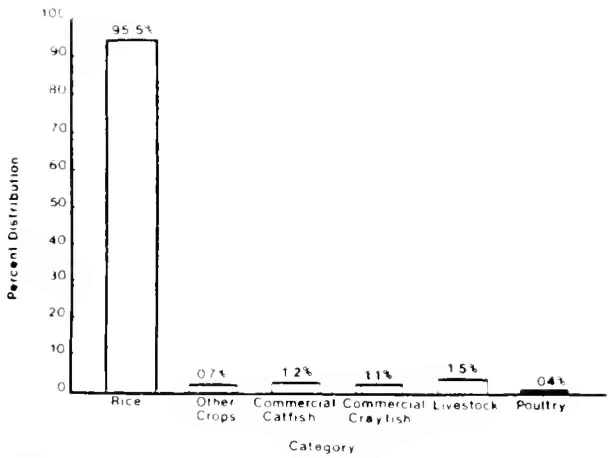


Figure 3-6. Water usage for agriculture in Louisiana in 1967 (Louisiana Department Public Works 1970).

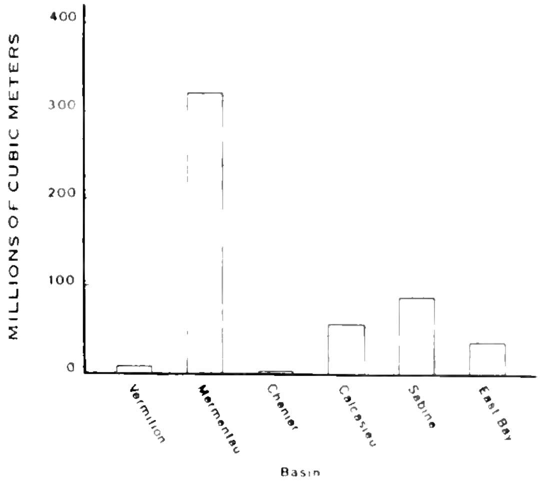


Figure 3-7. Volume of water used for agriculture in each basin (Louisiana Department of Public Works 1970).

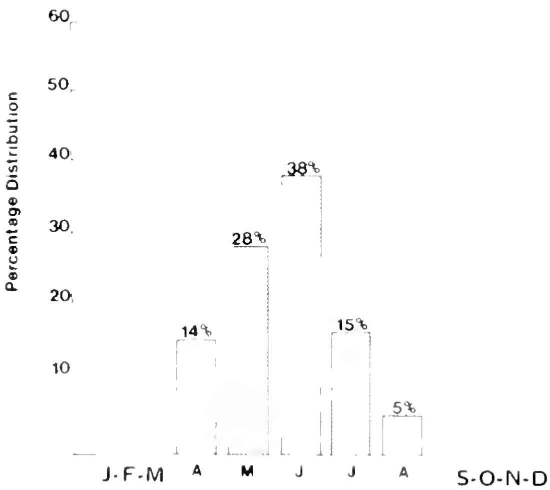


Figure 3-8. Percentage distribution of monthly water usage in southwestern Louisiana in 1967 (Louisiana Department of Public Works 1970).

Table 3.14. Source and volume (millions of cubic meters) of water for irrigation in southwest Louisiana (Louisiana Department of Public Works 1970).

Source	Surface water	Ground-water	Total
Purchased	787		787
Self-supplied	584	718	1,302
Total	1,371 (66%)	718 (34%)	2,089 (100%)

3.2.4. COMMERCIAL TRAPPING AND FISHING

Production. The commercial harvest of wildlife resources on the Chenier Plain includes furbearers and commercial fishes. The fur and commercial fishery industries are basically noncompetitive since they require different equipment and harvest from different habitats; however, both industries involve organisms which depend on wetlands for at least a portion of their life cycles.

Furbearers: The trapping of mammals (primarily muskrat and nutria) for fur is more closely controlled, since trapping occurs primarily on private lands or refuges for which permits or leases are required. Muskrats, which represent a significant proportion of the total fur catch, are fairly easy to quantify. The 1973 harvest of nutria and muskrat in southwest Louisiana amounted to 749,670 and 86,087 pelts, respectively (table 3.15). During the same period, the combined estimated harvest of both species from the Texas portion of the Chenier Plain was about 35,000 pelts (Bill Brownlee, pers. comm., Texas Parks and Wildlife Department).

In the western part of Louisiana, muskrat and nutria harvest totaled about 1,600,000 pelts in 1975 (fig. 3-9). The number of pelts harvested in eastern Louisiana has also fluctuated, but appears to be increasing after a low during the 1970 to 1974 period.

The annual harvest density of muskrat and nutria on the Chenier Plain was estimated at 147,000 and 429,000 pelts, respectively, by Palmisano (1972a and 1972b) (table 3.16). These estimates were in line with the actual pelt harvest statistics for western Louisiana and for eastern Texas (appendix 6.2). In addition, the expected harvest of nutria and muskrat by basin indicated that Sabine and Calcasieu basins should yield the most muskrat and the Mermentau Basin should be optimum for nutria (figs. 3-10 and 3-11). The values of the pelts to the trappers was around $3.2 million,

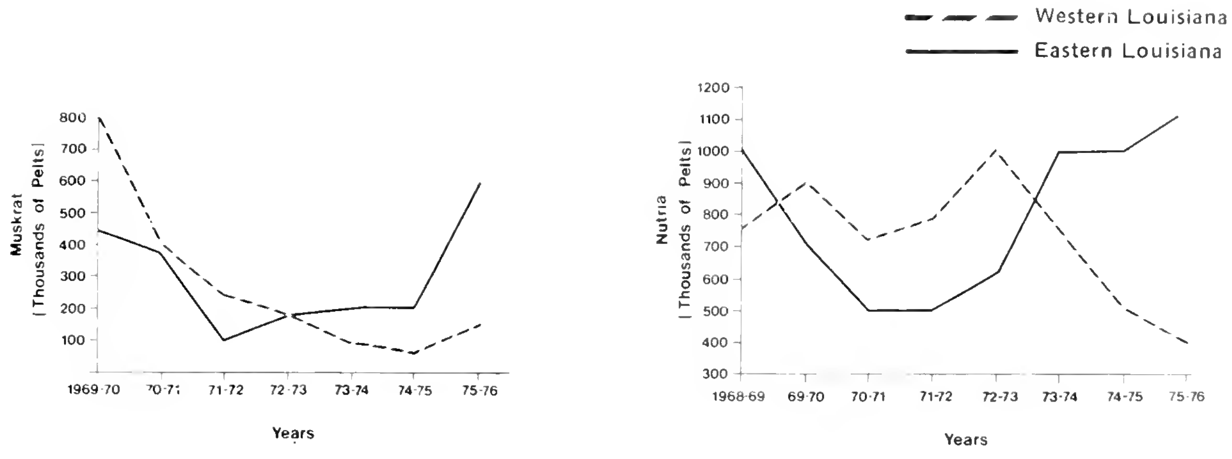


Figure 3-9. Annual muskrat and nutria pelt production for coastal Louisiana 1968-76 (Louisiana Department of Wildlife and Fisheries).

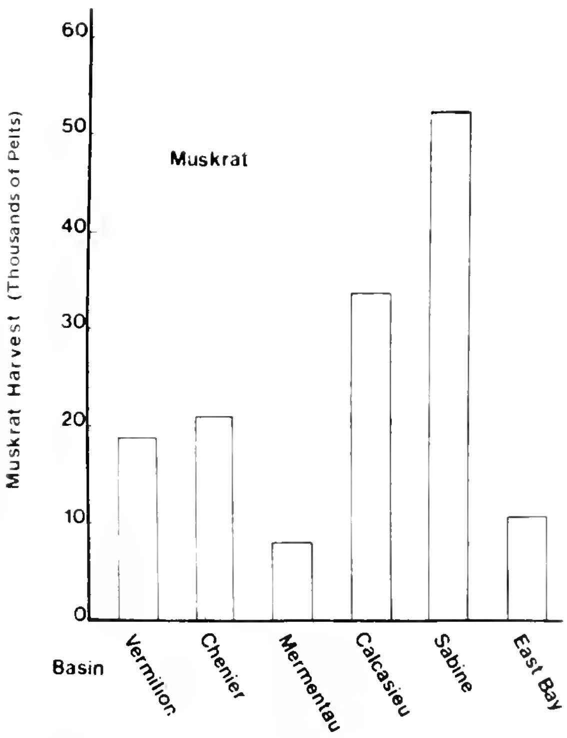


Figure 3-10. Estimated number of muskrat pelts produced from the Chenier Plain basins, based on 1975 habitat areas and on harvest densities determined by Palmisano (1972a).

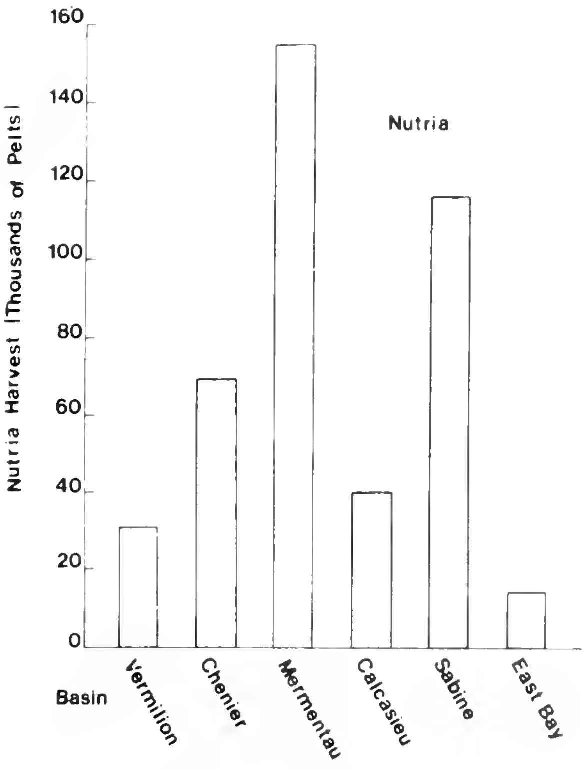


Figure 3-11. Estimated number of nutria pelts produced from the Chenier Plain basins, based on 1975 habitat areas and harvest densities determined by Palmisano (1972b).

Table 3.15. Harvest and value of fur animals in Louisiana in 1973 (Louisiana Department of Wildlife and Fisheries).

Species	Number of pelts	Average price per pelt ($) (1973 price)	Value ($)
Nutria (eastern La.)	1,000,000	4.50	4,500,000
Nutria (western La.)	749,670	6.00	4,498,020
Muskrat (eastern La.)	200,000	3.25	650,000
Muskrat (western La.)	86,087	4.50	387,392
Mink	38,940	7.00	272,580
Raccoon (coastal)	45,000	6.00	270,000
Raccoon (upland)	139,688	7.50	1,047,660
Opossum	33,676	1.50	50,514
Otter	5,989	30.00	179,670
Skunk	747	1.25	934
Fox	3,312	15.00	49,680
Bobcat	953	20.00	19,060
Beaver	472	6.00	2,360
Coyote	382	12.00	4,584
Total pelts and value	2,304,916		11,932,454
	Pounds of meats	Average price per pound	
Nutria	11,000,000	0.09	990,000
Muskrat	250,000	0.09	22,500
Raccoon	1,000,000	0.30	300,000
Opossum	300,000	0.25	25,000
Total meat and value	12,550,000		1,387,500
		Total	13,319,954

Table 3.16. Estimated Chenier Plain harvest of muskrat and nutria, based on habitat area and yield per unit area (Palmisano 1972a, b)

Habitat	Area (1,000 ha)	Pelt harvest/1,000 ha Muskrat	Pelt harvest/1,000 ha Nutria	Estimated harvest Muskrat (No. of pelts)	Estimated harvest Nutria (No. of pelts)
Fresh marsh & impounded	278	52	1,236	14,460	343,600
Intermediate marsh	85	346	741	29,400	63,000
Brackish marsh	101	971	222	98,100	22,400
Salt marsh	17	297		5,050	—
			Total	147,010	429,000
		Actual 1975 pelt harvest[a]		150,000	400,000

[a]For western Louisiana see figure 3.9.

using pelt values of $4.50/muskrat and $6.00/nutria. The highest returns of nearly $1 million each per basin for muskrat and nutria pelts came from Mermentau and Sabine (table 3.17).

Alligator: Closely controlled alligator harvests have been conducted in the Louisiana portion of the Chenier Plain since 1972. In 1976, the total revenue from this industry was about $0.5 million (table 3.18).

Commercial estuarine-dependent fishery: The commercial fishery includes the estuarine-dependent marine and brackish water fishery, shellfishery, and the freshwater fishery.

Commercial catches of estuarine-dependent species for the northern Gulf coast are recorded by major inshore estuarine lake or bay or by offshore grid zone [National Marine Fisheries Service (NMFS) 1976]. Many locally knowledgeable fishery biologists believe that only a fraction of the landings for species other than Gulf menhaden are actually recorded by NMFS statistics. However, these statistics are the only consistent landing records available. The bulk of the harvest occurs offshore, but part of the life of the commercially important species is spent in the inland marshes and estuaries. That is, each species must be able to enter marshes, estuaries, and offshore waters at appropriate stages of its life cycle (part 4.0). Furthermore, the commercial species move alongshore,

Table 3.17. Estimated value[a] of the muskrat and nutria fur industry for each basin.

Basin	Harvested pelts		Value		Total
	Muskrat	Nutria	Muskrat[b]	Nutria[c]	value $
Vermilion	19,500	31,324	87,750	187,944	275,694
Chenier	20,874	69,519	93,933	417,114	511,047
Mermentau	8,280	155,800	37,260	934,800	972,060
Calcasieu	34,050	40,320	153,225	241,920	395,145
Sabine	52,625	116,780	236,812	700,680	937,492
East Bay	11,402	14,895	51,309	89,370	140,679
Total	146,731	428,638	660,290	2,571,828	3,232,117

[a]Calculated from area and estimated harvest per unit area as in table 3.20.

[b]At $4.50/pelt.

[c]At $6.00/pelt.

Table 3.18. Value of alligators harvested from the Louisiana portion of the Chenier Plain for 1972 through 1976.

	Number of animals harvested and sold	Average size	Average price per linear foot ($)	Total revenue ($)
1972[a]	1,350 (1,337 sold)	6'11"	8.10	74,773.00
1973[b]	2,821 (2,916 sold)[c]	7'1"	13.13	268,542.45
1975[d]			8.00	251,876.00
1976[d]	4,300 (4,360 sold)[c]	7'0"	16.50	509,060.00

[a]Palmisano et al. 1973.

[b]Joanen et al. 1974.

[c]Included farm-raised animals.

[d]Louisiana Wildlife Fish Commission News Release, New Orleans, La., 19 October 1976.

probably westward with the prevailing currents so that the catch in a grid zone offshore of a particular basin may have little relationship to the ability of that basin to provide for the needs of a species throughout its entire life history. An excellent example is the Sabine Basin. The shrimp fishery offshore of Sabine is a thriving one, but in recent years the Sabine estuary has produced no commercial landings of shrimp (National Marine Fisheries Service 1976). Therefore, most of the shrimp caught offshore of the Sabine Basin use other inshore areas as nurseries.

The approach used in analyzing fishery data for this report was that of Lindall et al. (1972). The total offshore yield in Louisiana was attributed to various basins based on the relative densities of juveniles caught inshore and the estuarine habitat area of each basin (National Marine Fisheries Service 1976). Relative inshore juvenile densities were based on trawl catches reported in the Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana (Perret et al. 1971). This approach recognizes the value of the inland nursery ground even though it is not the immediate site of the fishery catch.

A total of 244,511 t (539 million lb) of fishery products were harvested from the Chenier Plain in 1975 (table 3.19). (Appendix 6.2 shows figures for 1970 through 1975.) Gulf menhaden accounted for about 95% of the tonnage landed in the Chenier Plain. Shrimp were a distant second with 2.9%. The only other species of significant commercial value were blue crab and American oyster. There are also small landings of other finfishes, such as sea trout and red drum (redfish). The catch of the estuarine-related freshwater species is also recorded. Of these, members of the catfish family are the only species currently reported. Apparently no commercial harvest of wild crayfish presently exists in the Chenier Plain, although landings were reported as recently as 1972.

In terms of dockside value, menhaden (49%) and shrimp (44%) produce most of the income, followed by oyster and blue crab. The total dockside value of the industry in the Chenier plain was about $31 million in 1975.

Table 3.19. Weight and value of commercial landings of fish in western Louisiana and the Galveston area in 1975 (U.S. Department Commerce 1976).

Fishery	Weight		Value	
	(kg x 1,000)	(Percent of total)	($ x 1,000)	(Percent of total)
Estuarine-dependent marine fisheries				
Menhaden	233,872	95.6	15,423	49.2
Shrimp	7,024	2.9	13,777	44.0
Blue crab	2,257	0.01	763.3	2.4
Oyster	561.0	0.002	957.3	3.1
Sea trout	216.3	0.001	183.3	0.01
Redfish	49.3	trace	38.1	0.001
Flounder	23.0	trace	18.2	0.0006
Subtotal	244,002.6		31,160.2	
Estuarine-related freshwater fishery				
Catfish & bullhead	124.6	trace	93.9	0.003
Other species	384.0	0.002	65.0	0.002
Subtotal	508.6	0.002	158.9	0.005
Total	244,511.2		31,319.1	

The calculated total harvest (offshore and inland) of estuarine-dependent fishes and shellfishes per hectare of inland water (salinity > 5‰) in the Chenier Plain showed that the Chenier Basin had the highest production (table 3.20). Vermilion Basin values were derived from Hydrologic Unit VII; Chenier Basin values, from Hydrologic Unit VIII; and Calcasieu and Sabine basins values from Hydrologic Unit IX as described in Lindall et al. (1972). East Bay Basin values were determined from Texas landings for grid zone 18, inshore and offshore. The mean 1970 through 1975 reported catch for each species was divided by the Galveston Bay inshore estuarine area (mean salinities > 5‰). Exceptions were blue crab and Gulf menhaden values. Blue crab production for Sabine Lake was calculated directly from landing data because of the high local production (appendix 6.2). No commercial menhaden landings occur in Texas although menhaden is a dominant juvenile fish in Galveston Bay and Sabine Lake (Reid 1955). The menhaden industry is based in Louisiana and Mississippi; catches in east Texas waters are reported in Louisiana today. The menhaden value determined for Hydrologic Unit IX (Lindall et al. 1972) was used for all three western basins.

The total production of each basin was calculated on the basis of unit area values (table 3.21). Calcasieu, Sabine, and East Bay basins had high menhaden production. Calcasieu and East Bay basins also support important shrimp fisheries. The Sabine Basin shrimp production (as contrasted to the Sabine offshore harvest) is probably insignificant; the last inshore commercial harvests occurred in 1972 (appendix 6.2). Some shrimp are occasionally caught in Sabine Lake, so the basin may make some contribution to the offshore fishery. Similarly, Atlantic croaker and sea trout harvests have fallen to nothing, and the oyster beds are permanently closed because of contamination (part 3.6.6). It should be noted that there is relatively large production of blue crab in Sabine Basin and large production of oysters in East Bay Basin. In effect, the Mermentau Basin is freshwater, having little exchange with the nearshore zone. It had been assumed to support no marine fishery, but recent water management practices may have changed this (part 3.6.3).

Table 3.20. Estimated commercial catch per hectare of inshore area in 1963 - 1973 for estuarine-dependent fishes and shellfishes.[a]

Species	Basin					
	Vermilion	Chenier	Mermentau[b]	Calcasieu	Sabine	East Bay[c]
Menhaden	183	1,391		439	439	439
Shrimp	9.8	47		27	(27)[d]	27
Blue crab	4.0	4.6		3.9	17.1	6.6
Oyster (meat)	0.1			1.2		8.1
Croaker	8.4	29.4		20.2		0.07
Sea trout	1.7	8.1		4.1		0.54
Spot	2.0	10.3		4.8		
Red drum	0.01	0		0.2	0.2	0.12
Total	209.01	1,490.4		500.4	483.3	481.43

[a]Based on 1963-1973 average Louisiana production and inshore juvenile density. From table 31, Fish and Wildlife Study (Lindall et al. 1972). The densities were reported by hydrologic unit for Louisiana. The value used for Vermilion was that of Unit VII; Chenier and Mermentau, Unit VIII; and Calcasieu and Sabine, Unit IX.

[b]Mermentau Basin has no salinity greater than 5‰.

[c]Mean inshore and offshore Grid 18 yield 1970-1976 divided by estuarine water area of Galveston Bay.

[d]This value is based on the 1963-73 production mean and 1967 trawl data. Since that time, commercial production has ceased in Sabine Lake and trawl catches showed low densities of shrimp.

Table 3.21. Estimated contribution[a] of each Chenier Plain basin to the commercial harvest of fishes and shellfishes (kg x 1000).

	Vermilion	Chenier	Mermentau[b]	Calcasieu	Sabine	East Bay
Menhaden	2,835	5,488		13,136	12,459	11,047
Shrimp	151	186		803	763[c]	679
Blue crab	62.6	18.2		117	85	166
Oyster	1.6			36.9		204
Croaker	13.1	116.1		603		1.7
Sea trout	26.1	31.9		124		13.5
Spot	31.3	40.8		144	137	
Red drum	0.2	trace		6.7	6.4	3.0

[a]Calculated from inland estuarine area and production per unit area of table 3.20.

[b]Mermentau basin has no salinity greater than 5 ‰.

[c]Sabine probably no longer contributes significantly to the offshore catch.

The commercial fishery harvest is largely dependent on the three westernmost basins (table 3.22). These basins appear to have near optimal conditions for estuarine-dependent species (part 4.0). Large expanses of wetlands connect to inland brackish bays and lakes. The Vermilion Basin appears to be less productive, perhaps because of excessive freshwater and silt discharged from the Atchafalaya River. The Chenier Basin is highly productive on a per unit area basis, but it is too small to support a high total production.

Table 3.22. Estimated landed value ($ x 1,000) of estuarine-related fishes and shellfishes, by basin.

	Value per kg[a] ($)	Value ($ x 1,000)					
		Vermilion	Chenier	Mermentau[b]	Calcasieu	Sabine	East Bay
Gulf menhaden	0.093	262.5	508.2		1,216.3	1,153.6	1,027.3
Shrimp	2.15	325.3	400.3		1,724.0	1,638.2[c]	1,459.9
Blue crab	0.26	16.6	4.8		31.1	126.1	3.2
Oyster	1.37	2.1			50.4		279.5
Atlantic croaker	0.073	0.9	8.4		43.9		0.1
Sea trout	1.10	28.8	35.2		136.5		14.9
Spot	0.055	1.7	2.2		8.0	7.5	
Red drum	0.46	0.1	trace		3.1	2.9	1.4
Total		638.0	959.1		3,213.3	2,928.3	2,826.3

[a]Calculated from table 3.21 and the 1973 dockside value (Lindall et al. 1972).

[b]Mermentau Basin has no salinity greater than 5‰.

[c]No commercial shrimp production currently exists in Sabine Lake, which suggests that the offshore catch is not dependent on Sabine Lake.

Estuarine-related freshwater fishes and shellfishes: The commercial value of the freshwater fishery on the Chenier Plain is negligible compared to the estuarine-dependent fishery (table 3.19). Production per unit area, total production, and dollar value were calculated by basin the same way as for the estuarine-dependent species (tables 3.23, 3.24, and 3.25). The largest calculated value of $100,000 in the Mermentau Basin would support only a few fishermen full time.

Table 3.23. Commercial production (kg) per unit of area (ha) of freshwater fishes for each basin (Lindall et al. 1972).

	Basin					
Species	Vermilion	Chenier	Mermentau	Calcasieu	Sabine	East Bay[a]
Catfish and bullhead	3.69	1.91	1.91	0.08	0.08	
Crayfish	0.61	0.30	0.30			
Buffalo	0.98	0.37	0.37			
Gar	3.25	0.40	0.40	0.47	0.42	
Carp	0.01	0.07	0.07			

[a]East Bay has no commercial freshwater fishery.

Table 3.24. Estimated total commercial production of freshwater fishes by basin[a] (number of hectares of freshwater area in parentheses).

	Basin					
Species	Vermilion (3,450)	Chenier (1,678)	Mermentau (104,545)	Calcasieu (11,000)	Sabine (17,503)	East Bay[b] (1,388)
Catfish & bullhead	12,760	3,197	117,177	863	1,373	
Crayfish	2,088	508	18,610			
Buffalo	3,364	620	22,745			
Gar	11,214	677	24,814	5,178	8,239	
Carp	39	113	4,136			

[a]Calculated from the unit area production and the area of water with mean salinity greater than 5 ‰ as shown in table 3.23.

[b]East Bay has no commercial freshwater fishery.

Table 3.25. Estimated value ($) of the freshwater fishery in the Chenier Plain, by basin[a].

	Value[b] per kg	Vermilion	Chenier	Mermentau	Calcasieu	Sabine
Catfish and bullhead	0.68	8,271	2,185	80,082	590	939
Crayfish	0.44	920	224	8,206		
Buffalo	0.31	1,038	191	7,020		
Gar	0.24	2,719	164	6,018	1,256	1,998
Carp	0.09	trace	trace	365		
Total		13,398	2,764	101,691	1,846	2,937

[a]East Bay Basin has no commercial freshwater fishery.

[b]Calculated from table 3.24 and the dockside value in 1973.

Summary. Table 3.26 summarizes, by basin, the estimated 1973 value of the commercial fish and fur industry in the Chenier Plain. The value of the combined industries is approximately $12 million. About 73% of this is the estuarine-dependent fishery, most of the remainder is the fur industry. Because of its extensive estuarine-dependent fishery, the Calcasieu Basin supports the largest combined industry. Despite their size, the Sabine and Mermentau basins have industries that are not as valuable. The Mermentau Basin has no significant estuarine-dependent offshore fishery, and in the Sabine Basin, man's activities have resulted in serious fishery decline.

Trapping and Commercial Fisheries Activities that Affect the Environment. The major ecological impact of trapping and commercial fisheries is the direct harvest pressure on the resource. In addition to the harvest of fish and mammals, there is the immense loss of the small fishes and shellfishes trapped in the trawls along with the harvested shrimp. It has been estimated that shrimp comprise only 5 to 32% of most trawl catches on a weight basis (Klima 1976). The noncommercial species are usually returned to the water, but few survive, and most become part of the detritus food base of the estuarine system prematurely. Apparently there have been no investigations into the effect of this loss of small fishes and shellfishes on estuarine ecosystem dynamics. In areas of intensive shrimp fishing, trawling could influence the trophic structure because it would tend to favor omnivorous feeders over top carnivores. Trawls also re-suspend bottom sediments and nutrients, increasing water turbidity. This increased turbidity of estuarine and nearshore Gulf waters is evident during periods of intensive trawling.

Seafood processing plants produce detrimental discharges, but with a few exceptions these seem to be minor. Discharges from menhaden processing plants south of Calcasieu lake near Cameron, Louisiana, contributed significantly to the high coliform counts that caused closure of the oyster beds in the lake late each summer.

Construction of docks and other facilities for the industry produces local ecological impacts. Canals significantly influence the inshore hydrologic flow. The large, deep channels in the Chenier Plain were constructed primarily for ocean-going freighters and tankers, but many of the smaller navigation channels are used extensively by the commercial fishing fleet. Pirogue ditches constructed by trappers can, in hydrologically critical places, erode rapidly into major waterways (Davis 1973). There are about 3,400 km (2,100 mi) of navigation channels in the Chenier Plain (table 3.27).

Table 3.26. Estimated value ($ x 1000) of commercial fishes, shellfishes, and the fur industry in the Chenier Plain (1973)[a].

Basin	Commercial harvest			Total
	Fur industry	Estuarine-dependent fishery	Freshwater fishery	
Vermilion	275.7	638	13.3	927
Chenier	511.0	959.1	2.8	1,472.9
Mermentau	972.1	0	101.7	1,073.8
Calcasieu	395.1	3,213.3	1.8	3,610.2
Sabine	937.5	1,290.1	2.9	2,012.8
East Bay	140.7	2,826.3		2,945.0
Total	3,232.1	8,926.8	122.5	12,281.4

[a]Summarized from tables 3.17, 3.22, and 3.25.

Table 3.27. Length (km) and area (km^2) of navigation canals in the Chenier Plain.

Basin	First order canals[a]		Second order canals[b]		Total	
	Area (km^2)	Length (km)	Area (km^2)	Length (km)	Area (km^2)	Length (km)
Vermilion	5.10	56.7	2.28	325.5	7.38	382.2
Chenier	1.53	17.0	3.77	538.3	5.30	555.3
Mermentau	13.44	149.4	6.92	987.9	20.36	1,137.3
Calcasieu	11.25	125.1	2.40	342.9	13.65	468.0
Sabine	15.84	175.9	4.10	586.4	19.94	762.3
East Bay	6.12	68.1	0.48	69.1	6.60	137.2
Total	53.28	592.2	19.95	2,850.1	73.23	3,442.3

[a]Major canals dredged and maintained to facilitate both interstate and intrastate navigation.

[b]Canals for small craft, or short, deep spurs to allow access from first order canals to industrial sites.

3.2.5 SPORT HUNTING AND FISHING

Magnitude of the Activity. The magnitude and value of sport fishing and hunting have traditionally been difficult to assess because reliable samples are difficult to obtain, and a large sampling effort is required. Three approaches have been used: license sales analysis, creel censuses, and telephone surveys. All have been used within the Chenier Plain, but none of them was designed for the study area specifically.

This report presents the available data from studies in southwestern Louisiana and eastern Texas. To evaluate the sport hunting and fishing effort in the Chenier Plain itself, average man-days/man/yr spent in hunting or observing wildlife were calculated from these studies and applied to population figures for the Chenier Plain basins. The value of each activity was then calculated by applying appropriate dollar values/ man-day. Thus, the results (the number of man-days, demand for, and dollar value of hunting and fishing) are directly proportional to the population size. The human population within the study area is so small (with the exception of the industrial area along Sabine Lake) that its sport fishing and hunting impact is almost negligible. The dense populations just north of the study area boundaries, however, use the Chenier Plain extensively for saltwater fishing and for hunting, particularly for waterfowl. It is known from the Fish and Wildlife Study (U.S. Army Engineers unpublished) telephone survey that 70% of the saltwater fishermen in the coastal parishes travel less than 80 km (50 mi) to fish, and that 84% of waterfowl hunters hunt within 80 km (50 mi) of their homes. Therefore, to estimate the present demand for sport hunting and fishing within the Chenier Plain, the basin population was augmented by the population of the parishes (counties) immediately adjacent on the north. In the case of East Bay Basin, the applicable population was arbitrarily placed at 250,000, about one-fifth the population of the adjacent Galveston County area. [This figure may be somewhat high since Heffernan et al. (1977) report from a creel census of the whole Galveston Bay, a total fishing effort of 909,000 man-days/yr. Using their estimate of 16.2 man-days/fishermen/yr, this is the equivalent of 56,000 fishermen. If 20% of the population fishes (table 3.28), the East Bay Basin area is only drawing from a population of about 280,000.] These population estimates should be reasonable for waterfowl hunting and saltwater angling for which the coastal areas must be used; the estimates may be less satisfactory for freshwater fishing and for small and big game hunting, since appropriate habitat exists north as well as south of the population centers.

Table 3.29 shows hunting and fishing license sales in the three-parish area of southwestern Louisiana for 1967 through 1975. These sales represent about 12.5% of the State total of resident fishing licenses, 7% of the resident hunting licenses, and 4.4% of the big game licenses. The influx of hunters to the Chenier Plain is shown by the large number of nonresident licenses issued (26% of the State total).

Table 3.28 summarizes estimates of participation rates for sport fishing and hunting. The best surveys for Louisiana were the 1974 State Comprehensive Outdoor Recreation Plan (SCORP) Survey (Louisiana State Parks and Recreation Commission 1974) and the Fish and Wildlife Study (U.S. Army Engineers unpublished). The latter agrees reasonably well with the 1970 national survey U.S. Fish and Wildlife Service (1972) in estimating that 20 to 27% of the Louisiana population engages in sport fishing, although the percentage is much lower for urban residents. The percent of license sales to the total population, when adjusted for hunters and fishermen younger than 16 and older than 59 years, coincides with a telephone survey conducted by SCORP. These survey estimates for all categories of hunters and fishermen are considerably higher than those reported in the Fish and Wildlife Study. The more conservative figures from the latter study were used in this report because the design of the survey and the statistical analysis of the results were considered the best available, even though the survey was conducted in 1968.

Table 3.28. Estimated percent of population that engages in sportfishing and hunting according to various studies in the United States and Louisiana.

Activity	United States			Louisiana		
	Urban	Rural	West-south central	Statewide	Coastal parishes	Calcasieu Cameron & Vermilion parishes
Sportfishing	12.3[a]	25.5[a]	27.4[a]	26[b]	23[b]	19.4[d]
Freshwater				55[c]		
Saltwater				30[c]		
Hunting (overall)			13.1[a]	11.3[b]	9[b]	15.7[d]
Small game				35[c]		
Big game				23[c]		
Waterfowl				21[c]		

[a]Fish and Wildlife Service 1972.

[b]U.S. Army Corps Engineers unpublished.

[c]Louisiana State Parks and Recreation Commission 1974.

[d]Based on Louisiana fishing and hunting license sales (1970), increased by 21% to adjust for hunters and fishermen younger than 16 years, and older than 59 years.

Table 3.29. Total fishing and hunting license sales for Calcasieu, Cameron, and Vermilion parishes, 1967 through 1975[a].

Year	Fishing		Hunting	
	Resident	Non-resident	Resident	Non-resident
1967-68	29,502	492	23,535	2,095
1968-69[b]	12,124	454	23,508	1,741
1969-70	34,577	526	24,189	2,162
1970-71	31,040	458	25,652	2,849
1971-72	30,091	425	23,277	2,882
1972-73	29,733	398	23,837	3,162
1973-74	35,231	576	23,020	2,799
1974-75	38,726	809	23,086	2,792

[a]This three-parish area had 187,126 residents 5 years of age or older, State Comprehensive Outdoor Recreation Plan (SCORP) 1974. This represents 5.4% of the State population.

[b]The second year of a two-year licensing experiment was dropped at the end of this period.

Hunting: Table 3.30 summarizes the man-days of use related to wildlife in the Louisiana coastal zone, from the Fish and Wildlife Study (U.S. Army Engineers unpublished) telephone survey conducted in 1968. The table shows that the per capita usage rate in the Chenier Plain was higher than the usage rate for the entire Louisiana coast. The study indicated a relatively high frequency of "nonconsumptive" wildlife-oriented recreation (bird watching and recreational boating). The total estimated wildlife-oriented recreational use for the southwestern part of the State was 2.75 man-days/individual/year.

Table 3.30. Man-days of hunting and recreation per year for coastal Louisiana.

	26 coastal parishes				Southwestern Louisiana (Hydrologic units VII-IX)			
	Man-days/yr[a] x 1,000		Man-days/man/yr[b]		Man-days/yr[c] x 1,000		Man-days/man/yr[d]	
Wildlife-oriented recreation[e]		888.5		0.42		202.6		0.42
Hunting								
Small game		1,083.9		0.51		576.5		1.21
Squirrels	256.3		0.12		129.0		0.27	
Rabbits	538.7		0.26		207.9		0.44	
Quail and dove	266.7		0.13		220.5		0.46	
Other small game	22.2		0.01		19.1		0.03	
Big game								
Deer and turkey		148.9		0.07		67.7		0.14
Waterfowl		764.9		0.36		466.4		0.98
Duck	603.4		0.29		358.7		0.75	
Geese	123.6		0.06		101.4		0.21	
Other marsh birds	37.9		0.02		6.3		0.01	
Total		2,886.2		1.36		1,313.2		2.75

[a]Table 25, app. D, Fish and Wildlife Study (U.S. Army Engineers unpublished).

[b]1968 population of 26 Louisiana coastal parishes = 2,104,800.

[c]Table 42, app. D, Fish and Wildlife Study (U.S. Army Engineers unpublished).

[d]Seven southwest parishes and one-half the population of St. Mary Parish = 477,861.

[e]Birdwatching, photography, etc.

The wildlife-oriented recreational use has an estimated value of over $13 million in the Chenier Plain basins (table 3.31). The man-days were calculated by multiplying the population by the man-days/man/yr value for southwestern Louisiana. The dollar values were calculated from values for different kinds of wildlife recreation prepared by the U.S. Water Resources Council (1973). The values range from $2 to $9/man-day, which appear to be conservative. The figures for each basin represent the expected use-level based on the resident population and on the adjacent parish (county) populations, and they have no relation to the relative availability of suitable habitat for wildlife within each basin. Therefore, one might expect considerable lateral movement of hunters across basin lines to locate optimum habitats. Thus, the total estimate of 2.5 million man-days of hunting/yr for the entire Chenier Plain may have more significance than the figures for individual basins.

Sportfishing and Shellfishing: The expected sportfishing demand amounted to 10.8 million man-days for the entire Louisiana coastal zone and 2.0 million man-days for the southwestern portion of the State (table 3.32). Sportfishing demand was about 4 man-days/man/yr for southwestern Louisiana, compared to an annual demand of 5 man-days/man/yr for the entire State. The saltwater sportfishing demand can be compared to the 305,600 man-days of fishing estimated from a recent saltwater creel census in Sabine Lake (Breuer et al. 1978). Ninety-five percent of the fishing parties using Sabine Lake came from Jefferson and Orange counties, which had a 1970 population of 315,943. The estimated 0.96 man-days/man/yr for these counties agrees closely with the 1.0 value for southwestern Louisiana (table 3.32).

The sportfishing demand in the Chenier Plain basins was calculated by using the sportfishing demand values for southwestern Louisiana. The method was the same as that used to calculate hunting demand. There was an estimated total annual demand of 3.8 million man-days for all types of sportfishing (table 3.33). Nearly one-half of this is for freshwater fishing; most of the rest is for saltwater angling. The total value of this demand is conservatively estimated at about $7.7 million. The combined demand value for fishing and hunting is estimated to be about 6.4 million man-days and $21 million.

Table 3.31. Estimated recreational and hunting use and value of wildlife in the Chenier Plain[a].

Basin	Population	Wildlife-oriented recreation		Small game		Big game		Waterfowl		Total	
		Use (man-days x 1,000)	Value[b] ($ x 1000)	Use (man-days x 1000)	Value ($ x 1000)	Use (man-days x 1000)	Value ($ x 1000)	Use (man-days x 1000)	Value ($ x 1000)	Use (man-days x 1000)	Value ($ x 1000)
Vermilion	802[c]	0.3	0.6	1.0	3.0	0.1	0.9	0.8	7.2	2.2	11.7
	112,547	47.2	94.4	136.2	408.6	15.7	141.3	110.3	992.7	309.4	1,321.5
Mermentau	9,194	3.8	7.6	11.1	33.3	1.3	11.7	9.0	81	252	133.6
& Chenier	90,857	38.1	76.2	110.0	330.0	12.7	114.3	89.0	801	249.8	1,321.5
Calcasieu	9,790	4.1	8.2	11.8	35.4	1.4	12.6	9.6	86.4	26.9	142.6
	127,483	53.5	107.0	154.2	462.6	17.8	160.2	125.0	1,125	350.5	1,854.8
Sabine	127,483	54.9	109.8	158.1	474.3	18.3	164.7	128.0	1,152	359.3	1,900.8
	337,730	141.8	283.6	408.7	1,226.1	47.3	425.7	331.0	2,979	928.8	4,914.4
East Bay	4,824	2.0	4	5.8	17.4	0.7	6.3	4.7	42.3	13.2	70
	250,000	105	210	300	900	35.0	315	245	2,205	685	3,630
										653.6	2,258.7
Total										2,523.5	13,042.2

[a]Based on man-days per man for southwestern Louisiana (table 3.30) and the 1970 population.

[b]Values per man-day were: wildlife-oriented recreation, $2; small game hunting, $3; big game hunting, $9; waterfowl hunting, $9; based on Principles and Standards for Planning Water and Related Land Resources (U.S. Water Resources Council 1973).

[c]The first population number for each basin is for the Chenier Plain boundaries. The second number includes the adjacent urban parishes/counties to the north.

Table 3.32. Estimated sportfishing demand in the Louisiana coastal zone[a].

	26 Coastal Parishes[b]		Southwestern Louisiana[c] (Hydrologic Units VII, VIII, and IX)	
	Man-days/man/yr	Man-days[d] per year (x 1,000)	Man-days/man/yr	Man-days[d] per year (x 1,000)
Saltwater sportfishing	1.92	4,045	1.00	479
Freshwater sportfishing	1.66	3,491	1.90	908
Sport shrimping	0.18	373	0.23	112
Sport crabbing	1.07	2,250	0.79	378
Sport crayfishing	0.29	610	0.26	125
Total	5.12	10,769	4.18	2,002

[a]U.S. Army Corps Engineers unpublished, Lindall et al. 1972.

[b]The 1968 population of the 26 Louisiana coastal parishes = 2,104,800.

[c]The 1970 population of seven western parishes (Acadia, Calcasieu, Cameron, Iberia, Jefferson Davis, Lafayette, Vermilion, and one half of St. Mary) = 477,861.

[d]Based on 1968 telephone survey.

Table 3.33. Demand for and value of sportfishing in the Chenier Plain.

Basin	Population	Saltwater	Freshwater	Shrimping	Crabbing	Crayfishing	Total	Value[b]
		Fishing activity, man-days/yr X 1,000[a]						
Vermilion	802[c]	0.8	1.5	0.2	0.6	0.2	3.3	6.6
	112,547	112.5	213.8	25.9	88.9	29.2	470.3	940.6
Mermentau & Chenier	9,194	9.1	17.5	2.1	7.3	2.4	38.4	76.8
	90,857	90.9	172.6	20.9	71.8	23.6	379.8	759.6
Calcasieu	9,790	10.0	18.6	2.3	7.7	2.5	41.1	82.2
	127,483	127.5	242.2	29.3	100.7	33.1	532.8	1,068.6
Sabine	130,636	130.6	248.2	30.0	103.2	33.9	545.9	1,091.8
	337,730	337.8	641.7	77.1	266.8	87.8	1,411.2	2,822.4
East Bay	4,824	4.8	9.2	1.1	3.8	1.3	20.2	40.4
	250,000	250.0	475.0	57.5	197.5	65	1,045.0	2,090.0
					Total annual demand[c]		648.9	1,297.8
							3,839.1	7,678.2

[a]Calculated from the indicated population and the man-days per man per year shown in table 3.32.

[b]Calculated at $2 per man-day (U.S. Water Resources Council 1973).

[c]The first population number for each basin is for the Chenier Plain boundaries. The second number includes the adjacent urban parishes (counties) to the north.

Sportfishing and Hunting Activities that Affect the Environment. The most important ecological effect of sportfishing and hunting is the direct harvest of fish and wildlife (part 3.5.2). Other impacts may be significant locally. Construction of recreation centers, boat launching ramps, picnic grounds, parks, camping spots, and private camps, may cause localized pollution and environmental disruption. The location and identity of such centers in the Chenier Plain are shown in plates 1A and 1B. The use of lead shot may modify the impact of hunting,but it has not been fully evaluated.

Wildlife Refuge Establishment. The factors that lead to the isolation of natural areas for refuges are varied. The concern of wildlife enthusiasts was undoubtedly one important factor. In the Chenier Plain 135,559 ha (334,974 a), including the 57,000 ha (140,850 a) Sabine National Wildlife Refuge have been set aside as refuges by Federal, State, and private organizations (table 3.34). The eight refuges comprise over 11% of the area of the Chenier Plain, exclusive of the nearshore Gulf habitat. They are discussed in some detail in part 4. Most of the refuges were established primarily for waterfowl management but controlled access, controlled development, and management practices make them important refuges for many other species.

3.2.6 COMMERCE, INDUSTRY, AND THE RESIDENT POPULATION

This section provides a general view of the magnitude and character of the local economy as a source of activities having an impact on the Chenier Plain ecosystem. The Chenier Plain basin boundaries, as described, do not correspond with political boundaries. Hence, extrapolations have been necessary to estimate economic indices for the basins. To do this, parish (county) data were multiplied by the proportion of that parish's population living within a basin's borders. This assumes that each parish is homogeneous. However, most of the industrial and commercial activity is concentrated just north of the Chenier Plain borders. As a result, the influence of the industrial-commercial sector is probably somewhat exaggerated. Also, employment figures (U.S. Department of Commerce 1975) record only employees covered under the Federal Insurance Compensation Act. Because of the provisions of the act, fishery and agricultural employees are underestimated, and self-employed individuals are not included in the U.S. Department of Commerce figures.

Population. The Chenier Plain is predominantly a rural area and with the exception of the Texas portion of the Sabine Basin, the population density is often less than one individual/5 ha (12 a). In comparison, the overall Louisiana population density is one person/3 ha (7 a) and the density of the adjoining industrialized Harris County, Texas, is about 4 persons/ha (3 a). The population of the Chenier Plain changed little from 1960 to 1970 (table 3.35). There has been modest growth, but the urban areas of Calcasieu Parish and Jefferson County have not grown. Bolivar Peninsula in the East Bay Basin is a rural appendage of Galveston County, separated from it by Galveston Bay, so that the Galveston County figures are not representative of East Bay.

Table 3.34. Refuges, parks, and management areas in the Chenier Plain.

Refuge	Basin	Size (ha)	Management objectives
Paul S. Rainey Wildlife Refuge	Vermilion	10,522	Preserve and improve habitat
Louisiana State Wildlife Refuge	Vermilion	6,070	Preserve and improve habitat
Rockefeller Wildlife Refuge	Chenier	34,800	Preserve and improve habitat
Sabine National Wildlife Refuge	Calcasieu and Sabine	57,809	Habitat improvement for waterfowl; hunting
Lacassine National Wildlife Refuge	Mermentau	12,856	Habitat improvement for waterfowl; hunting
Anahuac National Wildlife Refuge	East Bay	3,981	Habitat improvement for waterfowl
Sea Rim State Park	Sabine	6,117	Habitat improvement for waterfowl, preservation of estuarine marshes; recreation
J. D. Murphree Wildlife Management Area	Sabine	3,404	Habitat improvement for waterfowl; hunting

Table 3.35. Population of parishes (counties) overlapping the Chenier Plain region (U.S. Department Commerce, Bureau of Census 1973).

Parish (County)	Year 1960	1970	Change (%)
Louisiana			
Cameron	6,909	8,194	18.6
Calcasieu	145,475	145,415	0
Jefferson Davis	29,825	29,554	-0.9
Vermilion	38,855	43,071	10.9
Texas			
Chambers	10,379	12,187	17.4
Galveston	140,364	169,812	20.1
Jefferson	245,659	245,659	-0.4
Orange	60,357	71,170	17.9
Total	677,823	725,062	7.0

Employment. Manufacturing and mining are the major areas of employment in the Chenier Plain region (fig. 3-12). The $32 million payroll for the Sabine Basin is indicative of its industrial character. Manufacturers are the major employers in this basin, primarily those engaged in refining and petrochemical-related manufacturing. This is true also in the Calcasieu and East Bay basins although the total payroll is smaller. The large petrochemical complex at Lake Charles, Louisiana, lies outside of the Chenier Plain and will be treated as an outside influence on the region.

Oil and gas industries are the major employers in the eastern basins and account for about 40% of the total payroll value. As indicated, the agricultural, fishing, and trapping sectors are under-represented in these employment data.

Industrial and Urban Activities that Affect the Environment. Major environmental impacts of industrial and urban areas are effluent discharges (both domestic and industrial), habitat loss, and surface and groundwater use. In addition, construction activities increase runoff of sediments and nutrients into wetlands and streams, and this runoff is accelerated by drainage canals constructed in low areas (Gael and Hopkinson 1978).

Habitat loss: In the Chenier Plain, the major urban-industrial land occupied 26,137 ha (64,586 a) or 3.5% of the total land area in 1974 (table 3.36). This is an increase of 5,446 ha (13,457 a), or 26%, since 1952. The urbanized land is concentrated in the western half of the Chenier Plain, primarily in Texas. However, the Calcasieu Basin has shown the most rapid conversion of land to industrial and urban use between 1952 and 1974; most of this urbanization has occurred at the expense of wetlands (1,233 ha) (3,047 a) and agriculture (2,901 ha) (7,168 a) (table 3.37). Five hundred forty-six hectares of upland forest habitat were also cleared between 1952 and 1974 for urban use.

Urban and industrial discharges: The per capita water and energy requirements and effluent production from typical urban situations have been summarized in a number of studies (table 3.38). Because of the low population density in the Chenier Plain, domestic sewage loading rates within the basin must be low, but the total watershed includes several densely populated areas. In the rural areas, septic tanks or no treatment at all are the rule, and no records of discharge rates are available. Table 3.39 contains estimates of discharge (stated as phosphorus) for the Chenier Plain basins. Estimates were determined from discharge data from treatment plants, and industrial point sources (appendix 6.4) and urban runoff. Much of the total load of phosphorus entering the Chenier Plain is from the heavily populated areas of the Sabine Basin and the Lake Charles area just north of the Calcasieu Basin.

Industrial discharges vary greatly and may be much more toxic than domestic sewage. Particularly damaging to the ecosystem are heavy metal byproducts of manufacturing, and synthetic organic toxins that the natural biota can rarely degrade. Plates 5A and 5B show the location of these discharges within the Chenier Plain. The effects are often localized, e.g., in the Calcasieu ship channel, sediments have accumulated high concentrations of certain heavy metals. The effects of these discharges are discussed in part 3.5.3.

Table 3.36. Area and changes in urban-industrialized land in the Chenier Plain.

Basin	Area (1974) (ha)	Percentage of total land area (1974)	Increase in area 1954 to 1974 (ha)	Increase 1952 to 1974 (%)
Vermilion	199	0.4	87	78
Chenier	401	0.4	152	61
Mermentau	1,595	0.8	52	3
Calcasieu	2,277	2.4	1,428	168
Sabine	19,088	7.8	3,449	22
East Bay	2,577	4.7	278	12
Total	26,137	3.5	5,446	26.3

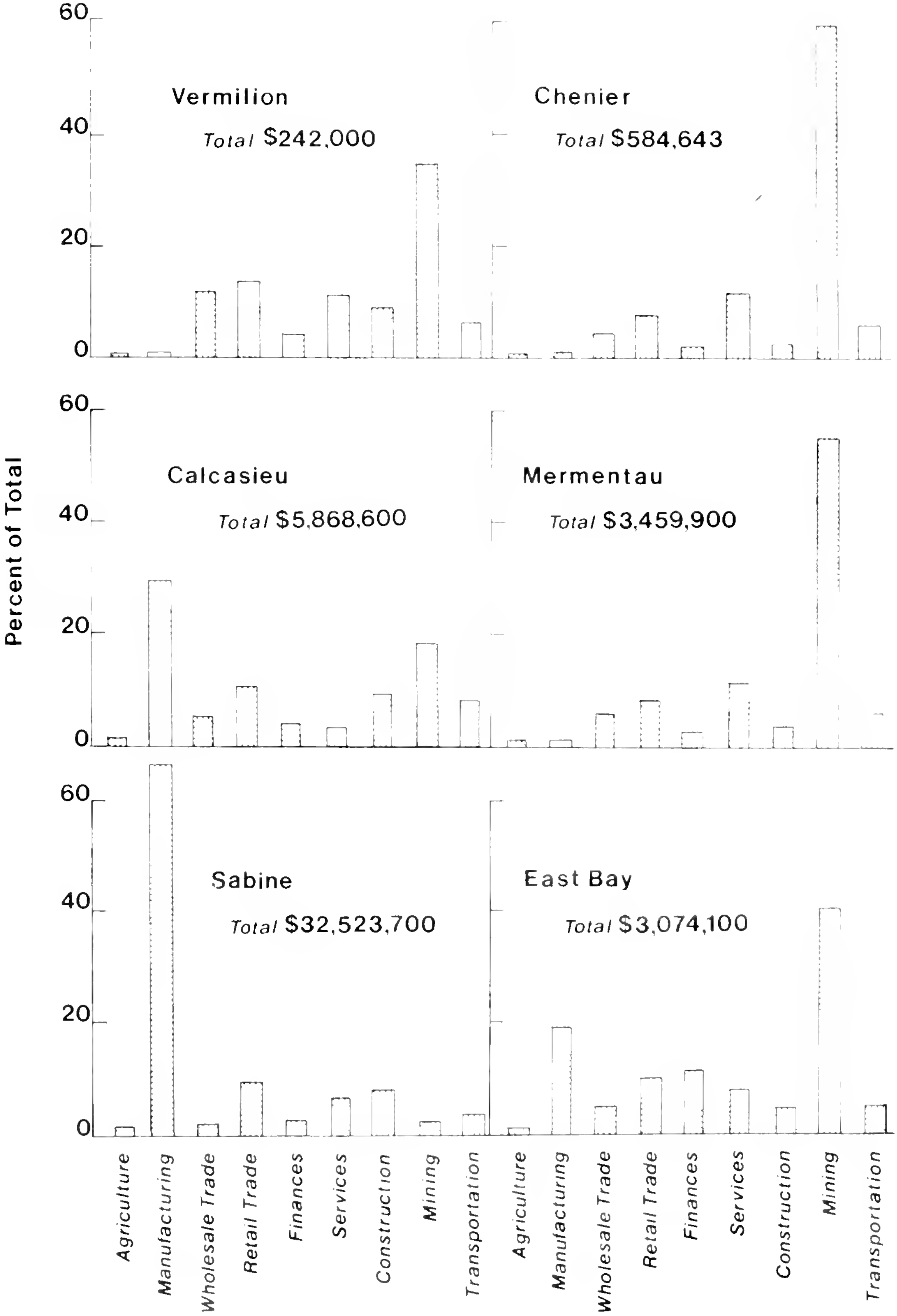


Figure 3-12. Income and percentage contributions from the various trades, industries and services for each of the basins in the Chenier Plain (U.S. Department of Commerce, Bureau of Census 1975).

Table 3.37. Habitat type and amount converted to urban and industrial use between 1952 and 1974 in Calcasieu Basin.

Habitat type	Hectares converted to urban and industrial use
Open water	9
Natural marsh	1,027
Impounded marsh	206
Spoil	171
Pasture	2,501
Cropland	400
Upland forest	546
Beach	79
Total	4,939[a]

[a]Does not agree with total socioeconomic land gain because 3 ha were lost to erosion in the same period.

Table 3.38. Typical daily per capita inputs and outputs of a U.S. city with one million residents (Wolman 1965).

Per capita inputs (kg/yr)		Per capita outputs (kg/yr)	
Water	207,320	Waste water	166,075[a]
Food	657	Solid waste	657
Fuel	3,139 (3.36×10^{10} kcal)	Air pollutants	329

[a]Not including surface runoff, which is generally smaller but highly significant in terms of nutrient load.

Table 3.39. Industrial and urban phosphorus discharges (kg/yr) in the Chenier Plain basins (appendix 6.4).

Basin	Urban	Industrial
Vermilion	11,920	30
Mermentau/Chenier	21,360	110
Calcasieu	30,800	250
Sabine	24,100	90
East Bay	130	trace

Domestic and industrial water use: Clean water is required by the industrial and domestic sectors of the economy. Over 90% of the municipal use is from ground water sources (table 3.40). Industrial use of water is much greater than municipal use. In southwestern Louisiana, 94% of the industrial use is for petroleum refining and for petrochemical plants (Louisiana Department Public Works 1970). The water is used primarily for cooling and only about 7% is consumed; the rest is returned to waterways. Monthly distribution of water use is fairly uniform, with a slight peak in August (appendix 6.2). Thermal effects of water used for cooling are particularly significant in regions such as the Chenier Plain, where summer temperatures are often naturally close to the thermal death temperature of aquatic organisms (Weston, Inc. 1974). However, no evaluation of the effects of thermal pollution on aquatic systems has been made in the Chenier Plain region.

The Louisiana Department Public Works (1970) estimates water usage for petroleum refining and related activities at 296 m^3 (10,453 ft^3) per employee per day; and for chemicals and allied products, at 311 m^3 (10,983 ft^3) per employee day. Municipal usage rates per individual in southwestern Louisiana are much lower, about 0.382 m^3 (13.5 ft^3) per day (Louisiana Department Public Works 1970). This is well below the national average of about 0.580 m^3 (20.5 ft^3)/day (Louisiana Department Public Works 1970). Many rural families in the region develop their own water supply and their use rates are even lower than the regional average. The estimated industrial and municipal water use in the Chenier Plain, based on these usage rates and the local populations is heaviest in the Sabine Basin where extensive refining and manufacturing is located (table 3.41). Water-use estimates made by the Texas Water Development Board (1977) for the Texas portion of the Sabine Basin were considerably higher (table 3.42) than estimates in table 3.41. However, estimates by basin serve as indicators of actual water use. The ecological effects of this water use are reported in part 3.5.3.

3.2.7 TRANSPORTATION

Navigation channels provide the least expensive long-haul transportation in the Chenier Plain. Highways and railroads provide access to inland areas. Pipelines are the major transportation method route for moving hydrocarbons; an estimated 7,549 km (2,972 mi) of pipelines crisscross the Chenier Plain (figure 3-13a and b). Data on the amount of crude and manufactured hydrocarbons transported through pipelines are not available. Although there is relatively low employment in the transportation sector, it is a major force in the economy and has many impacts on the environment.

Waterborne Transport. Waterborne commerce in the Chenier Plain accounted for 183 million short tons of various products in 1976 (table 3.43). Over 95% of

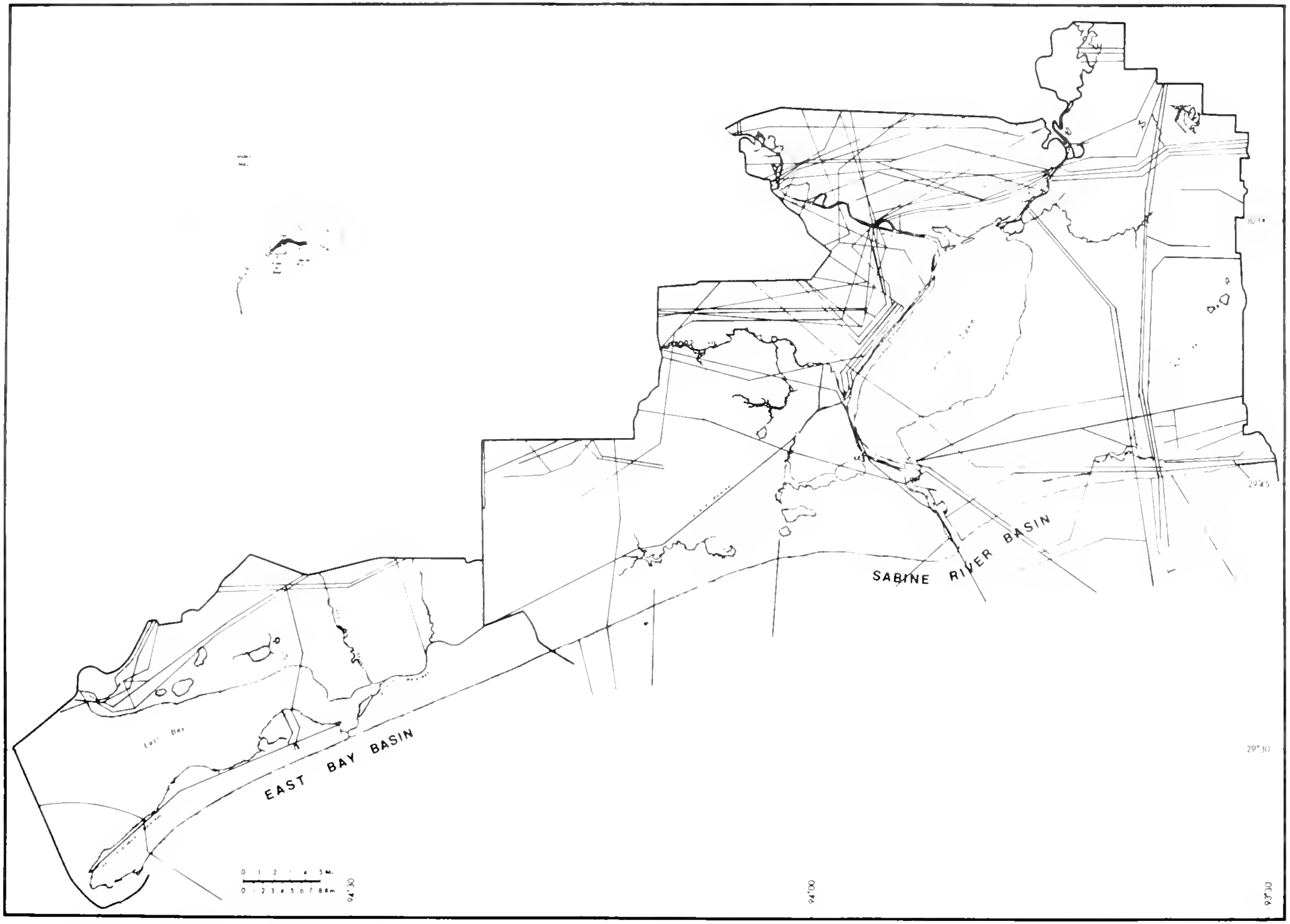


Figure 3-13a. Major pipeline routes in the western Chenier Plain (Texas Bureau of Economic Geology 1972, Fisher et al. 1972, Fisher et al. 1972).

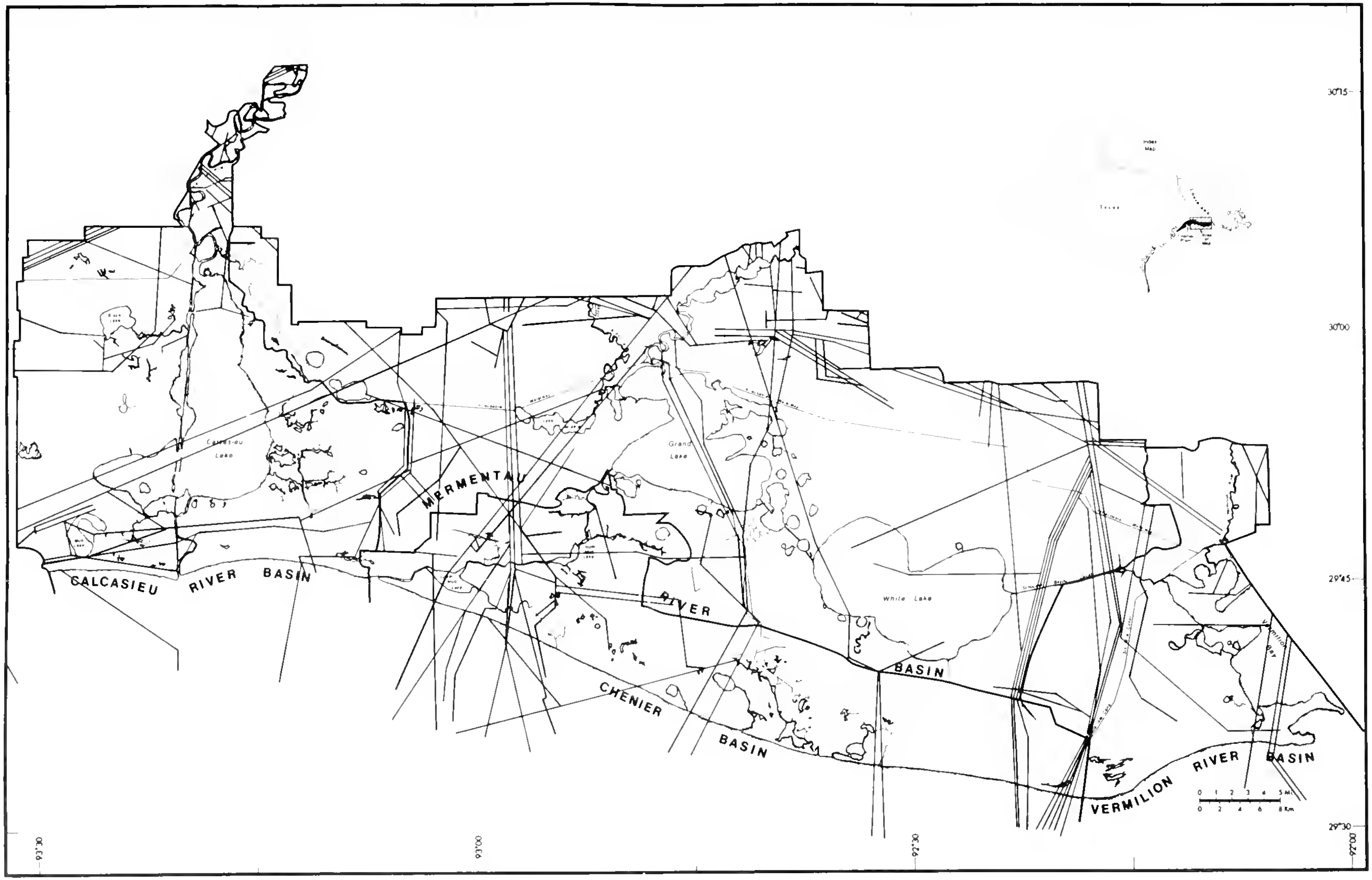


Figure 3-13b. Major pipeline routes in the eastern Chenier Plain.

Table 3.40. Volume of industrial and municipal water intake (millions of cubic meters) by source in southwestern Louisiana (Louisiana Department of Public Works 1970).

Source	Industrial Volume	Industrial Percent	Municipal Volume	Municipal Percent
Surface	226	31	6	8
Ground	484	67	63	92
Purchased[a]	10	1	—	—
Total	720	99	69	100

[a]Usually from surface water.

Table 3.41. Daily (cubic meters) and annual (millions of cubic meters) industrial and municipal water use by basin.

Basin	Population	Municipal[a] water use (daily)	Municipal[a] water use (annual)	Employees in refining and manufacturing	Industrial water use including return flows[b] (daily)	Industrial water use including return flows[b] (annual)
Vermilion	802	310	0.01	0	0	0
Chenier	1,220	470	0.02	0	0	0
Mermentau	7,974	3,050	1.1	16	4,800	1.8
Calcasieu	9,790	3,740	1.4	529	158,700	57.9
Sabine	130,636	49,900	18.2	17,020	5,106,300	1,863.8
East Bay[c]	4,824	1,840	0.7	173	51,900	18.9

[a]At 0.382 m^3/man/day (Louisiana Department of Public Works 1969).
[b]At 300 m^3/employee/day (Louisiana Department of Public Works 1970).
[c](Texas Water Development Board 1977).

Table 3.42. Annual volume of water use (millions of cubic meters) in the Sabine (Texas) Basin[a] (Texas Water Development Board 1977).

Use	Volume
Municipal	48.3
Industrial	359.8
Industrial return flows	1,046.2
Irrigation	266.3
Irrigation return flows at 40%	106.5
Livestock	7.0
Mining	11.4

[a]Sum of use for Orange County in Sabine River drainage, Jefferson County or Zone 2 in Neches drainage, and Zone 1 of the Neches-Trinity drainage. Some exaggeration results from inability to delineate data along boundary lines.

the export-import traffic is through the ship channels of Calcasieu and Sabine basins. Through traffic along the intracoastal waterway accounts for a large proportion of the total traffic. Local production is supplemented by crude petroleum imports for refining at Lake Charles and Port Arthur and exported as refined petrochemicals. Other imports and exports are small by comparison.

From 1967 to 1975 total traffic has been stable (fig. 3-14), but a significant increase occurred in the Sabine Basin in 1976.

Waterborne traffic requires construction of docks and other facilities for ships. This is often accompanied by land filling and draining. In the Chenier Plain the area involved is usually rather small, but localized disruptions of the environment have occurred. The major requirement for waterborne traffic is deep navigation access routes. Since natural channels in the Chenier Plain are rather shallow, all navigation canals are dredged. There are 3,442 km (2,139 mi) of navigation canals in the Chenier Plain (table 3.27). The major transport channels are: the Gulf Intracoastal Waterway (GIWW), which has a depth of 4 m (13 ft) and a

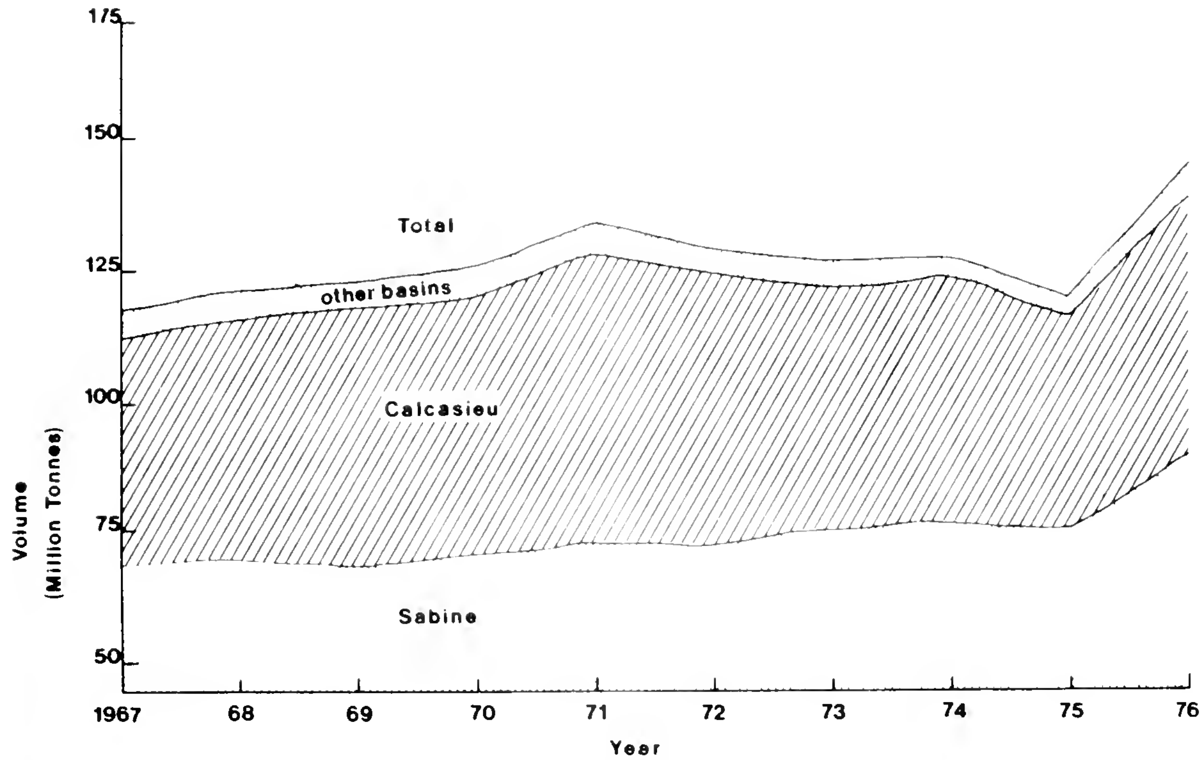


Figure 3-14. Total waterborne commerce in the Chenier Plain 1967 to 1976 (U.S. Army Corps Engineers 1976).

Table 3.43. Summary of waterborne commerce (short tons) in the Chenier Plain for 1976 (U.S. Army Corps Engineers 1976).

Commodity	Imported	Exported	Through traffic[a]	Total
Grains	·31,036	4,233,376	630,089	4,894,501
Raw fishery	243,506			244,228
Crude petroleum	44,239,677	3,895,254	12,153,791	60,288,722
Other "mined" products	3,147,620	18,796,864	3,533,822	25,478,306
Petrochemicals	5,682,803	32,742,911	39,193,239	77,618,953
Manufactured wood & food	14,844	530,794	267,404	813,042
Other manufactured products	291,579	591,381	1,988,804	2,871,764
Miscellaneous (all others)	141,961	1,357,742	10,021,504	11,521,207
Total	53,793,026	62,148,322	67,789,375	183,730,723

[a]Total for traffic through individual basins—continuous travel through two basins may be counted twice.

width of 100 m (328 ft) over most of its length and is used primarily for barge traffic; the Calcasieu Ship Channel, with a depth of 12 m (39 ft) and a width of 120 m (394 ft); and the Sabine Ship Channel, 13 m (43 ft) deep and 120 m (394 ft) wide. The latter two were dredged across the beachline removing the natural shallow (1 m) (3.3 ft) sill that historically prevented saltwater intrusion into Calcasieu and Sabine lakes. The ecological impacts of these navigation canals is described in Part 3.3. Accidental oil spills do occur in these navigation channels. The probability of oil spills from tanker traffic has been evaluated in Part 3.2.2. Spoil accumulations from the continued dredging to maintain these large channels are significant (table 3.44). Between 1952 and 1974, 5,365 ha (13,257 a) of land have been covered with dredged material associated with these three waterways. Dredged material from other activities, e.g., small recreation channels, pipeline channels, and access channels will substantially increase this figure. The impact of spoil disposal is discussed in parts 3.3.6 and 3.4.3.

Highways and Railroads. Highways and railroads through the coastal zone affect the ecosystem primarily through obstruction of, or change in, waterflow patterns. Embankments cut off natural water flows, sometimes inadvertently impounding wetlands. An example is the dividing line between the Calcasieu and Mermentau basins; it follows a highway because that highway effectively blocks most east to west water movement across large expanses of wetland. There are 300 km (186 mi) of canals associated with transportation embankments in the Chenier Plain (table 3.45).

3.2.8 GOVERNMENT

The responsibility for management of the coastal resources of the Chenier Plain rests with many government agencies; responsibilities are not always clearly defined. Governments, from the local level to the Federal level, have different functions; most policy decisions have significant environmental repercussions. The decisions can be as simple as the decision to pave a parking lot or as complex and far-reaching as to construct a major ship channel or to develop geothermal energy reserves.

Often the repercussions of a policy decision have little relationship to the funding levels involved. Expenditure of a small amount of energy or money by a government agency may control massive shifts in

Table 3.44. Comparison of area covered by dredged material in each basin in 1952 and 1974.

Basin	Area covered in 1952 (ha)	Increase in area covered from 1952 to 1974 (ha)	Increase (%)	Area covered in 1974 (ha)	Proportion of land area covered in 1974 (%)
Vermilion	494	1,099	222.5	1,593	2.8
Chenier	1,980	1,441	72.8	3,421	3.8
Mermentau	7,643	1,000	13.1	8,643	4.2
Calcasieu	2,462	848	34.3	3,310	3.5
Sabine	8,377	937	11.2	9,314	3.8
East Bay[a]	2,273	40	1.8	2,313	4.2
Total	23,222	5,365	23.1	28,587	3.8

[a]Comparison made for 1954 and 1974.

Table 3.45. Length (km) of canals associated with transportation embankments in the basins.

Basin	Length
Vermilion	8.13
Chenier	27.29
Mermentau	40.31
Calcasieu	131.14
Sabine	67.55
East Bay	27.1
Total	301.52

energy and expenditures by the private sector. The Federal Water Pollution Control Amendments Act of 1972 and the Rivers and Harbors Act of 1899 are examples of this kind of control mechanism.

The actions of government can significantly affect the economy and the coastal ecosystem. For instance, 1976 Federal per capita outlays were $874 in Vermilion Parish, $1,192 in Cameron Parish, and $1,230 in Calcasieu Parish. In Calcasieu Parish alone this resulted in a total Federal outlay of $164 million (U.S. Department of Commerce 1976b). In the coastal parishes (counties) 40 to 60% of the Federal funding is administered by the Department of Health, Education, and Welfare (HEW) and is distributed widely among the population. In some parishes, however, over 20% is administered by the Department of Defense through the U.S. Army Corps of Engineers. The latter outlays are often for large construction projects such as ship channels, storm levees, and river control structures, and have resulted in the most significant environmental modifications in the Chenier Plain (part 3.3).

3.2.9 SUMMARY

Mineral extraction is the major industry of the Chenier Plain. The dollar value of minerals extracted in 1974 was six times greater than the estimated total value of the renewable resources. Of the latter, agriculture is valued at about $28 million, recreational fishing and hunting at $21 million, and commercial fishing at $12 million.

About 1.4 x 10^{12} kcal/km^2 (3.6 x 10^{12} kcal/mi^2) or (1.4 x 10^{13} Btu/mi^2) of the sun's energy is received in the Chenier Plain each year. Much of this energy is used to heat the earth and to drive the hydrologic cycle and ultimately, on a worldwide scale, to determine the climate and the ocean's circulation. About 5.4 x 10^9 kcal/km^2/year (1.4 x 10^{10} kcal/mi^2) (5.6 x 10^{10} Btu/mi^2) (or less than one-half of one percent of the energy that strikes the Chenier Plain) is fixed in chemical form (net photosynthesis). This is the major renewable energy source on this planet, and the only practical source of food. In comparison, the fossil fuels extracted annually on the Chenier Plain have an energy equivalent of about 1.7 x 10^{10} kcal/km^2 (4.4 x 10^{10} kcal/mi^2) or (1.75 x 10^{11} Btu/mi^2), about three times that of photosynthesis or about one percent of the sun's annual energy flux. Although natural processes (including the formation of fossil fuels) depend on the energy of the sun, our economy depends heavily on fossil fuels that annually in the Chenier Plain actually represent much more energy than is utilized in photosynthesis. Unfortunately, fossil fuels are limited and are extracted at considerable cost to the natural environment. Therefore, mineral fuel extraction represents a trade-off between a photosynthesis-based long-term economy and a short-term economy based on a concentrated, non-renewable energy source. In the following parts of this report, the environmental costs of this trade-off are evaluated both in terms of the direct environmental costs of mineral fuel extraction and of the costs that arise indirectly from the use of mineral fuels to drive our economy.

3.3 HYDRODYNAMICS

3.3.1 INTRODUCTION

Water is an essential factor for the establishment and maintenance of coastal ecosystems. Water is necessary for the existence of nearshore and estuarine species, for sediment deposition, and for transporting minerals and detritus. Water flow and quality maintain the transition zone between land and sea.

The single most important driving force responsible for water level fluctuations, salinity changes, and circulation is the sun. The sun controls seasonal warming and cooling of the earth, seasonal storage and release of precipitation (river discharge patterns), wind patterns, weather systems, seasonal concentration and dilution of salts, and circulation. The combined effects of sun and moon also control the tides. Indirectly, the sun is responsible for storms—from small local summer thundershowers to massive hurricanes that cause dramatic, though ephemeral, variations in water level, salinity, and circulation.

Geomorphic processes also affect water level, salinity, and circulation. Sea level rise and land subsidence lower the level of land relative to the sea, increasing the amount of land inundation. Basin topography strongly affects circulation and salinity. For example, a deep tidal pass carries larger volumes of water into an estuary than does a shallow pass, and this in turn affects salinity.

Man also changes coastal systems. Hydrologic changes are associated with the construction of canals, impoundments, and dams, but these changes are infrequently studied; consequently total impacts are difficult to assess. These cumulative impacts shift natural cycles of freshwater supply, modify circulation, and allow saltwater intrusion.

This section identifies and discusses major hydrodynamic processes in Chenier Plain basins. Modification of these processes by man and the resulting effects are also documented.

3.3.2 APPROACH

Historical studies of estuarine circulation have been conducted in drowned river valley estuaries, e.g., Chesapeake Bay. Most of the information collected for these estuaries does not apply to shallow bar-built estuaries like those found along the Chenier Plain. Hydrography and hydrology predicted by models of river valley estuaries do not fit conditions found in areas with broad expanses of marshes cut by tidal channels.

The processes that control circulation in shallow estuaries are river discharge, tides, winds, evaporation, and precipitation. These processes do not operate equally over a basin. Lee and Rooth (1972) have suggested a modular approach to the description of shallow estuaries. They offer a qualitative estimate of important processes by dividing the basin into subunits or blocks, each dominated by a single process. Initially designed for Biscayne Bay, Florida, their model has been adapted for this study of the Chenier Plain.

Despite local geomorphic variation, all Chenier Plain basins can be characterized by the following general subunits (fig. 3-15):

A) Tidal region – responds to direct exchanges of water with the Gulf via tidal action.
B) Riverine region – primarily controlled by freshwater inflows.
C) Wind-driven region – responds to tides and river discharge but is dominated by wind-driven circulation.
D) Wetland region – responds to tides, winds, rain, and evaporation.

Many graphs and tables presented in this section represent a synthesis of long-term tidal records maintained by the U.S. Army Corps of Engineers (USACE). Salinity data are also primarily from USACE records (app. 6.1).

3.3.3 SUBUNITS HAVING DIRECT EXCHANGE WITH THE GULF

Tidal fluctuations can often be detected throughout a drainage basin. Due to the flat topography of the Chenier Plain much of the land is inundated, dissipating tidal energy. The part of an estuary within which water is directly exchanged with the Gulf, however, is usually restricted to the vicinity of tidal inlets. The direction of water flow depends upon the surface water slope set up by the astronomical tide. The strength of the current in the pass depends upon the magnitude of the surface water slope; that is, the difference in water height across the pass. The volun e of water exchanged through the opening depends on the width, length, depth, and straightness of the tidal pass. Marine waters scour tidal passes and directly exchange a semicircular estuarine area whose radius extends from the pass to a distance of about 500 times the mean depth of the tidal pass (Lee and Rooth 1972).

Characteristics of Gulf waters. The influence of the Gulf waters on estuaries and wetlands depends on the physical and chemical character of the nearshore Gulf habitat. For purposes of this discussion, pertinent parameters are salinity, tides, and water levels.

Murray (1976) has demonstrated that offshore salinity patterns are similar along the coast east of the Sabine Basin; no data are published for the section west of the Sabine Basin for the same period. He found the salinities were close to deep ocean salinity during months of low river discharge. Salinity values were low during months of high river discharge (fig. 3-16). During the flood month (December) of 1963 (a dry year in Louisiana), estuarine levels of salinity existed along most of the open Louisiana cost. The dilution of Gulf waters occurred because of the large amount of river discharge.

Dissolved salts are usually diluted by mixing with fresher waters as tidal currents carry them inland. Vertically stratified salt wedges can form in deep channels and allow saline water to move into a basin along the channel bottom. Tidal currents also mix this saline water with overlying fresher waters. Chenier Plain estuaries are shallow (1 to 2 m or 3.3 to 6.6 ft), and in the past the Gulf passes had shallow sills that prevented formation of a salt wedge. However, deep dredged channels (15 m or 49 ft) now exist in the Calcasieu and Sabine basins and these have allowed significant salt water intrusion. (Details about specific basins are addressed in parts 3.6.2 through 3.6.7).

Coastal ecosystems have adapted to tides for millenia. As a result, virtually every biotic response of these systems is keyed to some component of the tide. Important aspects of tide are period, range, and elevation or level.

There are semidiurnal, diurnal, and mixed tides in the Gulf of Mexico. A semidiurnal tide has two high waters and two low waters in a tidal day with comparatively little diurnal inequality (Coastal Engineering Research Center 1973). A diurnal tide has one high water and one low water in a tidal day. A mixed tide is one in which there is a large inequality in either the high or low water heights, with two high waters and two low waters usually occurring each tidal day. In the Gulf of Mexico, in contrast to most of the world oceans, a diurnal tide pattern predominates.

Along the Chenier Plain, the tidal phases shift slightly (fig. 3-17). Tides reach the center of the region first, lagging slightly both east and west (Byrne et al. 1976). The tide shows a nearly pure diurnal curve at Bayou Riguad, east of the Chenier Plain and in East Bay, Texas, on the west end of the Chenier Plain but has a distinct semidiurnal character in between. (For comparison, United States east and west coasts are both characterized by semidiurnal tides, but the east coast tides are generally equal whereas the west coast tides have large inequalities.)

In the Gulf of Mexico there is an orderly progression in time between the two types of tides, with the semidiurnal tides never being fully developed. The diurnal tide fades into a semidiurnal tide over a two-week period. The diurnal tides that occur when the moon is over the Tropics of Capricorn and Cancer at maximum angle relative to the equator have the largest range and are called "tropic tides." The tides exhibiting the most semidiurnal character are called "equatorial tides" and occur when the moon is over the equator.

Tidal ranges along the Chenier Plain are low in comparison to tides along other coasts. They fall in the micro-tidal range, i.e., tidal ranges less than 2 m (6.6 ft). The mean tidal range at the coast is about 60 cm (24 in), varying from about 30 cm (12 in) at East Bay to about 75 cm (30 in) at Calcasieu Pass (table 3.46). This range attenuates upstream depending on the depth, bottom, and shape of the channel.

The diurnal tidal cycle is superimposed on a seasonal water level cycle and on a long-term water level trend on the northern Gulf coast. Both the seasonal and the long-term trend are of major significance in the way the Chenier Plain ecosystem functions. The

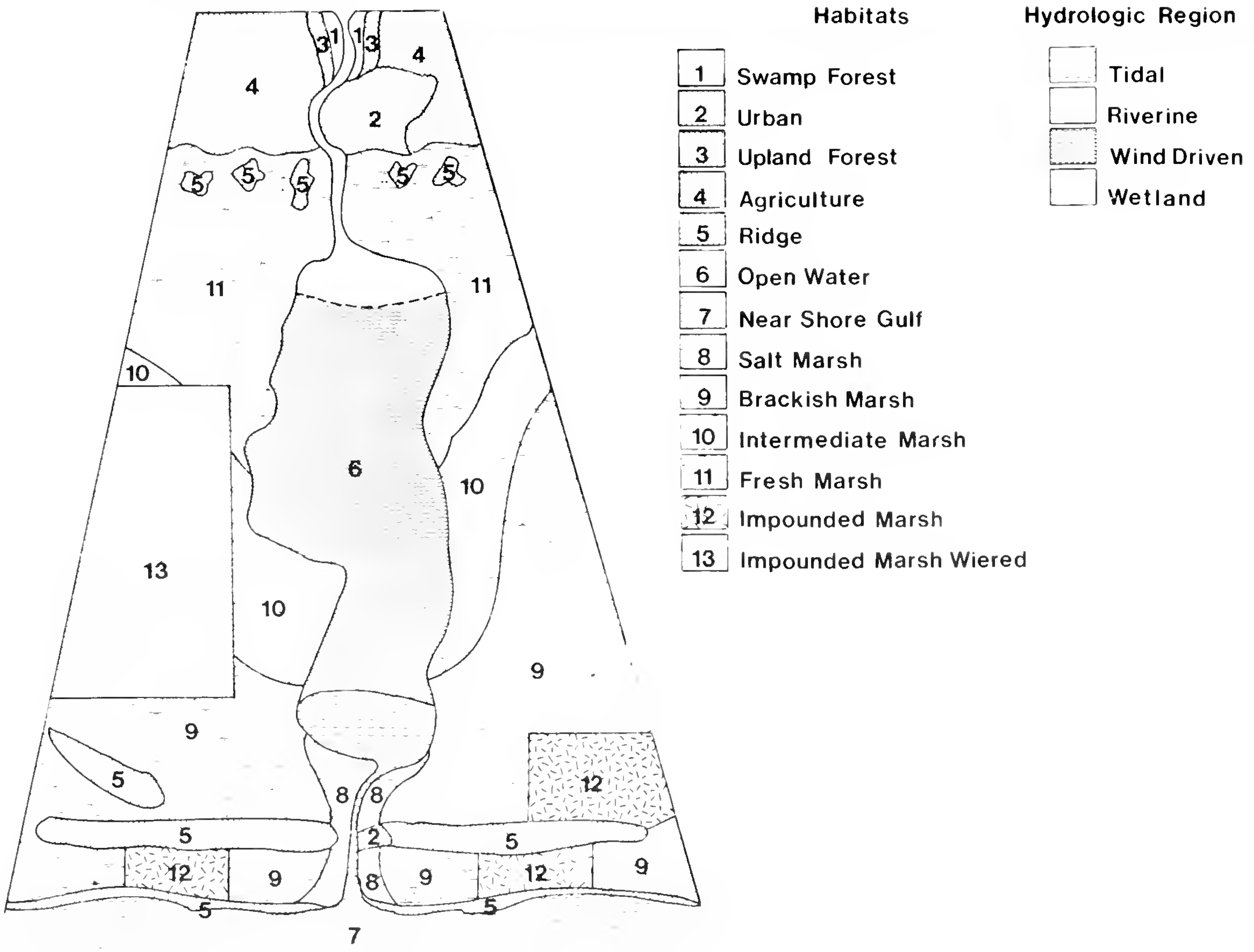
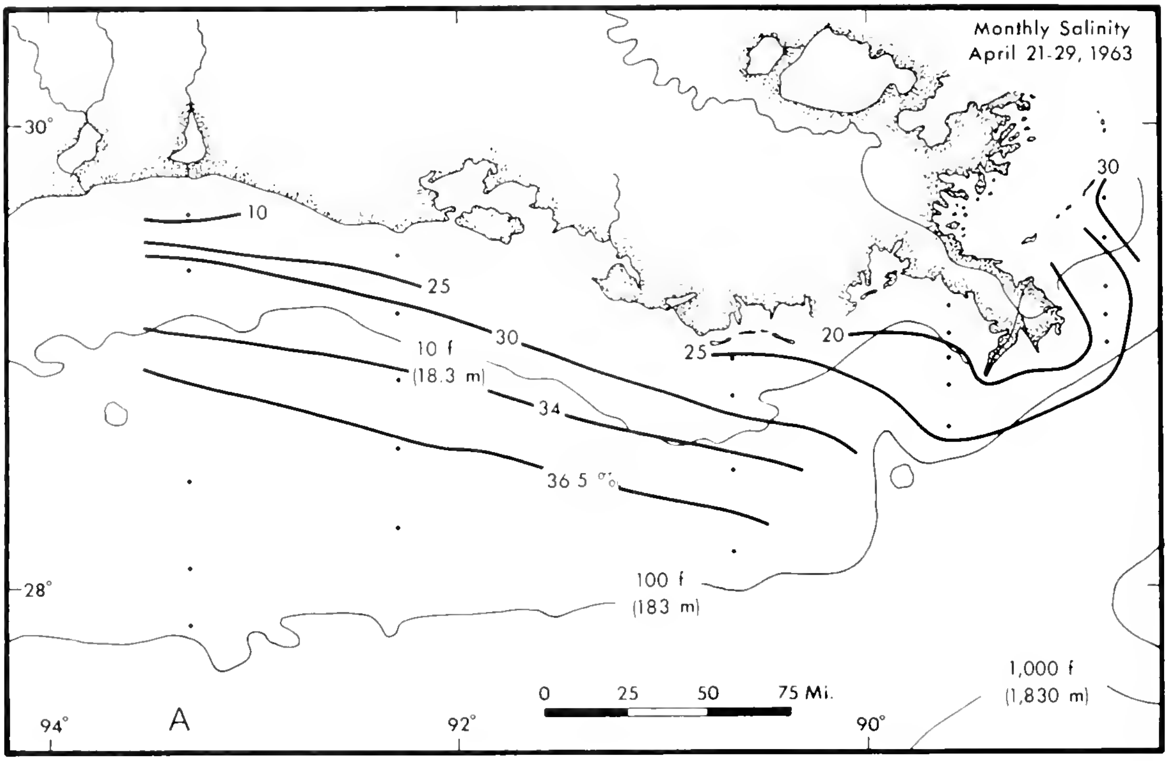


Figure 3-15. Hydrologic regions and habitats of a Chenier Plain basin.



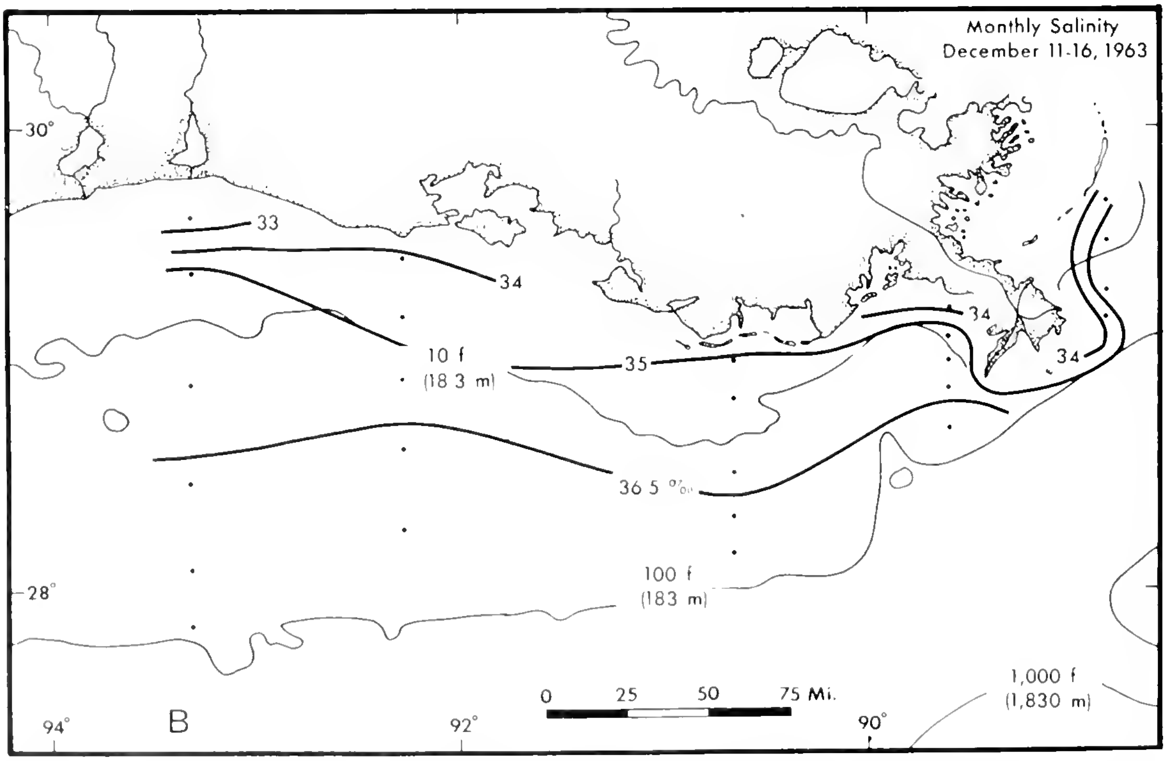


Figure 3-16. Average surface salinity (‰) contours along the Louisiana coast during (A) high river stage, April 21-29, 1963 and (B) low river stage, December 11-16, 1963 (Murray 1976).

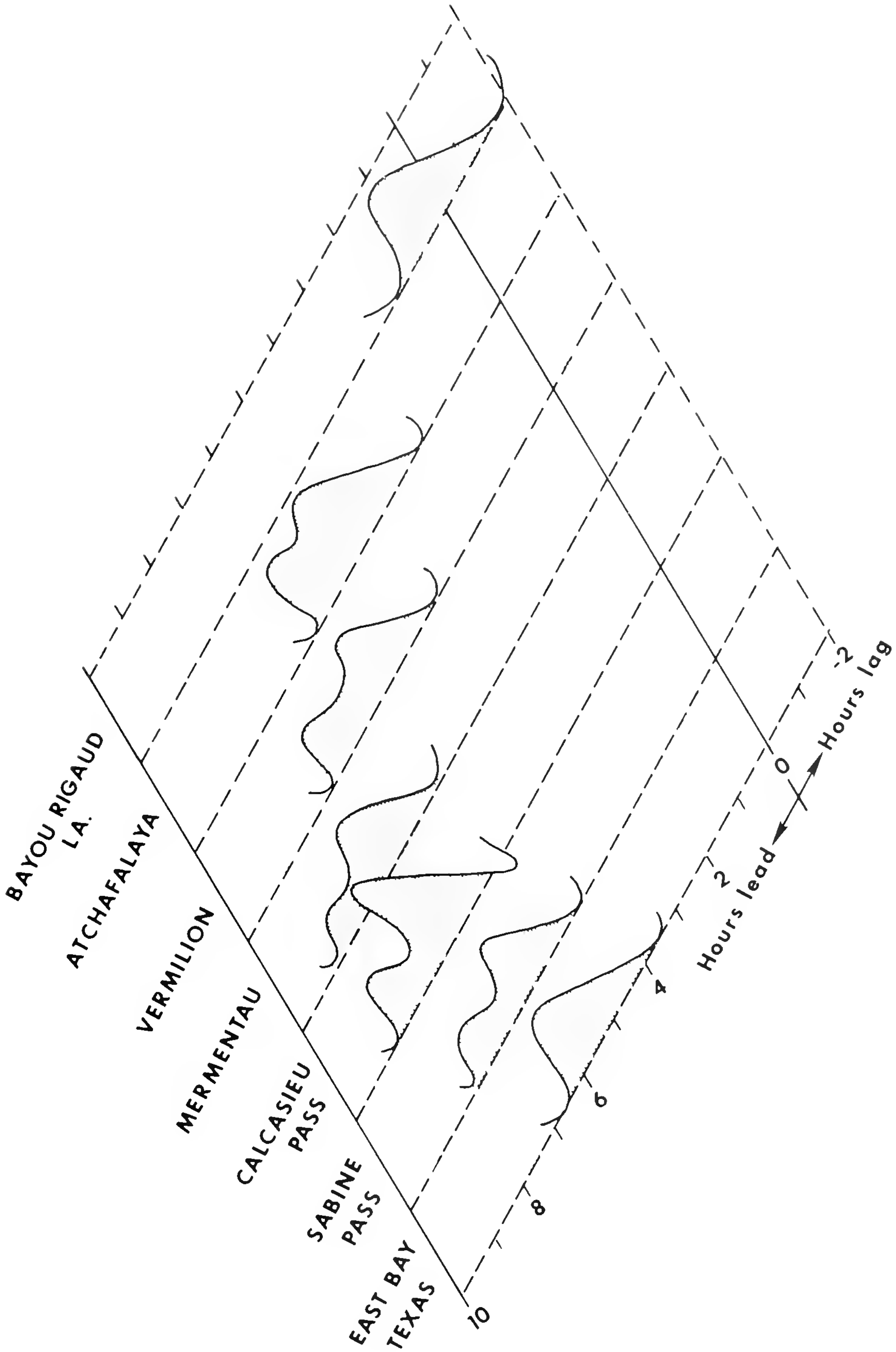


Figure 3-17. Tidal phases at several locations along the Louisiana and east Texas coasts.

water regime displays two highs, in spring and in late fall (fig. 3-18). The spring high may be associated with river stages and abundant local rainfall. The fall peak seems to be a result of the predominant southerly summer winds that gradually build up the water level along the northern Gulf coast. This seasonal cycle means that wetland inundation does not occur equally throughout the year.

Table 3.46. Mean coastal tidal fluctuations for Chenier Plain basins.

Basin	Tidal fluctuations: Mean (cm)	Tidal fluctuations: Standard deviation (cm)
Vermilion	37.5	±15
Mermentau[a]	0.0	0.0
Chenier	24-42	±19
Calcasieu	75	±41
Sabine	40	±47
East Bay	30	

[a]Has no tide.

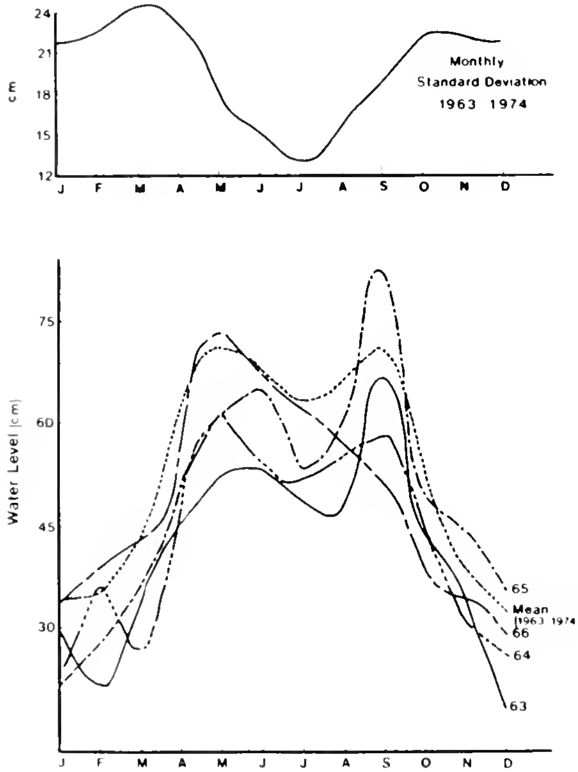


Figure 3-18. Monthly water-level fluctuations for 1963-66, and monthly mean and standard deviation, 1963-74, in the Calcasieu Basin (U.S. Army Corps of Engineers).

The importance of tides varies widely in the different Chenier Plain basins. Vermilion and East Bay are open estuarine systems with significant tidal action. Although the pass to the Gulf in the Chenier Basin is small, the basin lies parallel to the coast, and the wetlands that are not impounded are strongly influenced by tidal action. Both the Calcasieu and Sabine basins were formerly much fresher bodies of water than they are now, but they currently sustain significant tidal action because of the deep ship channels connecting the Gulf to inland waters. The Sabine ship channel has resulted in strong tides and salt intrusion directly into the northern end of Sabine Lake (part 3.6.6). In contrast, the Mermentau Basin is effectively cut off from any tidal action by control structures that impound the entire basin (part 3.6.3).

For the past 40 years, the water level has been increasing along the northern Gulf coast (Hicks and Crosby 1974). Tide gage records for most of the United States show the same phenomenon because of a combination of sea level rise and land subsidence. In the past 10 years, the rate of sea level rise seems to have accelerated. Rates on the Gulf coast are among the highest in the nation (Hicks and Crosby 1974). On the Chenier Plain, tide gages in all basins agree qualitatively. The average rate of apparent sea level rise (i.e., change in gage readings) is about 1.7 cm (0.7 in)/yr (table 3.47). Therefore, intertidal zone wetlands must aggrade at a rate equal to their subsidence; changes in the rate of net subsidence (due to all causes) signal major shifts in marsh formation or erosion.

Table 3.47. Mean annual rise in water level by basin.[a]

Basin	Annual rise (cm/year)
Vermilion	0.94
Mermentau	2.13
Chenier	2.10
Calcasieu	2.00
Sabine	No record
East Bay	1.50
Average	1.73

[a]Mean of one to five gages per basin. See part 3.6.

3.3.4 SUBUNITS INFLUENCED BY FRESHWATER

Both local rainfall and river discharge into the Chenier Plain significantly influence the hydrology of the basins. The region influenced by river runoff depends on the discharge volume of the river. If the volume of discharge is small in comparison to the tidal prism, then the river influence is secondary to tides. This is the case for most shallow embayments along the southeastern Atlantic coast and the northern Gulf of Mexico. However, the ridges that give the Chenier Plain its name are effective barriers to the Gulf, and tidal action in the estuaries is generally restricted. River runoff varies widely from year to year, and in high discharge periods the fresh water of the estuary expands but contracts again as discharge slows.

Upstream discharge. The upstream watersheds of all the rivers are less than 24,000 km^2 (9,266 mi^2). Only the Sabine watershed drains an area greater than 10,000 km^2 (3,861 mi^2). Rain surplus is similar throughout these watersheds, so discharge is proportional to watershed area (fig. 3-19). The Chenier Plain watersheds are small in comparison to that of the Mississippi River, which drains about 5 million km^2 (1.9 million mi^2) of upland surface. Since these watersheds are small, their seasonal discharge patterns conform closely to the local rainfall pattern, with only small lag times. A typical seasonal discharge pattern for Chenier Plain rivers is shown in figure 3-20. Here the surface water input into the Calcasieu Basin at Kinder, Louisiana, corresponds closely to the rain surplus in the upstream watershed.

The upstream discharge is important as a source of sediments and nutrients and as a moderator of salinity. Many organisms and processes are keyed to the annual cycle of fresh water input.

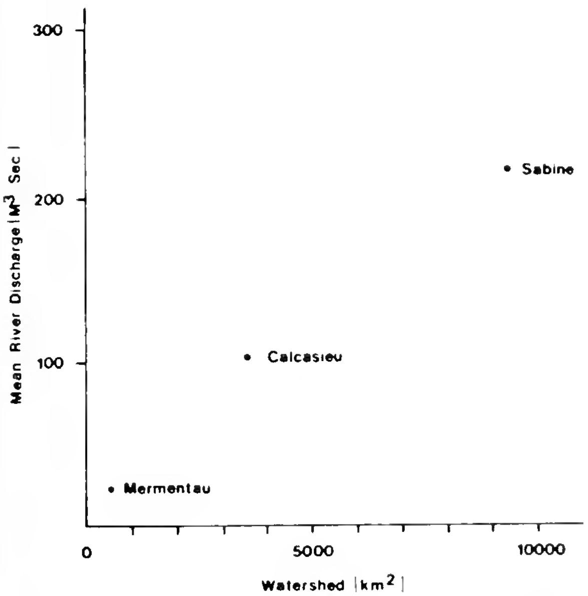


Figure 3-19. The relationship of mean river discharge to watershed area for three Chenier Plain basins (U.S. Geological Survey 1977).

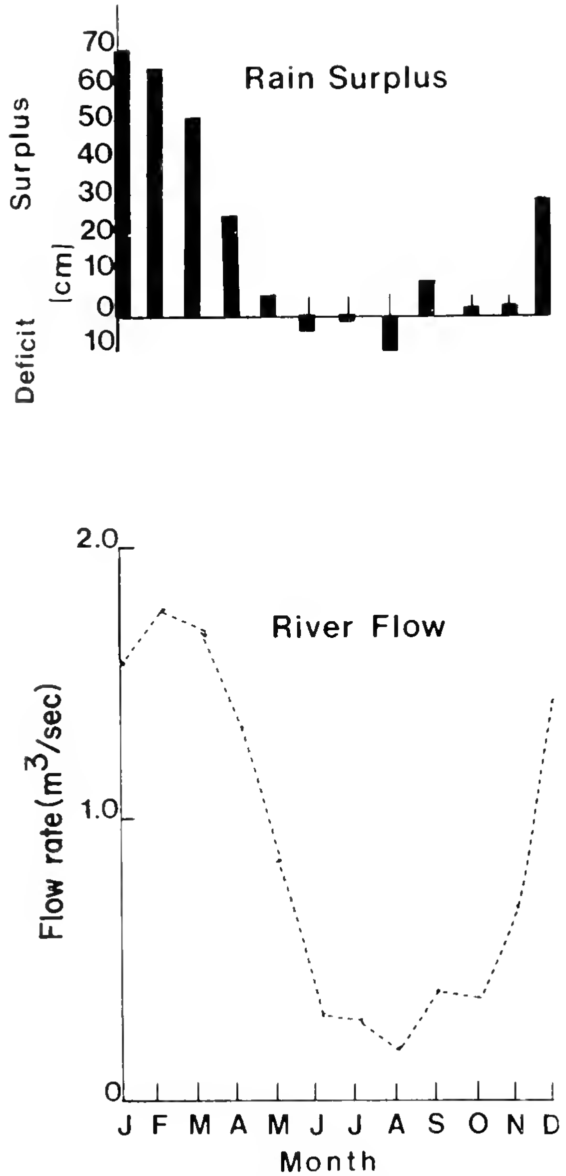


Figure 3-20. Mean monthly rain surplus or deficit estimated from rainfall, temperature, and evapotranspiration (Borengasser 1977) for the Upper Calcasieu River drainage basin, and the surface water flow into the Calcasieu River at Kinder, Louisiana (U.S. Geological Survey 1977).

Upstream inflow to coastal basins has, historically, been modified by cultural activities. Modifications range from indirect activities, such as clearing of forests, which dramatically increases runoff (Likens and Bormann 1974), to control structures and dams that directly modify flows. Within the Chenier Plain, the watershed most seriously affected by discharge modification is the Sabine. The creation of the Toledo Bend resevoir on the Sabine River (which carries most of the water discharge into Sabine Lake) has resulted in a large reduction in sediment load and total discharge, and in a change of the seasonal timing of discharge. This, in turn, has influenced salinity and biological changes in the estuary (part 3.6.6).

Renewal time. It is instructive to evaluate how much each basin depends on runoff to supply freshwater and to estimate roughly how often the waters in each basin are replaced or renewed. Renewal time is an important concept in water quality management, and has been modified by management practices in the Chenier Plain basins (table 3.48). First, the annual rain surplus decreases from east to west across the Chenier Plain, from 60 cm (23.6 in) in the Vermilion Basin to only 20 cm (7.9 in) in the East Bay Basin. This surplus multiplied by the surface area of each basin gives the total volume of freshwater generated within that basin and available for runoff or groundwater recharge. The large surplus from local runoff explains why the Chenier Plain region is so fresh in spite of its proximity to the coast. The volume of water entering each basin from upstream is shown for comparison. The freshwater budgets for the Calcasieu and Sabine basins are dominated by riverine input; the other basins depend primarily on local rainfall. Estimates of the renewal time of water for each basin listed in table 3.48 are based on the assumption that the freshwater surplus is the sole agent of water renewal. Since the tidal prism is a significant percentage of the mean water depth of these shallow estuaries, the renewal time would be different than indicated in table 3.48. However, the Gulf tidal waters tend to move in on flood tides and then recede again on ebb tides, with mixing only where they interface with estuarine waters, so that the net exchange is probably quite small (Happ et al. 1977). Wind-generated currents can also increase renewal time as discussed in part 3.3.5. In table 3.48, another calculation is made for the large inland lakes only, with the assumption that all runoff in a basin empties into these lakes. Calculations for the Vermilion and East Bay basins are misleading because they are parts of larger basin systems outside the Chenier Plain boundaries. However, the relatively long renewal time for East Bay is probably correct in a qualitative sense, and the system as a whole would be expected to have more marine influence than other basins. Vermilion Basin is probably fresher than indicated by the renewal time because the Atchafalaya River to the east depresses salinity throughout the Atchafalaya/Vermilion Bay systems.

The rapid renewal times for Calcasieu and Sabine basins result from the large riverine input. This rapid flushing of basin waters suggests a capacity to sustain higher nutrient loadings than poorly flushed systems.

An increase in the depth and width of tidal inlets should result in a faster renewal time. Small canals in the interior basin act the same way. They offer less resistance to water than natural, shallow, sinuous channels allowing water to move in and out more rapidly. They also change circulation patterns and decrease sheetflow across wetlands. Excessive diversion of water from upstream for agriculture and industry increases the renewal time (days) of the basin. Since the renewal time is related to the total nutrient load a body of water can assimilate, its modification can influence the eutrophic state of the water body.

3.3.5 SUBUNITS DOMINATED BY WIND-DRIVEN CURRENTS

The large, shallow lakes of the Chenier Plain are affected by tides, but wind is often the dominant mechanism controlling currents, water height, and flushing rates. Dominant winds along the coast are either from a southerly direction (usually in summer) or from the north (in winter), as previously indicated in figure 2-6. In large lakes, especially ones which are oriented north to south, such as Calcasieu and Sabine, these winds, acting over a long fetch, generate currents that can reach up to 3% of the wind velocity (Murray 1975).

The effect of wind on water levels is often dramatic, and waterflows generated by the buildup of a hydraulic pressure gradient across small inlets and narrow channels connecting lakes can be large. The initial response of the water surface to a wind change is rather rapid, usually occurring in less than 24 hr. Sustained winds blowing across a water surface tend to push the water in the direction of the wind, piling it up against the shore, until an equilibrium is reached between the wind stress in one direction and the opposing water slope created by the water buildup. This wind setup reaches a maximum value rather rapidly, depending on windspeed and the open water fetch (table 3.49). When tide is phased with winds, their combined action can change water levels several meters in a matter of hours. After the initial, predictable and rapid response, sustained winds have unpredictable effects (Wax 1977). For instance, the response to different weather types is shown at Hackberry about halfway up the western shore of Calcasieu Lake near the ship channel (fig. 3-21). Synoptic Weather Type 1 represents initiation of a typical cold front with northerly winds. It always results in a lowering of the water level, whether surplus water is available or not. However, Weather Type 3, typically weather following a cold front and representing northerly air flow sustained over several days, showed variable effects on water level. To explain the unpredictable results in Calcasieu Lake, Wax (1977) suggests that river runoff into the upper basin generated by the same weather conditions might arrive at the lake several days after cold front passage, or a long-term setup could occur as winds pile water at the outlet at the southern end of the lake causing a bottleneck in the flow and raising water levels at the Hackberry gage.

As shown in figure 3-21, Weather Types 1, 2, and 3 associated with northerly winds all tend to depress water levels, whereas easterly winds (Types 4 and 5) and south- southeasterly winds (Types 6 and 7) tend to increase water levels by forcing water into the inshore estuaries against the slight surface slope.

These weather events influence flushing times, turbidity, and wetland flooding. When turbulence and currents increase and water levels are abruptly changed by combinations of tide and winds, mixing of tidal and estuarine waters is increased. This mixing and the magnified flows through tidal inlets significantly increase the rate of flushing of the estuary. In shallow bays and lakes, wind-driven waters stir up bottom sediments and increase turbidity.

Table 3.48. Total freshwater input and estimated renewal time by basin for the Chenier Plain.

Basin	Area (ha x 10^3)	Rain surplus[a] Depth (cm/yr)	Rain surplus[a] Volume ($m^3 \times 10^8$/yr)	Upstream river discharge into basin[b] ($m^3 \times 10^8$/yr)	Total freshwater input ($m^3 \times 10^8$/yr)	Water area[c] (ha x 10^3)	Depth (m)	Renewal time[d] (days)
Vermilion	75.3	60.6	4.56	6.77	11.33	19.0	1	61
Chenier/Mermentau	362.9	55.2	20.0	9.67	29.7	67.1	1	83
Grand, White, & Misere lakes only[e]						34.7	1.5	58
Calcasieu	135.4	49.3	6.7	34.2	40.8	41.0	1	37
Lakes Calcasieu & Charles only[c]						17.7	1.7	24
Sabine	291.8	43.1	12.6	75.2	87.8	47.2	1	20
Sabine Lake only[e]						22.6	2	15
East Bay	81.4	20.6	1.7	Local	1.7	26.6	1	577

[a]Rain surplus is the amount of precitation minus losses due to evapotranspiration and soil moisture recharge. Surplus water is available for groundwater recharge and runoff. Calculated by method of Borengasser (1977), from U.S. Weather Service rainfall and temperature records.

[b]Data from U.S. Geological Survey 1977.

[c]Total basin inland open waters with 1 m depth assumed.

[d]Freshwater input divided by water volume (water area x depth); calculated solely on basis of freshwater inflow and does not include tidal exchange.

[e]For lakes only, it is assumed that all local runoff feeds into these lakes; that is, total freshwater input for the basin equals that for the large lakes. Lake area and depth from Barrett (1970).

Table 3.49. Minimum fetch and duration required for full development of set-up associated with various wind speeds.[a]

Wind speed (kn)	Fetch (km)	Duration (hr)
10	18.5	2.4
20	140	10
30	520	23

[a]Wax 1977, modified from Bascom 1964.

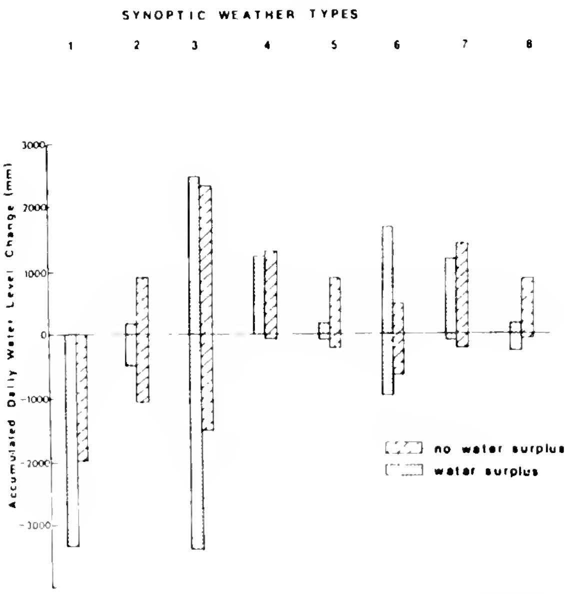


Figure 3-21. Relationship between water levels and different weather types for Calcasieu Lake near Hackberry, Louisiana (Wax 1977); text describes synoptic weather types.

3.3.6 SUBUNITS OF EXCHANGE BETWEEN WATER BODIES AND WETLANDS

Wetlands are built by the deposition of sediments carried by flooding waters. The growth of vegetation, the use of wetlands by aquatic organisms, the export and import of organic matter, and the cycling of nutrients are dependent on periodic flooding. It is difficult, therefore, to overemphasize the importance of the exchange of water between wetlands and adjacent water bodies.

Wetland processes tend to stabilize marsh elevation somewhere around mean sea level (MSL) (Sasser 1977). If elevations become too low, the vegetation is flooded for longer periods than it can survive and the marsh erodes. At the other extreme, as wetlands aggrade they are flooded less and less often until they no longer receive the sediment supply necessary for continued growth. Sasser (1977) found little difference in elevation within different marsh vegetation types in eastern Louisiana. There, marshes varied in elevation between about -9 cm and +9 cm (± 3.5 in) relative to local MSL.

Saline marshes receive regular flooding from tidal waters. As tides attenuate upstream meteorological forces affecting water levels become more dominant. If marsh elevation is assumed to be at local MHW, at Calcasieu Pass water exceeds this elevation 243 times per year and remains over the marsh for an average of 6.9 h/inundation. Upstream at Hackberry where freshwater runoff primarily controls water levels, the same elevation (e.g., local MHW) was exceeded only 200 times but the mean inundation was of longer duration. In Barataria Bay, Louisiana, where gage stations span the distance from the Gulf pass at Bayou Rigaud to the intermediate marshes upstream at Barataria, the same relationship holds but is even more dramatic. The frequency of inundation decreases upstream but the duration, both in terms of total hours per year and hours per event, increases (table 3.50).

Table 3.50. Duration of water above local MWH, frequency of inundation, and mean inundation duration in 1971 in the Calcasieu Basin and in Barataria Bay (data from U.S. Army Corps of Engineers).

Hydrologic unit	Time above MHW (% of yr)	Frequency (inundations/yr)	Mean duration of inundations (hr)
Calcasieu Basin			
Cameron Pass	19.2	243	6.9
Hackberry	29.1	200	12.7
Barataria Bay			
Bayou Rigaud	12.1	128	8.3
Lafitte	23.7	79	26.3
Barataria	41.3	75	48.2

The seasonal inundation regime of the marshes near Hackberry in Calcasieu Basin, which is fairly typical for the entire Chenier Plain, shows that marshes are inundated most often during the fall and winter months (fig. 3-22). This does not correspond with the months of highest mean water, May through September (fig. 3-18). However, it does correspond with the months when the variation in water level is high, as indicated by the standard deviation curve. During the summer, water levels are high but are below marsh elevation; they are less variable than water levels during winter months so they usually do not exceed marsh elevation. In the early winter and to a lesser degree in the spring, although the mean water level is lower, the range of fluctuation is much greater and marshes are flooded more often. The increased variability in winter is probably associated with storms and illustrates the importance of rain and wind for marsh flooding.

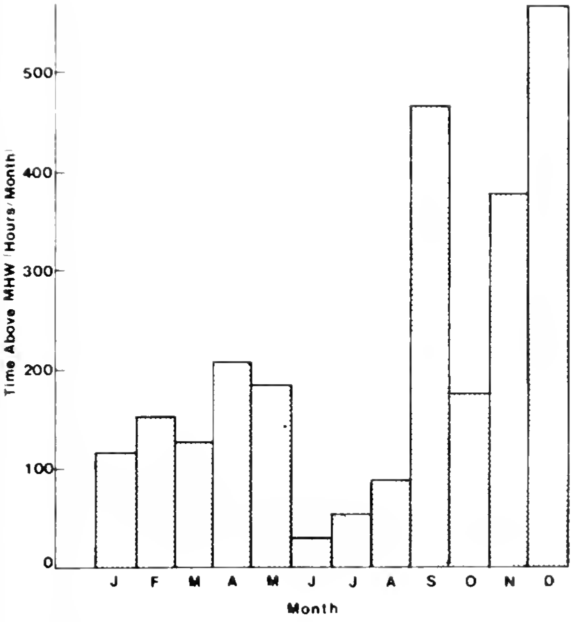


Figure 3-22. The hours per month that the water levels are above mean high water in marshes at Hackberry, Louisiana (U.S. Army Corps of Engineers).

The pattern of inundation is important for another reason (fig. 3-22). During the months of June, July, and August, salinities are highest in the estuaries because of a combination of high sea stage (fig. 3-18) and low rain surplus (fig. 3-20). During this period, marshes are infrequently flooded with water more saline than normal. When such floods occur during a period without rain and with high evapotranspiration rates, salts accumulate in marsh sediments. This may have serous consequences in fresh, intermediate, brackish, and salt marshes. For instance, there is some indication that periodic salt accumulation has killed stands of saltmeadow cordgrass in brackish marshes along Calcasieu Lake. The salt accumulation is a result of the overall salinity increase accompanying dredging of the Calcasieu Ship Channel (J. Valentine, Pers. Comm., U.S. Fish and Wildlife Service, Lafayette, La.).

In the Chenier Plain, the amount of wetland that is freely flooded by estuarine waters has been drastically reduced by human activities. Much of the wetland (162,000 ha, 400,311 a) is impounded, e.g., over one-half of the wetlands in the Chenier Basin are behind some type of levee. In addition, many marshes are semi-impounded by canal spoil banks and other levees that restrict or redirect water flows. The entire Mermentau Basin can be considered an impoundment in which water levels are controlled by structures in all the major channels draining the basin. Only the Calcasieu and Sabine basins have large areas of unimpounded wetlands. In both of these basins, hydrologic modifications have changed water flow and salinity patterns, which have resulted in high marsh loss rates (part 3.4).

3.3.7 SUBUNITS WITH LITTLE OR NO WATER EXCHANGE—UPLANDS AND IMPOUNDMENTS

Uplands are important to the hydrologic processes of a basin as a source of local runoff water and as natural barriers to water flow. Since much of the upland area in the Chenier Plain is impounded for rice, the quantity of free runoff is probably not as important as the quality of this water since it carries silt, nutrients, and toxic chemicals into the estuary. The draining of rice fields is controlled, so runoff from them does not correspond with heavy rainfalls. Impounded wetlands normally have very little exchange with surrounding waters, although undoubtedly there is seepage through levees, and overflows during high water conditions. Water-level management practices also result in some water exchange. However, in terms of the estuarine system, these impoundments are effectively cut off and no longer contribute to the normal hydrology of the basin. Also, sheet flow across wetlands is disrupted by impoundments, and continuous canals associated with levcee construction act as conduits that speed drainage and allow water to bypass marshes altogether.

3.3.8 HUMAN IMPACTS ON THE HYDROLOGIC REGIME

Man has modified the hydrologic regime of the Chenier Plain basins to such an extent that there are now no basins on the plain untouched by human intervention. These modifications can be classed as those that affect (1) the upstream water flow into the basins, (2) the circulation within the basin, or (3) the nearshore Gulf circulation (table 3.51). The direct effects can be measured in terms of a number of attributes of the hydrologic regime: freshwater supply, salinity, sediment input, sediment deposition and erosion, water levels, overland flow, and circulation. Table 3.51 indicates the sections of this report that discuss those effects. The primary hydrologic changes give rise to a series of secondary effects. The concern at the basin level is primarily for the secondary effects to habitat type, area, and interactions. However, the functional characteristics and the biota of habitats also respond to the changes (part 3.4.3) and are discussed in parts 4.0 and 5.0.

The quantitative evaluation of the effects of modification in the hydrologic regime of Chenier Plain basins is severly hampered by the absence of good hydrodynamic models. Good models should be a priority item for management because water flows are the key to the productivity of the Chenier Plain. Existing models have demonstrated their usefulness. Tracor, Inc. (1971) modeled water quality parameters in a two-dimensional model of Galvestion Bay that included East Bay. The U.S. Army Corps Engineers (1950) predicted saltwater intrusion from a model of the Calcasieu River and connecting waterways. More comprehensive hydrodynamic models have been developed for estuarine areas (Lauff 1967), but they have not been applied to the Chenier Plain basins nor have they been applied in any systematic way to predict the hydrological modifications associated with canals in general. However, certain large-scale water modifications lend themselves to evaluation. In the Chenier Plain, the management of water in the entire Mermentau Basin, the navigation channel in the Calcasieu Basin, the upstream reservoir and major ship channel in the Sabine Basin, and the Gulf Intracoastal Waterway (GIWW) are examples. All except the GIWW example are discussed in part 3.6. The GIWW runs from east to west across all of the basins except the Chenier Basin. In spite of its length and importance, there appears to be no comprehensive quantitative study of the hydrologic impact of the GIWW. It is known to facilitate the flow of water laterally across basin boundaries; an average flow of 110 m^3/sec (3,885 ft^3/sec) occurs westward from the Sabine Basin to the East Bay Basin. The quality of this water depends on its proximity to channels interconnecting with the Gulf; the GIWW can carry saline waters into formerly freshwater areas. In addition to facilitating east to west water flow, spoil banks of the GIWW are significant barriers to overland sheet flow and may also disrupt local animal movement patterns. North and south portions of the basins are, in effect, hydrologically cut off from each other by the GIWW. As a result, salinity and vegetation gradients across the GIWW can be much sharper than elsewhere in the basins.

The GIWW and other major public works are superimposed on a history of many smaller activities that have modified hydrology during the past 100 years or more. Their cumulative impact has been extremely difficult to evaluate because the effects have occurred over a long period of time. There is at least minimal information on freshwater flows from upstream gaging stations as well as some data on salinity. However, data on sediment inputs are extremely scarce. Net sediment deposition and erosion rates can be deduced from maps and aerial imagery. However, without a large major modeling effort, the ability to detect and/or predict modifications of water levels, circulation patterns, and wetland flooding regimes is limited, and only large-scale effects can be documented with any confidence.

The hydrologic effects of canals and their associated spoil banks are difficult to document quantitatively. Canals are a major measureable feature of human occupancy of the Chenier Plain, and there are 8,714 km (5,415 mi) of canals of various types (table 3.52). Plates 5A and 5B display the distribution of these canals. About one-third of the total are agricultural drainage canals; additional canals were constructed for other purposes and only incidentally

Table 3.51. Flow model of primary and secondary effects of cultural modifications of the hydrologic regime on the Chenier Plain ecosystem.

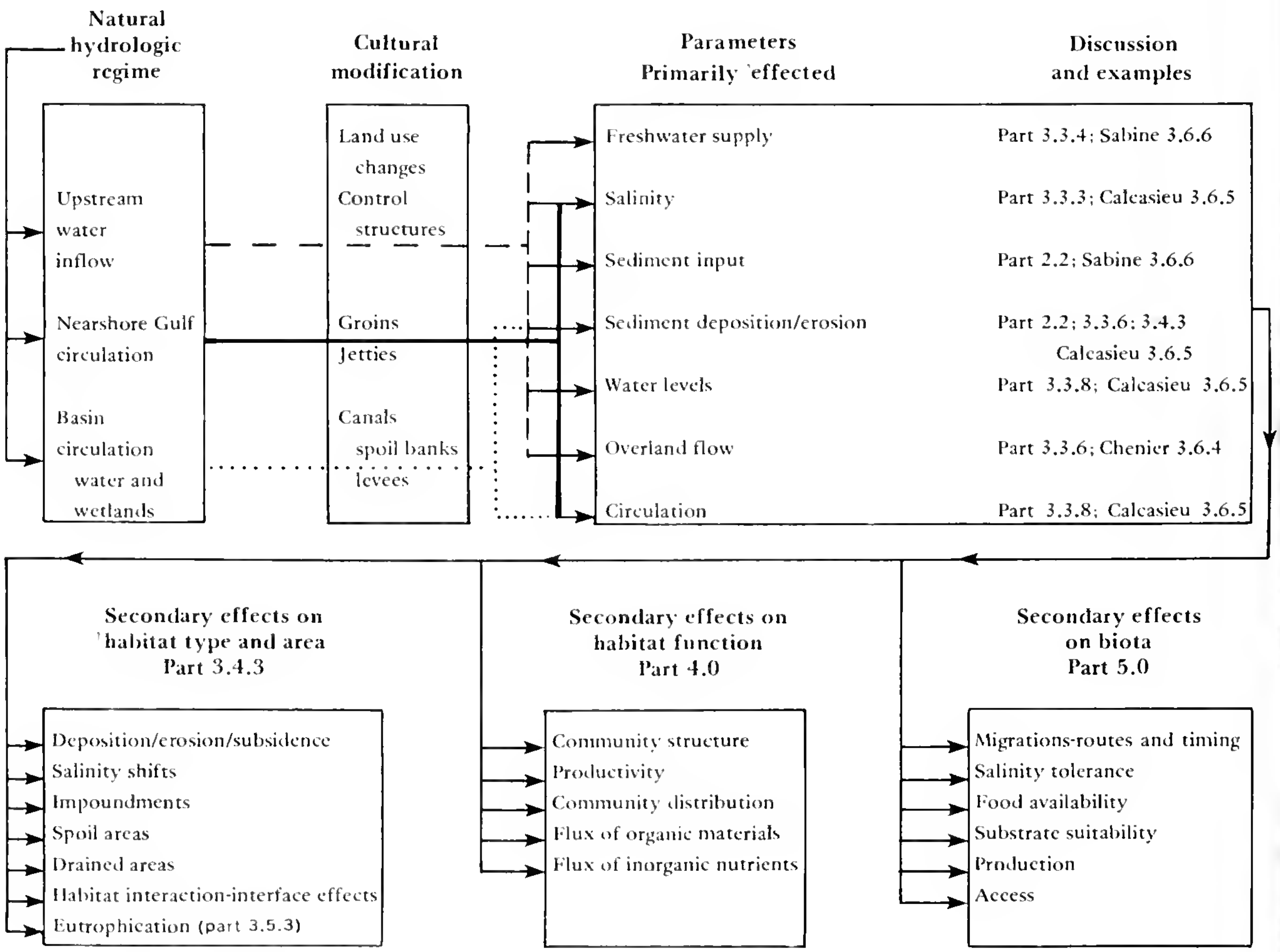


Table 3.52. Lengths (km) of various canal types in Chenier Plain basins.

Canal type[a]	Basins							
					Sabine			
	Vermilion	Chenier	Mermentau	Calcasieu	Texas	Louisiana	East Bay	Total
1. First order navigation	56.70	17.01	149.37	125.09	154.63	21.30	68.05	592.15
2. Second order navigation	325.50	538.29	987.91	342.86	181.70	404.65	69.14	2,850.05
						Total Navigation		3,442.20
3. Agricultural drainage								
a) Uplands	66.23	0	688.18	217.46	533.53	58.49	197.18	1,741.07
b) Wetlands	163.07	292.29	479.25	63.79	212.16	76.07	108.11	1,394.74
4. Agricultural access								
a) Adjacent canal	1.14	4.39	5.70	0	0	6.92	0	18.15
b) Borrow pits	3.20	32.51	3.30	18.73	0	0.92	0	58.66
						Total Agriculture		3,212.62
5. Oil activity								
a) Oil field navigation	137.28	150.32	310.44	122.68	41.34	120.21	5.54	887.81
b) Oil field embankments								
1. Adjacent embankments	12.89	66.12	39.71	61.43	1.72	51.89	2.05	235.81
2. Borrow pits	2.23	43.15	16.89	53.81	0	24.35	0	140.43
						Total Oil Field		1,264.05
6. Transportation embankments								
a) Adjacent canals	3.16	19.02	33.53	72.53	64.88	26.65	37.81	257.88
b) Borrow pits	4.97	8.27	6.78	58.61	2.67	0.45	0	81.75
7. Pipeline canals	25.32	75.10	84.74	41.33	0.60	13.25	0	240.34
8. Wildlife management impoundments canals	0	75.42	39.09	93.24	0	0	0	207.75
9. Other	2.06	0	2.02	0	3.97	0	0	8.05
TOTAL	803.75	1,321.89	2,826.91	1,271.56	1,197.20	805.15	487.88	8,714.34

[a]See appendix 6.4 for definition of canal types.

modify flows. The navigation and oil field access canals together account for over one-half of the total. These were built to provide the most direct and/or cheapest route from one point to another and were constructed without regard to hydrologic effects. There is little documentation on the hydrologic effects of these canals the relationship between the hydrologic alterations and wetland loss and salinity changes in the Chenier Plain are not clear. The complexity of the ecosystem has made it difficult to draw a causal connection. A study is needed similar to the modeling effort in the upper reaches of Barataria Bay (Light 1976). Light's model suggested that dredged canals in the basin have increased peak discharge rates by nearly 100%; consequently, runoff occurs more rapidly than it would normally, and low-water stages have been lowered about 15 cm (6 in). These changes result in a higher suspended load capacity and more wetland inundations of shorter duration.

At the basin level correlations between habitat modifications (such as erosion) and human activities (such as canal density) have been made. Although the approach does not concern itself with the mechanisms of the response—that is, the way the hydrologic regime is modified and in turn modifies habitats—it has produced useful insights that are discussed in part 3.4.6.

A correlation has recently been drawn between canal density and eutrophication. Bedient and Gatewood (1976) showed that in Florida, as agricultural drainage canal density increased, phosphorus concentrations in receiving waters also increased. Gael and Hopkinson (1978) reported a similar phenomenon in the Barataria Basin, southeastern Louisiana, for oil field access canals (fig. 3-23). They found that the eutrophic state indices (high index infers a dangerous eutrophic state) for various areas in the basin (as measured by an index of four water quality parameters—chlorophyll a, total nitrogen, turbidity, and total phosphorus) were directly proportional to canal density. Canals speed the runoff of sediment- and nutrient-rich agricultural water, and water from cleared forests and urban lands. Instead of flowing slowly over wetlands, where much of the sediment and nutrient load is captured, this water flows directly through the canals into downstream lakes and bays where the nutrients stimulate the plankton growth that results from increased eutrophication.

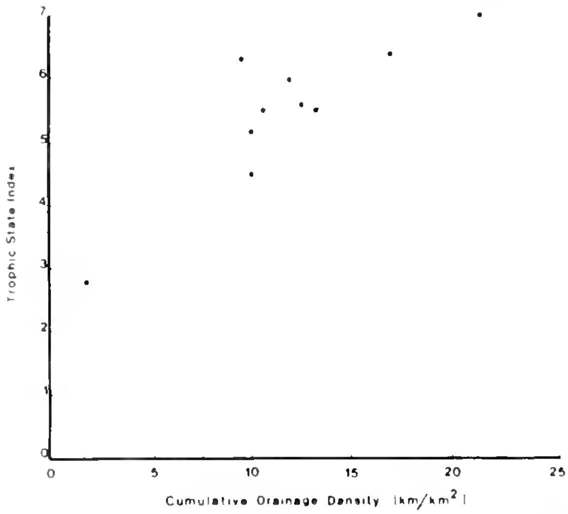


Figure 3-23. The relationship of the trophic state index of water to drainage density in the upper part of Barataria Basin, Louisiana. The regression line accounts for 59% of the variation among points and is highly significant statistically (Gael and Hopkinson 1978).

3.4 HABITATS AND LAND-MODIFYING PROCESSES

3.4.1 INTRODUCTION

Except for the major commercial and sports species, relatively little is known about the standing stock, life history, and ecological importance of the many species inhabiting the Chenier Plain. Normal year to year population fluctuations are wide, and a basin-level inventory at any one time (if it were possible) would yield little information about the factors that control population size.

Populations of individual species result from the interaction of many factors. A broad evaluation of living resources requires the use of describable units; the habitat is used for that purpose in this report. Regardless of what is not known about living organisms, it is known that they require a place to live—a habitat. (Part 4.1 considers further development of the concept.)

Certain attributes of habitats make them useful indices of living resources. First, they are objectively defined landscape units whose areal extent can be determined. Second, if the ecology of individual species is determined for small, representative habitat areas, the results can be extrapolated to similar habitats elsewhere. Third, the habitat as a unit contains an entire spectrum of species, many virtually unknown yet all functional parts of the habitat. Since our understanding of these non-resource species (Ehrenfeld 1976) and of their importance to ecosystems is fragmented, emphasis should be on interactions between species and their habitats. Finally, since a habitat is an irreducible requirement of a species, changes in extent of habitats can be expected to reflect long-term population shifts for species of interest. The habitat acts as an integrator of information about individual species.

The habitats and their location in a basin result from the interaction of geomorphic, climatic, hydrologic, and biotic processes on the geologic template of the Chenier Plain. Habitats are dynamic, and the interactions among habitats change constantly under the influence of these forces. The physical processes have been described in parts 2.0 and 3.3; biotic effects are dealt with in part 4.0. Documentation of the rates of change and processes responsible for major changes are provided in the following section. This section does not address the internal dynamics of these habitats (for instance, changes in productivity of existing habitats; part 4.0 deals with that topic).

3.4.2 APPROACH

The Chenier Plain region was divided into 14 habitats as defined in table 3.53. The habitat definitions are based on a combination of natural characteristics and land uses that are not always mutually exclusive. Overlap of natural and cultural processes occurs in every habitat. Ten of the habitats—the two aquatic habitats, the five natural wetlands habitats, and three upland habitats—are landscape units which function naturally. Three other "habitats" are clearly culturally modified. In these areas natural processes have been dramatically changed by cultural needs. The remaining habitat, impounded marsh, is rather diverse and contains areas where natural processes predominate as well as other areas where agricultural processes exert control. Impounded marsh is recognized by straight spoil bank or levee boundaries that isolate the impoundment from surrounding wetlands and water bodies. Controls on these levees range from "flap gates" which prevent the inflow of surface water but allow excess rainwater to run off, to impoundments that are routinely drained by pumping and are used for cattle grazing. In this study these drained impoundments are distinguished from pasture habitat by the fact that they are dominated by native vegetation.

These habitats were identified on the most recent (1974) U.S. Geological Survey 1:24,000 scale orthophotoquads or topographic maps. Wetlands were delineated by updating the marsh-type map of Chabreck et al. (1968), by information from the Texas Bureau of Economic Geology (Fisher et al. 1972), and photos from low altitude overflights supplemented with limited ground reconnaissance. Black and white aerial coverage was used to map habitat changes over the period 1952 to 1974. This coverage did not extend to the East Bay area, for which 1954 maps were used. Present habitat area was determined using a point converting (grid sampling) method developed by Gagliano and van Beek (1970). Canal lengths were digitized, and area was derived from average widths for different types (app. 6.4).

3.4.3 PRESENT HABITAT COMPOSITION AND DISTRIBUTION

The areal extent of habitats in the Chenier Plain in 1974 is listed in table 3.54, while the distribution of habitats within individual basins and habitat area changes since 1952 are provided in appendix 6.4. By eliminating the nearshore Gulf habitat, the reader is provided with a better perspective of the relative abundance of habitats landward of the shoreline. The distribution of the five major habitat groups is shown on Plates 3A and 3B.

The relative size of each habitat type does not necessarily correlate with its actual importance. The urban habitat occupies only 2.8% of the land area, but its influence extends to every other habitat of the Chenier Plain.

The generalized distribution of habitats in a Chenier Plain basin, in relation to various hydrologic subunits, is shown in figure 3-15. The agricultural habitats (pasture and rice field) are lumped together in this schematic because of their close association with one another. These habitats dominate the upper part of a basin on the Pleistocene surface. Pasture and a limited amount of land used for truck crops are also found on the cheniers.

The swamp forest habitat is typically found on river floodplains beyond "normal" tidal influence. This habitat is present in the Calcasieu, Mermentau, Sabine, and Vermilion basins. The East Bay and Chenier basins have no swamps because brackish tidal waters influence their wetland areas. In addition, since the East Bay Basin does not contain a major river system, there is no major floodplain for swamp forest to develop. Although the total area of swamp forest in the Chenier Plain is small, more extensive areas of this habitat type can be found on floodplains upstream from the study area. This is particularly true of the Calcasieu and Sabine floodplains.

Historically, upland forests have not been extensive in the Chenier Plain (Fisk 1944) but much of this habitat has been converted to agricultural lands. Only a few isolated stands of upland forest now exist in the northern portions of the basins.

The ridge habitat can be divided into two major types, natural and man-made. Natural ridges in the form of cheniers are concentrated near the coast and generally decrease in area as one moves inland. Pleistocene islands are topographic high areas surrounded by marsh. They are located close to the marsh-Pleistocene boundary. Natural levees of sufficient elevation to be classified as ridges are relatively rare in the Chenier Plain. The upper parts of the Calcasieu, Mermentau, Sabine, and Vermilion rivers contain small levees that support vegetation distinct from the surrounding swamp forest. Remnant levees of older river courses and shorelines appear occasionally in the Chenier Plain.

Man-made ridges, largely in the form of spoil banks, are found randomly throughout the Chenier Plain. Because spoil banks are associated with canals, their distribution is reflected by that for canals (Plates 5A and 5B). Spoil banks occupy 2% of the total area of the Chenier Plain, and this area is greater than that of the beach, swamp forest, upland forest, or salt marsh habitats. Perhaps more significant is the fact that spoil banks make up almost one-half of the total ridge habitat. Hydrologically, however, these man-made ridges function differently than natural ridges, because their orientation is random with respect to historic circulation patterns.

Most of the urban habitat is found on higher elevations landward of the fresh marsh zone. However, many small communities are located closer to the coast, on ridges and along major waterways (plates 1A and 1B).

The salt marsh habitat is generally found as a narrow zone between the beach and the first major landward ridge. At the site of major passes, salt marsh may extend inland and fringe the waterways.

Table 3.53. Definitions of the habitats of the Chenier Plain.

Habitat types

Aquatic

1. Nearshore Gulf – all waters between the coastline and the 9 m (30 ft) depth contour in the Gulf of Mexico. Intermittently exposed mudflats are considered part of this habitat.

2. Inland open water – all inland lakes, rivers, bayous and canals, including intermittently exposed mudflats.

Emergent wetland

3. Salt marsh – saline intertidal marshes dominated by smooth cordgrass[a], with saltgrass and blackrush common.

4. Brackish marsh – intertidal marshes and associated small ponds dominated by saltmeadow cordgrass and saltgrass; salinities generally less than 10 $^{0}/oo$.

5. Intermediate marsh – marshes and associated small ponds, periodically flooded with nearly fresh water, but occasionally by brackish water. Dominated by saltgrass, bulltongue, and seashore paspalum.

6. Fresh marsh – marshes flooded by fresh water, and with a diverse flora dominated by maidencane, bulltongue, and alligatorweed.

7. Swamp forest – forested freshwater wetlands with diverse flora dominated by baldcypress and tupelo.

8. Impounded marsh – marshes surrounded by dikes, spoil banks, or natural levees that modify normal flooding. These exist in saline to fresh areas. They may be permanently flooded or pumped dry, but all are dominated by native emergent wetland vegetation (as opposed to impounded agricultural land).

Upland

9. Ridge (cheniers, levees, spoil banks, Pleistocene islands) – landforms elevated above normal flood levels. Linear features within the wetlands except for Pleistocene islands. Usually forested except for recent spoil banks.

10. Beach – narrow strip of land along the Gulf, composed of fine sand and shell fragments. Sparsely vegetated.

11. Upland forest – areas of bottomland hardwood and pine forest on the upland Pleistocene terrace.

Agricultural

12. Rice field – cropland planted in rice or other crops, whether leveed or not. Often rotated with pasture.

13. Pasture – land improved for grazing by planting of improved grasses and by fertilization. Often rotated with rice field.

Urban

14. Urban – land areas developed for residential and industrial use. A land use category, but not described as a habitat for native fauna.

[a]Scientific names of plants listed in Table 4.27.

Table 3.54. The area of Chenier Plain habitats in 1974.

Habitat	Area (ha)	Percent of total	Percent of inland area[a]
Aquatic			
Nearshore Gulf	371,257	28.2	0.0
Inland open water	200,844	15.2	21.2
Wetlands			
Salt marsh	17,155	1.3	1.8
Brackish marsh	100,855	7.7	10.6
Intermediate marsh	84,843	6.4	9.0
Fresh marsh	116,331	8.8	12.3
Swamp forest	6,538	0.5	0.7
Impounded marsh	161,781	12.3	17.1
Uplands			
Ridge (cheniers, levees, spoil banks)	59,761	4.5	6.3
Beach	6,164	0.5	0.6
Upland forest	15,864	1.2	1.7
Agriculture			
Rice field	60,298	4.6	6.4
Pasture	90,125	6.8	9.5
Urban	26,137	2.0	2.8

[a]Inland area excludes the Nearshore Gulf Habitat.

Fresh, intermediate, and brackish marsh habitats show similar distribution patterns. These marshes tend to run parallel with the main avenue of water exchange, almost perpendicular to the coast in zones of decreasing salinity (fig. 3-15). As one moves along the coast away from the tidal passes, the marsh zones tend to form bands which are parallel with the shoreline. Collectively, these marsh types represent nearly one-third of the total area landward of the nearshore Gulf habitat.

In terms of area, impounded marsh represents the third largest habitat. It includes all leveed and flooded wetlands, regardless of salinity, within which water level is controlled to some extent. Impounded marsh tends to become increasingly fresh, since rainfall exceeds evapotranspiration. It comprises one-third of all marsh area and, as such, is indicative of the effort to manage marsh for one purpose or another. Impounded marsh is found within all the other marsh types except salt marsh. The average size of an impounded area is rather large, almost 800 ha (1,977 a). Some impoundments, however, are only a few hectares in size but one on the Sabine National Wildlife Refuge is well over 10,000 ha (24,711 a).

The inland open water habitat is the largest in area other than nearshore Gulf. Typically, each basin contains at least one large open lake or bay. The two flanking basins, Vermilion and East Bay, contain an open bay system, whereas the remaining basins contain large lakes. These large water bodies, which account for most of this habitat type, are relatively stable in comparison to the numerous small, shallow ponds scattered throughout the Chenier Plain. Many of the latter are rapidly increasing in size.

All basins except Mermentau contain beach and nearshore Gulf habitats. For area statistical analyses, the nearshore Gulf habitat is reported by basin although it is truly a regional habitat and has no real boundaries except for the coastline. The Vermilion Basin contains a large proportion of this habitat. The wide, shallow shelf in this area represents the western margin of Recent Mississippi River deltas (plate 2).

The beach habitat is typically bounded on its seaward side by the nearshore Gulf habitat and by either salt or brackish marsh on its landward side. It is a highly dynamic habitat. Morphological changes usually occur with seasonal frequency. Sediments comprising the beach are variable throughout the Chenier Plain. Beach morphodynamics was discussed in part 2 (see also part 4.11).

3.4.4 HISTORICAL CHANGES IN HABITAT COMPOSITION AND DISTRIBUTION

From the perspective of tens or even hundreds of years, drainage basins in the Chenier Plain are constant in area. However, habitats within these basins have gained or lost area in response to natural processes or to man-induced disturbances. This study focuses on the changes over the last 25 years, but natural processes have been at work for millennia and many culturally induced changes occurred before 1952.

Habitat changes can result from normal environmental processes. The beach habitat, for example, can be displaced seaward or landward depending on sediment supply and other factors. Beach displacement involves the loss and gain of other habitats. For instance, shoreline advance involves the gain of habitat landward of the beach (usually marsh) at the expense of the seaward habitat (nearshore Gulf).

Many recent changes have resulted directly from cultural activities. These are easily documented if the change is direct and intentional. The dredging of a canal through a marsh illustrates the direct conversion of marsh to inland open water habitat and to spoil (ridge habitat). However, the indirect and cumulative impacts of such activities are not easily determined.

These indirect and cumulative changes are the most significant long-term impacts of human activity in the Chenier Plain.

Natural and man-induced changes, in the habitat composition of a basin can be either desirable or undesirable depending on one's point of view. It is rare that a change is either wholly desirable or wholly undesirable in terms of man's interest in natural resources. For example, hurricanes modify wetlands, kill many wetland animals, increase soil salinities, and cause extensive damage to cultural features. On the positive side, the flood waters clear clogged waterways of nuisance floating vegetation, release organic detritus from the upper marshes to open waters bodies (Craig et al. 1979), and destroy perennials in the fresher marshes which are replaced by annuals that are more desirable as food for waterfowl (Louisiana Department of Wildlife and Fisheries 1959). Cultural features, such as canals and spoil deposits, often increase the extent of saltwater intrusion, alter historic flow patterns and, in some instances, cause impoundment or drainage of large areas of wetland. However, spoil banks provide areas suitable for nesting alligators and provide avenues of wetland access for deer and other mammals.

Of the 14 habitats described for the Chenier Plain, all have undergone some change in their relative area over the past 25 years (table 3.55 and app. 6.4). The habitats listed in this table do not correlate exactly with the 14 habitats previously described. The four natural marsh habitats have been combined since there was no accurate method to determine the 1952 distribution of each wetland habitat individually. The ridge habitat was divided into two categories: natural and spoil. This distinction was warranted since natural ridge habitat is being lost and spoil areas are increasing. The agricultural habitat was divided into three subhabitats (rice field, non-rice cropland, and pasture) in order to determine whether there were any temporal changes in these agricultural subhabitats with respect to land use.

The total change of 107,000 ha (264,290 a) during the 23-year period examined is equivalent to 8.1% of the total Chenier Plain area. A more realistic value of habitat change can be obtained by eliminating the changes within the agricultural subhabitats (e.g., rice to non-rice cropland) and by eliminating the nearshore Gulf from area calculations. This results in a total change of 93,000 ha (229,808 a) or 9.8% of the total inland area.

3.4.5 HABITAT CHANGE BY DIRECT HUMAN ACTION

It is apparent (table 3.55) that culturally-modified habitats are increasing in size. As of 1975, pasture, urban and impounded marsh habitats, and spoil and agriculture areas represented 38.5% (287,434 ha, 710,265 a) of nonaquatic habitats in 1974 and only 31.2% (232,717 ha, 575,056 a) in 1952. This increase was at the expense of natural habitats.

Table 3.55. Net habitat change in the Chenier Plain from 1952 to 1974[a].

Habitat	Net area change (ha)	Net percentage habitat change
1. Nearshore Gulf	+1,539	+0.4
2. Inland open water	+28,026	+16.2
3. Natural marsh[b]	-81,276	-20.2
4. Impounded marsh	+38,112	+30.8
5. a. Natural ridge	-1,247	-3.8
b. Spoil	+5,365	+23.1
6. a. Rice field	+2,787	+6.7
b. Non-rice cropland	+1,826	+29.0
7. Pasture	+1,181	+1.3
8. Urban	+5,446	+23.3
9. Beach	-116	-1.8
10. Upland forest	-1,247	-7.7
11. Swamp forest	-396	-5.7

[a]1954 to 1974 for the East Bay Basin.

[b]Includes salt, brackish, intermediate, and fresh marsh.

The net increase of 38,112 ha (94,177 a) of impounded marshes accounts for most of the 54,717 ha (132,209 a) increase in culturally-modified habitats. For the most part, these areas are privately owned, although some of the increase is the result of establishment of wildlife refuges in the Texas portion of the Sabine Basin during the period between 1952 and 1975. The privately owned impounded areas are used for several purposes. Some may eventually be drained for agriculture. Many areas were established for commercial recreation purposes, largely for waterfowl hunting. Others were created to prevent land loss (which decreases the number of possible land uses).

The urban habitat has increased by 5,446 ha (13,457 a) over the same period. About one-fifth of this increase was at the expense of fresh marsh. Most of the increase, however, was at the expense of upland habitats. Thus, residential areas, and industrial and commercial complexes have expanded at the expense of agricultural lands, ridge, upland forest, and (despite the threat of hurricanes) beach habitats. Continued expansion of the residential component will probably occur at the expense of upland agricultural areas. However, that portion of the industrial sector that requires access to navigable waters will probably expand at the expense of wetlands or inland open water habitat because of the lack of better drained land remaining along these waterways.

Although some agricultural land has been converted to other socioeconomic uses, there has been a net increase of 5,794 ha (14,317 a) between 1952 and 1974. A portion of the increase can be attributed to loss of upland forest and ridge habitat, but most agricultural expansion has been at the expense of wetlands. Because little upland forest and natural ridge area remains, future expansion in agriculture will involve the draining of wetlands. The recent (1952 to 1974) picture is clear: as agricultural land is preempted for urban and industrial expansion, it is replaced by the increased draining of wetlands.

The agricultural habitat has been divided into pasture, rice, and non-rice cropland in table 3.55. The non-rice cropland includes some sugarcane areas in the Vermilion Basin, soybeans scattered throughout the uplands, and truck crops in the uplands and along the ridges. All three categories have experienced a net gain from 1952 to 1974. The gains, however, have not been uniform. It appears that there has been a slight shift of agricultural land use within the confines of the study area, with rice expanding into wetland areas, and other crops that cannot succeed on wetland soils gaining more acreage on better drained surfaces.

3.4.6 NATURAL HABITAT CHANGES AND INDIRECT CHANGES CAUSED BY MAN

Indirect or unintentional habitat changes caused by man, and changes brought about through natural processes have been significant and are discussed by Gagliano (1973). The separation of indirect man-induced change from natural change is difficult. Some of the changes are the result of natural processes. Shoreline erosion that results in the loss of wetlands is predominantly a natural process, although man may act as a catalyst. In areas where man has constructed jetties and groins he has certainly altered erosion and deposition rates. Hurricanes are short-term, natural stresses that affect man-altered wetlands more than natural marsh areas (Chabreck and Palmisano 1973).

Peat burns resulting from either natural or man-made fires, and local "eatouts" of marsh grasses by geese and muskrats (O'Neil 1949) have been documented as factors involved in land loss. Whereas these factors may be significant on a local level, most of the land loss is goverened by other processes on a basin level.

The major change in habitat types during 1952 to 1974 in the Chenier Plain was the loss of natural marsh (includes salt, brackish, intermediate, and fresh marsh) (table 3.55). Although about one-half (40,242 ha, 99,440 a) of the natural marsh has become impounded marsh habitat, other habitat types have also replaced natural marsh (table 3.56). Impounded marsh habitat continues to function as wetland habitat for some species such as waterfowl and marsh mammals, but it has less value than natural marsh when viewed as a component of the estuarine ecosystem (part 4.2).

There has been some loss of natural marsh to agriculture and to spoil banks, but most (26,280 ha, 64,939 a) of the remaining loss has been to inland open water. Also, some inland open water habitat has been changed to impounded marsh to maintain adequate water quality and/or to control water level.

The 28,662 ha (70,825 a) loss is equivalent to a 7.2% loss rate of natural marsh to open water from 1952 to 1974. This rate is the overall loss for the six basins in the Chenier Plain and a high degree of variability exists between basins.

A portion of the 7.2% loss rate can be attributed to the direct conversion of wetlands to open water by canal dredging. The total area of marsh lost through this activity was 2,685 ha (6,635 a), a rate of 0.7% for the period 1952 to 1974. The present distribution of canals is shown in Plates 5A and 5B. The total area occupied by canals and accompanying spoil banks is 4.3% of the Chenier Plain excluding the nearshore Gulf. From 1.0 to 2.2% of the land area is occupied by canals in each basin (table 3.57).

Table 3.56. Loss of natural marsh[a] in the Chenier Plain in 1952 to 1974.

Habitats replacing natural marsh	Area (ha) of natural marsh converted	Percent of 1952 natural marsh area	Processes causing loss
Inland open water	26,280	6.4	Subsidence/erosion
Nearshore Gulf	1,903	0.5	Net shoreline erosion
Impoundments	40,242	9.9	Leveeing
Canals	2,685	0.7	Dredging
Spoil areas	5,370	1.3	Dredging
Agriculture	4,573	1.1	Draining
Urban	1,027	0.3	Draining
Total	82,080	20.2	

[a]Includes salt, brackish, intermediate, and fresh marsh.

Natural processes also erode marshes. These processes involve the relationship between the elevation of the marsh and of the sea. The northern Gulf coast is subsiding. The elevation of the marsh can never exceed the highest elevation of ambient water, for water carries and deposits sediment onto the marsh surface. The deposition of waterborne sediment coupled with the formation of peat elevate the marsh surface. Regional and local subsidence, along with a rise in sea level during this century, tends to lower the elevation of the marsh with respect to the sea. The net subsidence rate of the land in the Chenier Plain is about 1.7 cm (0.67 in) per year (equal to the net rise in water level, table 3.47). Unless marshes are elevated by sedimentation and peat deposition at a rate equivalent to the net subsidence rate, they eventually drown and become shallow, open water.

Table 3.57. **Percentage of onshore area occupied by canals in each basin in the Chenier Plain, excluding spoil bank area.**

Basin	Percentage (%)
Vermilion	2.2
Chenier	1.9
Mermentau	1.7
Calcasieu	1.8
Sabine	1.2
East Bay	1.0

The present distribution of habitats within individual basins and habitat area changes are provided in appendix 6.4. Over the entire Chenier Plain the unexplained natural marsh loss rate (that is, the conversion to open water, table 3.58) is 6.4%. However, in four of the basins (excluding Calcasieu and Sabine), this unexplained loss rate is only about 2%. Since the geological history of all basins is similar, and since all show about the same rates of net subsidence (or sea level rise), the estimated rate of marsh loss due to natural processes of 2.3% in 23 years, or 0.1% per year, appears reasonable. This suggests that the extraordinarily high rates of loss of natural marsh in the Calcasieu and Sabine basins are the result of the many indirect and cumulative stresses that locally upset the balance between aggradation and subsidence (part 3.6). This conclusion is supported by a recent study of marsh loss within the Louisiana coastal zone by Craig et al. (1979). They found that after a canal is dredged, it tends to widen at a rate of 4 to 15%/yr. The Humble Canal system and the Superior Canal, both in the Rockefeller Wildlife Refuge in the Chenier Basin, are widening at rates of 7 and 13%/yr, respectively (Nichols 1958, Craig et al. 1979).

Table 3.58. **Percentage of land loss[a] in the Chenier Plain**

Chenier Plain Basin	Land loss[b] (%)
Calcasieu	17.2
Sabine	6.5
Chenier	2.2
Mermentau	3.3
Vermilion	2.0
East Bay	1.9
All basins	6.4

[a]Land loss is defined as that area of natural marsh that has transformed into open water during the specified period of time, including shoreline retreat and direct conversion to canals.

[b]From 1952 to 1954 except for East Bay, which was computed for 1954 to 1974 and adjusted.

Craig et al. (1979) also found a direct relationship between land loss rates and canal density for the entire Louisiana coast and for sections of Barataria Bay (fig. 3-24). The regression lines for the two graphs cross the ordinate somewhere around 0.1% marsh loss per year. The 0.1% represents losses to processes other than those caused by man.

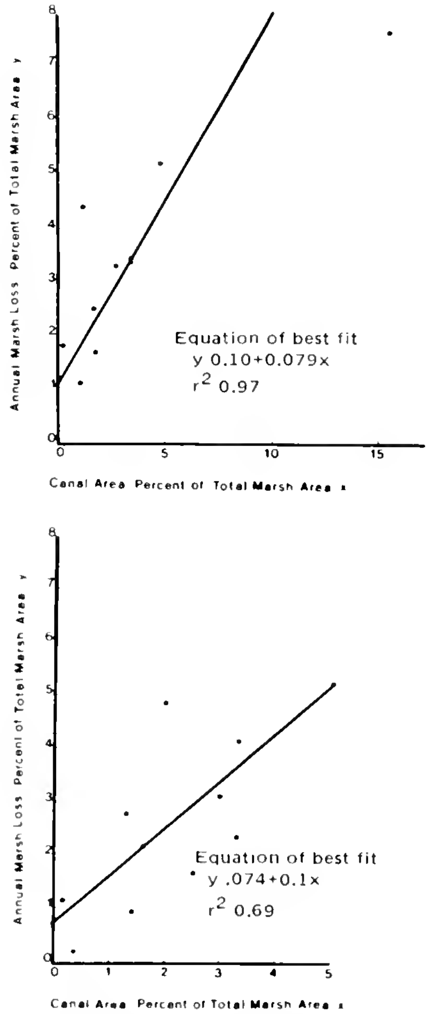


Figure 3-24. Relationship between canal density and wetland loss rates (A) in coastal Louisiana, and (B) in the Barataria Basin, Louisiana (Craig et al. 1979).

The major wetland changes in the last 25 years in the Chenier Plain have been cultural and include impoundment of wetlands, canal dredging and spoil deposition, and draining for agricultural and urban use. The rapid loss rate to inland open water habitat cannot reasonably be attributed to natural erosion and subsidence alone. These natural processes can explain about one-third of the wetland loss. The rest is presumed to be due to hydrologic changes incurred by the dredging of numerous canals and especially the major ship channels through the Chenier Plain wetlands and the removal of littoral sediments which are placed in spoil banks during channel maintenance.

3.5 RENEWABLE RESOURCE PRODUCTIVITY

3.5.1 INTRODUCTION

Analysis of the quantity and quality of renewable resources of the Chenier Plain is the heart of this ecological characterization. The living resources have evolved along with the major long-term geologic and climatic processes that formed the Chenier Plain. The mixture of land and water areas, which we have called habitats, continue to change slowly with time under the influence of natural processes characteristic of any coastal zone.

These habitats, maintained to a large extent by the flow of water over, around, and through them, support a characteristic flora and fauna. Some plants and animals are commercially important; some are prized by sportsmen; some have important functions in habitats; and others are threatened with extinction. One could consider these living organisms to be the end products of the physical and chemical processes of the Chenier Plain. The organisms interact with each other in a complex trophic web. The environment limits species diversity and productivity.

By modifying any of the physical and chemical processes in this long chain of events, man can alter the living resources. The human activities that affect the environment, described in part 3.2, have been shown to influence the system's hydrology (part 3.3) and the system's habitats (part 3.4). Habitat modification in turn is responsible for long-term changes (perhaps the most significant changes) in the potential living resource production in the Chenier Plain. Direct exploitation of living resources is also capable of changing the resource potential (part 3.5.2). Deterioration of the quantity and quality of water can change habitats both in areal extent and in their ability to maintain their characteristic flora and fauna. Water quality on the Chenier Plain is evaluated in part 3.5.3.

3.5.2 THE POTENTIAL FOR RENEWABLE RESOURCE PRODUCTION IN THE CHENIER PLAIN

This section discusses the importance of habitat potentials for renewable resource production in the Chenier Plain. In part 3.4, the area of habitats was considered. In this section net photosynthesis and an index of wetland-water coupling (ratio of marsh edge to marsh area) are two indices of quality that will be examined to evaluate the potential for resource production. Water quality is a third facet of basin quality and is treated separately in part 3.5.3. Renewable resource productivity has already been defined (part 3.1.3) as representing the "quality" of a basin. This quality is partially expressed as the capacity of a basin to support organisms that are valued by man for their food, recreational and esthetic value, and/or functional value to the system; but the concept of habitats also includes refuge value for the many species whose ecological function is poorly recognized or whose existence is still unknown.

A primary requirement for a high quality ecosystem is an abundant source of food energy. Emergent wetland vegetation is the main energy source for fish and wildlife resources in the Chenier Plain basins. (A detailed description of the function of wetland habitat is presented in part 4.2.) The organic carbon produced in emergent wetlands is deposited as peat, grazed or decomposed in place, or washed into the inland open water habitat. This last energy pathway, the export of organic carbon, is critical to many important aquatic species that are supported by a detritus-based food web (part 4.3). Thus, the interplay between wetlands and water bodies is important.

The average annual net photosynthesis for the Chenier Plain calculated from annual production estimates is 17,628,519 t (19,432,116 tons) (table 3.59) and is discussed in part 4. The magnitude of production for each basin varies directly with the amount of wetland area. All vegetation produced is not eaten by consumers in the food web so the values listed in table 3.59 represent the potential organic energy available in each Chenier Plain basin. Average values exceed 1,300 t/km^2 ($3,711 tons/mi^2$ or $1300 g/m^2$ or $4.26 oz/ft^2$) and are extremely high when compared to ecosystems worldwide. The resource potential of the Chenier Plain is probably as high as that found anywhere else in the United States.

Natural habitats are steadily being lost to those modified by man, and wetland habitats in particular are being lost at a rate of about 0.1%/yr (part 3.4.6). In addition, productivity of existing habitats may be decreasing because of culturally induced stress; that is, habitat quality may be degraded. In both cases, the long-term trend is a decrease in net photosynthesis and living resources in the Chenier Plain.

The second index of basin quality, marsh edge: marsh area ratio, has been used less as a diagnostic tool. However, the importance of wetland-aquatic coupling in general, the evidence for high diversity and productivity along marsh-water edges (part 4.2), and the relative ease of determining this index suggests that it may be a useful tool for comparing productivity in coastal environments.

Because tidal currents scour small channels in the marsh, the marsh edge: marsh area ratio tends to be highest in salt marsh habitat and decreases as marshes become increasingly fresh (fig. 3-25). The ratios were calculated from 1:24,000 USGS maps by digitizing. The area totals are conservative because many small marsh ponds were excluded. In the Sabine and Calcasieu basins the edge: area ratios were higher in fresh marsh than in brackish or intermediate marsh habitats, perhaps because land loss (marsh degradation) is occurring so rapidly in those basins. If the ratios are indices of marsh productivity, then data indicate that salt and brackish marsh habitats are more productive than fresh marsh for estuarine-dependent organisms.

Canals in wetlands have been shown to change hydrologic patterns, thereby modifying habitats and basin quality. Canals, because they are straight rather than sinuous and edged with high spoil banks that do not permit overbank flooding, have low edge: area ratios. For this reason alone, one would suspect that these factors reduce habitat and basin quality. In a recent study, it was found that the area of natural sinuous channels in marshes, and the edge : area ratios were reduced as the canal density increased (R. E. Turner, Pers. Comm. Center for Wetland Resources,

Table 3.59. Calculated net photosynthesis (primary production) by basin.

Basin	Area (km^2)	Average net photosynthesis per km^2 (t/yr))	Estimated net photosynthesis/ basin (t/yr)[a]
Vermilion	1,909.10	1,047.14	1,999,100
Mermentau	2,680.64	1,591.92	4,267,374
Chenier	1,954.47	1,222.44	2,389,228
Calcasieu	1,756.27	1,452.11	2,550,299
Sabine	3,759.79	1,369.10	5,147,516
East Bay	1,119.26	1,139.15	1,275,002
Total	13,179.53		17,628,519

[a]Summarized from appendix 6.3.

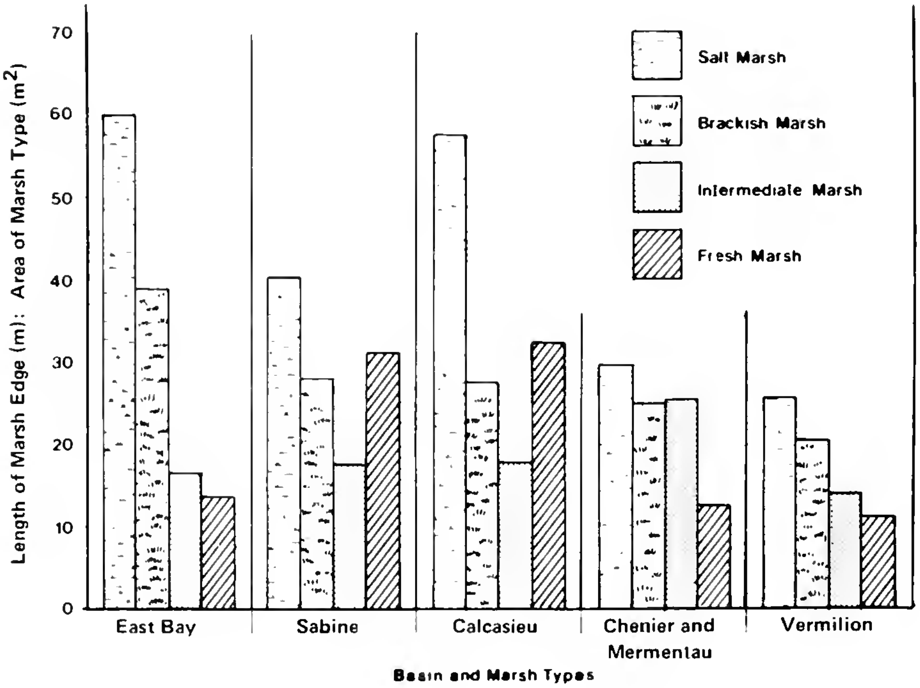


Figure 3-25. The ratio of marsh edge length to total wetland area, by marsh type, in each basin.

Louisiana State University, Baton Rouge). Apparently shallow natural channels fill with sediments because man-made canals capture waterflow. This phenomenon also occurs where highway embankments cross tidal marshes and disrupt natural channels, which subsequently fill in. The reduction in the edge: area ratio under these circumstances suggest that the quality of the natural environment has been reduced. Documentation is poor, but in at least one case it has been shown that marsh macrophyte production was significantly reduced (Allen 1975) when edge: area ratios were reduced.

Refuges. An important component of the natural resource productivity of a basin is its capacity to serve as a refuge for animals. The term "refuge" implies a variety of uses for a habitat in addition to use primarily for its food (trophic) value. "Refuge" also includes shelter provided by habitats which may lie outside officially designated private, State, or Federal refuge boundaries. For threatened and endangered species and perhaps others, the value of the gene pool may far outweigh other values. A habitat, e.g., ridges, may provide refuge for migrating species at a critical time, which gives it a value far in excess of its normal carrying capacity.

Species that require refuges can include animals that migrate daily over short distances (intrabasin) as well as seasonal, long-range migrants. Intrabasin migrants include roseate spoonbills and bald eagles, as well as reptiles and mammals that spend part of their lives on ridges and feed in wetlands. Seasonal long-range migrants include a wide range of organisms such as warblers, waterfowl, juvenile shrimp, and even monarch butterflies.

Natural marshes (salt, brackish, intermediate and fresh) are being lost in the Chenier Plain at the rate of about 1%/yr (table 3.56). Other less abundant habitats are often destroyed by man because they are particularly desirable for development. Wooded cheniers are scarce in the low-lying areas of the Chenier Plain and are particularly suitable for building sites.

The location and size of private, State, and Federal refuges within the Chenier Plain are identified in plates 6A and 6B and table 3.34. These refuges represent 14% of the inland area of the Chenier Plain and are comprised of wetland and aquatic habitats whose primary use is for waterfowl, alligator, and fur management. The fact that they are closely supervised, that hunting is controlled, and that development is restricted make them excellent refuges for threatened and endangered species. For instance several pairs of red wolf are believed to reside on the Sabine National Wildlife Refuge. On the other hand most of the refuge land within the Chenier Plain has been impounded so that movement of migratory fishes and shellfishes between impounded areas and estuaries is discouraged. These refuges therefore represent tradeoffs between fish species and game species.

Forested cheniers and swamps are two habitats that are rapidly being exploited and should be considered "critical" in the sense of their vulnerability to complete eradication in the region. The latter are abundant elsewhere along the Louisiana coast, but local areas of undisturbed swamp within each basin cover less than 1% of the area and are being lost at a rate of about 0.25%/yr (table 3.55). Forested cheniers are perhaps the major unique feature of the Chenier Plain. These ridges have been extensively developed, and are in danger of being irretrievably lost.

Bird rookeries and archeological sites (plates 6A and 6B) are other unique features on the Chenier Plain landscape that fall under the general category of refuges.

Commercial and Sport Species. Harvest of the most commercially important species in the Chenier Plain—menhaden, shrimp, oyster, blue crab, nutria, and muskrat—was discussed in part 3.2.4. Long-term harvest trends for these species suggest that they are being exploited at their maximum, and with the present carrying capacity the possibility of significantly increased harvests is remote.

Menhaden. Menhaden harvest has increased regularly since 1946 (fig. 3-26). The effort expended during the 1969 to 1974 period seems to be resulting in the maximum sustainable yield (Schaaf et al. 1975). Similar clupeid fisheries on the East and West coasts have suffered dramatically from over exploitation.

Shrimp. Although year-to-year catch fluctuations are fairly large, the white and brown shrimp harvest (1959 to 1973) shows no consistent upward or downward trend (figs. 3-27 and 3-28). It is possible that enlightened management can result in some increase, but this would be through control of the size of harvested shrimp, not through increased production potential. Continued wetland loss will eventually be reflected in harvest reduction.

Oyster. Oyster production varies a great deal locally, since oyster growth depends on suitable substrate, favorable salinities, and flowing waters. The trend in the Chenier Plain has been to a reduction in size or loss of oyster beds, or at least to closure because of pollution. This has occurred in the Calcasieu and Sabine basins and in part of East Bay Basin. Oyster production can be increased by appropriate management as is shown by the development of oyster beds where spoil banks have washed out along the Calcasieu Ship Channel (Van Sickle 1977). However, unless pollutant discharge is controlled, oyster production will undoubtedly continue to decline.

Blue Crab. The small size of the blue crab industry suggests that exploitation could be expanded in the Chenier Plain. Blue crabs are scavengers that seem to adapt to conditions associated with man's developments. For instance, the blue crab industry in Sabine Lake is thriving despite the decline of other species. It would be surprising if the environmental degradation did not adversely affect the edibility of crabmeat. Even if fully exploited the value of this fishery would be small compared to shrimp and menhaden.

Other Fishery Species. The only other group of fish for which an unexploited potential seems to exist is the industrial bottomfishes. The industrial bottom-

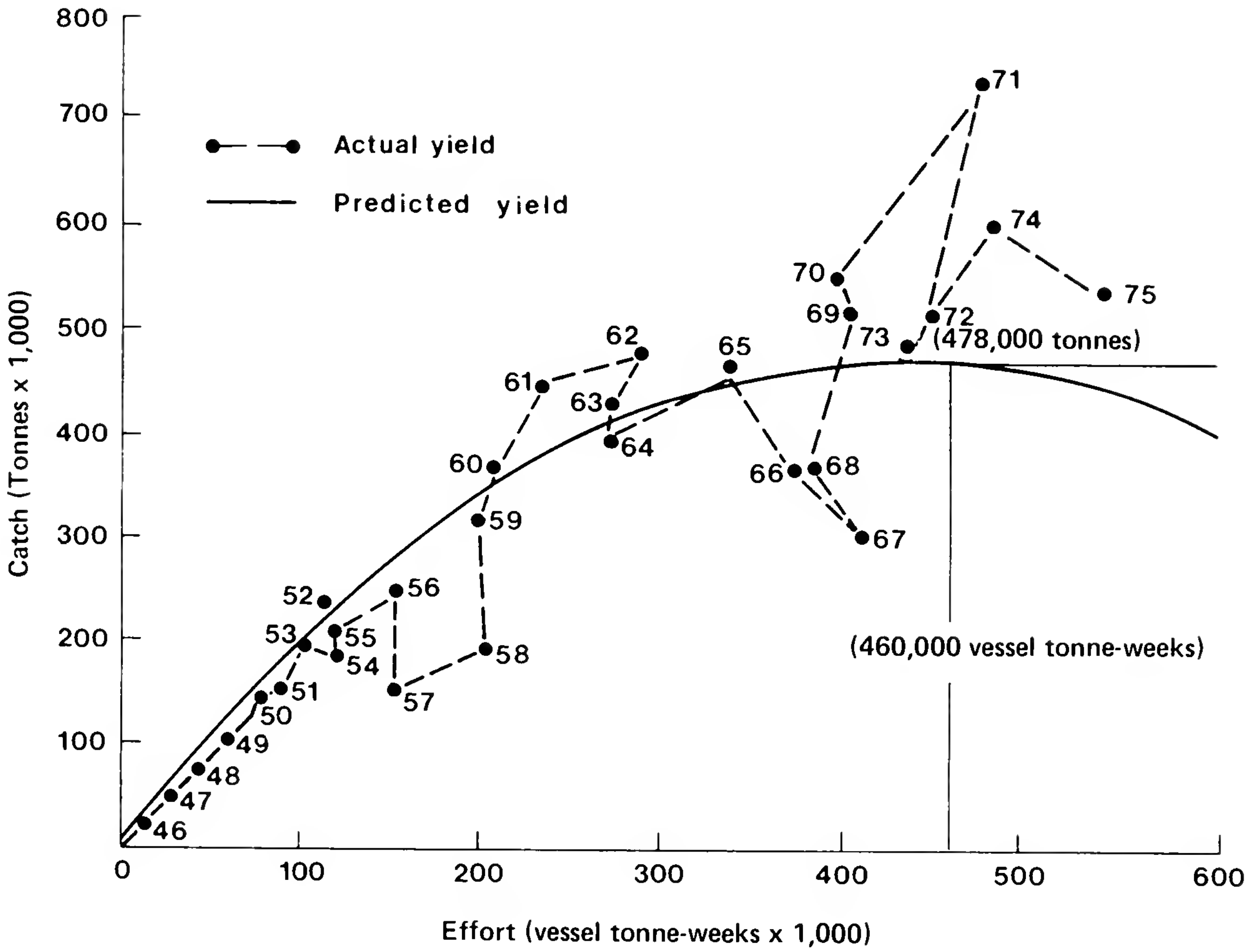


Figure 3-26. Relationship between menhaden catch and fishing effort (Christmas and Etzold 1977). Estimated average maximum sustainable yield is 478,000 tonnes.

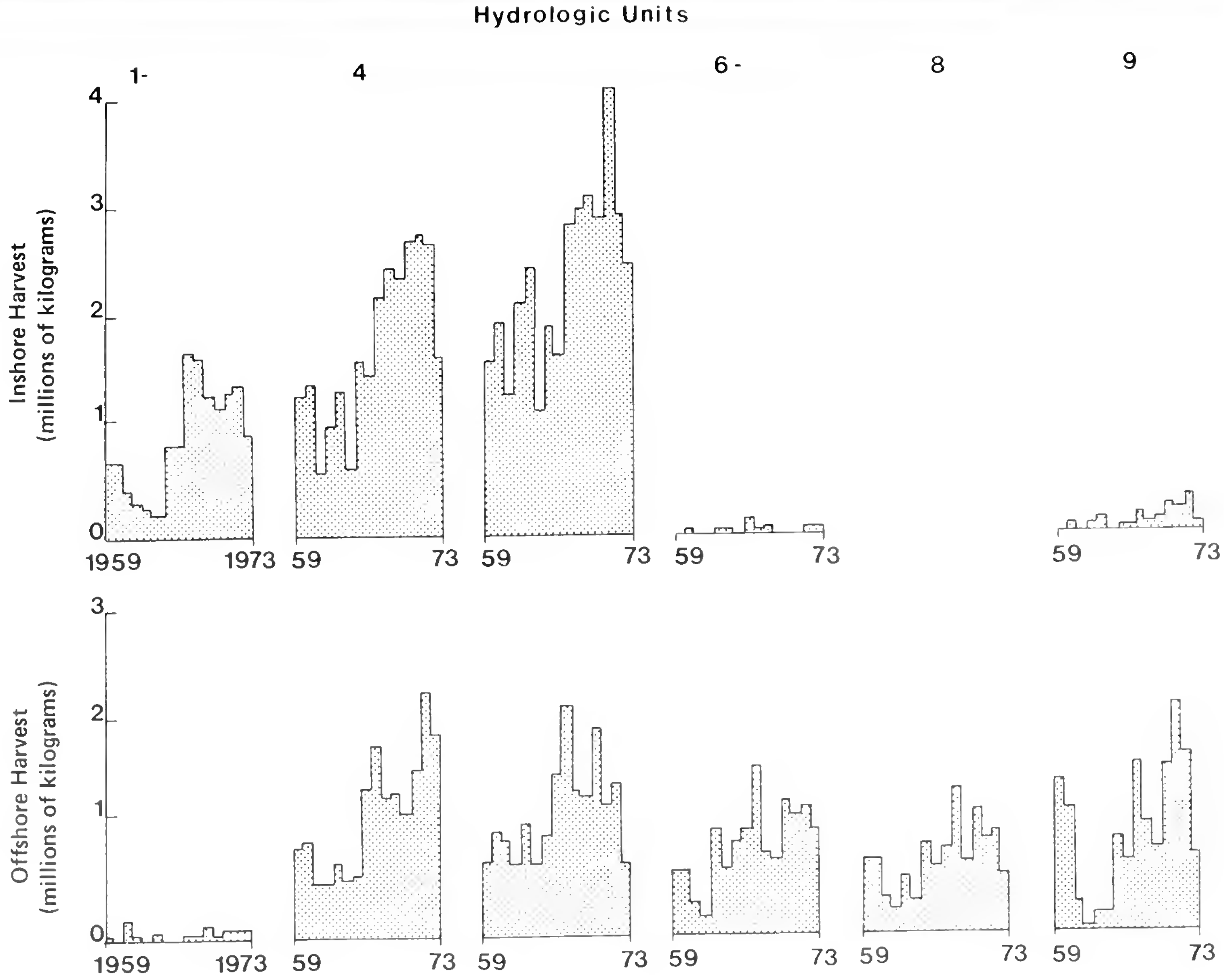


Figure 3-27. Inshore and offshore commercial landings of white shrimp in Louisiana by hydrologic unit (U.S. Dept. Commerce 1976).

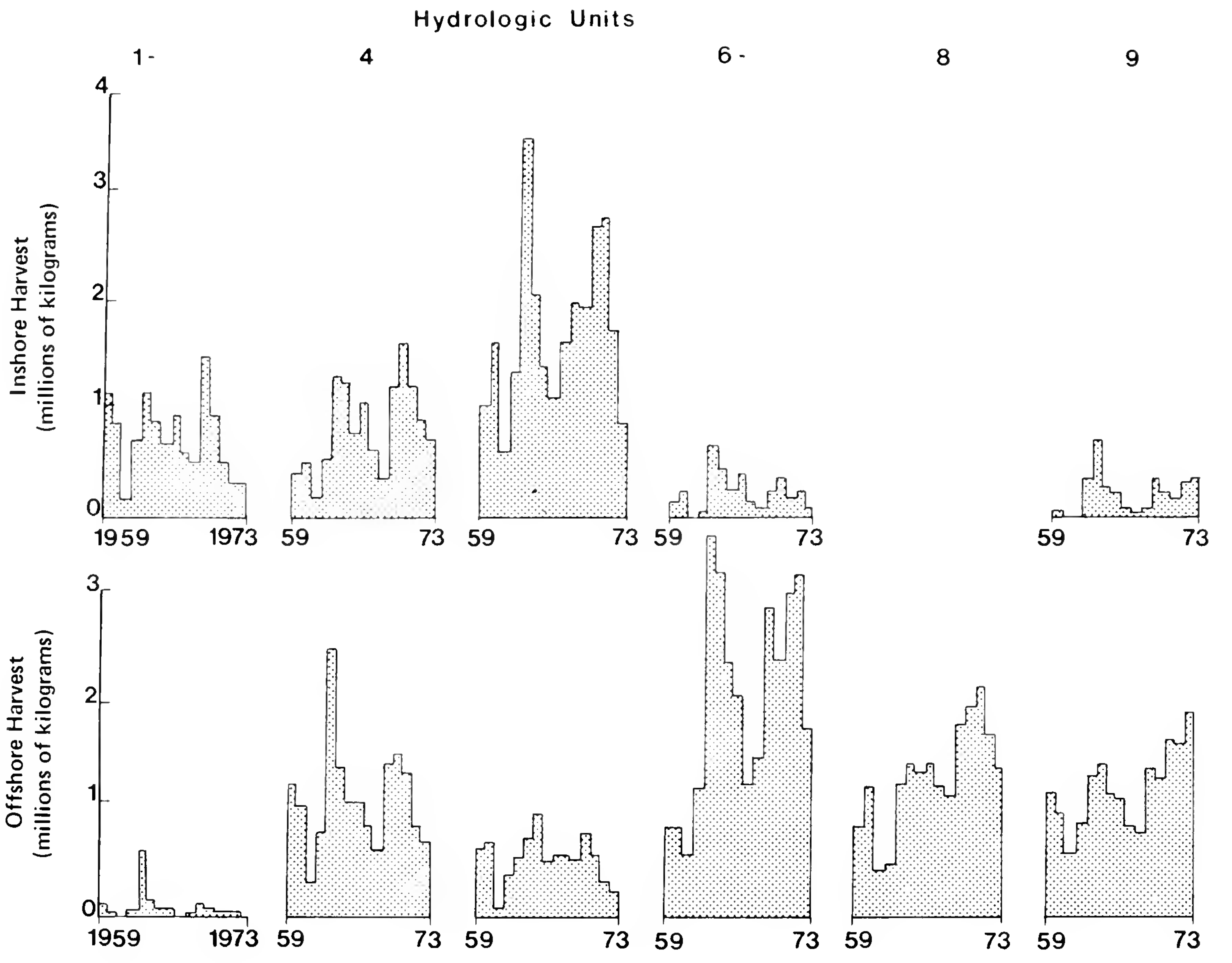


Figure 3-28. Inshore and offshore commercial landings of brown shrimp in Louisiana by hydrologic unit (U.S. Dept. Commerce 1976).

fish industry, which depends primarily on the Atlantic croaker, is just beginning to develop in the Chenier Plain (fig. 3-29). Since 1953 the harvest in the nearshore Gulf has increased from 14 to 43 million kg (31 to 95 million lb) (Gutherz et al. 1975).

Nutria and Muskrat. As indicated in part 3.2.4, muskrat and nutria harvests have been declining in the Chenier Plain since 1971 in spite of sustained harvests in the southeastern part of the State (fig. 3-9) and in spite of increased license sales (part 3.2.4). Reasons for the declining harvests in the Chenier Plain are not obvious. Habitat area loss is occurring at a much slower rate than harvest decline. There is some evidence for competition between nutria and muskrat where their habitats overlap, but long-term trends of muskrat production are difficult to assess because of extreme variability. The most conservative assumption is that production cannot be expected to increase because the resource is fully exploited and that careful management is required to maintain present levels of production.

Sportfishing and Hunting Potential. The sportfishing potential on the Chenier Plain was evaluated on the basis of available area of aquatic habitat and estimated potential yield, using the method described in the Fish and Wildlife Study (U.S. Army Corps of Engineers, unpublished). These estimates are based on the best available information from fishery biologists familiar with the Chenier Plain. The desired sportfish catch is estimated at 4.5 kg (10 lb) of saltwater sport fish and 0.9 kg (2 lb) of freshwater sport fish per man-day (table 3.60). The saltwater estimate is somewhat conservative because it does not include the nearshore Gulf.

Wildlife hunting potential was calculated by estimating the area required each year to support various types of hunting for different habitats in the Chenier Plain (table 3.61). The numbers for each species are in terms of man-days of hunting per unit area to allow comparison with demand figures generated in part 3.2.5. Data are based on estimates from wildlife biologists of productivity and standing stock as well as the sustained harvest potential for each habitat. The estimates indicate that 1 ha (2.47 a) of fresh, intermediate, or brackish marsh will sustain about two man-days of hunting per year. Saline marshes are less useful for hunting purposes.

Peak populations of waterfowl reach 3.8 million and the estimated annual harvest is 561,013 (table 3.62).

The total supply of saltwater fishing and sporthunting is estimated [app. 6.3 (10)] by multiplying area times man-days of potential use for each habitat. In figure 3-30, this supply is compared to the demand estimated in part 3.2.4. Freshwater sportfishing is excluded from this analysis. Freshwater fishing is available north of the Chenier Plain as well as in the Chenier Plain, so it is difficult to estimate the demand for this type of recreation. In contrast, saltwater fishing is confined to the coast. Similarly, for hunting the supply represented in the figure is generated by waterfowl and other wetland species unavailable outside the Chenier Plain.

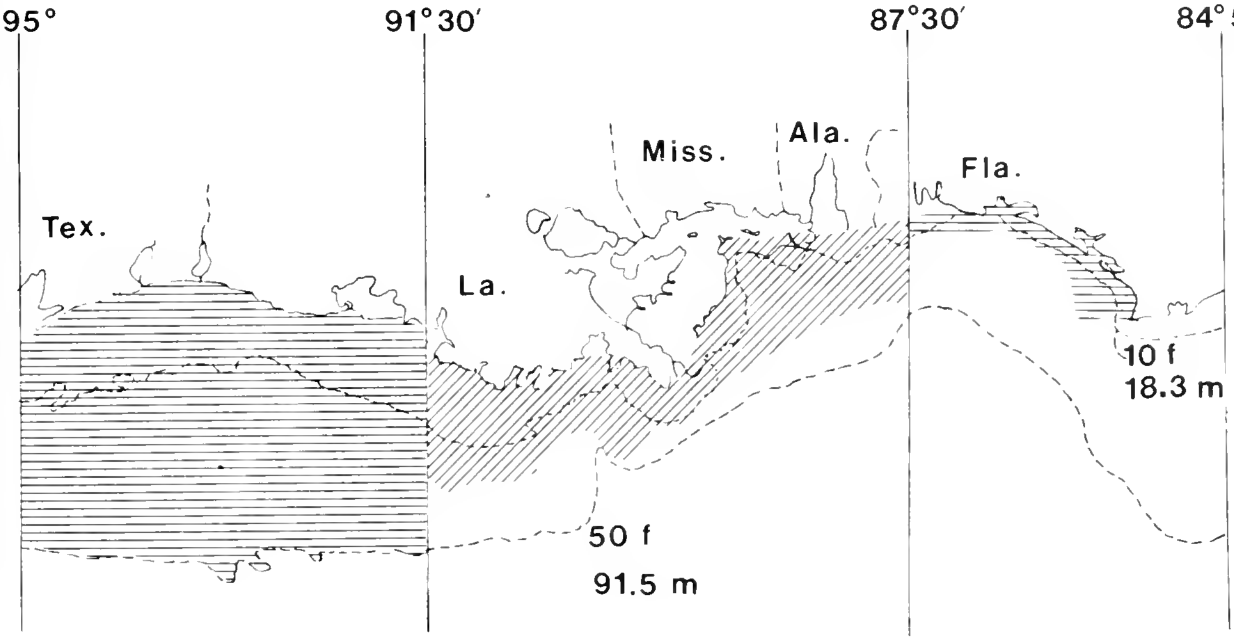


Figure 3-29. Fishing areas for industrial bottom fish along the northern Gulf coast (Gutherz 1975).

Table 3.60. Estimated annual sportfish catch and the effort this catch will support by basin, in the Chenier Plain[a]

Basin	Type of activity	Estimated obtainable yield (kg/ha)	Water[b] area (ha)	Potential sport fish catch (x 1000 kg)	Potential[c] effort (man-days x 1000)
Vermilion	Saltwater finfishing	22.4	15,532	348	77
	Freshwater finfishing	33.6	3,451	116	128
Chenier	Saltwater finfishing	22.4	3,962	88	20
	Freshwater finfishing	56.0	1,679	94	104
Mermentau	Saltwater finfishing[d]	0	0	0	0
	Freshwater finfishing	56.0	61,522	3,446	3,799
Calcasieu	Saltwater finfishing	22.4	29,910	670	148
	Freshwater finfishing	22.4	11,004	247	272
Sabine	Saltwater finfishing	22.4	28,368	635	140
	Freshwater finfishing	22.4	17,570	392	433
East Bay	Saltwater finfishing	22.4	25,175	564	124
	Freshwater finfishing	22.4	1,389	31	34
		Total Saltwater finfishing		2,305	509
		Total Freshwater finfishing		4,326	4,770

[a]Data from tables 3 and 7, Appendix D, Fish and Wildlife Study (U.S. Army Corps of Engineers unpublished).

[b]Saltwater area greater than 5 ‰ salinity includes salt and brackish marshes. Freshwater area less than 5 ‰ salinity includes fresh and intermediate marshes.

[c]Calculated at 10 lb/man-day for saltwater fishing and 2 lb/man-day for freshwater fishing.

[d]Mermentau has no saltwater fishery.

Table 3.61. The area (ha) of various habitat types required to support one man-day of hunting for various wildlife species.

	Hectares per man-day of hunting[a]							
Habitat type	Deer	Turkey	Dove & quail	Rabbits	Squirrels	Ducks	Geese	Other marsh birds
Salt marsh	16.24		33.67	13.48		134.68	26.95	1.62
Brackish marsh	8.00		33.39	3.33		2.67	1.60	1.47
Intermediate marsh	5.27		33.02	2.93		1.05	7.89	2.14
Fresh and impounded marsh	2.29		15.42	2.67		4.45	8.01	1.24
Pasture			3.64	4.50				27.03
Rice			3.87	6.73		26.91	4.05	22.50
Forest	0.95	3.37	33.77	2.70	1.35	9.00		

[a]Calculated from Fish and Wildlife Study tables 29 and 33 (U.S. Army Corps of Engineers unpublished).

Table 3.62. Average peak populations and harvest of waterfowl species in the Chenier Plain.

Species	Peak populations[a]	Percentage of total peak population	Annual harvest[b]	Percentage of total annual harvest[c]
Mottled duck	49,414	1.3	36,361	6.8
Mallard	236,972	6.1	78,632	14.8
Gadwall	611,451	15.8	52,296	9.8
Baldpate	383,895	9.9	33,607	6.3
Green-winged teal	586,400	15.1	76,601	14.4
Blue-winged teal	327,941	8.5	43,257	8.1
Northern shoveler	159,896	4.1	21,503	4.0
Northern pintail	474,210	12.2	63,131	11.9
Wood duck	N.A.	N.A.	4,608	0.9
Ring-neck duck	40,720	1.0	2,117	0.4
Scaup	47,021	1.2	8,001	1.5
Redhead	1,319	0.03	787	0.14
Canvasback	2,400	0.06	827	0.15
Hooded merganser	2,012	0.05	1,302	0.3
Fulvous tree-duck	N.A.	N.A.	0	0.0
Lesser snow goose	448,727	11.6	72,965	13.7
White-fronted goose	49,826	1.3	20,260	3.8
Canada goose	3,272	0.08	16,030	3.0
Coot	455,553	11.7	43	.01
Total	3,881,029	100.02	532,328	100.00

[a]Hugh A. Bateman; Louisiana Wildlife and Fisheries Commission, Waterfowl Inventory Field Sheet 1969-1977; Texas Parks and Wildlife Dep., 1955-1957, 1974-1975; aerial waterfowl survey results. Federal Aid Projects W-106-R-2.

[b]U.S. Fish and Wildlife Service, 1975. Distribution in parishes (counties) of waterfowl species harvested during 1961-1970 hunting seasons.

[c]This figure represents the percentage of the total harvest of all species.

A heavy demand exists for sporthunting, and saltwater sportfishing in the Chenier Plain, since the demand projected from telephone surveys far exceeded the available supply (figure 3-30). In addition, the hunting supply may be overstated, since some of the refuge land and some privately owned land is closed to hunting.

The saltwater sportfishing supply-demand relationship survey determined that an average Louisiana fisherman felt he needed to catch 4.5 kg (10 lb) of fish a day [0.9 kg (2 lb)/hr based on 5-hr day] to satisfy his requirements (U.S. Army Corps of Engineers, unpublished). The demand figures are based on this estimate. However, in recent censuses in Sabine Lake and Galveston Bay, Texas (Heffernan et al. 1976, Breuer et al. 1978), it was found that fishermen were landing only about 0.22 kg (0.50 lb)/hr in Sabine Lake and 0.3 kg (0.66 lb)/hr in Galveston Bay.

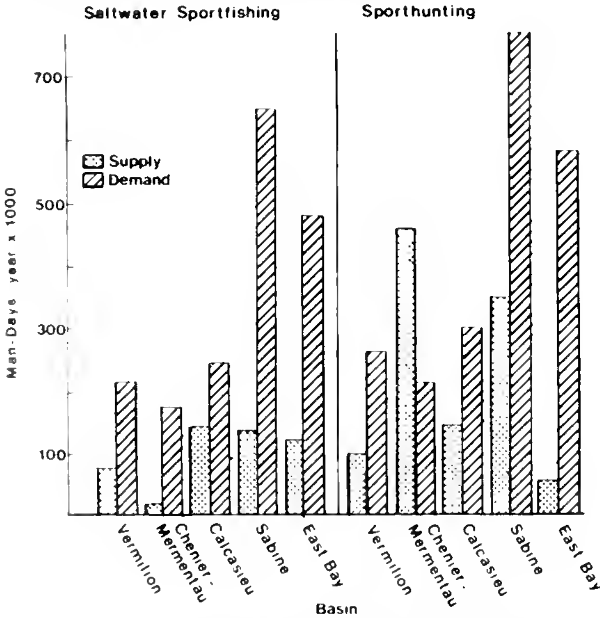


Figure 3-30. Supply of and demand for saltwater fishing and sporthunting by basin, in the Chenier Plain, excluding the Nearshore Gulf Habitat (U.S. Army Corps of Engineers, unpublished).

3.5.3 SURFACE WATER

Surface water and ground water aquifers extending beyond the Chenier Plain boundaries have been discussed earlier in general terms (parts 2.4 and 3.3). This section evaluates the adequacy of surface water supplies.

Surface Water Quantity. The sources of fresh surface water are rain and upstream runoff into each basin. The largest amount of this freshwater is absorbed and evaporated by natural vegetation. One important reason for the high productivity of Chenier Plain vegetation is the normally abundant water supply. Fresh surface water is also required by wildlife species. After the requirements of the natural biota, agriculture is the largest user of freshwater in the Chenier Plain, followed by industrial and residential use. Table 3.63 summarizes an approximate annual budget for water sources and uses and assumes that all water was evenly spread over the total basin surface. Rainfall amounts to 113 to 146 cm (44 to 57 in)/yr and is supplemented by riverine inflows that significantly affect the water budgets. East Bay has the least rainfall and no significant river inputs. As a result, its total surface freshwater supply is only 113 cm (44 in)/yr. In contrast, because of their large river systems, the Sabine and Calcasieu basins have nearly 400 cm (157 in) of fresh water each year. Eighty-four to 97 cm (33 to 38 in) of this water is evaporated, mostly by plants. However, this water reenters the basin in various forms of precipitation. In comparison, total use by agriculture and industry is less than 21 cm (8 in), excluding the Sabine Basin where 70 cm (28 in) is used per year. The use figures are somewhat inflated since much of the industrial water is returned to the stream from which it was pumped, and about 40% of the agricultural water is returned. Ignoring these return flows, all basins but East Bay, Texas have net annual surpluses of more than 76 cm (30 in). East Bay has almost no surplus (17 cm, 6.7 in), and estimated deficits [periods when soil moisture was insufficient to supply maximum evapotranspiration as calculated by the method of Borengasser (1977)] accumulated over an average year are 24.5 cm (9.6 in). Thus, fresh surface water is a critical factor in the East Bay Basin. Other basins have sufficient supplies on an annual basis, primarily because of riverine inputs. However, the summer agricultural demands in the Mermentau Basin exceed the summer surplus. During this period, surface water levels fall and salt intrusion would occur if control structures were not present (part 3.6.3).

Surface water surpluses help to maintain the freshwater head necessary to prevent serious saltwater intrusion, and to flush the lower estuaries. Hence the term "surplus" is a misnomer. Without this water moving through the basins and offshore, the estuaries and wetlands would be significantly more saline and the entire character of the coastal region would be different.

Surface Water Quality. The chemical composition of a water body reflects local and basin-wide chemical inputs. A disturbance in the chemical composition of an aquatic system, either through the introduction of a foreign substance or through an increase in concentration of a natural component, may be followed by a change in the biotic community. Thus, the biotic composition of an aquatic system reflects the water quality of that system.

Eutrophication. A complete evaluation of water quality in Chenier Plain basins would require the consideration of phosphorus and nitrogen; ion balance (the relative abundance of sodium and potassium to magnesium and calcium); trace metals–mercury, cobalt, zinc, cadium, iron, manganese, chromium, copper, and lead (at a minimum); numerous organic pesticides and petrochemical compounds; the dissolved gases (oxygen and ammonia); and bacterial concentrations. The available data are too fragmentary for a

Table 3.63. Annual water balance for Chenier Plain basins.[a]

Source	Vermilion	Mermentau & Chenier	Calcasieu	Sabine	East Bay
River input (cm/yr)	89	27	253	258	0
Rain (cm/yr)	114	146	138	140	113
Total	303	173	391	398	113
Use					
Evapotranspiration	83.6	90.8	96.7	97.3	91.4
Agriculture	0.03	5.9	3.0	6.1	2.5
Industry		0.05	4.3	64	2.3
Accumulated surplus (cm/yr)	139	76	287	231	17
Accumulated deficits (cm/yr)	17.5	17	15.5	19	24.5

[a]Rainfall 30 year average from U.S. Weather Bureau records; Riverine input long term average USGS 1977; evapotranspiration calculated from Borengasser 1977; agriculture and industry use from table 3.41 and figure 3-7 assuming all industrial water and 2/3 agricultural water from surface. It is assumed all water was evenly layered over each basin.

broad evaluation. Therefore, eutrophication is evaluated by using phosphorus as a general index of water quality. "Eutrophication" refers to the natural or artificial addition of nutrients to bodies of water, and the effects of these additional nutrients on the biota (National Academy of Sciences 1969). The ecological consequences of nutrient additions, beneficial and/or deleterious to the aquatic habitat, are discussed in part 4.8. Generally, excess nutrient addition results in aquatic community changes that may be detrimental to sport and commercial fisheries.

Phosphorus (P) is the critical limiting nutrient in freshwater ecosystems (Likens 1972). It is a convenient indicator of eutrophication because it is not lost as a gas through biological decomposition or chemical change. Furthermore, it is a common constituent in most of the common sources of materials that cause eutrophication: municipal sewage, urban runoff, drainage from agricultural land, and natural sources (detritus, waterfowl wastes, eroded minerals). It is a poor index of industrial wastes which can contain a wide variety of toxins. Because P is a normal component of most pollutants, its analysis within the Chenier Plain waters allows a useful evaluation of water quality. This general analysis will be supplemented by information about other pollutants that appear to be important in individual basins.

Because of the rapid transformations of P (and other nutrient elements) in the water column, the concentration of inorganic P alone is a poor index of eutrophication (Hutchinson 1969). A more significant indicator is the total amount of P contained in inorganic and organic dissolved forms. Phosphorus drains into the major water bodies of each basin. This input load, expressed in grams per cubic meter (g/m^3), provides an index of the eutrophic state of different water bodies. The "input load" retained in the water, the biota, and the underlying sediments of a basin, constitute the "storage" compartment of an aquatic ecosystem.

In this analysis the nutrients are assumed to be homogeneously distributed throughout the water bodies. Point sources of discharges are identified and their magnitudes are listed when available (plates 5A and 5B). Concentrations generally decrease as a function of distance from the source and of the volume of the receiving waters because of mixing and dilution. Circulation patterns determine how well these nutrients become mixed throughout the system. As a result, localized areas of high biotic production (advanced stages of eutrophication) can occur even though the entire water body may not exhibit over-enrichment. If nutrient inputs continue to exceed the capacity of the system to assimilate them over time, advanced stages of eutrophication proceed from point sources and affect more extensive areas. Thus, the average input load provides an indication of nutrient enrichment of a water body even though the eutrophic state may vary from place to place (Craig et al. 1979).

It is assumed in this report that processes occurring in saline waters are similar to those in freshwater systems and that it is valid to average quantities over an entire basin, regardless of the fact that differences occur in salinity. For instance, salt water flocculates colloidally suspended nutrients so that they sink. The relationship between the loading rate and P retention in the sediments was worked out for freshwater lakes and may not apply equally in brackish areas. Finally, nitrogen (N) is more often limiting as a nutrient than P in coastal marine systems (Ryther and Dunstan 1971). This, however, does not invalidate the use of P as a tracer of eutrophication, since N and P appear together in equal amounts in most pollutants.

Input loading rate. Critical P levels were taken as indicators of eutrophication from previous studies (table 3.64). The values of Shannon and Brezonik (1971) stated on a volumetric basis are used in this report. They considered P loads less than 0.12 g/m^3 (1.2×10^{-4} oz/ft^3)/yr as permissible, and loads greater than 0.22 g/m^3 (2.2×10^{-4} oz/ft^3)/yr as dangerous.

Table 3.64. Permissible, and excessive loading rates for phosphorus as an index of eutrophication.

Reference	Rate	Permissible	Excessive
Shannon and Brezonik (1971)	Volumetric ($g/m^3/yr$)	0.12	0.22
Shannon and Brezonik (1971)	Areal ($g/m^2/yr$)	0.28	0.49
Vollenweider (1968) for lakes <5m	Areal ($g/m^2/yr$)	0.07	0.13
Craig and Day (1979)	Aeral ($g/m^2/yr$)	0.4	0.40

These levels are useful indices for many different kinds of water bodies. The stage of eutrophication in an entire water body is influenced, however, by the flushing or replacement rate of the water body, retention of nutrients in bottom sediments, the previous history of eutrophication, the water depth, and the total water volume. These factors should be considered in site-specific analyses.

Output and storage (retention). A portion of the nutrients discharged into a lake is later discharged from the lake in the stream outflow. Inorganic P can be transformed to organic forms within minutes and subsequent chemical changes depend on cycling rates of the biota and on sedimentation rates. Eventually some of the P entering the water body leaves downstream, although it may not be in the same form. The losses of P increase as the areal water load increases. The areal water load of a body of water (m/yr) is defined as the ratio of the outflow volume[(m^3/yr to its surface area (m^2)]as shown by the empirical relationship developed by Kirchner and Dillion (1975) in figure 3-31.

Retention and outflow are influenced by the previous history of the water body (Craig et al. 1979). In fresh waters with a previous history of low P loading rates, the sediment acts as a sink and traps P efficiently. But if excess nutrients are introduced, the sediments gradually become saturated with P and are able to store new P only at slow rates related to the net rate of sedimentation. Estuarine sediments naturally trap P (Pomeroy 1970). In shallow water areas such as those in the Chenier Plain, where wind, dredging activities, or other factors stir up these enriched sediments, P is released into the water column. Thus, the concentration in the water is buffered by the underlying sediments. Tidal flux is an additional factor that influences the export of P from estuarine waters. In tidal areas, the areal water load, based on freshwater flow through the lake, underestimates the dilution of a pollutant. This was demonstrated by Ketchum (1969) for the Hudson River estuary. His findings suggest that (1) retention values from Kirchner and Dillion (1975) are probably overestimated in estuaries with significant tidal action and (2) pollutant discharge into tidal waters can be expected to influence upstream as well as downstream areas. An example of the latter is the discharge from menhaden plants in the lower Calcasieu River that resulted in closure of the oyster beds upstream in Calcasieu Lake.

P loading rates in Chenier Plain estuaries were determined from the total water discharging into a basin and the P concentration in runoff entering each basin from its drainage area. The analysis was performed for the entire watershed area of each basin, not just the area within the Chenier Plain boundaries. The P loading rates were determined by multiplying the Shannon and Brezonik (1971) coefficients of P runoff from different land types (urban, industrial, agriculture, forests, wetlands, etc.), by the area of each

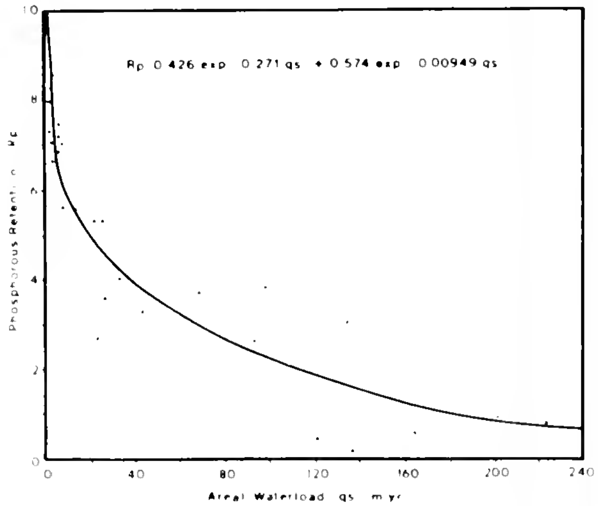


Figure 3-31. The relationship between the areal waterload (qs) and phosphorus retention (Rp) in fifteen southern Ontario lakes, from Kirchner and Dillion (1975) as shown in Craig et al. (1979).

type. The total loading rate was them compared with P loading rates from earlier studies to determine the sensitivity of the basin to eutrophication. Details of the methodology are given in appendix 6.4. The values obtained across the Chenier Plain are shown in table 3.65. In all cases the heaviest contributor to P runoff

Table 3.65. Summary of discharge, loading rate, and eutrophic state of surface waters of Chenier Plain Basins.[a]

Item	Vermilion	Mermentau and Chenier	Calcasieu	Sabine	East Bay
Total discharge into major water body (m^3/year x 10^8)	15.89	53.42	49.75	149.58	5.22
Total phosphorus (g/year x 10^8)	3.86	10.72	12.96	4.90	0.42
Loading rate (g/m^3/year)	0.24	0.20	0.26	0.03	0.08
Eutrophication sensitivity	Excessive	Borderline	Excessive	Permissible	Permissible

[a]See Appendix 6.4 for sources and details.

was the agricultural land. Not only does each watershed have a large proportion of its land tied up in agriculture, but the P coefficients are high because of soil erosion and excess fertilizer runoff. Vermilion and Calcasieu basins have high loading rates and dangerous stages of eutrophication could develop. Mermentau Basin is borderline; P loads in Sabine and East Bay basins appear to be in the permissible range. The Vermilion Basin has a high rate because of the Vermilion River discharge volume. The loading rate of the river suggests that dangerous eutrophic states could develop, but when emptied into Vermilion Bay and exchanged with West and East Cote Blanche bays, the volume is probably diluted to the permissible range. Measurements of P indicate a decreasing concentration as one progresses eastward.

The Calcasieu Basin, on the other hand, has a high loading rate (0.26) and is probably very prone to eutrophication problems. The P loading is high because of the high proportion of agricultural land in the upstream watershed. The low P load in the Sabine Basin results from the relatively high discharge rate that effectively dilutes P.

Brine. Salt is a naturally occurring material, but in high concentrations it may become a toxin, rather than a nutrient. Marine organisms are adapted to concentrations of about 36 ‰, and estuarine organisms are usually able to tolerate wide fluctuations in salt concentration. However, sudden severe changes or extreme concentrations can kill flora and fauna. Small changes in the mean concentration result in shifts in the dominant plant species. The greatest damage occurs in fresh waters and fresh marshes where endemic species usually have a low salt tolerance.

The Gulf of Mexico provides the largest source of salt on the Chenier Plain. Intrusion of this salt into freshwater estuaries was discussed in part 3.3.8. In addition, release of large quantities of highly concentrated brines from industrial sites has severe local effects and perhaps long-term general effects. Major sources of brine are oil wells and leachate from salt domes (particularly in the Calcasieu Basin). A 1956 survey conducted by the Louisiana Department of Conservation reported that salt water composed almost 70% of the total liquids produced by oil and gas wells. Brines which are separated and released at wellsites, contained concentrations of dissolved constituents (table 3.66) that range from 20 ‰ to more than 300 ‰ (Collins 1970). The average concentration is 110 ‰ (Lisa Levins, Pers. Comm., Energy Resources Co., Cambridge, Massachusetts).

As an oil field becomes older, its saltwater production tends to increase. Not only is there a higher concentration of salt in the water, but the ratio of salts differs from that of sea water. Because of the differences in major ions, brines are often far more toxic than sea water.

Whether an oil field brine will damage the marsh environment depends in part upon the method of disposal. The return of brine through injection into suitable subsurface formations below the lowest known freshwater aquifer is the most satisfactory method of disposal. In addition to subsurface injection, brine is sometimes retained in pits. Large voumes are then released into surface waters. This is the most deleterious disposal technique.

Another significant source of brine is leachate from salt domes. Some of the salt domes are leached to create caverns for storing wastes and oil. For oil storage, a large surface reservoir of brine must be kept to pressurize the well (Gosselink et al. 1976), but most of the leachate is disposed of permanently. Disposal offshore in Gulf waters is projected for the extremely large volumes of brine anticipated for the proposed Louisiana Offshore Oil Port storage caverns (Gosselink et al. 1976) and the Hackberry dome Strategic Petroleum Reserves Program (NOAA 1977). In the latter case, it was predicted that under normal conditions, a brine diffuser located about 9.6 km (6 mi) off the Calcasieu Basin coast (at the basin/Gulf boundary) would produce a salinity change at the bottom of the water column greater than 1 ‰ over

Table 3.66. Comparison of constituents of brine water from some southwestern Louisiana oil fields with consituents found in sea water (Collins 1970).

Constituent	Brine 0/00	Sea water 0/00
Li	1 - 4	0.2
Na	11,791 - 46,789	11,000
K	45 - 328	350
Ca	867 - 3,026	400
Mg	375 - 1,283	1,300
Sr	15 - 188	7
Ba	5 - 95	0.03
B	3 - 31	5
Cl	20,548 - 78,136	19,000
Br	18 - 97	65
I	8 - 42	0.05
HCO_3	83 - 334	160
SO_4	0 - 466	3,900

an area of 730 ha (1804 a). Under stagnant conditions the area involved would be 1,215 ha (3002 a).

Disposal of smaller amounts of brine into inland water bodies would have more serious consequences because of the shallow depths and surrounding wetlands. There is indication that brine discharge has been a contributing factor in the rapid marsh degradation north and west of the Hackberry salt dome in Calcasieu Basin.

The uncontrolled dilution and disposal of brines into streams and surface waters has been permitted in some areas during periods of high stream flow or surface water runoff. There is a danger of creating undesirable concentrations of dissolved salt during periods of low flow. Concentrations that are dangerous to aquatic flora and fauna and can also cause water to be unfit for irrigation or other human use during the periods of greatest need (Louisiana Geological Survey 1960). Additional information on the effects of brines may be found in Chipman (1959), Simmons (1957), Renfro (1960), Bernstein (1967), Gunter (1967b), Waisel (1972), Mosely and Copeland (1974).

Industrial toxins. Waters in several areas of the Chenier Plain have been subjected to significant toxin loads. The toxins can take many forms, but in general (in addition to brines), they include heavy metals, organic toxins (pesticides, etc.), oxidizable organic compounds that reduce available oxygen, thermal effluents, and bacterial contaminants. There is qualitative summary information on the severity of the water quality problems in each Chenier Plain basin (table 3.67).

Industrial pollution in the Chenier Plain occurs in the Sabine Lake and Sabine River, the Calcasieu River and its tributaries, the lower reaches of the Vermilion River, and in some stretches of the GIWW. Most of the pollution is localized. The enormous amounts of organic materials, indicated by the total biological and chemical oxygen demand load, must be considered against a background of a naturally high level of organics and sediments in the region. This load depletes dissolved oxygen locally to create anoxic conditions, such conditions, however, can also occur naturally in waterways.

Most of the discharged organic toxins are aliphatic hydrocarbons that are discharged in fairly large amounts in both the Sabine and Calcasieu basins. In addition, at least one industry in the Calcasieu Basin discharges chlorinated hydrocarbons that are extremely toxic to aquatic organisms and are readily degraded. Thermal pollution is widespread in both the Sabine and Calcasieu industrial areas. Local effects must be fairly severe since temperatures over 40°C have been recorded in receiving streams (Environmental Protection Agency 1972), but no studies have been made of the consequences in the Chenier Plain.

The Calcasieu River is contaminated with heavy metals. In the late 1960's, high concentrations of mercury were found in many fishes and shellfishes from the area. The major source of the mercury was apparently one industry (Pittsburgh Plate Glass, Inc.) in the Lake Charles area. In 1971, the plant installed treatment facilities that reduced the discharge to about 0.25 kg/day (0.55 lb/day). Since that time, rather high concentrations of mercury have still been found in fishes, but a 1972 investigation failed to turn up any significant mercury sources (Environmental Protection Agency 1972). Chromium is a highly toxic contaminant released in large amounts in the petroleum refining process (309 kg/day, 681 lb/day in the Calcasieu Basin). Lead is released (primarily by one industry) at over 4,000 kg/day (8,818 lb/day).

Analyses of water samples taken any distance downstream from discharge sources generally fail to show elevated concentrations of these heavy metals

Table 3.67. Water quality of Chenier Plain basins.

Status or water quality problem	Basin				
	Vermilion	Mermentau/Chenier	Calcasieu	Sabine	East Bay
EPA water quality status[a,b]	WQ[c]	EL	WQ[d]	WQ[e]	EL
Industrial BOD[f] and COD discharge kg/day[k]		6341[g,h] 4650[g]	249,700[g]	61,000[h]	O
Organic toxins discharged			Chlorinated hydrocarbons	LAS (detergent)[h]	
Thermal	+[i]		+	+	
Heavy metals[j]			Lead (4000 kg/day) Copper (100 kg/day) Zinc (23 kg/day) Chromin (309 kg/day) Mercury (1 kg/day) Cadmium (1.8 kg/day)		

[a]WQ - does not meet water quality standards even after application of effluent limitations required by the Federal Water Pollution Control Act Amendments of 1972 (FWQA). EL - water quality is meeting water quality standards of the FWQA.

[b]Weston 1974.

[c]Vermilion River from Interstate 10 Bridge to GIWW.

[d]Calcasieu River from Oakdale above Lake Charles to Gulf; West Fork Calcasieu River from Houston River downstream, Bayou D'Inde.

[e]Sabine River and Sabine Lake.

[f]BOD = Biological oxygen demand; COD = chemical oxygen demand.

[g]Domingue et al. 1974.

[h]Diener 1975.

[i]+ Indicates heating causes significant local effects.

[j]Environmental Protection Agency (1972).

[k]Nearly all discharges occur above the Vermilion Basin Boundaries.

because they bind readily to suspended clays and are rapidly sequestered in the sediments. The importance of benthic organisms in the trophic structure of estuaries (part 4) makes this behavior of heavy metal pollutants particularly critical.

Dredging of contaminated sediments suspends and disperses heavy metals. When these sediments are piled on spoil areas, the heavy metals are absorbed by plants and thereby enter the food web, or they may be carried into water bodies by runoff.

The most heavily populated and industrialized basins, Sabine and Calcasieu, are experienceing serious contamination problems from heavy metals and organic pesticides. Although these heavy metals are, for the most part, confined locally they move into the food chain through benthic and nektonic feeders that spread the toxins throughout the estuarine system.

3.6 ECOLOGY OF INDIVIDUAL BASINS

3.6.1 INTRODUCTION

Previous chapters of this report have dealt with the major processes that control basin systems on the Chenier Plain. In each basin all of these processes are at work, but because physiography, hydrology, and socioeconomics differ, the basins are dissimilar. This chapter describes the major features of each basin and identifies the dominant forces shaping each one and the critical problems.

3.6.2 VERMILION BASIN

General features. The Vermilion Basin lies on the eastern edge of the Chenier Plain. The boundaries, as drawn for this study, (plate 1B) do not describe a complete drainage unit. The basin is part of the Vermilion Bay system. Vermilion Bay is open to the east and strongly influenced by westward flowing waters of the Atchafalaya River (fig. 3-32).

As circumscribed for this study, the Vermilion Basin is a small unit, 1,909 km^2 (741 mi^2). Sixty percent of this area is a large, shallow shelf in the near-

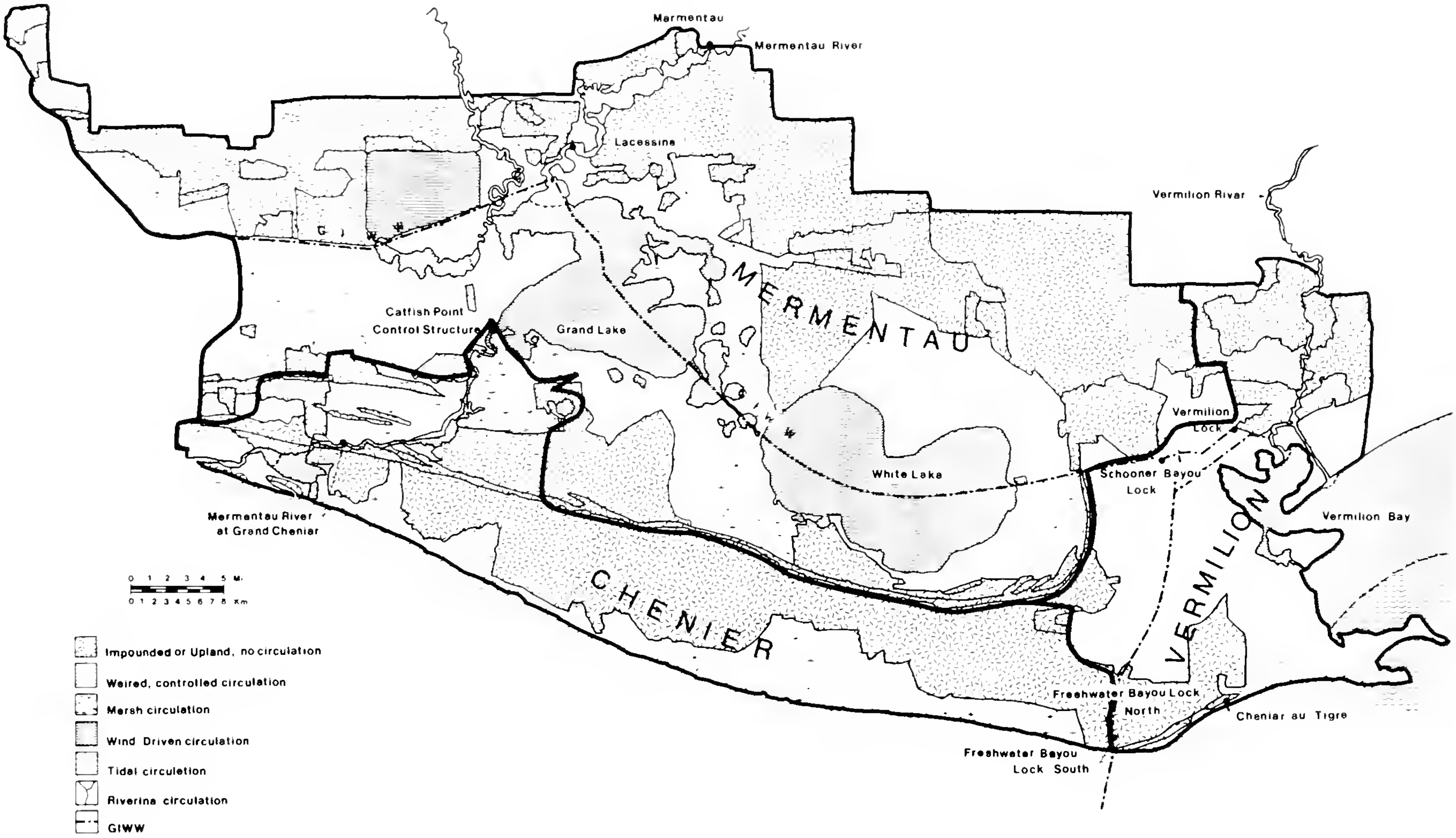


Figure 3-32. Hydrologic regions of the Vermilion, Mermentau, and Chenier basins.

Table 3.68. Summary of natural and cultural features of Vermilion Basin.

A. Hydrology of the Vermilion Basin

Riverine Processes

Freshwater flow volume (into basin) (fig. 3-33)

Vermilion River $15.9 \times 10^8 m^3/yr$

Atchafalaya River
dilution of Vermilion Bay from the east

Annual rainfall 144 cm (Lafayette)

Annual rain surplus (fig. 3-33)

60.6 cm/yr

Minimum freshwater renewal time:

61 days

Surface water slope:

Vermilion River 1.25 cm/km

Freshwater B/Schooner B—0.28 cm/km

Tides:

Range: Vermilion River at Vermilion Lock
37.5 cm ± 15 cm (standard deviation)

Period: Diurnal (predominantly)

Water level variation

Seasonal: Spring-Summer peaks, winter minimum (fig. 3-34)

Long term: 0.94 cm/yr rise (1945-1974) (fig. 3-34)

Salinity:

Seasonal: (fig. 3-35)

Long-term: (fig. 3-36)

Control structures and modifications

At Schooner Bayou, Vermilion Lock

B. Primary production, potential yield and harvest of living resources of Vermilion Basin.

	Per km^2	Per basin
Net primary production (t/yr) Appendix 6.3	1,047	1,999,100
Sport hunting and fishing use estimated potential yield[a]		
Big game (man-days x 1000/yr)		14.2
Small game (man-days x 1000/yr)		23.7
Waterfowl (man-days x 1000/yr)		63.0
Saltwater finfishing (man-days x 1000/yr)		76.7
Freshwater finfishing (man-days x 1000/yr)		127.0
Total		304.6
Agriculture	380	2,839
Commercial species harvest[b]		
Shrimp (kg x 1000/yr)	0.98	151
Menhaden (kg x 1000/yr)	18.3	2,835
Blue crab (kg x 1000/yr)	0.4	62.6
Oyster (kg meat x 1000/yr)	0.01	1.6
Other saltwater finfishes (kg x 1000/yr)		70.7
Freshwater finfishes (kg x 1000/yr)		32.9
Nutria (pelts /yr)		31,324
Muskrat (pelts /yr)		19,500

[a]Method explained in part 3.5.2

[b]Present harvest attributed to basin (part 3.2.4)

continued

Table 3.68. Summary of natural and cultural features of Vermilion Basin (continued).

C. Habitats of Vermilion Basin

C1. Habitat area in 1974 and net changes since 1952

Habitat	Area 1974 (ha)[a]	Percent of total area[b]	Change in area 1952 to 1974 (ha)	(%)
Nearshore Gulf	115,599	–	200	0.5
Inland open water	18,977	25.2	1,485	8.5
Natural marsh	36,031	47.9	-6,800	-15.9
Impounded marsh	7,962	10.6	2,673	50.5
Swamp forest	464	0.6	-91	-16.4
Natural ridge	1,062	1.4	-154	-12.7
Spoil	1,593	2.1	1,099	222.5
Rice field	730	1.0	551	307.8
Non-rice cropland	1,326	1.7	451	51.5
Pasture	3,318	4.4	676	25.6
Urban	199	0.3	87	77.7
Beach	396	0.5	0	0
Upland forest	3,253	4.3	-177	-5.2
Total	190,910			

[a]1 hectare (ha) = 2.47 acres (a)

[b]Calculation excludes area of nearshore Gulf habitat

C2. Habitat modification from 1952 to 1974 due to identifiable human activities

Cause of change	1952 Habitat	1952 Area (ha)	Changed to (by 1974) Habitat	Changed to Area (ha)	Change in 1974 as percent of original 1952 habitat
Filling and draining	Natural marsh	42,831	Agricultural	619	1.4
			Urban	15	0.04
	Impounded marsh	5,289	Agricultural	800	15.1
Impounding	Natural marsh	42,831	Impounded marsh	3,473	8.1
Canal dredge and spoil	Natural marsh	42,831	Spoil	1,099	2.6
	Natural marsh	42,831	Canal	550[a]	1.3
Upland construction	Upland forest	3,430	Agricultural	117	5.2
	Natural ridge	1,216	Agricultural	104	8.6
	Ridge	1,216	Urban	50	4.1
	Agricultural	4,989	Urban	22	0.4

[a]Calculated as 1/2 spoil area

continued

Table 3.68. Summary of natural and cultural features of Vermilion Basin (continued).

C3. Natural wetland loss (1952-1974)—summary

To	Process	Area (ha)	Percent of 1952 area
Canals	Dredging	550	1.3
Inland open water	Subsidence	844	2.0
Nearshore Gulf	Shoreline erosion/deposition	200	0.5
Impounded marsh	Leveeing	3,473	8.1
Spoil	Dredging	1,099	2.6
Agriculture	Draining	619	1.4
Urban	Draining	15	0.04
Total		6,800	16.04

D. Cultural Features of the Vermilion Basin

D1. Socioeconomics

Population: 804
Employment: (Figure 3-12)

	Production (1974)	Value ($ x 1000)
Minerals		
Gas (mcf)	112,943,923	34,674
Crude oil (bbls)	2,833,930	18,477
Total		53,151
Agriculture		
Crops		917
Other		1,071
Total		1,988
Sport hunting/fishing		
Saltwater sportfishing		454.6
Freshwater sportfishing		486.0
Small game hunting		408.6
Big game hunting		141.3
Waterfowl hunting		992.7
Total		2,483.2

Commercial harvest	Value ($ x 1000)
Fishing	
Shrimp	325.3
Menhaden	262.5
Blue Crab	16.6
Oyster	2.1
Other estuarine-dependent species	31.5
Freshwater finfish	13.4
Subtotal	651.4
Trapping	
Nutria	187.9
Muskrat	87.8
Subtotal	275.7
Total	927.1

Navigation
Total traffic: 998,284 tons, 1976; declining from peak 1.9 million tons, 1967
Imports: non-fuel mined products
Exports: Oil and petrochemicals

continued

Table 3.68. Summary of natural and cultural features of Vermilion Basin (concluded).

D2. Total 1974 canal area

	Area (ha)	Length (km)
Navigation	738	382
Agricultural drainage	72	234
Oil activity	848	178
Transportation embankment canals	5	8
Other	1	2
Total	1,664	804

D4. Estimated sport fishing and hunting supply and demand (man-days x 1000)

	Supply	Demand	Harvest as percent of estimated sustained yield
Big game	14.2	15.7	110
Small game	23.7	136.2	574
Water-fowl	63.0	110.3	175
Saltwater fishing	76.7	112.5	147

D3. Water use

	Annual volume ($m^3 \times 10^6$)
Agriculture	7.1
Municipal	0.1
Industrial	0.0
Total	7.2

D5. Nutrient and toxin discharges

Phosphorus (P) loading rates to entire Vermilion Basin drainage area

Cultural	P input (g/yr x 10^6)	Natural	P input (g/yr x 10^6)	Total P input
Urban	12.00	Forest	1.10	
Industrial	0.03	Lake	51.80	
Rice	65.00	Barren land	0.05	
Non-rice agriculture	265.00			
Total	333.03		52.95	385.98

Surface water discharge ($m^3 \times 10^8$/yr)	15.9
P load ($g/m^3/yr$)	0.24
Eutrophic state	Excessive

Oil well brine disposal (mbbls)

To wells	To pits	To surface waters
1,648.7	34.1	3,601.8

Vermilion River is heavily polluted with industrial wastes shore Gulf habitat, a remnant of an early delta lobe built when the Mississippi River flowed in its most westward course. Because of sediment discharge by the Atchafalaya River, mudflats are again rapidly forming off the Vermilion coast, and the coastline is accreting at Chenier Au Tigre.

Within Vermilion Basin most of the inland open water is that part of Vermilion Bay within the basin boundaries. The bay is protected from the Gulf by Marsh Island, and exchanges water with the Gulf through the narrow, deep Southwest Pass. The bay is also open to the east, connecting with the West Cote Blanche Bay. Westward-flowing freshwater from the Atchafalaya River and the Wax Lake Outlet keeps the whole basin rather fresh. Although the wetlands of the basin exchange water freely with Vermilion Bay, the area of salt marsh habitat is very small and most of the marshes are brackish or intermediate (table 3.68).

Most freshwater flow from the north is through the Vermilion River (fig. 3-33). Bayou Teche water is also diverted to the Vermilion River through Bayou Fusilier and Ruth Canal. This fresh water is confined by the high banks of the lower Vermilion River so that overbank flooding does not occur normally except near the mouth. Drainage is complicated by the complex network of dredged canals that include the Gulf Intracoastal Waterway (GIWW), that intersects the Vermilion River about 5 km (3 mi) above its mouth, the Vemilion River cutoff that bypasses Little Vermilion Bay and Little White Lake, and the Schooner Bayou cutoff that connects the GIWW with Schooner Bayou (plate 1B).

On the west and northwest, drainage into the Vermilion Basin is restricted by the embankment of Louisiana Highway 82, by spoil banks along the Schooner Bayou/Freshwater Bayou system, and by control structures at Vermilion Lock, Freshwater Bayou, and Schooner Bayou designed to preserve fresh supplies in the Mermentau Basin (part 3.6.3). Docks on Freshwater Bayou restrict direct exchange of water with the Gulf and probably reduce the use of wetlands by estuarine-dependent organisms in the area north of the locks.

North of Vermilion Bay some high land exists with a small forested area, agriculture, and a few villages. The lower part of the basin has poor access, except by boat, and no permanent settlements are found there.

Diurnal tides are pronounced as far north as Abbeville. They average 37.5 cm (14.8 in) at Vermilion Lock (fig. 3-33). Seasonal water levels peak in spring and early fall (fig. 3-34), but do not show the distinct low level during the summer found elsewhere on the coast, perhaps because of Atchafalaya River water.

Since 1945, mean annual water levels have shown an annual increase of 0.94 cm (0.37 in) per year at Vermilion Lock (fig. 3-34). This is comparable to, or slightly lower than, rates elsewhere along the Chenier Plain. At the Lock, water is nearly fresh (fig. 3-35). The long-term trends at this location show a decrease in salinity since 1947 (fig. 3-36), due probably to a combination of wet years and freshwater discharges from the Mermentau Basin.

Vermilion Bay and its adjacent wetlands support large populations of shrimp, Gulf menhaden, blue crab and other estuarine-dependent organisms. Nutria and muskrat are harvested from the wetlands, and waterfowl are abundant. The potential for fresh and saltwater finfishing is also high (table 3.68).

Socioeconomics. The Vermilion Basin has an extremely small human population—804 individuals. The work force is employed primarily in mining and mineral fuel-related jobs (fig. 3-12). Only in Intracoastal City is there industrial development in the basin. The annual values of commodities produced by the basin are: oil and gas $53.2 million; agricultural products, $2 million; fish and fur animals, $913,000; and sport fish and game, $2.5 million (table 3.68). As in other basins, the mineral extraction industry dominates the economy.

Waterborne transport into and through the basin was about 1 million tons (0.9 million tonnes) in 1976, representing a decline from the peak of 1.9 million tons (1.7 million tonnes) in 1967. Nonfuel mined products are imported into the basin and oil and petrochemicals are exported.

Effects of Human Activities on the Environment. Hydrologic effects: The effects of modifications of the normal hydrologic regime by canals, spoil banks, and control structures in the Vermilion Basin may be masked by the overpowering influence of the Atchafalaya River, which floods Vermilion Bay with fresh water and high nutrient sediments.

Habitat effects: Unexplained wetland losses in the Vermilion Basin are occurring at a rate of about 0.09%/yr (844 ha or 2,086 a since 1952), the lowest rate along the Chenier Plain coast, inspite of the extensive hydrologic alterations (table 3.68). The relative stability of the marshes may result from the heavy sediment influx from the Atchafalaya River. Total wetland losses have been 15.9% (6,800 ha or 16,803 a) since 1952. Over one-half of this loss (3,473 ha or 8,582 a) has resulted from impoundment. Canal and spoil area increases have amounted to 1,649 ha (4,075 a). Drainage for agriculture accounts for the majority of the remaining area. Although there is shoreline accretion along the eastern coast of the basin, the retreating shoreline on the western coast has resulted in a net loss of 200 ha (494 a) for the entire basin.

Spoil area has tripled since 1952, indicating a significant increase in the rate of canal construction. In the entire Chenier Plain, about 85% of the present canal system was dredged prior to 1952.

The rate of conversion of wetlands to agricultural land also has increased. As indicated in part 3.2.3, agricultural area in the Louisiana coastal parishes has been declining slowly since the early 1930s. The Vermilion Basin is an exception; its agricultural area increased 24% since 1952 and shows the highest dollar return per hectare of farmland in the Chenier Plain.

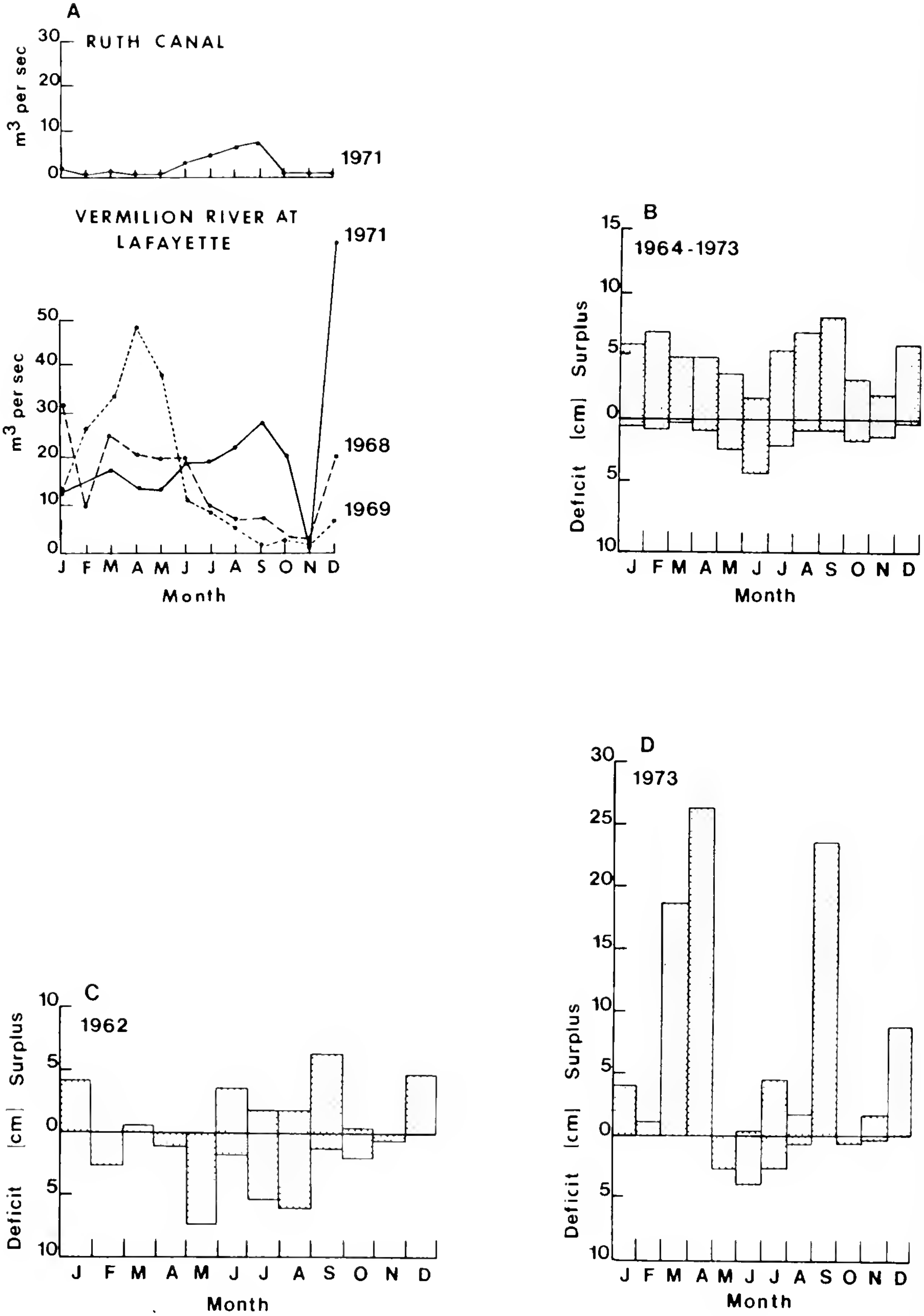


Figure 3-33. Freshwater supply of Vermilion Basin: (A) riverine input from U.S. Geological Survey discharge data; (B) mean monthly water surplus (deficit); (C) monthly water surplus deficit in a dry year; and (D) monthly water surplus (deficit) in a wet year. Calculated from U.S. Weather Service data as described by Borengasser 1977.

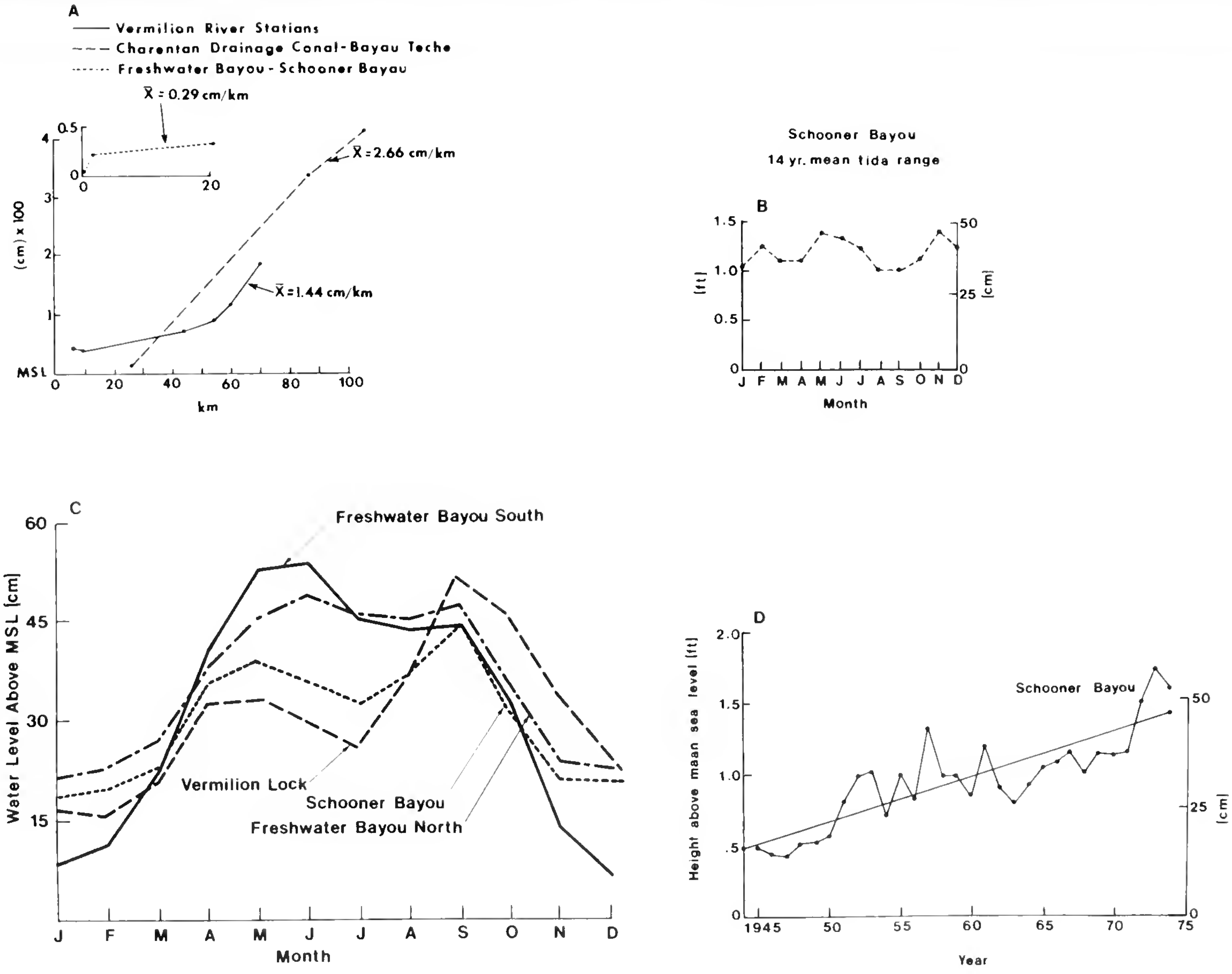


Figure 3-34. Water levels in Vermilion Basin: (A) Surface water slopes; (B) monthly variation in daily tidal range; (C) seasonal variation in mean water level; (D) long-term annual mean water level.

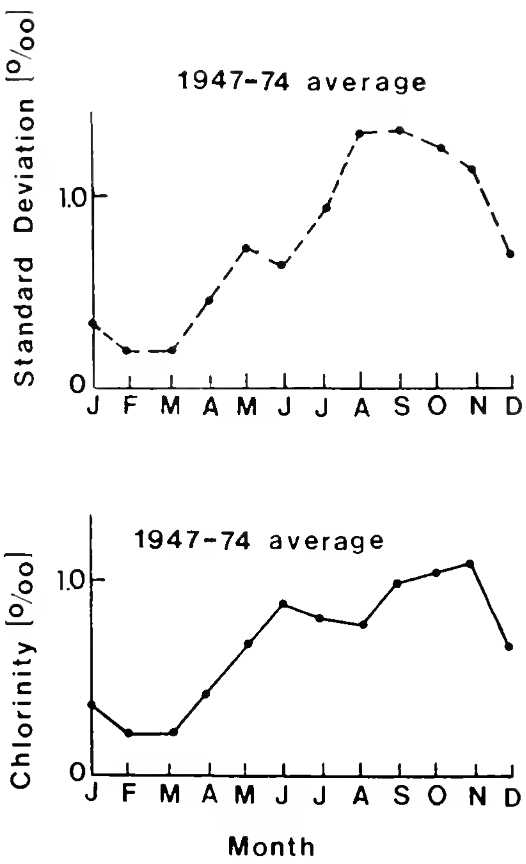


Figure 3-35. Monthly means and standard deviations (1948-1974) of chlorinity at the Vermilion Lock from U.S. Army Corps of Engineers records.

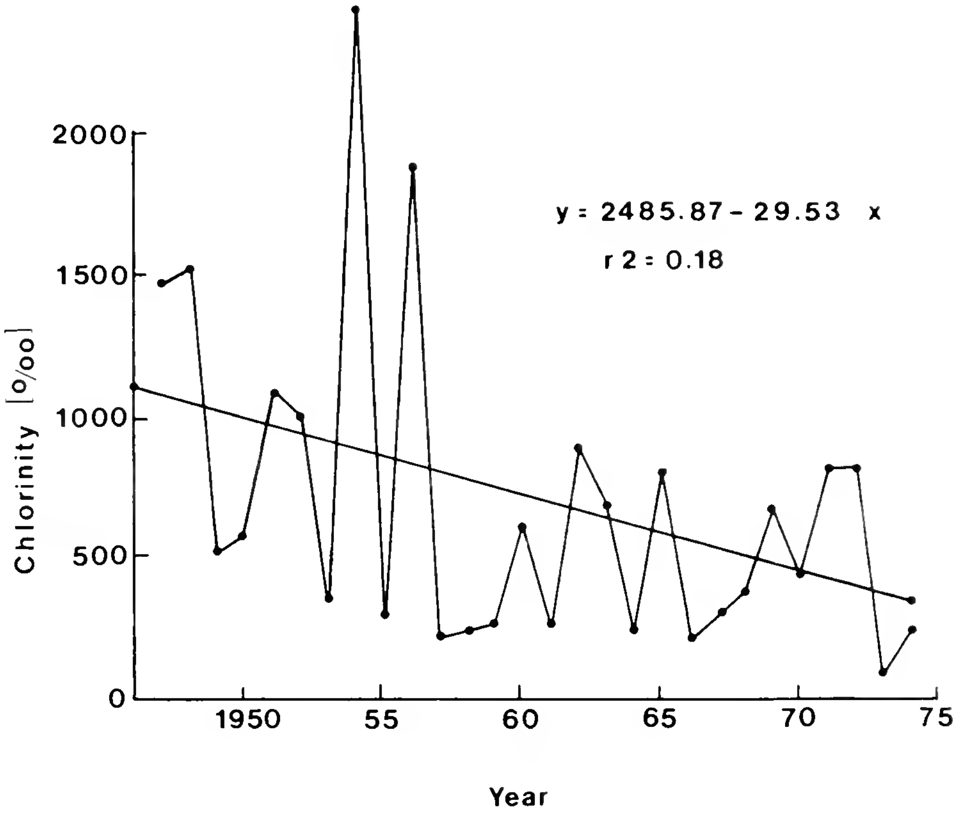


Figure 3-36. Yearly means and standard deviations (1947-1974) of chlorinity at the Vermilion Lock, from U Army Corps Engineers records. The regression coefficient is significiant ($P < .05$).

The reasons for the high returns, however, are not clear (see part 3.2.3). It is likely that continued agricultural expansion into marginal wetlands will accelerate drainage canal construction and nutrient runoff. Water quality is already a problem in the Vermilion River. Loading rates of P to the basin place it in the excessive eutrophic state, primarily because of runoff from upstream agriculture (table 3.68). Agricultural expansion, therefore, is likely to aggravate eutrophication problems in the more enclosed bays and small lakes. The Atchafalaya River undoubtedly influences the productivity and diversity of Vermilion Bay but its significance has not been totally considered.

Effects on renewable resources: The overall trend in habitats is for a continuous, slow conversion of natural areas to culturally maintained systems. The conversion of relatively unique swamp forest and ridge habitats in particular, can be expected to result in permanent loss of some of the rarer animal species that live in these habitats. Both habitats normally support a diverse flora and fauna. Because they are elevated areas in the middle of lands subject to inundation, ridges have a particularly valuable function during storms and as a refuge for migratory song birds (part 4.13)

The silt-laden Atchafalaya waters are probably the most important influence on the fishery resources of the Vermilion Basin. The extensive oyster reefs that once fringed the gulfward edges of the bay have been smothered by silt or killed by the freshwater. The average salinities decreased to 3 ‰ in the bay (Juneau 1975). Throughout the Atchafalaya and Vermilion bays, typical freshwater species such as white crappie, bluegill, sheepshead minnow, and blue catfish are found in the same waters as such marine organisms as the Atlantic midshipman, Gulf toadfish, Atlantic cutlassfish, and Atlantic stingray (Juneau 1975). As mudflats build out and become stabilized over the shallow shelf, a diverse benthic fauna should develop. This in turn should benefit demersal fishes.

The Vermilion Basin is severly impacted by activities associated with oil and gas recovery, and with agriculture. These activities generally lead to accelerated rates of wetland loss, and eutrophication is already evident. At the same time, rapid land accretion, extreme turbidity, and high nutrient loads are resulting from the delta-building processes of the Atchafalaya River. Because of both cultural and natural processes, this basin is an area of intense ecological interest and worthy of wise management practices.

3.6.3 MERMENTAU BASIN

General features. The Mermentau Basin is unique in the Chenier Plain for several reasons. It was formerly part of the Mermentau/Chenier drainage system, but the natural chenier ridges along its southern boundary and a number of water control structures have essentially resulted in a single, large freshwater impoundment. Therefore, the basin has no nearshore Gulf habitat. Several large shallow lakes cover about one-quarter of the basin area (fig. 3-32). The natural and impounded wetlands (47% of the area) are all fresh. Most of the remaining land, which lies along the northern edge of the basin, is used for rice cultivation and for cattle.

The basin is supplied with fresh water (fig. 3-37) by the Mermentau River, which cuts diagonally across it. Water control structures at Catfish Point, Schooner Bayou and the Superior Canal, the Vermilion and Calcasieu locks on the GIWW, and locks at Freshwater Bayou (fig. 3-32) restrict the flow of fresh water out of the basin and of salt water into the basin. The main purpose of the control structures is to provide a large freshwater reservoir for agricultural (rice) irrigation so as to prevent tidal flooding, and to provide higher water levels for navigation. The locks and control structures are manipulated to maintain minimum water levels within the basin at 60 to 70 cm (24 to 28 in) above Gulf MLW and to prevent salt intrusion. They are generally closed on incoming tides and when inside stages decline below 0.66 m (2.17 ft) MLG. However, they are opened when stages exceed 0.60 to 0.67 m (1.97 to 2.20 ft) MLG and flows are adequate to prevent salt intrusion.

Before 1951, surface water in the basin was pumped into rice fields and the flow in the Mermentau River was often reversed. Upstream flows of up to 56.6 m^3/ sec (2000 ft^3/sec) were recorded. This caused saltwater intrusion into the lower basin (Army Corps of Engineers 1961). Fresh water moves laterally between the Mermentau and Calcasieu basins via the Calcasieu Lock, depending on the direction of the hydraulic head.

Because of these control structures, there is no significant diurnal tide within the basin. Wind tides dominate the circulation of Grand and White lakes. Seasonal water levels are modified from the typical dual spring and fall peaks. They are relatively high all year except during June and July (fig. 3-38). The water is nearly fresh year round, but chlorinity rises to about 1.7 ‰ inside the Catfish Point control structure in June and July (fig. 3-39). Since the control structures were installed in 1950, salinity appears to have been declining slowly, although year-to-year variability is high. Since 1965, rainfall has generally been above normal, and it appears that of the control structure has reduced salinities (fig. 3-38) under these circumstances. Gages show a net long-term water level increase of 2.13 cm (0.83 in) per year in the basin (fig. 3-38).

Historically, the Mermentau was an estuarine nursery ground, but it no longer functions in this capacity as far as fisheries are concerned (Gunter and Shell 1958, Morton 1973). Commercial freshwater fishing for catfish and other species exists in Grand Lake, White Lake, and adjacent waters. The major commercial living resource is nutria (table 3.69). The area attracts large numbers of waterfowl, both because of the extensive fresh marshes and also because of the nearby rice fields. The potential for freshwater finfishing is also high, although there is very little recorded commercial use of this resource.

Socioeconomics. Most of the residents of the Mermentau Basin are members of farming families.

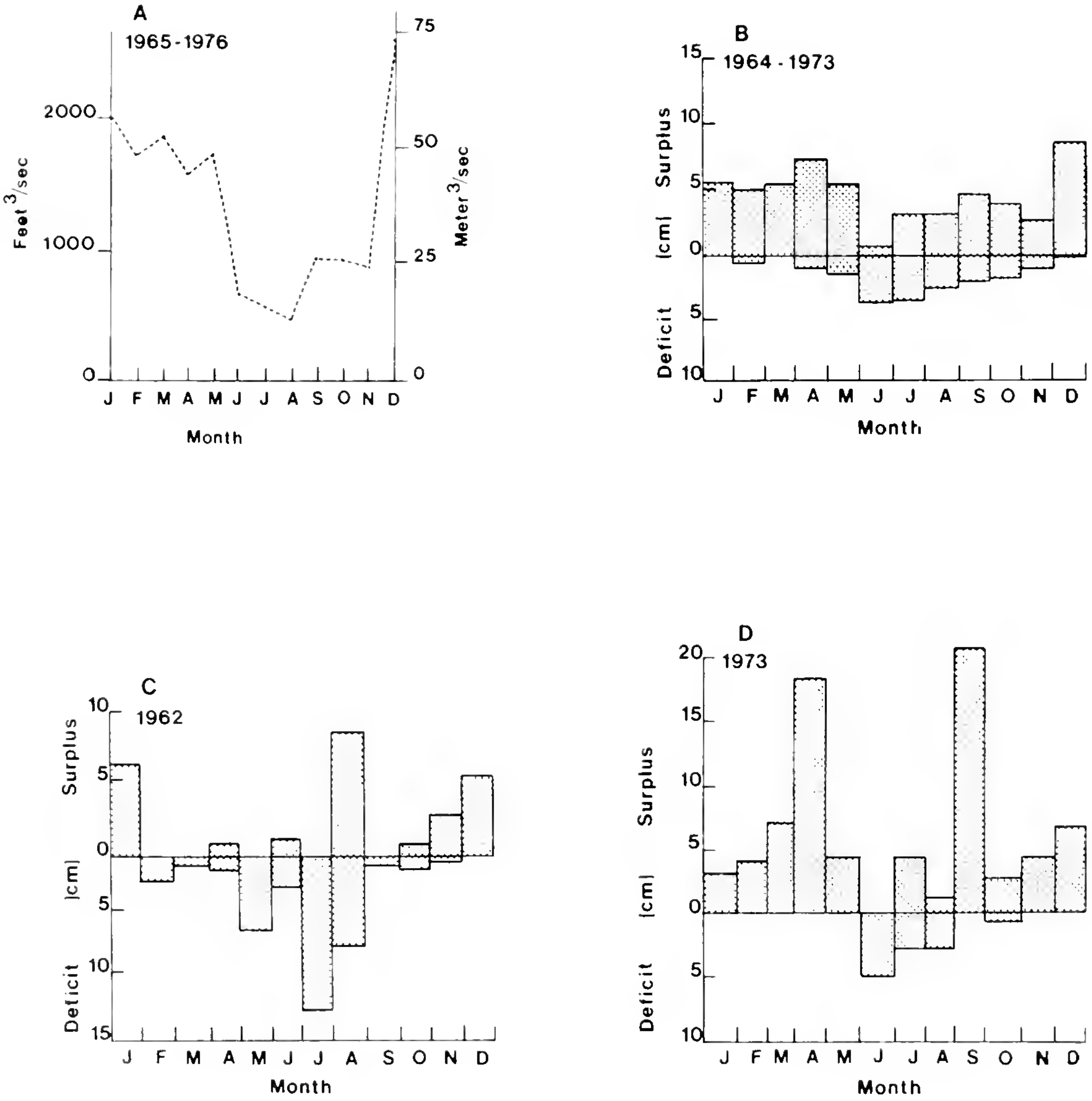


Figure 3-37. Freshwater supply of Mermentau Basin: (A) riverine input from U.S. Geological Survey discharge data; (B) mean monthly water surplus (deficit); (C) monthly water surplus (deficit) in a dry year; and (D) monthly water surplus (deficit) in a wet year. Calculated from U.S. Weather Service data, as described by Borengasser 1977.

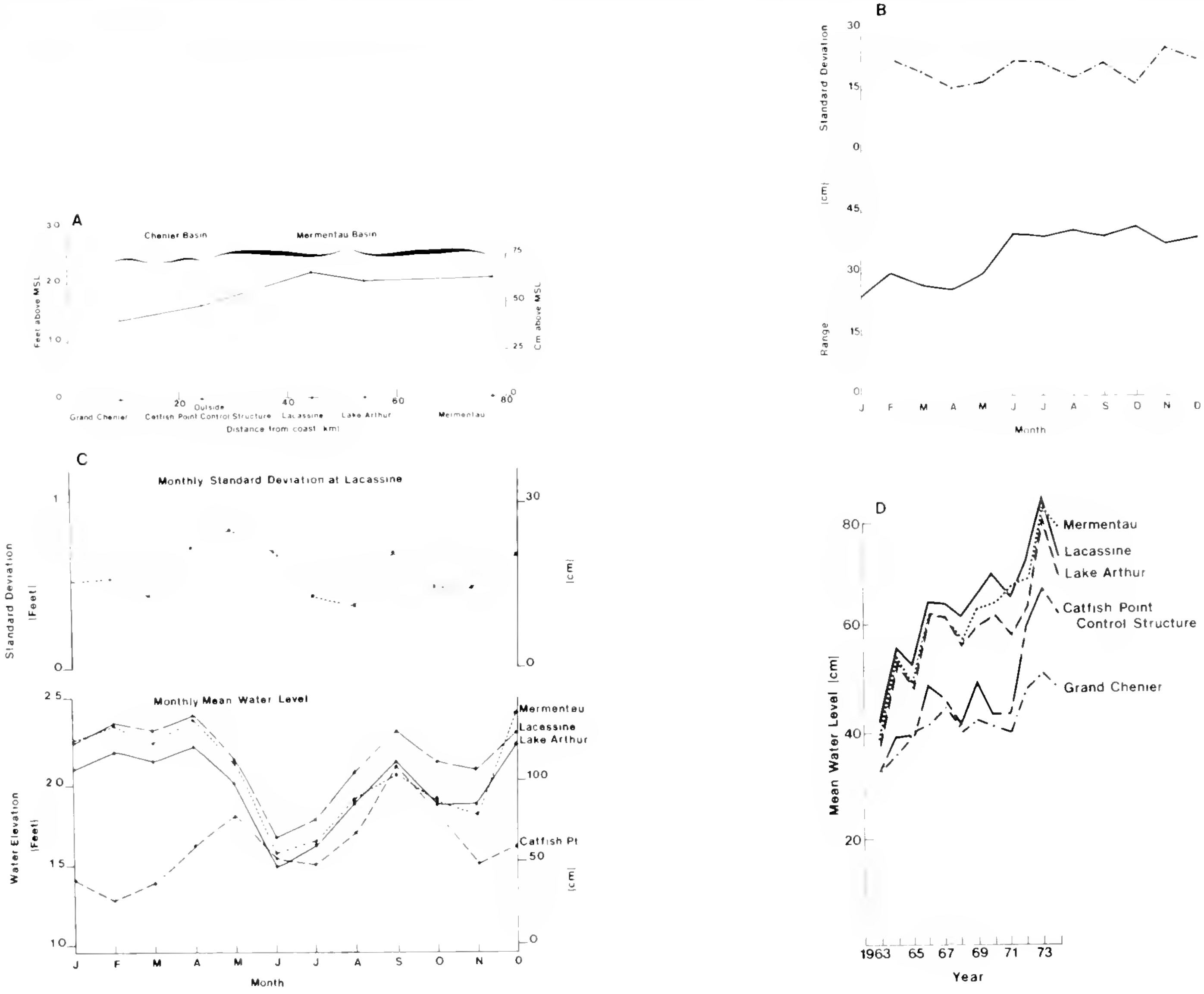


Figure 3-38. Water levels in Mermentau Basin: (A) surface water slopes in the Mermentau and Chenier basins, from U.S. Army Corps of Engineers gages; (B) monthly variation in daily tidal range; (C) seasonal variation in water level at Lacassine; and (D) long-term mean annual water level.

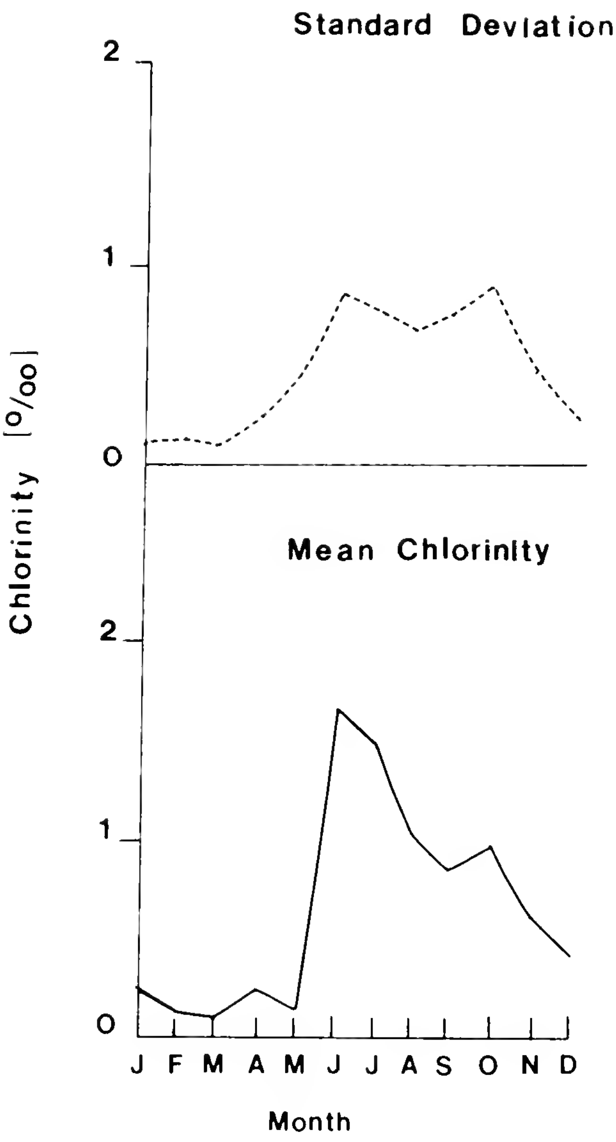


Figure 3-39. Monthly means and standard deviations (1947 to 1974) of chlorinity in the Mermentau Basin inside Catfish Point control structure, from U.S. Army Corps of Engineers records.

The few communities along the northern boundary of the basin are agriculturally oriented. These people are not adequately represented in the employment statistics in figure 3-12, which report only employees covered by the Federal Insurance Compensation Act.

Despite the importance of farming, the largest industry in the basin is mineral extraction. Minerals, the most valuable products of the basin, were worth \$114 million in 1974. Agricultural products are worth about \$14 million per year; commercial fishing and trapping, about \$1 million; and sport fishing and hunting, \$2 million.

The volume of waterborne commerce into and through the basin is stable at about 2 million tons (1.8 million tonnes) per year, most of it (1.4 million tons or 1.27 million tonnes) involves the export of crude petroleum. This volume is small compared to the 50 million tons (45 million tonnes) of traffic in the Calcasieu Basin and 100 million tons (91 million tonnes) in the Sabine area.

Effects of Human Activities on the Environment. Hydrologic effects: The extensive modification of the natural hydrologic regime of the Mermentau Basin by control structures has been described. Within the basin, circulation patterns have undoubtedly been modified by the extensive canal network 2,826 km (1,756 mi) long (plate 5B), covering 2.1% of the basin area (table 3.69). In addition, impounded wetlands within the basin cover 18% of the area and further modify the inundation and flushing patterns of the wetlands. A final factor is the withdrawal of fresh water for rice irrigation. This is calculated at 3×10^8 m^3 (1.1×10^{10} ft^3), about one-third of the total flow of the Mermentau River (table 3.69), the major stream feeding the basin, and about 10% of the total annual water surplus of the basin, including rain. This demand occurs almost entirely during April, May, June, and July when the basin normally sustains rainfall deficits (fig. 3-37) and river discharge is at its minimum. About 40% of the irrigation water is returned to the basin when rice fields are drained toward the end of summer (Texas Water Development Board 1977). Because about one-third of the total irrigation requirement is supplied by groundwater, the volume of water released is actually greater than the surface water withdrawn earlier in the season. Thus, surface waterflows out of the basin are actually larger at present than before the control structures were installed. The net effect has been to modify the normal flow and water level patterns in the basin. Figure 3-40 shows how effective the control structures are in controlling water level in the basin and in preventing saltwater intrusion. At the northern station on Freshwater Bayou, the water level inside the lock in the winter is as much as 30 cm (12 in) above the level one-half mile downstream outside the lock (Freshwater Bayou, south). During the summer when Gulf water levels are higher than water levels in the basin, the structures prevent intrusion of salt water.

Habitat effects: Wetland loss is occurring at an annual rate of 0.88% (20,132 ha or 49,751 a from 1952 to 1974). All but 3,356 ha (8,293 a) can be accounted for by direct cultural modification: impounding of wetlands accounts for 12,797 ha (31,622 a or 63%) and draining for agriculture, another 2,584 ha (6,385 a) 13% (table 3.69). The residual wetland loss was 3.3% between 1952 and 1974, or 0.14%/yr. This rate is a little higher than the residual loss rates for the Vermilion-Chenier, and East Bay basins. Wildlife biologists familiar with the basin attribute this loss to erosion of lake shorelines. This erosion results from maintenance of high water levels behind the control structures. Except for occasional dry years, abnormally high water levels over the marshes also prevent germination of annual grasses and sedges which are valuable waterfowl food (Vaughn, R. R., U.S. Fish and Wildlife Service, Atlanta, Ga., letter dated 1 April 1977 to District Engineer, U.S.A.C.E., New Orleans, La.).

Table 3.69. Summary of natural and cultural features of Mermentau Basin.

A. Hydrology of the Mermentau Basin

Riverine Processes

Upstream drainage area 9,539 km^2

Freshwater flow volume (into basin) 53.4 x $10^8 m^3$/yr (fig. 3-37)

Seasonal:

Annual rainfall 146 cm (at Lake Arthur)

Annual rain surplus (Chenier and Mermentau) 55.2 cm/yr (fig. 3-37)

Maximum freshwater renewal time: (Chenier and Mermentau) 83 days

Surface water slope: 0.011 ft/mi = 0.2 cm/yr (fig. 3-38)

Tides: No significant diurnal tide

Range: 0

Period: 0

Water level variation

Seasonal: One minimum only in June-July (fig. 3-38) variability highest in May

Long-term: 2.13 cm/yr rise (fig. 3-38)

Salinity: negligible

Seasonal: Peak in May-June (fig. 3-39) Variability highest during summer

Long-term: Slight decrease but variability high

Control structures and modifications

- At Catfish Point Control Structure
- Vermilion Lock
- Schooner Bayou Control Structure
- Calcasieu Lock
- Freshwater Bayou Control Structure
- Small structure on Superior Canal on Rockefeller Refuge
- GIWW

B. Primary production, potential yield and harvest of living resources of Mermentau Basin.

	Per km^2	Per basin
Net primary production (t/yr) Appendix 6.3	1,592	4,267,000
Sport hunitng and fishing use estimated potential yield[a]		
Big game (man-days x 1000/yr)		59.3
Small game (man-days x 1000/yr)		88.7
Waterfowl (man-days x 1000/yr)		141.5
Saltwater finfishing (man-days x 1000/yr)		0
Freshwater finfishing (man-days x 1000/yr)		3,799
Total		4,088.5
Agriculture	380	128,109
Commercial species harvest		
Shrimp (kg x 1000/yr)		0
Menhaden (kg x 1000/yr)		0
Blue crab (kg x 1000/yr)		0
Oyster (kg meat x 1000/yr)		0
Other saltwater finfishes (kg x 1000/yr)		0
Freshwater finfishes (kg x 1000/yr)		187
Nutria (pelts/yr)		155,800
Muskrat (pelts/yr)		8,280

[a]Method explained in part 3.5.2

[b]Present harvest attributed to basin (part 3.2.4)

continued

Table 3.69. Summary of natural and cultural features of Mermentau Basin (continued)

C. Habitats of Mermentau Basin

C1. Habitat area in 1974 and net changes since 1952

Habitat	Area 1974 (ha)[a]	Percent of total area[b]	Changes in area 1952 to 1974 (ha)	(%)
Nearshore Gulf	0		0	0
Inland open water	61,497	22.9	3,873	6.7
Natural marsh	79,052	29.5	-20,132	-20.3
Impounded marsh	49,399	18.4	10,767	27.9
Swamp forest	1,660	0.6	-134	-7.5
Natural ridge	3,998	1.5	-145	-3.5
Spoil	8,636	3.2	1,000	13.0
Rice field	32,976	12.3	2,238	7.3
Non-rice cropland	3,390	1.3	877	34.9
Pasture	23,069	8.6	1,893	8.9
Urban	1,595	0.6	52	3.4
Beach	0	0	0	0
Upland forest	2,772	1.0	-289	-9.4
Total	268,044			

[a] 1 hectare (ha) = 2.47 acres (a)

[b] Calculation excludes area of nearshore Gulf habitat

C2. Habitat modification from 1952 to 1974 due to identifiable human activities

Cause of change	1952 Habitat	1952 Area (ha)	Changed to (by 1974) Habitat	Changed to Area (ha)	Change in 1974 as percent of original 1952 habitat
Filling and draining	Natural marsh	99,184	Agricultural	2,466	2.5
	Impounded marsh	38,632	Agricultural	2,030	5.3
	Swamp forest	1,794	Agricultural	118	6.6
Impounding	Natural marsh	99,184	Impounded marsh	12,797	12.9
Canal dredge and spoil	Natural marsh	99,184	Spoil	1,019	1.0
			Canal	510	0.5
Upland construction	Natural ridge	4,143	Agricultural	145	3.5
	Upland forest	3,084	Agricultural	289	9.4
	Agriculture	51,427	Urban	40	0.1

continued

Table 3.69. Summary of natural and cultural features of Mermentau Basin (continued)

C3. Natural wetland loss (1952-1974)–summary

To	Process	Area (ha)	Percent of 1952 area
Canals	Dredging	510	0.5
Inland open water	Subsidence	3,340	3.4
Nearshore Gulf	Shoreline erosion/deposition	0	0
Impounded marsh	Leveeing	12,797	12.9
Spoil	Dredging	1,019	1.0
Agriculture	Draining	2,466	2.5
Urban	Draining	0	0
Total		20,132	20.3

D. Cultural Features of the Mermentau Basin

D1. Socioeconomics

Population: 7,974
Employment: See figure 3-12

	Production (1974)	Value ($ x 1000)
Minerals		
Gas (mcf)	189,940,493	58,312
Crude oil (bbls)	8,543,329	55,702
Total		114,014
Agriculture		
Crops		12,655
Other		1,609
Total		14,264
Sport hunting/fishing		
Saltwater sportfishing		367.2
Freshwater sportfishing		392.4
Small game hunting		330.0
Big game hunting		114.3
Waterfowl hunting		801
Total		2,005

	Value ($ x 1000)
Commercial harvest	
Fishing	
Shrimp	115.1
Menhaden	0
Blue crab	70
Oyster	0
Other estuarine-dependent species	0
Freshwater finfish	101.7
Subtotal	286.8
Trapping	
Nutria	934.8
Muskrat	37.3
Subtotal	972.1
Total	1,358.9

Navigation

Total traffic: 2,086,473 tons, 1976 fairly stable last 10 years

Exports: chiefly crude petroleum (1.4 million tons)

continued

Table 3.69. Summary of natural and cultural features of Mermentau Basin (concluded)

D2. Total 1974 canal area

	Area (ha)	Length (km)
Navigation	2,036	1,137
Agricultural drainage	350	1,156
Oil activity	1,945	452
Transportation embankment canals	228	40
Other	40	41
Total	4,399	2,826

D3. Water use

	Annual volume ($m^3 \times 10^6$)
Agriculture	319.6
Municipal	1.1
Industrial	1.8
Total	322.5

D4. Estimated sport fishing and hunting supply and demand (man-days x 1000)

	Supply Mermentau	Supply Chenier	Demand	Harvest as percent of estimated sustained yield
Big game	59.3	24.9	2.7	15
Small game	88.7	31.1	110.0	92
Waterfowl	141.5	97.2	89.0	37
Saltwater fishing	0	147.8	379.8	257

D5. Nutrient and toxin discharges

Phosphorus (P) loading rates to entire Mermentau and Chenier basins drainage area

Cultural	P input (g/yr x 10^6)	Natural	P input (g/yr x 10^6)	Total P input
Urban	213.60	Forest	7.87	
Industrial	0.11	Lake	112.60	
Rice	737.10	Barren land	0.07	
Non-rice agriculture	193.10			
Total	1,143.91		120.54	1,264.4

Surface water discharge ($m^3 \times 10^8$/yr)	53.4
P load (g/m^3/yr)	0.2
Eutrophic state	Borderline

Oil well brine disposal (mbbls)

To wells	To pits	To surface waters
32,415.24	34.12	1,388.9

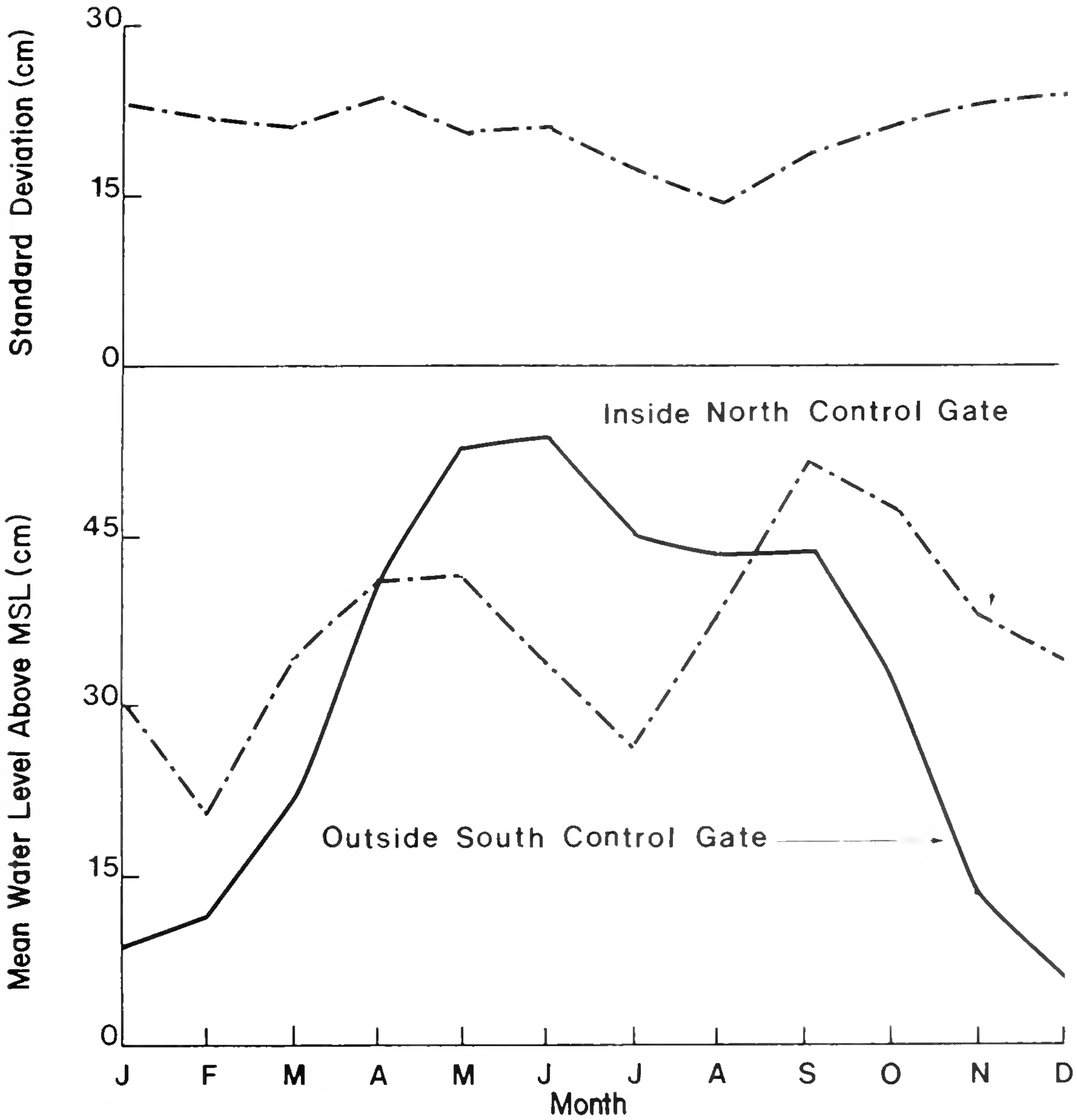


Figure 3-40. Monthly mean water levels above mean sea level (MSL) inside and outside the Freshwater Bayou control structure (1963-1974), from U.S. Army Corps of Engineers gages.

In addition to loss of natural marsh, there has been a small loss of upland forest and swamp forest habitats, primarily to agricultural use. These habitats each compose less than 1% of the basin area. Swamp forest habitat, in particular, is rapidly disappearing from the Chenier Plain region.

Effects on renewable resources: In a study conducted from September 1951 through June 1953, immediately after installation of the locks and control structures, Gunter and Shell (1958) found that marine and estuarine organisms dominated Grand Lake, and nearby Little Bay. Morton (1973) has shown that the basin now functions as a fresh-water impoundment and 80% of the aquatic species are those typical of freshwater areas. Erosion of the shorelines of White and Grand lakes has been extensive and severe. Nutria, the most important furbearer, appears to be declining because of the high water levels, and muskrats have not occurred in the basin since installation of the control structures.

The results of impounding wetlands may have long-term implications for water quality management. The impoundment of wetlands within the Mermentau Basin may have different implications than elsewhere. Because of water control structures, the basin does not function effectively as an estuarine nursery. The marshes within the impounded basin do function effectively as habitats for waterfowl, nutria, alligators, wading birds, and other marsh wildlife. The impoundments may have long-term implications for water quality because the basin has a relatively long freshwater flushing time (83 days, table 3.69). Heavy loads of agricultural fertilizer are drained from the rice fields, and the drainage network of canals accelerates the runoff process and bypasses normal overland flow, dumping nutrients directly into the shallow lakes. Impoundments do not have the nutrient filtering cap-

Table 3.70. Summary of natural and cultural features of Chenier Basin.

A. Hydrology of the Chenier Basin

Riverine Processes

Freshwater flow volume (into basin)
no data

Upstream drainage area
9,539 km^2 drains into Mermentau Basin, which, in turn, drains partially into Chenier Basin

Annual rainfall 146 cm (at Lake Arthur)

Annual rain surplus
(Chenier and Mermentau) 55.2 cm/yr

Maximum freshwater renewal time:
(Chenier and Mermentau) 83 days

Surface water slope: See Mermentau Basin (fig. 3-38)

Tides:

Range: 24 to 42 cm (monthly mean) (fig. 3-32)

Period: Primarily diurnal

Water level variation

Seasonal: Minimum November-February, high all summer (fig. 3-41)

Long term: See Mermentau Basin (fig. 3-38)

Salinity:

Seasonal: No data

Long term: No data

Control structures and modifications

Flow into Chenier Basin is discharged from Mermentau Basin at Catfish Point Control Structure (CPCS).
GIWW

B. Primary production, potential yield and harvest of living resources of Chenier Basin.

	Per km^2	Per basin
Net primary production (t/yr) Appendix 6.3	1,222.4	2,389,228
Sport hunting and fishing use estimated potential yield[a]		
Big game (man-days x 1000/yr)		24.9
Small game (man-days x 1000/yr)		31.4
Waterfowl (man-days x 1000/yr)		97.2
Saltwater finfishing (man-days x 1000/yr)		147.8
Freshwater finfishing (man-days x 1000/yr)		103.7
Total		405.0
Agriculture		
Rice (t/yr)	69	
Commercial species harvest[b]		
Shrimp (kg x 1000/yr)	4.7	186
Menhaden (kg x 1000/yr)	139.1	5,488
Blue crab (kg x 1000/yr)	0.5	18.2
Oyster (kg meat x 1000/yr)	0	0
Other saltwater finfishes (kg x 1000/yr)		188.8
Freshwater finfishes (kg x 1000/yr)		5.1
Nutria (pelts/yr)		69,519
Muskrat (pelts/yr)		20,874

[a]Method explained in part 3.5.2
[b]Present harvest attributed to basin (part 3.2.4)

continued

Table 3.70. Summary of natural and cultural features of Chenier Basin (continued).

C. Habitats of Chenier Basin

C1. Habitat area in 1974 and net changes since 1952

Habitat	Area 1974 (ha)[a]	Percent of total area[b]	Changes in area 1952 to 1974 (ha)	(%)
Nearshore Gulf	100,658	–	927	0.9
Inland open water	5,638	6.0	498	9.7
Natural marsh	28,242	29.8	-13,727	-32.7
Impounded marsh	48,834	51.5	10,876	28.7
Swamp forest	0	0	0	0
Natural ridge	3,288	3.5	-475	-12.6
Spoil	3,420	3.6	1,441	72.8
Rice field	67	0.1	29	76.3
Non-rice cropland	604	0.6	196	48.2
Pasture	2,751	2.9	120	4.6
Urban	401	0.4	152	61.0
Beach	1,544	1.6	-36	-2.3
Upland forest	0	0	0	0
Total	195,447			

[a]1 hectare (ha) = 2.47 acres (a)

[b]Calculation excludes area of nearshore Gulf habitat

C2. Habitat modification from 1952 to 1974 due to identifiable human activities

Cause of change	1952 Habitat	1952 Area (ha)	Changed to (by 1974) Habitat	Changed to (by 1974) Area (ha)	Change in 1974 as percent of original 1952 habitat
Filling and draining	Natural marsh	41,969	Urban	22	0.05
Impounding	Natural marsh	41,969	Impounded marsh	10,136	24.2
	Inland open water	5,140	Impounded marsh	740	14.4
Canal dredge and spoil	Natural marsh	41,969	Inland open water(canal)	590	1.4
			Spoil	1,181	4.8
	Inland open water	5,140	Spoil	249	2.8
Upland construction	Natural ridge	3,288	Agricultural	376	11.4
	Natural ridge	3,288	Urban	99	3.0
	Agriculture	3,077	Urban	31	1.0

continued

Table 3.70. Summary of natural and cultural features of Chenier Basin (continued).

C3. Natural wetland loss (1952-1974)–summary

To	Process	Area (ha)	Percent of 1952 area
Canals	Dredging	590	1.4
Inland open water	Subsidence	912	2.2
Nearshore Gulf	Shoreline erosion/deposition	927	2.2
Impounded marsh	Leveeing	10,136	24.2
Spoil	Dredging	1,181	2.8
Agriculture	Draining	0	0
Urban	Draining	22	0.05
Total		13,768	32.8

D. Cultural Features of the Chenier Basin

D1. Socioeconomics

Population: 1,220
Employment: (Figure 3-12)

	Production (1974)	Value ($ x 1000)
Minerals		
Gas (mcf)	193,579,634	59,429
Crude oil (bbls)	2,485,233	16,204
Total		75,633
Agriculture		
Crops		210
Other		450
Total		660
Sport hunting/fishing		
Saltwater sportfishing		367.2
Freshwater sportfishing		392.4
Small game hunting		633.0
Big game hunting		114
Waterfowl hunting		801
Total		2,005

	Value ($ x 1000)
Commercial harvest	
Fishing	
Shrimp	400.3
Menhaden	508.2
Blue crab	4.8
Oyster	
Other estuarine-dependent species	45.8
Freshwater finfish	2.7
Subtotal	960.8
Trapping	
Nutria	417.1
Muskrat	93.9
Subtotal	511.0
Total	1,472.8

Navigation (Chenier and Mermentau combined)
Total traffic: about 2,000,000 short tons (1978); declining from about 3,000,000 in 1967
Imports: non-petroleum mined products
Exports : crude petroleum

continued

Table 3.70. Summary of natural and cultural features of Chenier Basin (concluded).

D2. Total 1974 canal area

	Area (ha)	Length (km)
Navigation	530	555
Agricultural drainage	114	329
Oil activity	1,016	335
Transportation embankment canals	19	27
Other	75	75
Total	1,754	1,321

D3. Water use

	Annual volume ($m^3 \times 10^6$)
Agriculture	0.7
Municipal	0.2
Industrial	0
Total	0.9

D4. Estimated sport fishing and hunting supply and demand (man-days x 1000)

	Supply			Harvest as percent of estimated sustained yield
	Mermentau	Chenier	Demand	
Big game	59.3	24.9	12.7	15
Small game	88.7	31.4	110.0	92
Waterfowl	141.5	97.2	89.0	37
Saltwater fishing	0	147.8	379.8	257

D5. Nutrient and toxin discharges

Phosphorus — See Mermentau Basin

Oil well brine disposal (mbbls)

To wells	To pits	To surface waters
2,657.8	42.1	4,461.7

abilities of wetlands, but data are not available to determine the quantitative effects on water quality of converting natural wetlands to impounded wetlands. Judging by phosphorus loading, water-quality is marginal in the basin (table 3.69).

There may be considerable potential for increased commercial production of freshwater finfish species and crayfish in the Mermentau Basin, since they do not appear to be exploited to any great extent. The supply of waterfowl for hunting exceeds the demand in the mermentau Basin.

The decline in wetland area can be expected to lead to a decline of wildlife and water resources. Further expansion of agriculture in the basin can occur only at the expense of natural or impounded wetlands. As agriculture expands, problems of advanced stages of eutrophication will be compounded by increased nutrients from fertilizer runoff, increased water use for irrigation, and increased density of drainage canals.

An informal agreement among the U.S. Fish and Wildlife Service (FWS), the Louisiana Department of Wildlife and Fisheries (LDWF), and the U.S. Army Corps of Engineers (USACE) was implemented during the summer and fall of 1976. Under this agreement, the timing and extent of drawdowns needed to encourage wildlife food-plant production and to partially restore the use of the Mermentau Basin by estuarine organisms was attempted. Vaughn (Pers. Comm.) reported an estimated inshore harvest of white shrimp in excess of 160,000 kg (353,000 lb), and an offshore harvest of 53,000 kg (117,000 lb), based on sampling and surveys in White and Grand lakes. In addition 160,000 kg (353,000 lb) of blue crab were harvested. The combined dockside value was estimated at $1,221,000. A remarkable increase in annual grasses and sedges was also reported. There seemed to be no major conflict between this drawndown program and rice culture, navigation, or flood control.

3.6.4 CHENIER BASIN

General features. The Chenier Basin is a long, narrow, east-to-west strip of land and water sandwiched between the Mermentau Basin and the deep Gulf waters. Well-developed chenier ridges along the northern boundary, and control structures in operation since 1950 on the Mermentau River and Freshwater Bayou effectively cut this basin off hydrologically from the Mermentau and Vermilion basins (plate 1B). Beach ridges and smaller cheniers protect the inland area from direct Gulf influence (fig. 3-32). Freshwater input is limited to local rainfall and to the Mermentau River discharge in the extreme western end of the basin. The tidal action is strong and the natural wetlands of the basin are all salt-influenced. Because sediments from the Atchafalaya River drift westward, mud flats are developing along the Vermilion Basin coastline and are expected to develop westward across the Chenier Basin. However, shoreline erosion is occurring from Rollover Bayou to Hackberry Beach. The beach is accreting slowly west of Hackberry Beach to the Calcasieu River.

Inland water bodies are few and cover only 2.9% of the land area; most of them are associated with the lower reaches of the Mermentau River. Over two-thirds of what was once natural marsh has been impounded (25% of the total basin area). As a consequence, natural circulation patterns through the basin are severly modified.

Nearly all hydrographic records are from the lower Mermentau River at Grand Chenier and at Catfish Point control structure, both at the extreme western end of the basin.

Tidal range at Grand Chenier is 24 to 42 cm (9.4 to 16.5 in), but at Catfish Point this tide is completely masked by the flow through the control structure, when it is open (fig. 3-41). The sudden release of large volumes of fresh water also causes dramatic short-term salinity decreases in the proximity of the control structure (Perret et al. 1971). Long-term mean water levels at Grand Chenier show peaks in April and September, with little depression during the summer months. Over the years, mean water level has been rising (about 2.1 cm/yr or 0.83 in/yr) with respect to the gage elevation at a rate comparable to the Mermentau Basin (fig. 3-41).

In addition to the Mermentau River pass, a number of other ephemeral passes connect the inland portion of the basin to the Gulf. These connections allow a high diversity of estuarine-dependent fishes and shellfishes in the inland water (Perret et al. 1971). Shrimp and menhaden are the primary estuarine-dependent commercial species caught in the basin. Trapping of nutria and muskrat is an important industry. Large populations of waterfowl and sport-fishes are also found here.

Socioeconomics. The population of the Chenier Basin is scattered along the ridges. No dense population centers nor manufacturing industries exist. Mineral extraction is virtually the only industry (table 3.70). The value of extracted oil and gas in 1974 was $75 million, $0.7 million for agriculture, $1.5 million for fishing and trapping, and an estimated $2 million for sport fishing and hunting (Chenier and Mermentau combined).

Effects of Human Activities on the Environment. Hydrologic effects: Normal flows of water in the Chenier Basin have been modified by control structures and extensive impoundments (part 3.6.3). Manipulation of the Catfish Point control structure changes the volume and timing of discharge from the Mermentau Basin into the Chenier Basin. In addition, an extensive network of canals, 1,321 km (821 mi) in length, covers 2% of the land area; and spoil banks along these canals and along the lower Mermentau River further restrict and modify drainage.

Habitat effects. Since 1952, 33% of the natural marshes have been lost. Four percent of the marshes has been directly changed by canals either to water or to spoil. Over 900 ha (2,224 a) have been lost to shoreline erosion by the Gulf.

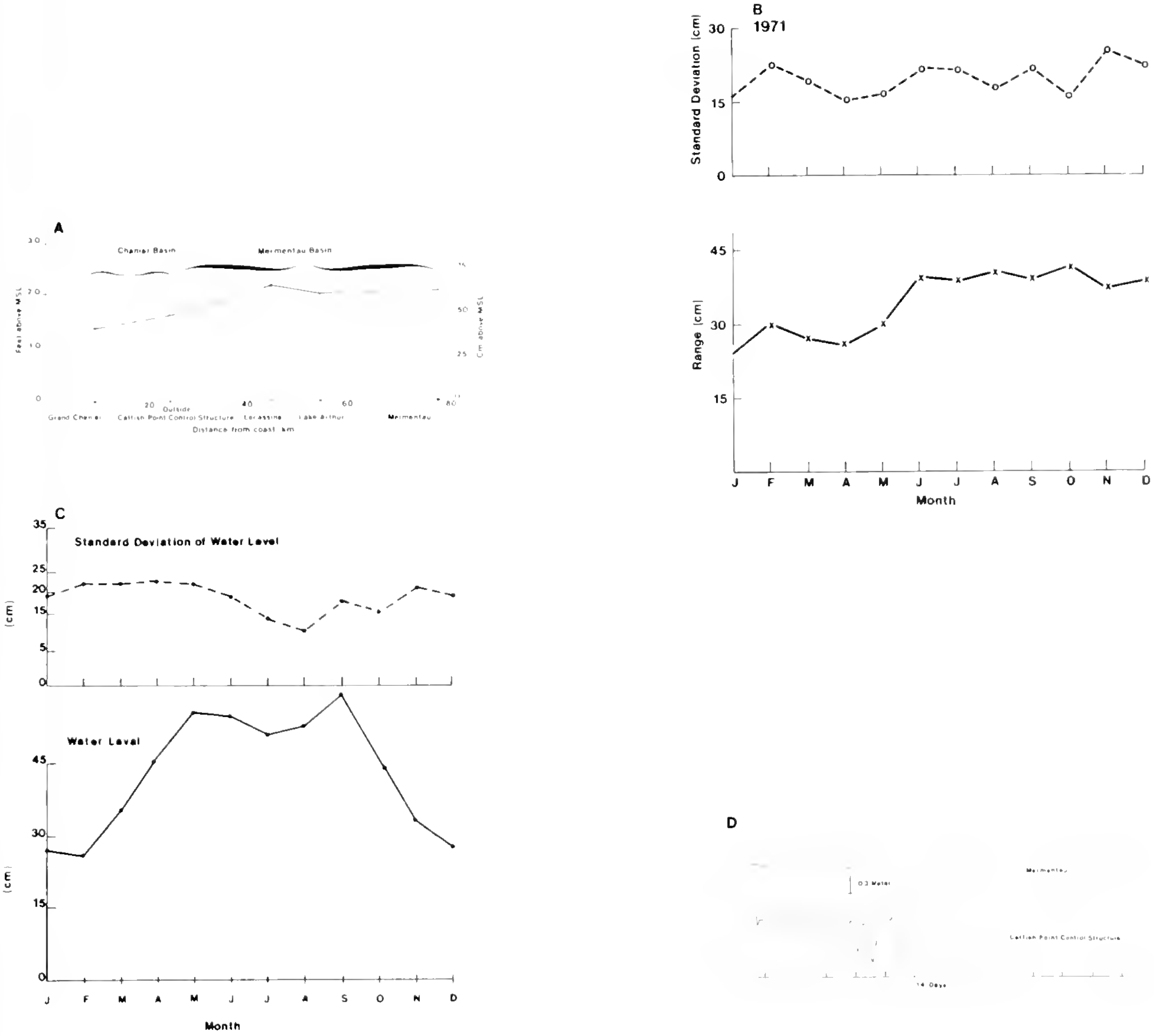


Figure 3-41. Water levels in Chenier Basin; (A) surface water slope in the Chenier and Mermentau basins from U.S. Army Corps of Engineers data; (B) monthly variation in daily tidal range at Grand Chenier; (C) seasonal variation in water level in Grand Chenier over a year; and (D) typical tide record.

By far the major impact on natural wetlands has been impounding. Over 10,000 ha (24,700 a) have been impounded since 1952. These impoundments tend to become increasingly fresh; their function as a detritus source and as a refuge for estuarine species is considerably decreased. Residual wetland loss to inland open water habitat has been only about 0.1%/yr (912 ha or 2,254 a since 1952), comparable to the Vermilion and East Bay basins.

Urban and agricultural land use has reduced the natural ridge habitat by 475 ha (1,174 a), a 12.6% loss between 1952 and 1974. This unique habitat is most fully developed in the Chenier Basin.

Effects on renewable resources: The density of estuarine-dependent fishery species is high in the inland open water habitat of the Chenier Basin (Perret et al. 1971), and free water exchange with marshes adjacent to the Mermentau River above upper Mud Lake does occur. However, access to marshes from the lower Mermentau River is restricted and over two-thirds of the Chenier Basin wetlands are now impounded. The dependence of estuarine organism on the linkage between marine waters and inland marshes has been well documented, so it seems inevitable that impoundments have seriously and adversely affected these living resources.

Estimates of waterfowl hunting compared to waterfowl numbers in the Mermentau and Chenier basins suggest that some increase in hunting is possible without endangering these resources. These figures must be interpreted with care, however, since they are based on rather arbitrary assumptions about the population served by these basins.

Estimates of water quality made for the combined Mermentau/Chenier basins indicated that loading rates are high enough so that a borderline eutrophic state exists. The problem is probably confined primarily to the Mermentau Basin where runoff from rice fields is heavy. The Chenier Basin is isolated from population centers to the north by the extensive Mermentau wetlands. The area is sparsely populated; agriculture is not a major industry, and much of the land is public or private refuges. For these reasons, and because it is important to protect the unique natural cheniers, the Chenier Basin seems most appropriate for the maintenance, futher development, and protection of its considerable recreation potential.

3.6.5 CALCASIEU BASIN

General features. The Calcasieu Basin is a shallow wetland/aquatic system with a single major freshwater input at the north end and a generally north to south circulation pattern through a large central lake (plates 1B and 3B and fig. 3-42). Some east-to-west water movement through the GIWW also occurs. The chenier ridges are well developed and effectively protect the inland marshes from the marine environment. A single major pass allows circulation with the Gulf of Mexico. In addition, Creole Canal allows freshwater drainage to the Gulf through a one way flapgate control structure at Oak Grove. Brackish and intermediate marsh habitats predominate in the basin (table 3.71; plate 3B). Along the upper edge of the basin much of the land is in agriculture, chiefly rice. The Hackberry salt dome protrudes to an elevation of about 10 m (33 ft) midway up the basin. Hydrologically the basin is fed by a fairly modest upstream water flow (table 3.71) which, combined with an annual rain surplus of 49 cm (19 in), gives a maximum freshwater renewal time of about 37 days. Therefore, the basin is well-flushed. Salinities in the upper basin adjust with the discharge of fresh water into the basin (fig. 3-43). Of all the Chenier Plain coast, tides are the most well-developed along this area. They are primarily semidiurnal and are strong as far north as the Calcasieu Lock. Mean water level shows typical seasonal peaks in April and September (fig. 3-44). Water level is rising at an apparent rate of 2 to 3 cm/yr (0.8 to 1.2 in/yr), a rate characteristic of the rest of the Chenier Plain.

Major living resources of the basin are shrimp, Gulf menhaden, nutria, muskrat, and waterfowl. There are two major menhaden processing plants in Cameron.

Socioeconomics. The basin itself is rural, with a few small villages. However, the large industrial centers of Lake Charles, Westlake, and Sulphur lie just outside the basin to the north. As with other basins, the main industry is mineral extraction, but petrochemical manufacturing plants outside the basin are the major employers. In terms of production of crude products, minerals bring in about $52 million annually. Commercial fishing and trapping are a distant second with $3.6 million. Sport hunting and fishing are conservatively estimated at $2.8 million and agriculture at $2.2 million. Thus, as elsewhere in the Chenier Plain, the renewable resources are overshadowed by the mineral extraction industry.

Waterborne commerce is also important economically and volume has been fairly stable for the past 10 years. In recent years, imported crude oil and exported petrochemical products have been the primary commodities.

Effects of Human Activities on the Environment. Hydrologic effects: In the mid-1800's a natural channel with a maximum depth of 4 m (13 ft) ran through the central part of Calcasieu Lake and exited via the natural sinuous portion of the lower Calcasieu River. The shallowest depth of the system was 1 m (3 ft) at the bar at the mouth of Calcasieu Pass. This bar controlled intrusion of salt water into the basin to the extent that every spring during the freshet, the lake and pass were flushed with fresh water for periods prolonged enough to result in oyster mortality near St. John's Island (Van Sickle 1977). From 1871, Calcasieu Pass was dredged continuously to various depths to allow ship traffic entry into the channel to Lake Charles. During these dredgings the depth did not exceed 4 m (13 ft) at the mouth, but increasing salinities allowed the oyster population to move progressively up the lower Calcasieu River (Van Sickle 1977).

Navigation into Lake Charles from Sabine Lake was first made possible by deepening and widening the GIWW between Lake Charles and Sabine Lake. In 1937, a land-cut channel was dredged to a depth of 10 m (33 ft) along the western edge of Calcasieu Lake and was separated from the lake by spoil banks. The lower sinuous shallow pass to the Gulf was bypassed by a 10 m (33 ft) bar channel that extended some distance offshore. Although supportive data are lacking, later studies (U.S. Army Corps of Engineers 1950, Van Sickle 1977) suggest that saltwater intrusion up the ship channel did occur at this time.

In 1946 the existing ship channel was deepened to 12 m (39 ft). In the mid-1960's the ship channel width was doubled and the channel was dredged to a depth of 15 m (49 ft). Van Sickle (1977) demonstrated a resultant increase of surface salinity at Lake Charles from 5.5 to 7.7 ‰ for the 8-year period before (1955 to 1963) and after the channel dredging from 1963 to 1971 (fig. 3-45).

The dredged material from the channel was used to levee off the ship channel from the lake to the east so that Calcasieu River water that once circulated through Calcasieu Lake now was confined to the Calcasieu Ship Channel. At the same time (1968), the U.S. Army Corps of Engineers constructed a saltwater barrier above Lake Charles to keep the saltwater wedge from moving upstream.

The levee system designed to isolate the ship channel from Calcasieu Lake has subsequently been breached at both the northern and southern ends. Oyster populations have subsequently become established in the washout fans and there is a hand-tong fishery in the basin. There is some suggestion that the Creole Canal can act as a saltwater pump. Salt water coming in through Calcasieu Pass flows east into Lake Calcasieu to Grand Bayou. It pushes fresher water over the marsh along the southeastern shore of the lake and into Creole Canal. This fresh water flows to the Gulf and is replaced by saline water through Calcasieu Pass.

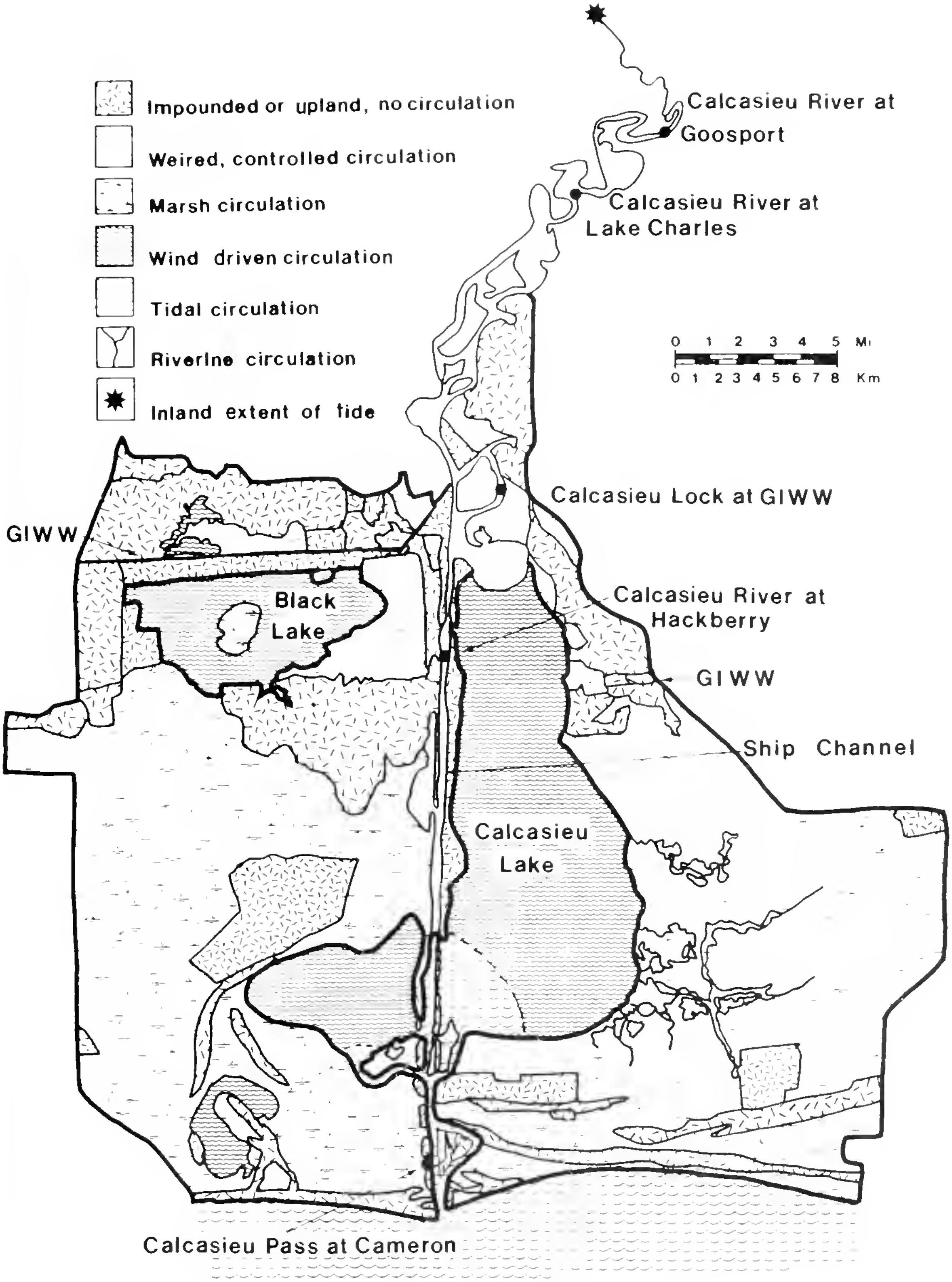


Figure 3-42. Hydrologic regions of Calcasieu Basin.

Table 3.71. Summary of natural and cultural features of Calcasieu Basin.

A. Hydrology of the Calcasieu Basin

Riverine Processes

Freshwater flow volume (flow upstream)
$49.8 \times 10^8 m^3/yr$

Seasonal: (see fig. 3-43)

Upstream drainage area
$13{,}723 km^2$

Annual rainfall 138 cm (at Lake Charles)

Annual rain surplus 49.3 cm/yr

Seasonal: (see fig. 3-43)

Minimum freshwater renewal time: 37 days

Surface water slope:

Cameron Pass to Hackberry 0.76 cm/km

Hackberry to Lake Charles 0.19 cm/km
(see fig. 3-44)

Tides:

Range: 500 cm (average of 1961-71 annual mean)
(see app. 6.4)

Period: Semi-diurnal with large diurnal inequality
(see fig. 3-44)

Water level variation

Seasonal: Peaks in April and September
(see fig. 3-44)

Long-term: 2.0 to 3.1 cm/yr raise
(see fig. 3-44)

Salinity:

Seasonal: (see fig. 3-43)

Long-term: (see fig. 3-45)

Control structures and modifications

Salt water barrier above Lake Charles
Major ship channel from Gulf to Lake Charles
GIWW

B. Primary production, potential yield and harvest of living resources of Calcasieu Basin.

	Per km^2	Per basin
Net primary production (t/yr) Appendix 6.3	1,452	2,550,299
Sport hunting and fishing use estimated potential yield[a]		
Big game (man-days x 1000/yr)		16.3
Small game (man-days x 1000/yr)		46.8
Waterfowl (man-days x 1000/yr)		98.2
Saltwater finfishing (man-days x 1000/yr)		147.8
Freshwater finfishing (man-days x 1000/yr)		272.0
Total		581.1
Agriculture		
Rice (t/yr)		5,839
Commercial species harvest[b]		
Shrimp (kg x 1000/yr)	2.7	803
Menhaden (kg x 1000/yr)	43.9	13,136
Blue crab (kg x 1000/yr)	0.4	117
Oyster (kg meat x 1000/yr)	0.1	36.9
Other saltwater finfishes (kg x 1000/yr)		878
Freshwater finfishes (kg x 1000/yr)		6.0
Nutria (pelts/yr)		40,320
Muskrat (pelts/yr)		34,050

[a]Method explained in part 3.5.2

[b]Present harvest attributed to basin (part 3.2.4)

continued

Table 3.71. Summary of natural and cultural features of Calcasieu Basin (continued).

C. Habitats of Calcasieu Basin

C1. Habitat area in 1974 and net changes since 1952

Habitat	Area 1974 (ha)[a]	Percent of total area[b]	Changes in area 1952 to 1974 (ha)	(%)
Nearshore Gulf	40,243	-	-161	-0.4
Inland open water	40,956	30.3	13,107	47.1
Natural marsh	54,803	40.5	-18,832	-25.6
Impounded marsh	9,751	7.2	3,559	57.5
Swamp forest	715	0.5	-171	-19.3
Natural ridge	8,060	6.0	-345	-4.1
Spoil	3,310	2.4	848	34.4
Rice field	5,713	4.2	1,300	29.5
Non-rice cropland	1,555	1.1	214	16.0
Pasture	5,970	4.4	-352	-5.6
Urban	2,277	1.7	1,428	168.0
Beach	844	0.6	-65	-7.2
Upland forest	1,430	1.1	-530	-27.0
Total	175,627			

[a]1 hectare (ha) = 2.47 acres (a)

[b]Calculation excludes area of nearshore Gulf habitat

C2. Habitat modification from 1952 to 1974 due to identifiable human activities

Cause of change	1952 Habitat	1952 Area (ha)	Changed to (by 1974) Habitat	Changed to Area (ha)	Change in 1974 as percent of original 1952 habitat
Filling and draining	Natural marsh	73,635	Agricultural	1,049	1.4
	Natural marsh	73,635	Urban	534	0.7
Impounding	Natural marsh	73,635	Impounded marsh	3,392	4.6
	Inland open water	27,849	Impounded marsh	272	1.0
Canal dredge and spoil	Natural marsh	73,635	Spoil	899	1.2
	Natural marsh	73,635	Canal	459	0.6
	Inland open water	27,849	Spoil	28	0.1
	Swamp forest	886	Spoil and canal	24	2.7
Upland construction	Natural ridge	8,402	Urban	262	3.1
	Natural ridge	8,402	Agricultural	62	0.7
	Upland forest	1,960	Urban	295	15.1
	Upland forest	1,960	Agricultural	199	10.2
	Agriculture	12,076	Urban	272	2.2

continued

Table 3.71. Summary of natrual and cultural features of Calcasieu Basin (continued).

C3. Natural wetland loss (1952-1974)—summary

To	Process	Area (ha)	Percent of 1952 area
Canals	Dredging	450	0.6
Inland open water	Subsidence	12,668	17.2
Nearshore Gulf	Shoreline erosion/deposition	36	0.05
Impounded marsh	Leveeing	3,392	4.6
Spoil	Dredging	899	1.2
Agriculture	Draining	1,049	1.4
Urban	Draining	534	0.7
Total		19.029	25.8

D. Cultural Features of the Calcasieu Basin

D1. Socioeconomics

Population: 9.790

Employment: $5,868,600 - mostly manufacturing (Figure 3-12)

	Production (1974)	Value ($ x 1000)
Minerals		
Gas (mcf)	43,191,467	13,260
Crude oil (bbls)	6,003,821	39,145
Total		52,405
Agriculture		
Crops		2,369
Other		0
Total		2,369
Sport hunting/fishing		
Saltwater sportfishing		515.0
Freshwater sportfishing		550.6
Small game hunting		162.6
Big game hunting		160.2
Waterfowl hunting		1,125.0
Total		2,813.4

	Value ($ x 1000)
Commercial harvest	
Fishing	
Shrimp	1,724.0
Menhaden	1,216.3
Blue crab	31.1
Oyster	50.4
Other estuarine-dependent species	191.5
Freshwater finfish	1.8
Subtotal	3,215.1
Trapping	
Nutria	241.9
Muskrat	153.2
Subtotal	395.1
Total	3,610.2

Navigation

Total traffic: 1976-56 million short tons, stable volume

Imports: Crude petroleum, petrochemicals

Exports: Petrochemicals (Appendix 6.1)

continued

Table 3.71. Summary of natural and cultural features of Calcasieu Basin (concluded).

D2. Total 1974 canal area

	Area (ha)	Length (km)
Navigation	1,365	468
Agricultural drainage	97	300
Oil activity	848	279
Transportation embankment canals	92	131
Other	93	93
Total	2,485	1,271

D3. Water use

	Annual volume ($m^3 \times 10^6$)
Agriculture	55.3
Municipal	1.4
Industrial	57.9
Total	114.6

D4. Estimated sport fishing and hunting supply and demand (man-days x 1000)

	Supply	Demand	Harvest as percent of estimated sustained yield
Big game	16.3	17.8	109
Small game	46.8	154.2	329
Waterfowl	98.2	125.0	127
Saltwater fishing	147.8	127.5	86
Freshwater fishing	272.0	242.8	89

D5. Nutrient and toxin discharges

Phosphorus (P) loading rates to entire drainage area

Cultural	P input ($g/yr \times 10^6$)	Natural	P input ($g/yr \times 10^6$)	Total P input
Urban	30.8	Forest	43.7	
Industrial	0.25	Lake	1.02	
Rice	715.4	Barren land	0.14	
Non-rice agriculture	4.04			
Total	750.5		44.9	795.4

Surface water discharge ($m^3 \times 10^8/yr$)	49.8	
P load ($g/m^3/yr$)	0.3	
Eutrophic state	Dangerous	

Oil well brine disposal (mbbls)

To wells	To pits	To surface waters
3,308.6	50.0	4,134.6

Other important pollutants: industrial toxins - heavy loads of organic toxins and heavy metals (Hg, Zn, Cu); oyster beds closed each summer due to high coliform counts.

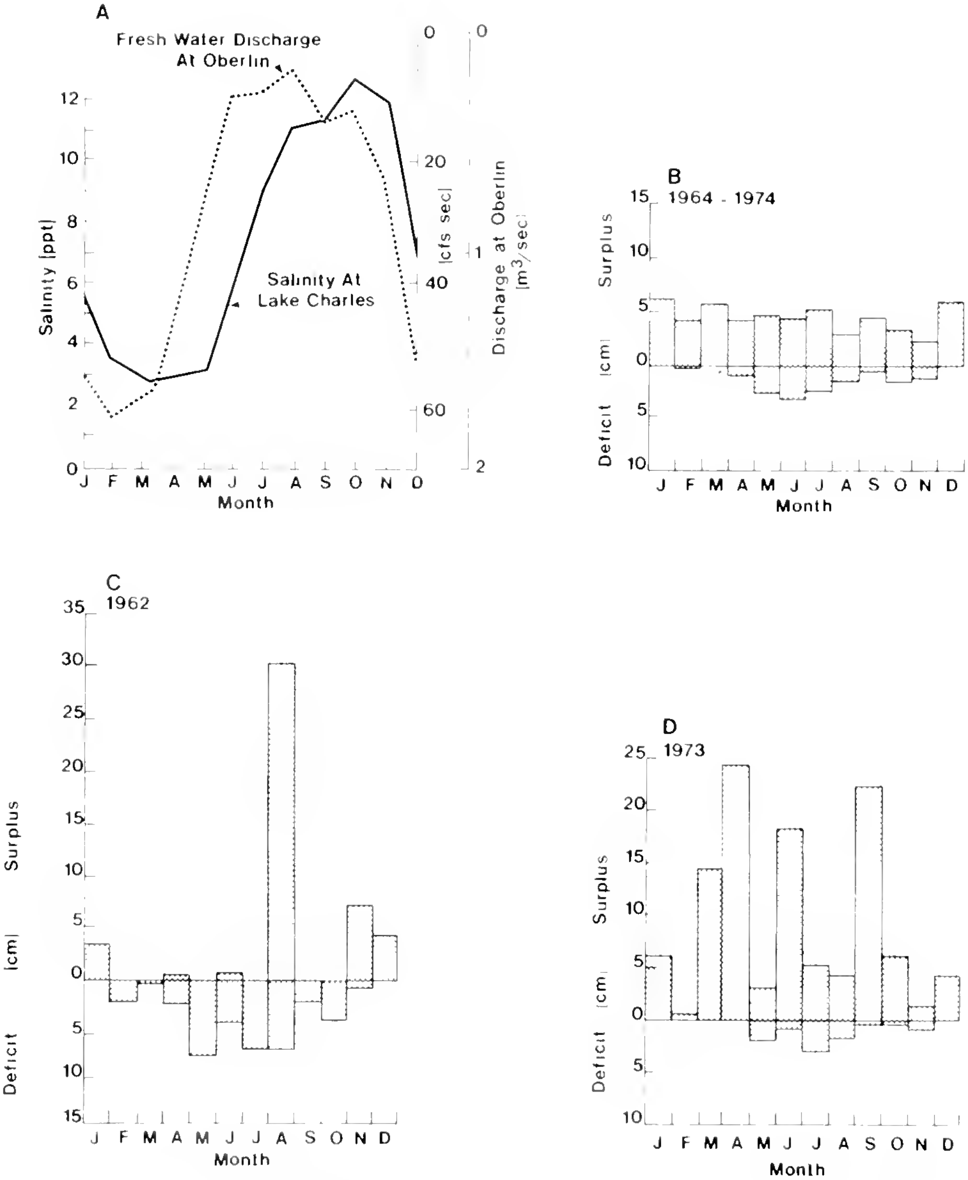


Figure 3-43. Freshwater supply of Calcasieu Basin: (A) mean monthly freshwater discharge and salinity; (B) mean monthly rainfall surplus; (C) monthly rainfall surplus for a dry year; and (D) monthly rainfall surplus for a wet year.

One device used to prevent salt intrusion is wetland impoundment. These impoundments can provide excellent habitats for waterfowl and furbearers, but they no longer function effectively as nursery grounds for estuarine-dependent fish and shellfishes.

Indications are that water is becoming a limiting factor for further industrial and agricultural development in the Calcasieu Basin. Large groundwater withdrawals for agriculture and industry are depleting the ground water reservoirs. Currently local groundwater levels around Lake Charles are falling at the rate of about 4 m/yr (13 ft/yr) in the 150 m (492 ft) sand stratum and 3 m (10 ft) per year in the 60 m (197 ft) sand stratum (part 2.5). Salt intrusion into the 60 m sand stratum has caused many industries to suspend pumping (Zack 1973). Continued withdrawals of surface water during critical summer months may increase saltwater intrusion in surface waters. However, the aquifer is a large one and regional ground water supplies are adequate for some time (Harder et al. 1967).

Analysis of P loads indicates that present input levels will result in excessive states of eutrophication. Industrial discharges into the ship channel are known to have reached the dangerous levels, particularly the concentration of mercury.

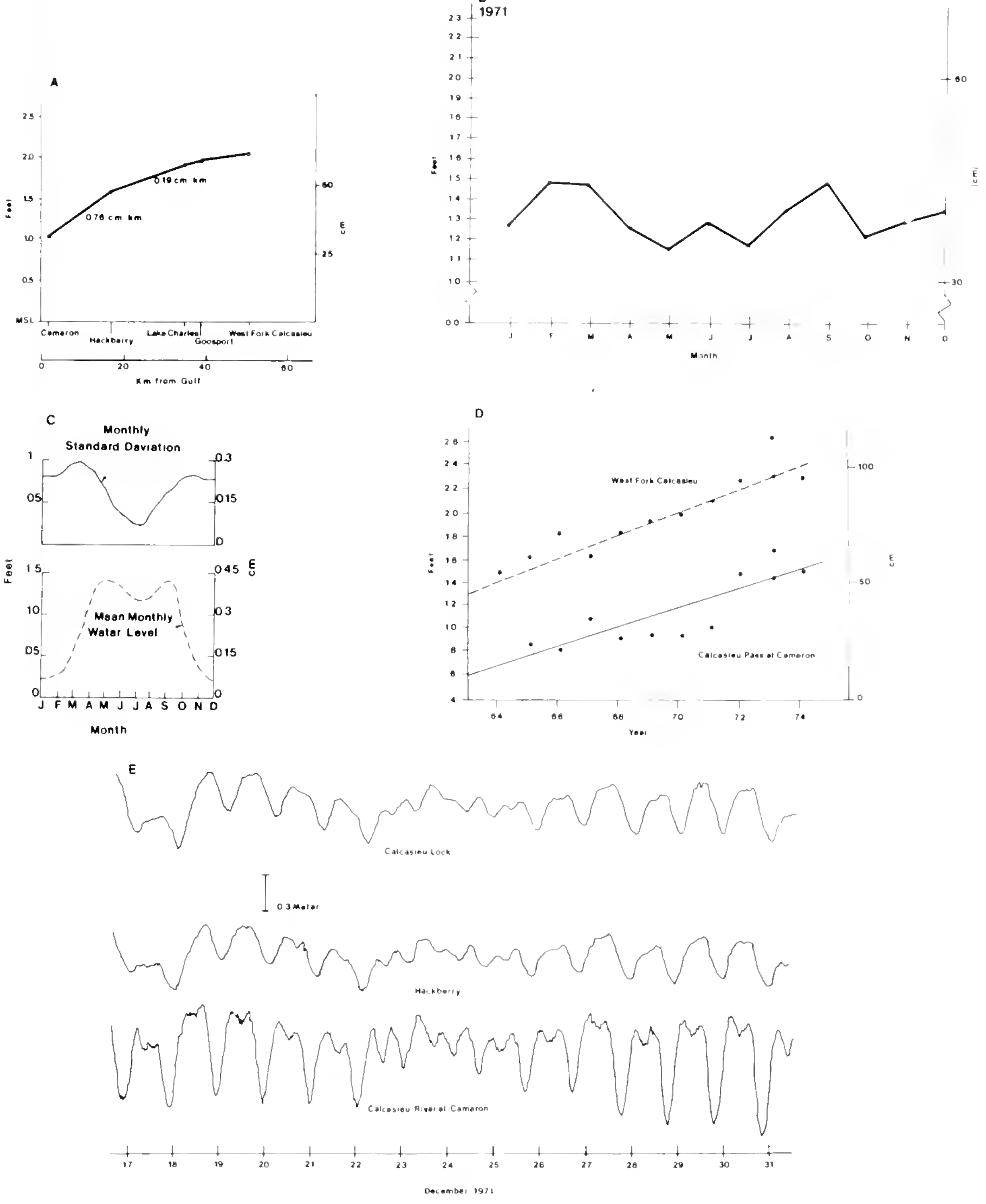


Figure 3-44. Water levels in Calcasieu Basin: (A) surface water slope; (B) 1971 monthly variation in the semi-diurnal tidal range at Cameron; (C) seasonal variation in water level at Cameron (1963-1974); (D) long-term annual mean water level; and (E) typical tide records. From U.S. Army Corps Engineers gage records.

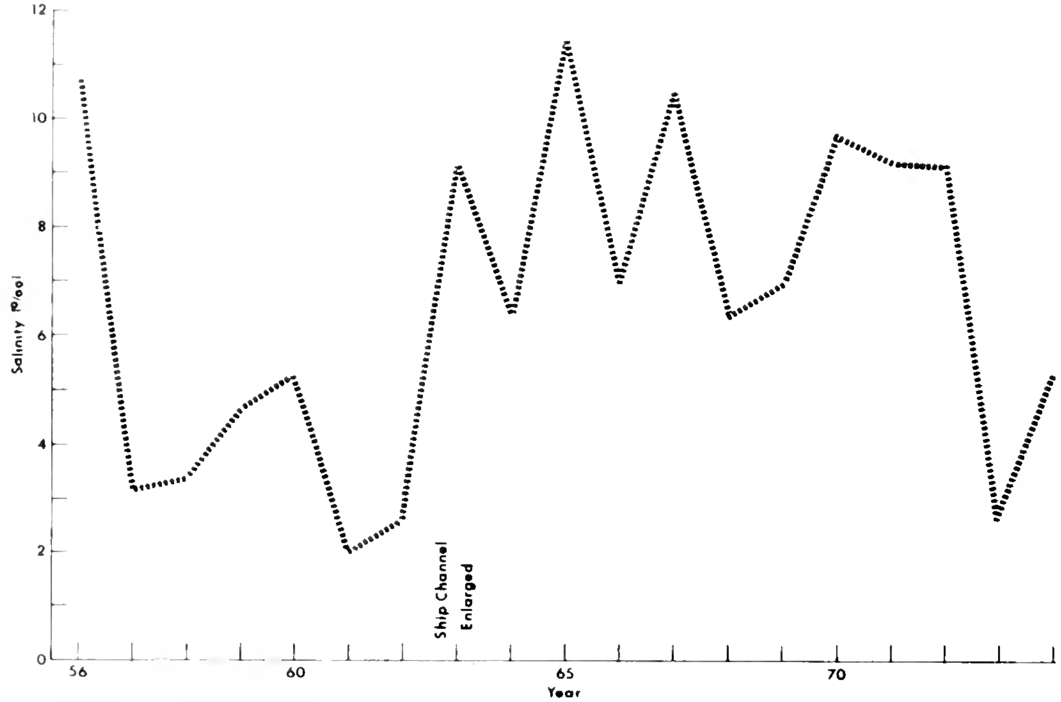


Figure 3-45. Mean annual salinities at Lake Charles, Louisiana (1956-1975) from U.S. Army Corps of Engineers data.

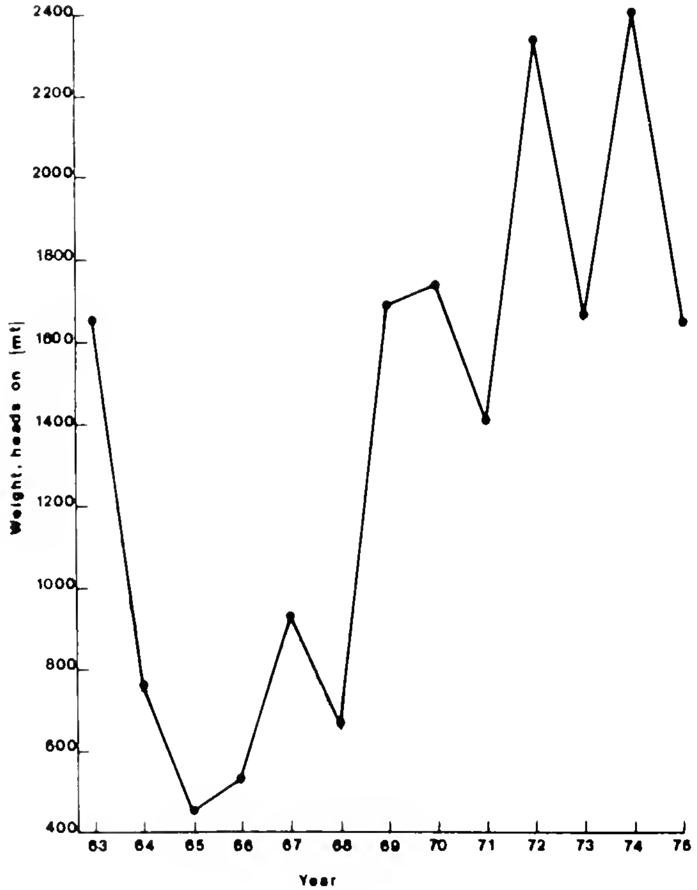


Figure 3-46. Commercial landings of brown and white shrimp in the Calcasieu Basin in 1963-1975 (U.S. Dep. Commerce 1976a).

On the west edge of the basin, canals in the Sabine National Wildlife Refuge allow water flow across basin boundaries and connect the Calcasieu and Sabine basins. Because water follows the deeper, straighter dredged canals the natural streams, such as North Bayou, become filled with sediments.

In addition to the ship channel, construction of other canals has been extensive. Canals 1,271 km (790 mi) in length now cover 2.6% of the land area of the basin (table 3.71). Most of these canals were constructed either for navigation or for access to oil and gas sites.

These navigation projects have resulted in significant modifications to the natural hydrologic patterns: north-to-south circulation now largely bypasses the Calcasieu Lake. The river presumably drops much of its sediment load in the ship channel rather than in the lake and adjacent wetlands. The channel permits saltwater intrusion which increases the salinity. Higher salinities have resulted in oyster beds becoming established further upstream nearer to Lake Charles (Van Sickle 1977). The many interconnecting channels of the GIWW, Alkali Ditch, and oil well access canals allow the salt to penetrate far into wetlands.

Further modifications have occurred because levees and spoil bank construction has purposefully or inadvertently impounded large wetland areas, reducing flushing and overland flow.

Habitat effects: These hydrologic modifications have profoundly influenced wetland and aquatic habitats. Since 1952, 19.029 ha (47,022 a) of natural wetlands in Calcasieu Basin have been lost. Only 6,361 ha (15,718 a or 9%) can be accounted for by direct cultural changes such as impounding, draining, etc. (table 3.71). The remaining 12,668 ha (31,303 a or 17%) are lost to open water, a loss rate 0.75%/yr. By contrast, although the rates of natural processes such as sea level rise are similar in other basins, the unexplained residual wetland loss rate is only about 0.13%/yr (except Sabine Basin). The high wetland loss rate in the Calcasieu Basin is almost certainly caused by the changed hydrology coupled with saltwater intrusion, and the possible effects of discharges of toxic materials and brine into the basin.

Aside from the loss of wetlands to inland open water habitat, agricultural area has increased by 1,162 ha (2,871 a) mostly by draining wetlands; urban expansion has claimed 1,428 ha (3,529 a) from wetland, agriculture, and upland forest habitat (table 3.71). Net shoreline erosion is very small, but erosion at Holly Beach (a vacation town) is a critical problem. There is some evidence of the development of offshore mudflats also, but this is poorly documented.

Effects on renewable resources: The loss of natural habitats, particularly wetlands, signals a long-term gradual decline in the living resources of the basin. As discussed in part 3.5, these resources appear to be exploited at their maximum potential. In the Calcasieu Basin there appears to have been an increase in the harvest of certain estuarine-dependent species such as shrimp (fig. 3-46) since the widening and deepening of the ship channel. This may result from two factors. First, the increase in salinity in the estuary and second, the temporary increase in the marsh to water interface associated with the wetland degradation. The potential fishery increase is balanced by other factors; the probable inland migration of the marsh zones with increasing salt and brackish marshes accompanied by loss of intermediate and fresh marshes as degradation continues. The increase in brackish marsh at the expense of fresh and intermediate marsh can be expected to be deterimental to the nutria harvest and to most waterfowl. Waterfowl hunters in the basin already complain of the effects of salt encroachment on habitat changes.

3.6.6 SABINE BASIN

General Features. The Sabine is the largest basin on the Chenier Plain (plates 1A, 3A, and 4A, and fig. 3-47). Because it straddles the Louisiana-Texas border, there may be political problems in managing it as a single hydrologic unit. The land surface slope is slight and about one-half of the inland area is wetland (table 3.72 and figs. 3-48 and 3-49). Sabine Lake is approximately 32 km (20 mi) long and 13 km (8 mi) wide and has an average depth of about 2 m (6.6 ft). Sabine River empties into Sabine Lake from the northeast; it has a drainage area of 24,152 km^2 (9,325 mi^2). Most of the river is impounded by the Toledo Bend Dam. The Neches River, emptying into the Sabine Lake from the northwest, has a drainage area of 20,584 km^2 (7,948 mi^2). Much of this river is impounded by the Sam Rayburn Reservoir.

A deep draft ship channel enters the basin through Sabine Pass from the Gulf and follows the western edge of Sabine Lake to the mouth of the Neches River. Here the dredged channel divides into two segments. One segment goes up the Neches River to Beaumont and the other goes up the Sabine River to Orange (fig. 3-47). The channel is separated from the Sabine Lake proper by a narrow strip of land, predominantly a man-made spoil island. The Gulf Intracoastal Waterway (GIWW) enters Texas from Louisiana about 4.8 km (3 mi) below Orange and continues southwestward along the deep draft ship channel on the west side of Sabine Lake. At the mouth of Taylor Bayou near Port Arthur, the GIWW leaves the lake and proceeds toward East Bay in a channel that is almost completely man-made (fig. 3-47). An outcropping of high land along the ship channel on the western side of Sabine Lake has provided a site for the city of Port Arthur and intense industrial development. Likewise, the cities of Beaumont and Orange located on the Neches and Sabine rivers, respectively, are industrial centers. This is the most industrialized basin in the region and the only basin within which high population densities occur. Even so only 5% of the total basin area is urbanized (table 3.72), but activities in this area have a strong influence on the whole basin, and particularly on Sabine Lake. Thirteen percent of the inland area of the basin is in agricultural production, chiefly for rice and cattle. Most of the farm land is located along the northern boundary of the basin. On the Louisiana side of the basin the large Sabine National Wildlife Refuge encompasses

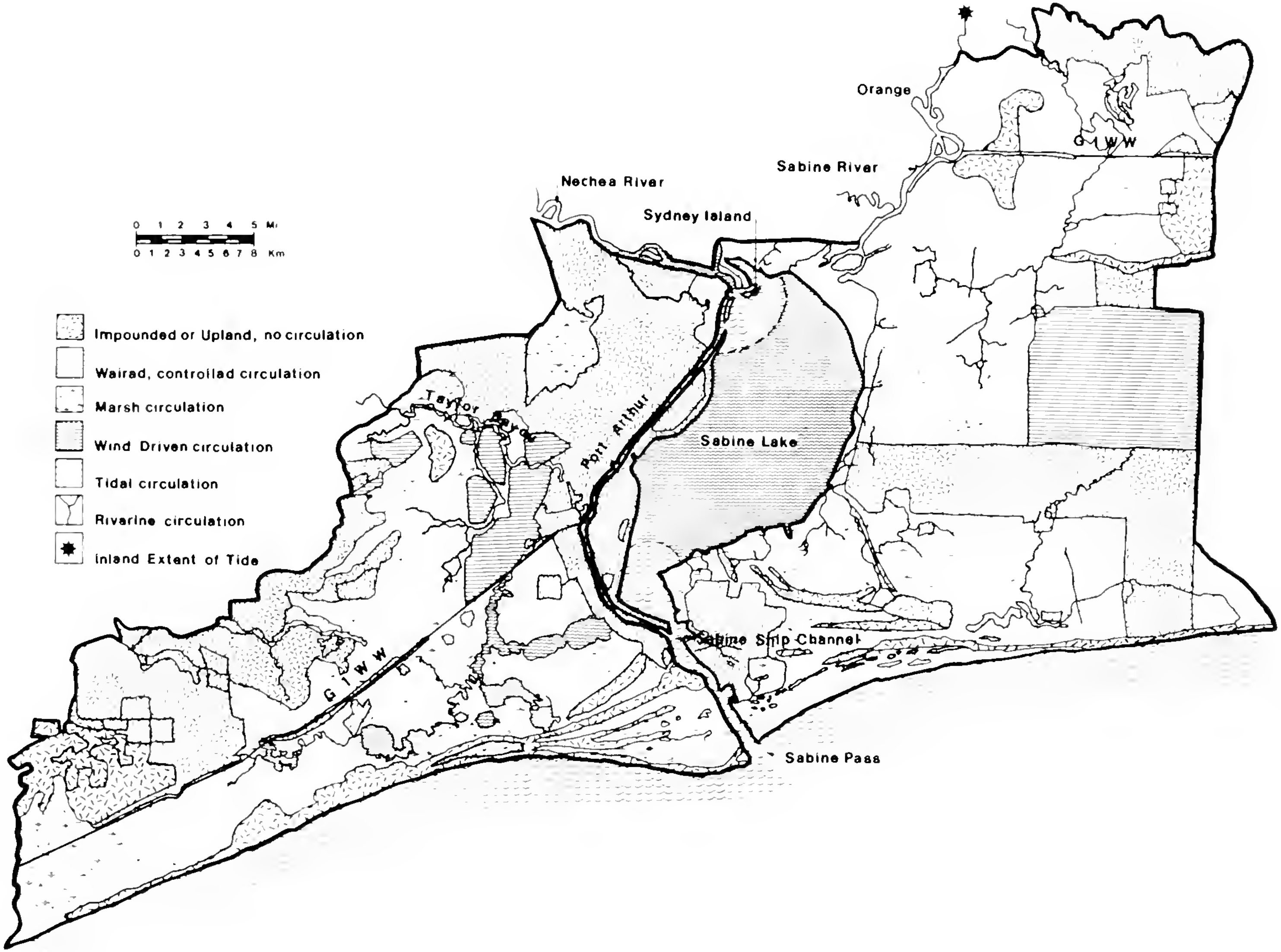


Figure 3-47. Hydrologic regions of Sabine Basin.

Table 3.72. Summary of natural and cultural features of Sabine Basin.

A. Hydrology of the Sabine Basin

Riverine processes

Upstream drainage area

25,000 km^2
24,000 km^2 controlled by Toledo Bend Reservoir

Freshwater flow volume (from upstream)
87.8 x $10^8 m^3$/yr

Seasonal: Figure 3-48

Annual rainfall 140 cm (at Port Arthur)

Annual rain surplus 43.1 cm/yr

Seasonal: Figure 3-48

Minimum freshwater renewal time: 20 days

Surface water slope: 0.64 cm/km (fig. 3-49)

Tides:

Range: 40 cm at Sabine Pass (monthly mean)
20 cm at Sydney Island (monthly mean) (fig. 3-49)

Period: Principally diurnal, with small semi-component (fig. 3-49)

Water level variation

Seasonal: At the coast peak in early summer, low in winter
Much less variation at Sydney Island (fig. 3-49)

Long term: Data unavailable

Salinity

Seasonal: Figure 3-50

Long-term: Data not available

Control structures and modification

Toledo Bend Reservoir on Sabine River
Salt barrier on Neches River
Sabine-Neches ship channel
GIWW

B. Primary production, potential yield and harvest of living resources of Sabine Basin.

	Per km^2	Per basin
Net primary production (t/yr) (appendix 6.3)	1,369	5,147,516
Sport hunting and fishing use estimated potential yield[a]		
Big game (man-days x 1000/yr)		53.6
Small game (man-days x 1000/yr)		95.6
Waterfowl (man-days x 1000/yr)		260.4
Saltwater finfishing (man-days x 1000/yr)		140.1
Freshwater finfishing (man-days x 1000/yr)		433.
Total		982.7
Agriculture		
Rice (t/yr)		9,318
Commercial species harvest[b]		
Shrimp (kg x 1000/yr)	(2.7)[c]	(763)[c]
Menhaden (kg x 1000/yr)	43.9	12,459
Blue crab (kg x 1000/yr)	1.4	410
Oyster (kg meat x 1000/yr)		0
Freshwater finfishes (kg x 1000/yr)		143
Nutria (pelts/yr)		9.6
Muskrat (pelts/yr)		116,780

[a]Method explained in part 3.5.2.
[b]Present harvest attributed to Basin (part 3.2.4).
[c]Doubtful that Sabine contributes to the offshore fishery.

continued

Table 3.72. Summary of natural and cultural features of Sabine Basin (continued).

C. Habitats of Sabine Basin

C1. Habitat area in 1974 and net changes since 1952

Habitat	Area 1974 (ha)[a]	Percent of total area[b]	Changes in area 1952 to 1974 (ha)	(%)
Nearshore Gulf	84,211	–	548	0.7
Inland open water	47,223	16.2	8,619	22.3
Natural marsh	101,372	34.8	-20,405	16.8
Impounded marsh	41,212	14.1	9,363	29.4
Swamp forest	3,699	1.3	0	0
Natural ridge	10,000	3.4	-58	-0.6
Spoil	9,303	3.2	937	11.2
Rice field	9,103	3.1	-945	-9.4
Non-rice cropland	1,068	0.4	20	1.9
Pasture	39,363	13.5	-1,277	-3.1
Urban	19,088	6.5	3,449	22.1
Beach	2,124	0.7	0	0
Upland forest	8,125	2.8	-251	-3.0
Total	375,979			

[a]1 hectare (ha) = 2.47 acres (a).

[b]Calculation excludes area of nearshore Gulf habitat.

C2. Habitat modification from 1952 to 1974 due to identifiable human activities

Cause of change	1952 Habitat	1952 Area (ha)	Changed to (by 1974) Habitat	Changed to Area (ha)	Change in 1974 as percent of original 1952 habitat
Filling and draining	Natural marsh	121,777	Agricultural	321	0.3
	Natural marsh	121,777	Urban	456	0.4
	Impounded marsh	31,849	Urban	206	0.6
	Inland open water	38,604	Urban	9	0.03
Impounding	Natural marsh	121,777	Impounded marsh	9,569	7.9
Canal dredge and spoil	Inland open water	38,604	Spoil	73	0.2
	Natural marsh	121,777	Spoil	1,098	0.9
	Natural marsh	121,777	Canal	549	0.5
Upland construction	Natural ridge	10,088	Urban	29	0.3
	Natural ridge	10,088	Agricultural	20	0.2
	Upland forest	8,376	Urban	251	3.0
	Agriculture	51,736	Urban	2,339	4.5

continued

Table 3.72. Summary of natural and cultural features of Sabine Basin (continued).

C3. Natural wetland loss (1952-1974)–summary

To	Process	Area (ha)	Percent of 1952 area
Canals	Dredging	549	0.4
Inland open water	Subsidence	7,864	6.5
Nearshore Gulf	Shoreline erosion/deposition	675	0.6
Impounded marsh	Leveeing	9,569	7.9
Spoil	Dredging	1,098	0.9
Agriculture	Draining	321	0.3
Urban	Draining	456	0.4
Total		20,532	16.9

D. Cultural Features of the Sabine Basin

D1. Socioeconomics

Population: 130,636
Employment: Figure 3-12

	Production (1974)	Value ($ x 1000)
Minerals		
Gas (mcf)		
Crude oil (bbl)		
Total		
Agriculture		
Crops		2,222
Other		4,020
Total		6,242
Sport Hunting/Fishing		
Saltwater finfishing		1,363.4
Freshwater finfishing		1,459.0
Shellfishing		0.0
Small game hunting		1,226.1
Big game hunting		425.7
Waterfowl hunting		2,979.0
Total		7,453.2

	Value ($ x 1000)
Commercial harvest	
Fishing	
Shrimp	1,638.2[a]
Menhaden	1,153.6
Blue crab	108.4
Oyster	------
Other estuarine-dependent species	10.4
Freshwater finfishes	2.9
Subtotal	1,275.3
Trapping	
Nutria	700.7
Muskrat	236.8
Subtotal	937.5
Total	2,212.8

Navigation

Total traffic: About 100,000,000 short tons in 1976, up sharply from 80,000,000 in previous year (appendix 6.2)

Imports: Crude oil

Exports: Other mined products and petrochemicals.

[a]Doubtful that Sabine contributes significantly to the offshore fishery.

continued

Table 3.72. Summary of natural and cultural features of Sabine Basin (concluded).

D2. Total 1974 canal area

	Area (ha)		Length (km)	
	Tex.	La.	Tex.	La.
Navigation	1,519	475	336	426
Agricultural drainage	224	47	746	142
Oil activity	249	781	44	210
Transportation embankment canals	47	20	68	27
Other	3	0	4	0
Total	2,042	1,323	1,198	805

D3. Water use

	Annual volume ($m^3 \times 10^6$)
Agriculture	88.3
Municipal	18.2
Industrial	1863.8
Total	1970.3

D4. Estimated sport fishing and hunting supply and demand (man-days x 1000)

	Supply	Demand	Harvest as percent of estimated sustained yield
Big game	53.6	47.3	88
Small game	95.6	408.7	428
Waterfowl	260.4	331.0	127
Saltwater fishing	140.1	337.8	241

D5. Nutrient and toxin discharges

Phosphorus loading rates to entire Sabine Basin drainage area (appendix 6.4).

Cultural	P input (g/yr x 10^6)	Natural	P input (g/yr x 10^6)	Total P input
Urban	24.1	Forest	33.4	
Industrial	0.09	Lake	31.2	
Rice	320.9	Barren land	0.11	
Non-rice agriculture	75.6			
Total	420.7		69.7	490.4

P load (g/m^3 x 10^8/yr) 0.03

Eutrophic state Permissible

Surface water discharge (m^3 x 10^8/yr) 87.8

Other important pollutants: industrial toxins and coliform bacteria

Sabine Lake, Sabine River, and Neches River closed to shellfishing (plates 5A, 6A; Diener 1975).

most of the wetlands. The refuge contains about 57,000 ha (140,850a) of fresh and brackish marshes.

Impoundments are a significant feature. Impounded marshlands make up 14% of the inland area. Three large fresh marsh impoundments total about 13,700 ha (33,853a) in the Sabine Refuge. The largest of these is 10,000 ha (24,711a) and is maintained by a system of spillways and dikes. In other areas, weirs control water flow through wetlands that are not fully impounded. In addition to the impoundments in the Sabine Refuge, approximately 4,000 ha (9,884a) of wetlands have been impounded near Taylor Bayou which drains into the Port Arthur Canal. A portion of these impoundments is within the J. D. Murphree State Wildlife Management Area and the Big Hill Reservoir upstream from the Sabine Basin boundaries.

The hydrology and hydrography of the Sabine Basin is among the most complex in the Chenier Plain. Freshwater input to the Sabine estuary is from precipitation (net annual rain surplus is 43 cm or 17 in) and by runoff from the Sabine and Neches rivers (fig. 3-48). Combined annual inflow into Sabine Lake from these two rivers and the ungauged runoff below the river gauges at Ruliff and Evadale varies from less than 4×10^9 m^3 (1.4×10^{11} ft^3) to greater than 30×10^9 m^3 (1.06×10^{12} ft^3). This is equivalent to an average flow rate of 130 to 950 m^3/sec (4,590 to 33,550 ft^3/sec). These are the largest inflows into the Chenier Plain, four times as much as any other basin.

Tides are well developed with a 40 cm (15.75 in) mean range at Sabine Pass and attenuation upstream to Sydney Island (figs. 3-47 and 3-49). The construction of the Sabine-Neches ship channel along the western edge of Sabine Lake has had a strong influence on tidal action and salt water intrusion into the basin. Salt water enters through Sabine Pass from the Gulf and forms a dense wedge extending up the bottom of the Sabine-Neches Ship Canal and the Neches and Sabine rivers. Direct tidal exchange occurs in Sabine Lake at its southern end and to a lesser extent at the northwest corner of the lake when tidal action produces a hydraulic gradient strong enough to push salt water into the lake through the Sabine-Neches Canal (fig. 3-47).

Freshwater flows are also affected by the ship channel. Freshwater moving down the Sabine and Neches rivers enters the upper lake area, but an estimated average of 80% of this flow (Ward 1973) bypasses Sabine Lake by traveling down the Sabine-Neches Canal to the Gulf as a freshwater layer, on top of the denser saline waters in the bottom of the channel (Espey-Huston 1976). The predominant north-south winds and tidal currents tend to push the remaining fresh river water to the east side of the lake where it forms a large pool surrounded by more saline water (fig. 3-50). Water within the main body of the lake flows seaward at Sabine Pass and to a lesser extent flows into the northern end of the Sabine-Neches Canal.

It appears that much of the time a portion of the water which bypasses Sabine Lake flows toward East Bay through the GIWW. Since the Sabine-Neches Canal has a controlled depth of 12.2 m (40 ft) compared to a depth of 3.7 m (12 ft) in the GIWW, the less saline water flowing near the surface of the Sabine-Neches Canal flows into the GIWW but the underlying saltwater remains in the deeper ship channel. Because of the small tidal range in the GIWW, winds and/or abnormally large freshwater inflows from upstream can create a significant flow towards Galveston Bay. Under average conditions a maximum flow rate of 113 m^3/sec (3,991 ft^3/sec) and a maximum current velocity of 0.4 m/sec (1.3 ft/sec) can be expected (James et al. 1977).

Freshwater input from upstream has little impact on water levels in the basin. Rather, seasonal water levels are controlled by variations in Gulf waters (fig. 3-49). The Sabine Pass water level record for 1974 shows a late spring peak, with a less well-developed late summer high. As is typical along the northern Gulf coast, mean water levels are low in winter. No long term uninterrupted records are available for analysis of annual mean water level, but water levels are expected to increase at a rate of about 2 cm/yr (0.79 in/yr).

The high volume of freshwater inflows into Sabine Lake from the Sabine and Neches rivers leads to a short flushing time about 20 days, ignoring tides. The ratio of the tidal prism to river discharge over a tidal cycle gives an index of the importance of tidal forces versus river discharge for basin flushing. For Sabine, the annual mean ratio is 3.2; for January 1974 it was 0.78; and in October 1973 it was 20.3 These ratios show that tidal action contributes to the flushing of Sabine Lake.

Wetlands are a significant feature of the Sabine Basin although their loss rate is high. A large expanse of this habitat occurs between Orange and Beaumont on the north shore of Sabine Lake. Some of the most productive wetlands are located adjacent to the Neches River near the city of Beaumont. Prime habitat for wintering waterfowl stretches southward from Sabine Lake towards the East Bay Basin. These wetland areas, particularly in the vicinity of Sea Rim State Park, serve as the key waterfowl areas on the Texas Coast. Lard (1978) reported that the 1977 winter waterfowl inventory showed in excess of 200,000 ducks and 140,000 geese in Jefferson and Chambers counties. Early flights of ducks and geese use this area for resting and feeding before proceeding on to Mexico and South America. The inland lakes and ponds provide excellent habitat for many bird species. Most common are the roseate spoonbills; common, snowy, and cattle egrets; great blue, little blue, Louisiana, and green herons; and black-, and yellow-crowned night herons. In addition, six species of rail reside here sometime during the year.

In the surrounding area white-tailed deer, muskrat, mink, nutria, raccoon, skunk, bobcat, grey fox, oppossum, and the river otter are abundant. The alligator, and possibly the red wolf, are now resident species south of Sabine Lake. At one time the Southern bald eagle, Attwater's prairie chicken and the

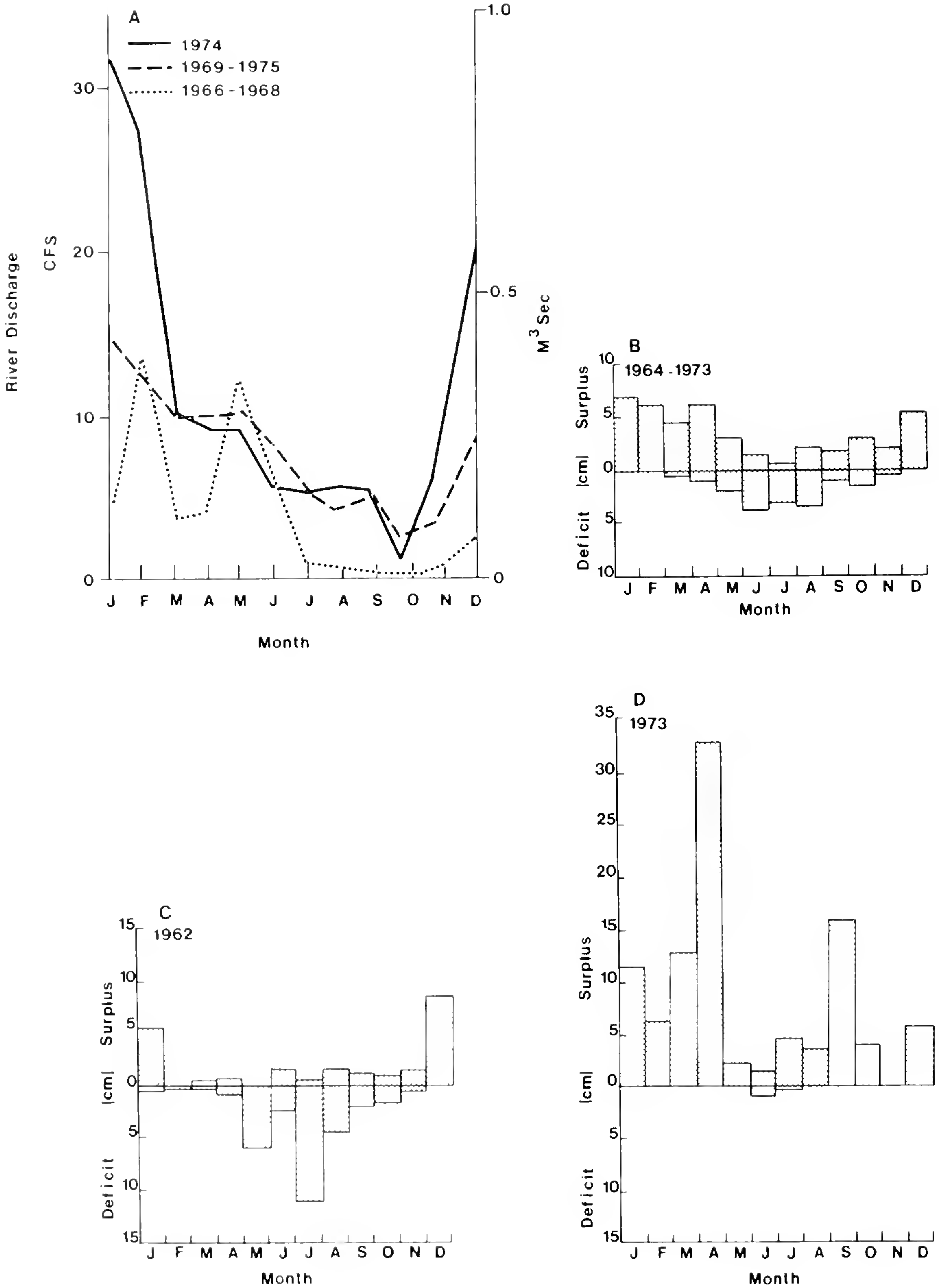


Figure 3-48. Freshwater supply of Sabine Basin: (A) discharges from Sabine River into Sabine Basin, comparing the mean for two years before 1968 with the mean for seven years after 1968, from U.S. Army Corps of Engineers gages; (B) mean (1964-1973) monthly rainfall surpluses (deficits); (C) monthly rainfall surplus (deficit) for a dry year; and (D) monthly rainfall surplus (deficit) for a wet year.

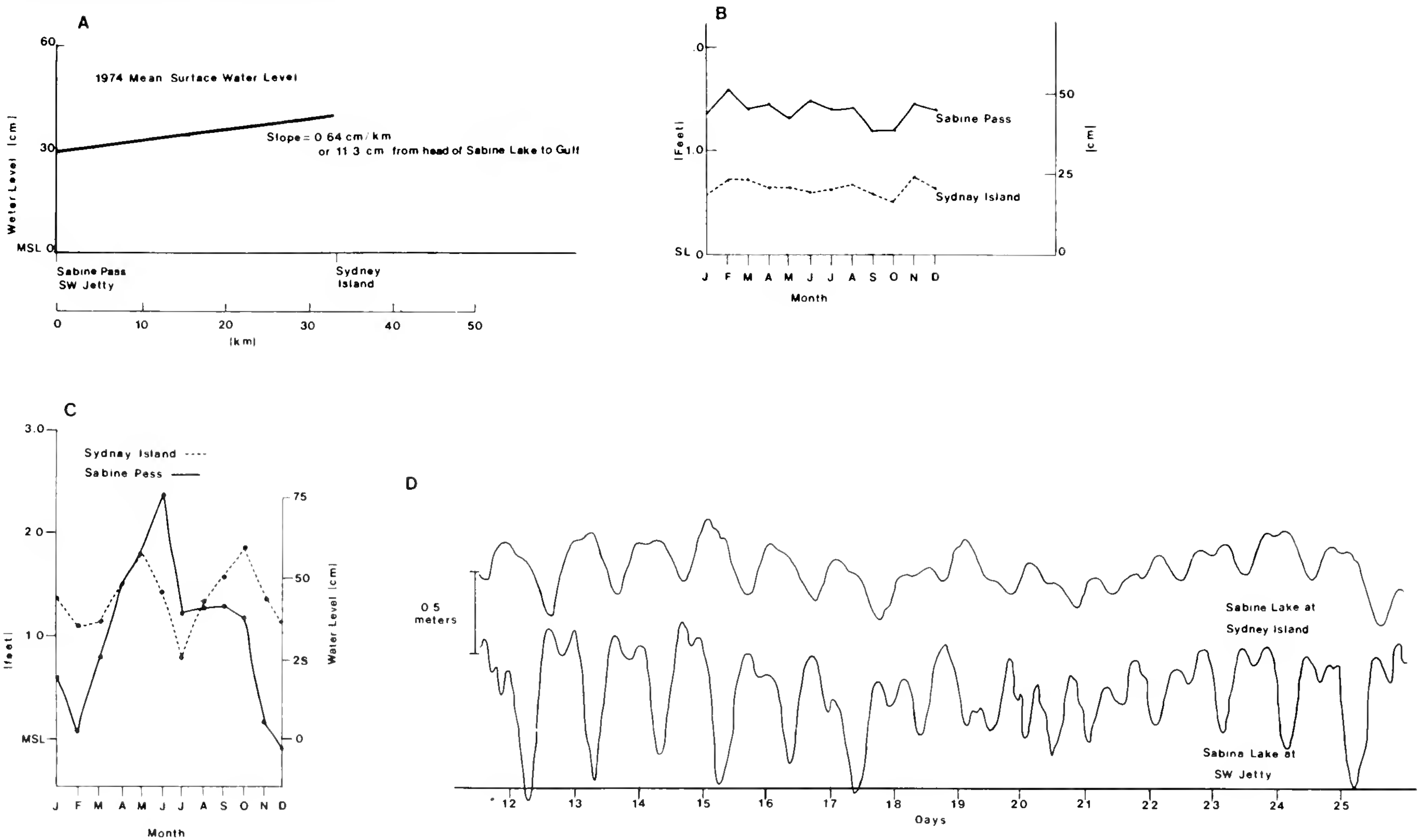


Figure 3-49. Water levels in Sabine Basin: (A) surface water slope; (B) monthly variation in daily tidal range; (C) seasonal variation in daily tidal range; and (D) typical tide record. From U.S. Army Corps of Engineers gage records.

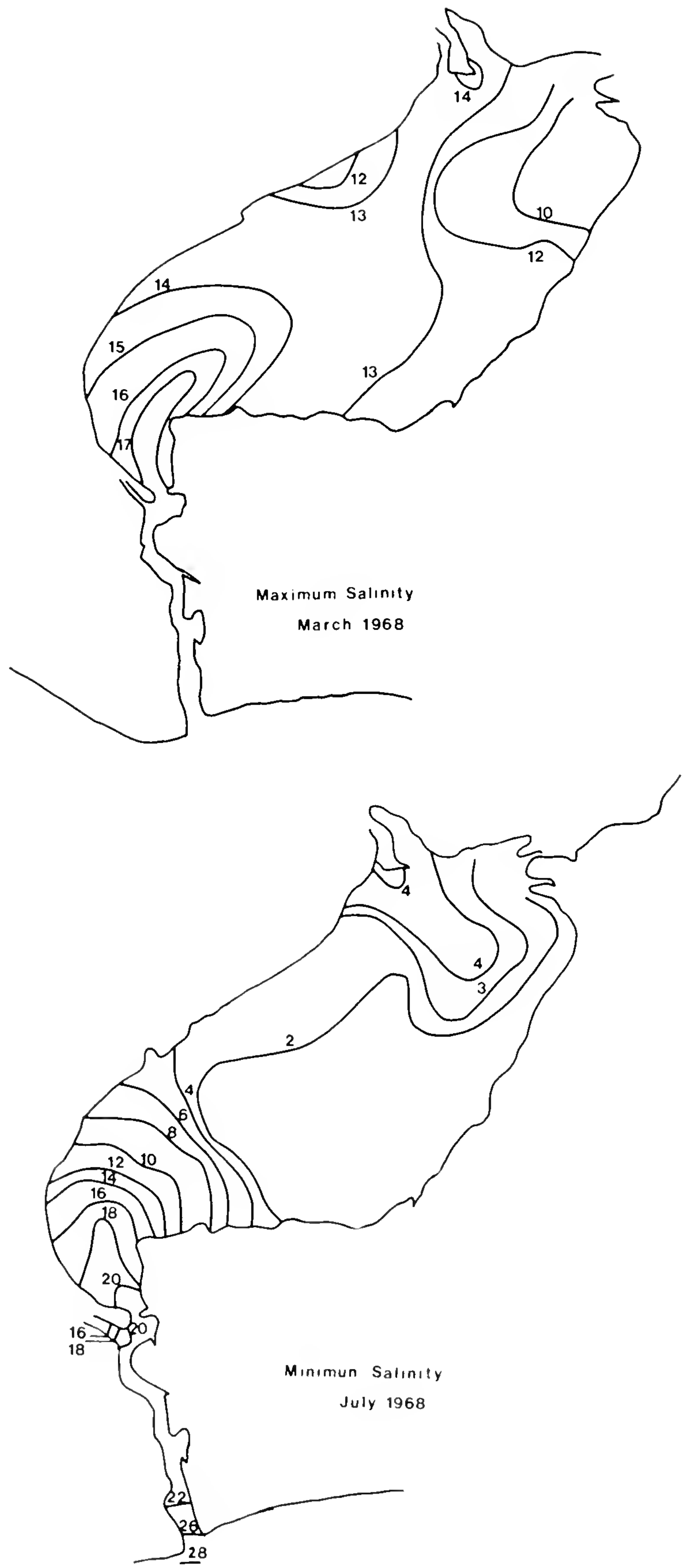


Figure 3-50. Maximum and minimum salinity (°/oo) in Sabine Lake when the Sabine River flow was low in March 1968 and when it was high in July 1968 (White and Perret 1973).

brown pelican were common in the area but they have not been recorded for several years. The peregrine falcon uses the area for feeding and resting. The Texas Parks and Wildlife Department lists five species of sea turtles as indigenous to the area.

Other general features of the basin are included in table 3.72.

Socioeconomics. As elsewhere in the Chenier Plain, oil and gas are the most valuable products in the Sabine Basin. The 1974 value of oil and gas production was $51 million, an estimated $7.4 million for sport fishing and hunting, $6.2 million for agricultural products, and $2.2 million for commercial finfishes, shellfishes and furs.

Manufacturing industries are the major employers in the basin. The total employment payroll of $32 million for the basin is far greater than that for other basins (fig. 3-12).

Waterborne traffic is much greater in this basin than elsewhere in the Chenier Plain. Traffic increased dramatically in 1976 over previous years, mostly due to increased imports of crude oil and to petrochemical exports.

Effects of Human Activities on the Environment. Hydrologic effects: The population concentration and heavy industrial development have modified the basin dramatically. A combination of port development and the construction of reservoirs has significantly modified the hydrodynamic regime, especially affecting sediment and nutrient transport.

Prior to construction of the Sabine-Neches Canal, the entire flow of the Sabine and Neches rivers was directed through Sabine Lake. The water from both the Neches and Sabine rivers is now diverted from Sabine Lake into the Sabine-Neches Canal. A second effect of port development is the intrusion of saltwater up the dredged channels, including the Sabine-Neches Ship Channel, into the north end of Sabine Lake. Other interconnecting canals with their associated spoil deposits and ridges have further modified circulation, particularly on the west side of the lake. Total canal length is 2,002 km (1,244 mi) covering an area of 3,365 ha (8,315a) or 1.4% of the basin's total land area.

In addition to the increasing amounts of water being diverted from the Sabine and Neches rivers, the completion of the two large reservoirs upstream has had a major impact on the basin. White and Perret (1973) relate habitat loss in the basin to resulting salinity changes, changes in the timing of the freshwater inflow from the reservoirs, and the reduction of suspended sediments normally introduced by the rivers. The average salinity for Sabine Lake at three locations for the year prior to the filling of the Toledo Bend Reservoir (May 1967 to April 1968) was 11.7 ‰. When the total discharge of the Sabine River was reduced to 2.4 m^3/sec (84.8 ft^3/sec) (fig. 3-50) the salinity was 2.4‰. Since that time river discharge has been dramatically curtailed during the spring of the year, because the water impounded in the reservoir is released later in the summer.

Habitat effects: Nearly 17% of the Sabine Basin wetlands (20,532 ha or 50,736a) has been lost since 1952. Direct habitat alterations have been reviewed by Wiesema and Mitchell (1973). These authors have attributed habitat loss to the following modifications:

1. The leveeing of Keith Lake in 1967 which cut off 21,992 ha (54,343a) of marshland from Sabine Lake. (Note: Keith Lake was reopened by the Texas Parks and Wildlife Department in 1976);
2. Widening of the Sabine-Neches Canal to 60 m (197 ft), from the mouth of the Neches River to the mouth of the Sabine River;
3. Enlargement of Port Arthur Canal to a depth of 12 m (39 ft) (below mean low tide) and to a width of 150 m (492 ft);
4. Realignment of the 120 m (394 ft) wide Sabine-Neches Canal, construction of a turning point at Port Arthur, and deepening this channel to 12 m (39 ft);
5. Realignment of Sabine Pass Channel and enlargement of this channel to a depth of 12 m (39 ft) and a width of 150 m (492 ft);
6. Construction of two disposal areas in Sabine Lake, one of 1,250 ha (3,089a) and the other of 800 ha (1,977a);
7. Construction of approximately 1,200 m (3,937 ft) of earth levee at Port Arthur to an average elevation of 4.5 m (14.8 ft);
8. Construction of 4,000 m (13,123 ft) of concrete flood wall and 8,760 m (28,740 ft) of earth levee at Port Arthur to an average elevation of 4.6 m (15.1 ft);
9. The dredging of approximately 3,600 ha (8,896a) of shell along the eastern edge of Sabine Lake southwest of Johnson's Bayou;
10. The deepening of the ship channel from Beaumont from 10.8 m (35.4 ft) to 12 m (39.4 ft);
11. The construction of levees and removal of marsh by the U.S. Army Corps of Engineers, particularly along Taylor's Bayou;
12. The impoundment of 10,000 ha (24,711a) of marshes in Louisiana which apparently had connections with Sabine Lake prior to construction of Gray's Ditch and Trail.

Of the 20,532 ha (50,736a) of wetland lost since 1952 (16.9% of the 1952 wetland area), 9,569 ha (23,646a) were impounded; 1,647 ha (4,070a) were used for canals or spoil deposits; and 777 ha (1,920a) were used for urban and agricultural purposes. The remaining 8,539 ha or 21,100a (7.0% of the 1952 area) were converted to open water by a combination of natural and cultural processes. Shoreline erosion accounts for 675 ha (1,668a), but the conversion of the rest of the wetlands to open water is unexplained. Elsewhere on the Chenier Plain, excluding Calcasieu Basin, this unexplained loss rate for wetlands is about 0.10% (2% since 1952). The higher rate of wetland loss in the Sabine Basin probably reflects hydrologic and salinity modifications resulting from construction of the extensive network of canals, and the Toledo Bend and Sam Rayburn reservoirs.

Other habitat changes since 1952 reflect urban growth in the basin. Urban needs were responsible for the loss of 2,339 ha (5,780a) of agricultural land between 1952 and 1974 (table 3.72).

Effects on renewable resources: The influence of cultural activities on renewable resources in the Sabine Basin has reduced both habitat quality and quantity. The continued loss of natural wetlands will inevitably result in a further decline of those living resources dependent upon those habitats.

In addition to the indirect effects of habitat loss, the discharge of organic and inorganic pollutants can kill aquatic species. Sections of the ship channel, the GIWW, and the Neches and Sabine rivers are seriously contaminated, especially with high organic loads, coliform bacteria, and organic toxins (Diener 1975). Much of the industrial pollution from the developed areas appears to bypass Sabine Lake by flowing through the ship channel and GIWW.

Decline in the harvest of croakers, black drum, red drum, flounder, spotted sea trout, oysters, and shrimp in Sabine Lake (table 3.73) can be related to past development and reservoir construction. Presently the only commercial harvest of any significance is blue crab (table 3.74). In 1974 and 1975 it too had decreased to about one-half the 1973 peak.

Additional considerations in Sabine Basin are sport fishing and hunting. Comparison of available sustainable supplies of sportfish and game with the estimated demand indicates that for all species the demand far exceeds the supply (sec. 3.5). Not only does the human population of the basin directly exploit the living resources, but cultural activities at the same time cause habitat degradation and loss.

Heavy industrial use of water has resulted in local declines in ground-water levels. Ground water is drawn from the Chicot Aquifer, which is large enough to sustain high withdrawal rates. Nevertheless, saltwater intrusion is a serious problem in southeastern Texas because of high pumpage rates (Baker and Wall 1976), and the fresh-saltwater interface is moving northward at the rate of 10 to 80 m/yr (33-262 ft/yr) (Harder et al. 1967).

3.6.7 EAST BAY BASIN

General Features. East Bay Basin is located on the southwestern end of the Chenier Plain and is a part of the Galveston Bay system, which also includes West Bay, Trinity Bay and Galveston Bay (fig. 3-51 and plates 1A and 1B). East Bay is a narrow estuary, 10 km (6.2 mi) wide at its western end, paralleling the coast and extending eastward about 37 km (21 mi) from Galveston Bay. It is bound on the north by fresh and brackish marshes and on the south by Bolivar Peninsula, which separates it from the Gulf. This peninsula is about 30 km (18.6 mi) long, varying in width from 1 to 10 km (0.62 to 6.2 mi) (Lard 1978). It is separated from Galveston Island on the southwest

Table 3.73. Commercial fish landings (kg) for Sabine Lake for 1970-1975[a].

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Croaker	NI[b]	NI	91										318
Black drum	1,591		273	273	727	545	364				636		273
Red drum	4,000	1,182	6,091	2,864	7,227	4,136	1,818				318		227
Flounder (unclassified)			9,091	3,636	1,000	227	2,682	227					227
Sea catfish (gafftopsoil)				273	500								
Spotted sea trout	6,136	2,364	7,545	1,955	7,091	21,000					1,818		
Unclassified													
For food				9,045	1,364		500						
Total	11,727	3,546	23,091	18,046	17,909	25,908	5,364	227			2,772		1,045

[a]Source: National Marine Fisheries Service. Texas landings, annual summary, 1970-1975, and 1969. Texas landings, 1968-1972. U.S. Fish and Wildlife Service.

[b]NI - not included in 1963 and 1964 as a separate species.

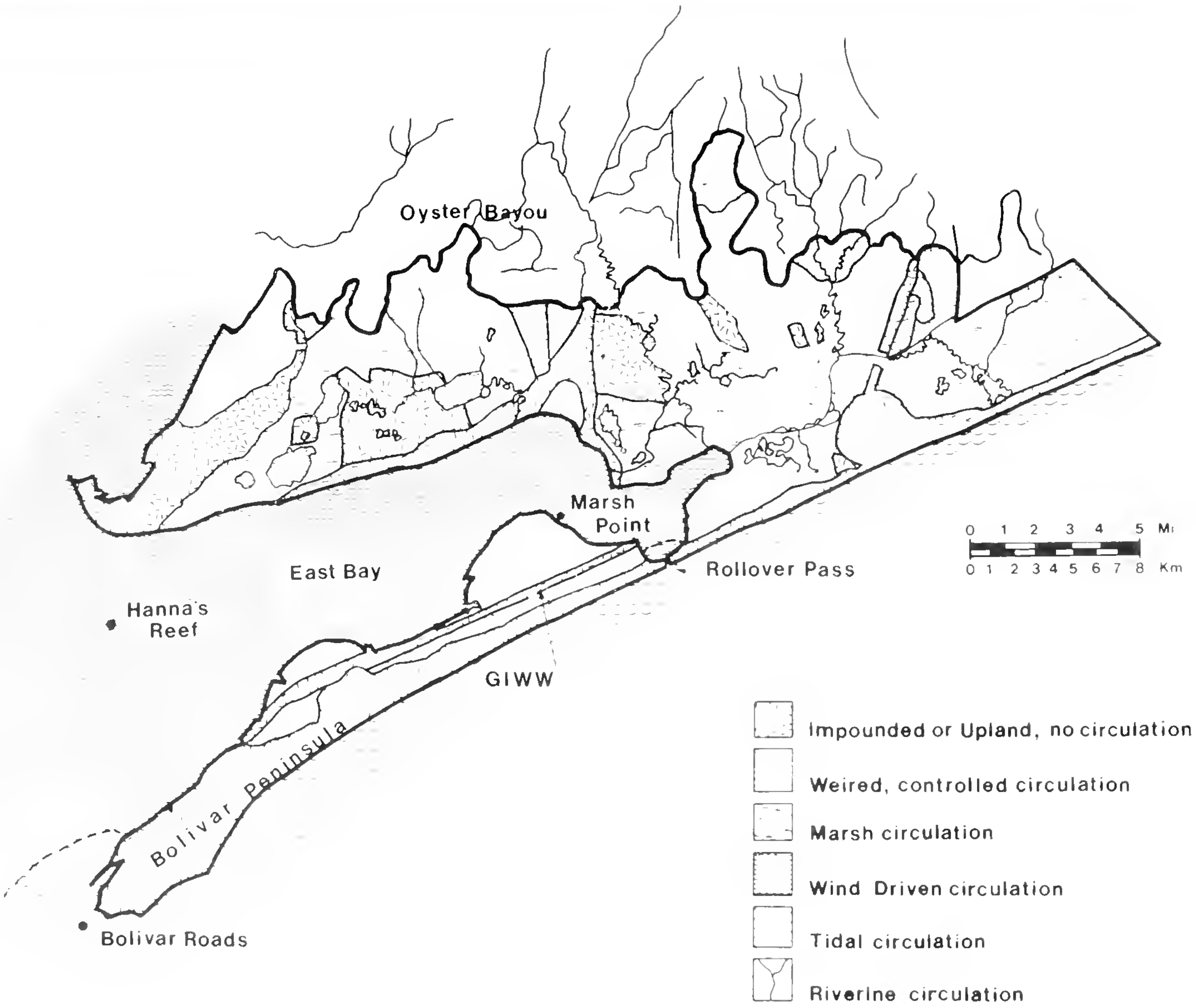


Figure 3-51. Hydrologic regions of East Bay.

Table 3.74. Texas landings of blue crab for Sabine Lake, and Galveston and Trinity bays, showing amount and value of landing, 1962 to 1975.

Year	Sabine Lake (kg)	Sabine Lake ($)	Galveston and Trinity Bays (kg)	Galveston and Trinity Bays ($)
1962	107,639	16,611	141,206	15,569
1965	230,973	38,044	824,599	147,345
1969	374,492	76,502	773,706	157,538
1970	310,716	63,998	1,189,339	244,798
1971	870,005	188,008	980,139	213,240
1972	584,554	127,369	848,277	191,649
1973	616,079	158,433	925,344	254,376
1974	254,379	77,090	899,489	273,301
1975	281,640	96,740	845,284	287,019

by Bolivar Roads, an improved natural pass between the Gulf and Galveston Bay which is flanked by jetties several miles in length projecting into the Gulf. Water depths in East Bay range from about 1.5 to 2 m (0.9 to 1.2 ft) at its western end to about 1 m (0.62 ft) at the eastern end. The eastern arm of the bay, called Rollover Bay, contains about 255 ha (556a) and is about 0.5 m (1.6 ft) deep. It opens to the Gulf through an old natural pass, Rollover Pass, which was reopened by dredging in 1955.

East Bay Bayou, Oyster Bayou, and Onion Bayou constitute the natural drainage system (approximately 660 km^2 or 255 mi^2) of East Bay. The Gulf Intracoastal Waterway extending from Sabine Lake enters the East Bay Basin through East Bay Bayou, crosses the northern end of Rollover Bay and extends along the bay side of Bolivar Peninsula to deep water in Bolivar Roads.

Geologically the East Bay Basin has attributes of the Barrier Strand Plain of Texas as well as the Chenier Plain. Most of East Bay Basin consists of Recent deposits of sand which form dune ridges on Bolivar Peninsula. Behind the beach ridge is coastal marsh. Farther inland appears the Beaumont clay surface, a coastal Pleistocene terrace that dips seaward under the Recent marsh and beach deposits (Houston Geological Society 1959). Most of the area is nearly level coastal plain comprised of the Harris-Veston Soil Association with poor internal and surface drainage (U.S. Department Agriculture 1976). The average ground surface slope is about 0.2 m/km (1.06 ft/mi). Marsh elevations are somewhat higher than those further east toward Sabine Lake. The bay shoreline generally lacks sand beaches and in many places is associated with low-lying marshes, particularly on the back side of Bolivar Peninsula (plates 3A and 4A). On the north shore of East Bay low bluffs exist where wave-action has eroded the Pleistocene terrace deposits.

Mean rainfall surplus is 20.6 cm/yr or 8.1 in/yr (table 3.75 and fig. 3-52). Most of the small bayous are weired, have low flow rates, and drain southward and southeastward into East Bay. The average annual flow of freshwater from Oyster, Onion, and East Bay bayous into East Bay is only about 2.1 x $10^8 m^3$ (7.4 x $10^9 ft^3$) (Rice Center 1974). The primary drainage into the whole Galveston Bay system, however, is via the San Jacinto and Trinity rivers, and these discharges indirectly modify salinities in East Bay through mixing with Galveston Bay waters. The Trinity River Basin is outside of the study area and its influence on East Bay will only be briefly described.

Based on local freshwater drainage the maximum freshwater renewal time for East Bay is calculated to be about 577 days. This estimate is undoubtedly high because of three factors: freshwater input via the GIWW from the Sabine Basin, indirect input of freshwater from the San Jacinto and Trinity rivers, and tidal mixing. Freshwater from the Sabine Basin draining into the GIWW is considerable. Maximum flow rates of 113 m^3/sec 3,991 ft^3/sec) have been measured in the GIWW with maximum current velocities of 0.396 m/sec or 1.3 ft/sec (James et al. 1977). This results from a difference in water elevation between ends of the GIWW, brought about by the difference in tidal ranges and lag times between Sabine Lake and East Bay, the small tidal range in the GIWW, wind set-up and/or excess freshwater inflow into Sabine Lake (James et al. 1977).

Water renewal times in East Bay are also strongly influenced by tides, which are well-developed at both ends of the bay (fig. 3-53). The tides in the Gulf near Rollover Pass lag behind those at Bolivar Roads by 3.2 hr at high tide and 4.3 hr at low tide. However, since the tide gage trace at Hanna's Reef does not consistently lead or lag the one at Marsh Point, the tidal waters apparently enter and exit the adjacent passes without much interaction. This conclusion is supported by Prather and Sorensen (1972) who predicted that only 1% of the flow through Bolivar Roads will be exchanged at Rollover Pass, and that the area in East Bay affected by water exchange through Rollover Pass is only about 205 ha (507a). Tides from both passes are probably attenuated somewhere in mid-bay. Wind-driven circulation is also apparently poor, probably because the bay is oriented east-to-west, whereas predominant winds are north to south. Figure 3-54 shows patterns of mean, extreme high, and extreme low salinities that document the poor circulation in mid East Bay because salinity changes occur most slowly there. The presence of live oysters in the bay is somewhat contradictory to those conclusions, and further studies of East Bay circulation are needed. Seasonal peaks in mean water level occur in spring and late summer, as elsewhere in the Chenier Plain (fig. 3-53). Since 1964 the mean annual water level has risen at the rate of about 1.5 cm/yr (0.6 in/yr), approximating changes elsewhere on the Chenier Plain.

The rather saline estuary provides excellent habitat for estuarine-dependent fishes and shellfishes. Coupled with West Bay and Galveston Bay, this is the most productive estuary on the Texas Coast, particularly for shrimp, trout, redfish, Gulf menhaden, and oysters. Texas catch data for these species, as tabulated

Table 3.75. Summary of natural and cultural features of East Bay Basin.

A. Hydrology of the East Bay Basin

Riverine Processes

Freshwater flow volume (into basin)
$0.4\ m^3 \times 10^8$/yr

Annual rainfall 113 cm (at Galveston)

Seasonal: Figure 3-52

Maximum freshwater renewal time: 577 days

Surface water slope: Not computed–large open bay system. Transient slope due to tide.

Tides

Range: 30 cm (fig. 3-53)

Period: Diurnal

Water level variation

Seasonal: Low January-April; peaks in May and September (fig. 3-53)

Long term: 1.5 cm/yr (fig. 3-53)

Salinity: 1965-1967 Mean: 14-24‰ (fig. 3-54)

Seasonal: Extreme low salinity: 2-10‰
Extreme high salinity: 24-30‰

Long term: No data

Control structures and modifications

Rollover Pass constructed 1955
Weirs on most streams
GIWW

B. Primary production, potential yield and harvest of living resources of East Bay Basin.

	Per km^2	Per basin
Net primary production (t/yr) Appendix 6.3	1,139	1,275,001
Sport hunting and fishing use estimated potential yield[a]		
Big game (man-days x 1000/yr)		5.2
Small game (man-days x 1000/yr)		18.0
Waterfowl (man-days x 1000/yr)		35.2
Saltwater finfishing (man-days x 1000/yr)		124.4
Freshwater finfishing (man-days x 1000/yr)		34.3
Total		217.5
Agriculture		
Rice (t/yr)	3,646	
Commercial species harvest[b]		
Shrimp (kg x 1000/yr)	2.7	685
Menhaden (kg x 1000/yr)	43.9	11,057
Blue crab (kg x 1000/yr)	0.7	188
Oyster (kg meat x 1000/yr)	0.7	181
Other saltwater finfishes (kg x 1000/yr)		20
Freshwater finfishes (kg x 1000/yr)		0
Nutria (pelts/yr)		14,895
Muskrat (pelts/yr)		11,402

[a]Method explained in part 3.5.2

[b]Present harvest attributed to basin (part 3.2.4)

continued

Table 3.75. Summary of natural and cultural features of East Bay Basin (continued).

C. Habitats of East Bay Basin

C1. Habitat area in 1974 and net changes since 1954

Habitat	Area 1974 (ha)[a]	Percent of total area[b]	Changes in area 1954 to 1974 (ha)	(%)
Nearshore Gulf	30,540	–	25	0.1
Inland open water	26,553	32.6	444	1.7
Natural marsh	19,674	24.2	-1,380	-6.6
Impounded marsh	4,623	5.7	874	23.3
Swamp forest	0	0	0	0
Natural ridge	4,725	5.8	-70	-1.5
Spoil	2,278	2.8	40	1.8
Rice field	3,567	4.4	-386	-9.8
Non-rice cropland	199	0.2	68	51.9
Pasture	15,654	19.2	121	0.8
Urban	2,577	3.2	278	12.1
Beach	1,256	1.5	-14	-1.1
Upland forest	264	0.3	0	0
Total	111,910			

[a]1 hectare (ha) = 2.47 acres (a)

[b]Calculation excludes area of nearshore Gulf habitat

C2. Habitat modification from 1954 to 1974 due to identifiable human activities

Cause of change	1954 Habitat	1954 Area (ha)	Changed to (by 1974) Habitat	Changed to Area (ha)	Change in 1974 as percent of original 1954 habitat
Filling and draining					
Impounding	Natural marsh	21,064	Impounded marsh	874	4.1
Canal dredge and spoil	Natural marsh	21,064	Spoil	58	0.3
	Natural marsh	21,064	Canal	29	0.1
	Inland open water	26,109	Spoil	25	0.1
Upland construction	Natural ridge	4,741	Urban	70	1.5
	Beach	1,270	Urban	24	1.1
	Agriculture	19,617	Urban	197	1.0

continued

Table 3.75. Summary of natural and cultural features of East Bay Basin (continued).

C3. Natural wetland loss (1954-1974)--summary

To	Process	Area (ha)	Percent of 1952 area
Canals	Dredging	29	0.1
Inland open water	Subsidence	397	1.9
Nearshore Gulf	Shoreline erosion/deposition	65	0.3
Impounded marsh	Leveeing	874	4.1
Spoil	Dredging	58	0.3
Agriculture	Draining	0	0
Urban	Draining	0	0
Total		1,423	6.7

D. Cultural Features of the East Bay Basin

D1. Socioeconomics

Population: 4,824

Employment: $3,074,100 (fig. 3-12)

	Production (1974)	Value ($ x 1000)
Minerals		
Gas (mcf)	123,346,093	
Crude oil (bbls)	8,163,375	
Total		91,092
Agriculture		
Crops		1,212
Other		1,429
Total		2,641
Sport hunting/fishing		
Saltwater sportfishing		1,010
Freshwater sportfishing		1,080
Small game hunting		900
Big game hunting		315
Waterfowl hunting		2,205
Total		5,510

	Value ($ x 1000)
Commercial harvest	
Fishing	
Shrimp	1,471.7
Menhaden	1,023.8
Blue crab	44.0
Oyster	246.8
Other estuarine-dependent species	19.0
Freshwater finfish	0.0
Subtotal	2,804.3
Trapping	
Nutria	89.4
Muskrat	51.3
Subtotal	140.7
Total	2,945.0

Navigation

Total traffic: 1,200,000 short tons/yr

Imports: non-fuel mined products

Exports: non-fuel mined products

continued

Table 3.75. Summary of natural and cultural features of East Bay Basin (concluded).

D2. Total 1974 canal area

	Area (ha)	Length (km)
Navigation	660	137
Agricultural drainage	91	305
Oil activity	34	8
Transportation embankment canals	26	38
Other	0	0
Total	811	488

D3. Water use

	Annual volume ($m^3 \times 10^6$)
Agriculture	34.6
Municipal	0.7
Industrial	18.9
Total	54.2

D4. Estimated sport fishing and hunting supply and demand (man-days x 1000)

	Supply	Demand	Harvest as percent of estimated sustained yield
Big game	5,357	300.0	5.6
Small game	194	35.0	18.0
Water-fowl	696	245.0	35.2
Saltwater fishing	200	250.0	124.4

D5. Nutrient and toxin discharges

Phosphorus loading rates to entire Sabine Basin drainage area (appendix 6.4).

Cultural	P input (g/yr x 10^6)	Natural	P input (g/yr x 10^6)	Total P input
Urban	0.13	Forest	0.02	
Industrial	0.0	Lake	10.3	
Rice	0.0	Barren land	0.44	
Non-rice agriculture	29.0			
Total	29.13		10.76	39.89

Surface water discharge ($m^3 \times 10^8$/yr) 5.2
P load (g/m^3/yr) 0.08
Eutrophic state Permissable

Other important pollutants: industrial toxins and coliform bacteria
East end of East Bay closed to shellfishing because of high coliform levels (plates 5A, 6A; Diener 1975).

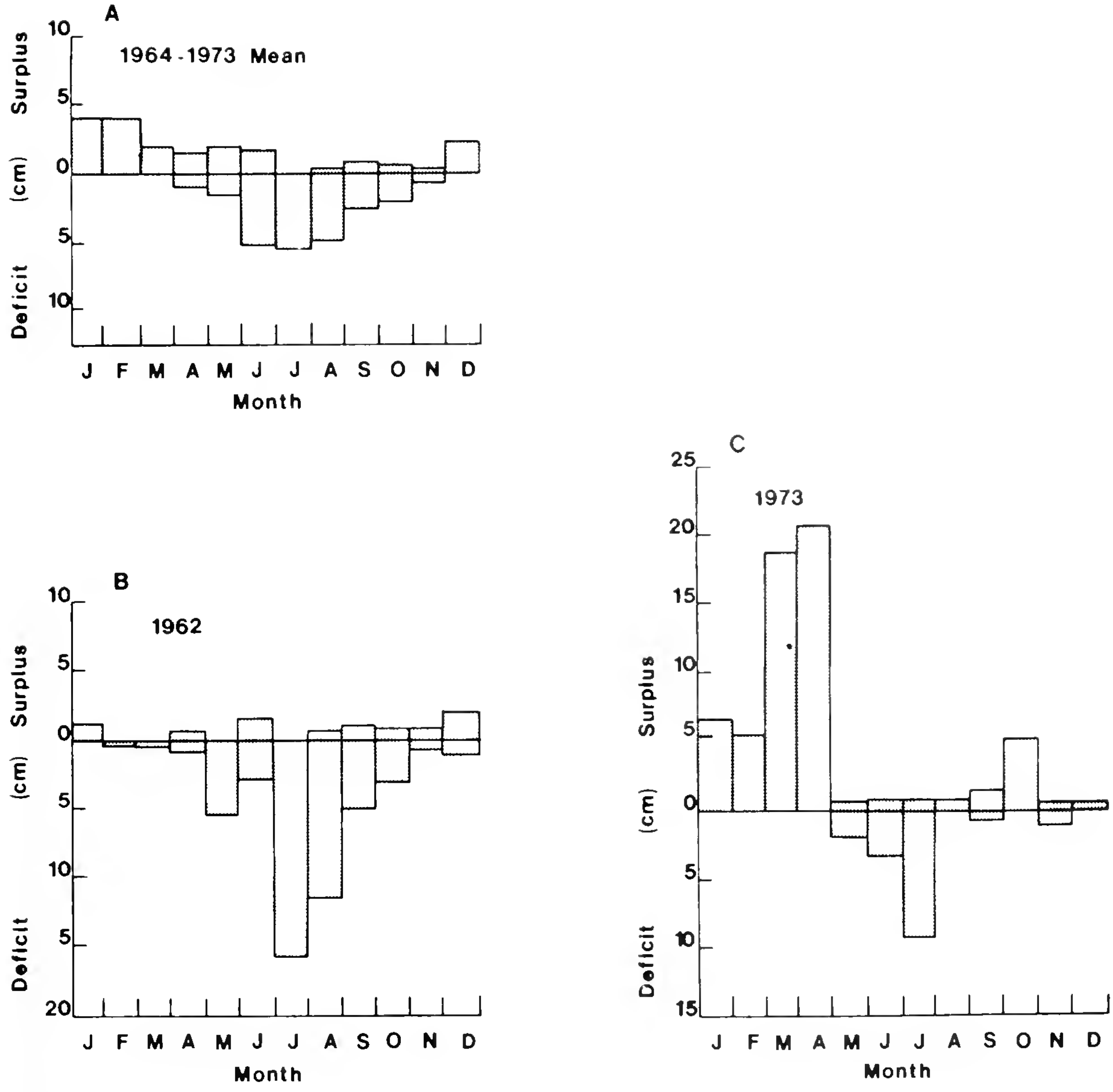


Figure 3-52. Freshwater supply of East Bay: (A) mean (1964 to 1974) monthly rainfall surpluses (deficits); (B) monthly rainfall surplus (deficit) for a dry year; and (C) monthly rainfall surplus (deficit) for a wet year.

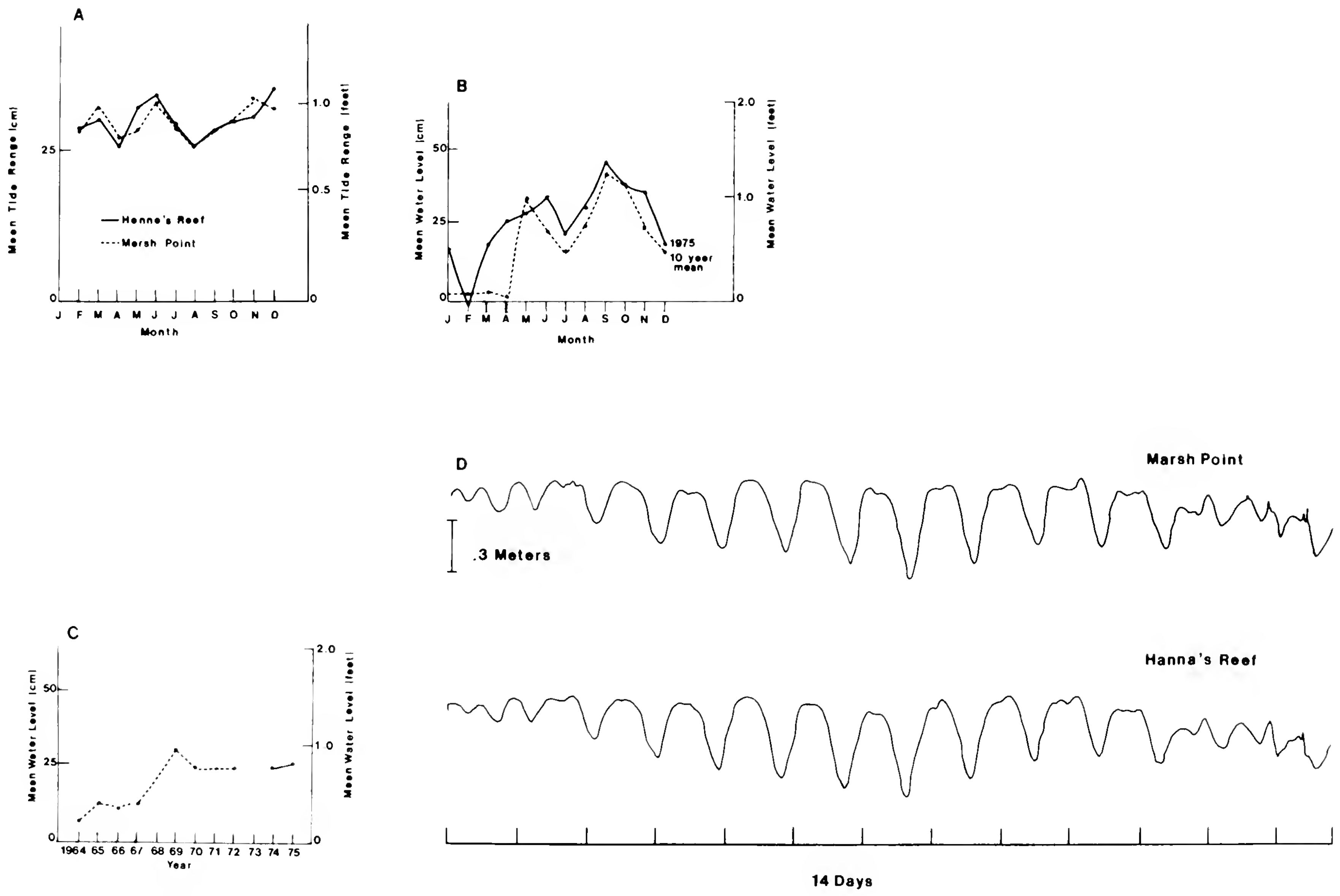


Figure 3-53. Water levels in East Bay Basin: (A) monthly variation in daily tidal range; (B) seasonal variation in mean water level; (C) long-term annual mean water level; and (D) typical tide record. (U.S. Army Corps of Engineers gage records.)

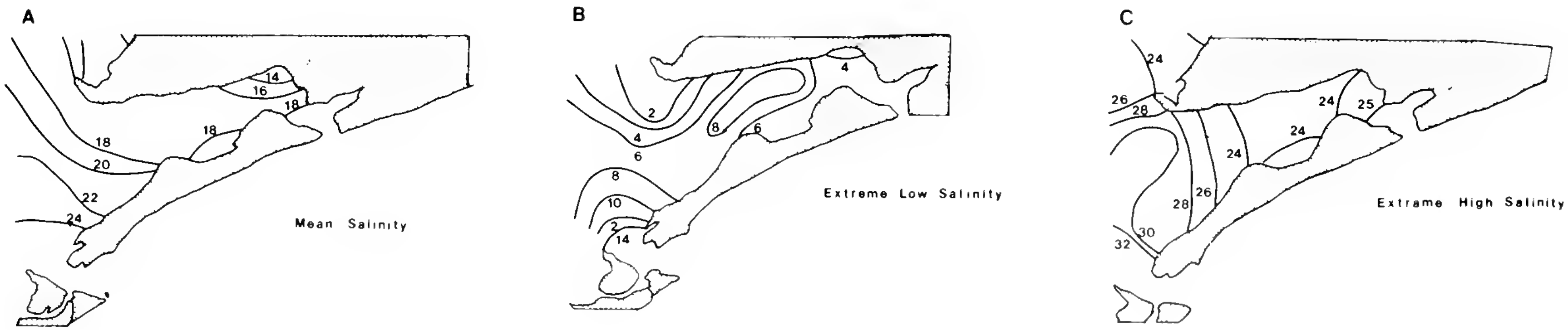


Figure 3-54. Mean, extreme low and extreme high salinity (0/00) in East Bay Basin (Texas Bureau of Economic Geology).

for the Galveston Bay System, are strongly influenced by the significant amount of nursery area in East Bay (appendix 6.2). Parker (1970) documented the significance of East Bay as a nursery and migratory route for juvenile brown shrimp, Atlantic croaker, and spot in the Galveston Bay System. The oyster harvest of Galveston Bay is greatly dependent on reefs in East Bay, particularly Hanna's Reef, Elm Grove Reef, Moody's Reef and Frenchy's Reef. These reefs have been in approved oystering areas since the mid 1950's (Hofstetter 1977). Records of the Texas Parks and Wildlife Department (see appendix 6.3) indicate that muskrat and nutria densities are comparable to the Louisiana portion of the Chenier Plain but the habitat for these species is less extensive in Texas.

Waterfowl are also valuable resources of the basin. Some 20 species of ducks and geese winter in this area around the Anahuac National Wildlife Refuge. Other marshes on the north shore of East Bay centering around Robinson Lake, Wallis Lake, Lake Surprise, and East Bay Bayou support large populations of the lesser snow goose, Canada goose, white-fronted goose, mottled duck and the fulvous tree-duck. This area also provides habitat for marsh and shorebirds and includes such species as roseate spoonbill; common, snowy, and cattle egrets; yellow-and-black-crowned night herons; least and American bitterns; eared and pied-bill grebes; long-billed curlew; whimbrel; common snipe and a variety of smaller shore birds and gulls. Less common species include: white-faced, and white ibises; olivaceous, and double-crested cormorants; anhingas; and white pelicans. All six species of North American rails reside here. Mourning doves and bob-white quail are found in the area. Five species of sea turtles are indigenous to the area and include the Atlantic ridley, hawksbill, leatherback, green, and loggerhead. The peregrine falcon, Southern bald eagle, brown pelican and the red wolf have been sighted in the area (Lard 1978).

Socioeconomics. Mineral extraction, manufacturing, and agriculture (fig. 3-12) provide the main sources of employment in East Bay Basin. Oil and gas are by far the most valuable product of the basin, worth $91 million per year. Commercial fish and furbearers produce an annual income of about $2.9 million, agriculture $2.6 million, and sportfishing and hunting an estimated $5.5 million. These figures suggest that because of the basin's proximity to large urban centers the game sportfish, and waterfowl are the most important renewable resources of the basin.

Effects of Human Activities on the Environment. Hydrologic effects: The hydrology of East Bay Basin has been modified by several cultural activities and is influenced seasonally by others. River discharge, tidal currents, and circulation patterns have been modified by human activity. The predominant factors appear to be the opening of Rollover Pass and the GIWW. The opening of Rollover Pass has improved circulation, particularly in the upper end of East Bay.

Oyster reefs in most of East Bay are healthy, showing that water quality and circulation is adequate. Upland agriculture, particularly rice farming, uses weirs on streams to control drainage and salinity. This restricts water exchange between the marshes and the bay. However, little information is available about the flushing frequencies for these wetlands. The banks of East Bay Bayou are actively eroding because of agricultural development, and creating sedimentation problems downstream (U.S. Department of Agriculture 1976). Water that is rich in nutrients, particularly nitrogen and phosphorus, enters East Bay via the GIWW from the Sabine Basin, suggesting the chemical pollutants could be transported to East Bay from the Beaumont-Port Arthur-Orange area (James et al. 1977).

Canal density in East Bay basin is the lowest of the entire Chenier Plain (1.5% of the land area). Oil and gas development has resulted in the impoundment of wetlands through road construction (appendix 6.2).

Beach and shoreline erosion and the effects of Rollover Pass and Bolivar Roads on sedimentation and erosion have been well documented (U.S. Army Corps of Engineers 1951, Jaworski 1971, Prather and Sorensen 1972, Seelig and Sorensen 1973, McGowen et al. 1977, and Morton 1977). Rollover Bay appears to be filling with sediment derived from the Gulf beaches as well as from upstream drainage areas. Approximately 200 ha (494a) of this bay are now less than 0.5 m (1.6 ft) deep. Likewise, beach erosion and sediment movement out of Rollover Pass appears to have contributed to progradation of beaches on Bolivar Peninsula north of the north jetty.

Habitat effects: Habitat distribution in the East Bay Basin is shown in plates 3A and 4A, and table 3.75. The rate of wetland loss to open water that cannot be explained by cultural activities is 0.08%/yr, a figure comparable to the low rate in the Vermilion Basin. This low rate is attributed to the natural firmness of the substrate in East Bay Basin. The overall wetland loss for East Bay Basin was 6.9% during the period from 1954 to 1974 (table 3.75). The largest loss resulted from fill placed on wetlands for impoundment levees. Since 1954, 87 ha (215a) have been used for the construction of canals and for the disposal of dredged material from the GIWW and from canals for housing developments on Bolivar Peninsula.

Other habitat changes since 1954 are rather small. Urban growth has altered natural ridge and agricultural habitat and is expected to continue, particularly on Bolivar Peninsula.

Effects on renewable resources: The opening of Rollover Pass seems to have been beneficial to estuarine organisms. Reid (1955, 1956) conducted an ecological study of East Bay before and after the opening of the pass. His data revealed a nearly two-fold increase in salinity in the upper end of the bay and an accompanying increase in salt-tolerant organisms. The oyster fishery has continued to thrive in East Bay although the salinity levels have increased. Shell dredging activities during the 1960's removed large quantities of oyster shell from East Bay and surrounding areas. Sedimentation from these dredging activities smothered many adjacent live oysters and covered valuable shallow water habitat (Benefield 1976). Viable finfish, shrimp, and oyster fisheries depend on this estuarine area.

The marsh areas in East Bay Basin have been used for cattle grazing since the turn of the century (U.S. Army Corps of Engineers 1900). However, the ecological effects of cattle grazing in marshes need more study.

The most critical resource of the basin is water. Rainfall deficits always occur in summer, even in wet years, and can be severe in dry years. (fig. 3-52). Surface water quality appears to be adequate, judging from the phosphorus loading rates, even though the renewal time of the bay is long, approximately 577 days. Ground water supply, i.e., safe annual yield, in the Neches-Trinity coastal basin which includes the East Bay area is about $13 \times 10^6 m^3$ ($4.6 \times 10^8 ft^3$). In 1974 about $5.3 \times 10^6 m^3$ ($1.9 \times 10^8 ft^3$) was pumped within the Trinity-Neches basin. Another $5.1 \times 10^6 m^3$ ($1.8 \times 10^8 ft^3$) was pumped from outside that basin but was used in it (Texas Water Development Board 1977). Most of the latter was for manufacturing and industrial use north of the East Bay Basin. Artesian well pressures are declining and saltwater intrusion is occurring near the Gulf (Wesselman 1971). In the Texas City area just west of East Bay, 1 to 1.5 m (3.3 to 4.9 ft) of land subsidence has occurred as a result of ground-water withdrawal and oil and gas extraction (Fisher et al. 1972). Similar subsidence can be expected in the East Bay Basin, particularly with continued ground-water withdrawal.

4.0 CHENIER PLAIN HABITATS

4.1 INTRODUCTION

Habitats are the key components of the Chenier Plain ecological hierarchy. As used in this report, they are components of basins and are also communities where individual species live and reproduce.

The term "habitat" refers to the place occupied by an entire community of organisms (Odum 1971). A habitat can be described in terms of a range of physical or abiotic parameters such as salinity and temperature, water availability, soil type, and geographic relief. It has geographic boundaries that can be measured and mapped.

Odum (1971) defines a community as "an organized unit that has characteristics additional to its individual and population components and functions as a unit through coupled metabolic transformations." The term "habitat," as used in this report, defines the boundary of this community; it is not applied to individual species, except to the extent that they belong to defined communities.

Any classification system is to some extent arbitrary. In this study, basins were subdivided into geographic units called habitats (table 3.53, and plates 3A and 3B). Because man is a significant influence on the Chenier Plain, some of these habitats were also land-use categories (e.g., rice field habitat). But they, like the naturally occurring habitats, could also be treated as functionally identifiable units. Fourteen habitats were defined: nearshore Gulf, inland open water, salt marsh, brackish marsh, intermediate marsh, fresh marsh, swamp forest, impounded marsh, ridge, beach, upland forest, rice field, pasture, and urban.

Most of the land in the Chenier Plain basins is wetland. Wetland habitats include the swamp forest, impounded marsh, and four natural marsh types identified by vegetation and salinity differences: salt marsh, brackish marsh, intermediate marsh, and fresh marsh (Penfound and Hathaway 1938, O'Neil 1949, Chabreck et al. 1968, Chabreck 1972).

The plant community in a wetland area depends upon the range of physical and chemical parameters in that area. Generally speaking, as one moves inland from the coast and salinities decrease, coastal salt marshes grade into brackish, intermediate, and fresh marshes. Figure 4-1 shows the vegetational trend in southeastern Louisiana along an 80 km (50 mi) south to north transect. The salt marsh habitat is in the southernmost zone, where smooth cordgrass is dominant (table 4.27 lists common and scientific names of most vascular plants identified in this study). A fairly distinct change occurs inland where saltmeadow cordgrass and saltgrass become dominant in the brackish marsh habitat. A third change in plant composition and diversity is observed in the intermediate marsh habitat. This occurs with the appearance of such plants as alligatorweed, maidencane, and Walter's millet. Halfway along the transect, the fresh marsh habitat is distinguished by the presence of species such as water hyssop, water hyacinth, and cattail.

Vegetational transitions in the Chenier Plain are generally similar to those shown in figure 4-1. However, they are less distinct, because ridge plants are mixed with wetland species where cheniers modify the natural salinity gradient. Figure 4-2 shows an example of plant distribution in the region on a south to north transect through the Calcasieu Basin. Salt marsh species do not show up on this transect, but three discernible groups of plants are evident. With the exception of aster and seashore paspalum, the southern group of brackish marsh species (saltmeadow cordgrass, smooth cordgrass, and saltgrass) are identical to those found in figure 4-1. The intermediate marsh zone contains a variable group of common freshwater species that can tolerate low salt concentrations (alligatorweed, bulltongue, Olney's three-corner grass). At the north end of the transect, this group is augmented by strictly freshwater species such as stonewort and yellow lotus. Even though the zones are not distinct, the distribution of plant species provides a plausible criterion for distinguishing the four natural marsh habitat types.

Vegetation differences also correlate with differences in soil chemistry. Chabreck (1972) and Brupbacher et al. (1973) reported that vegetation in Louisiana marshes varied with the chemical characteristics of soil sediments. As an example, figure 4-3 compares soil calcium and total salt concentrations within four marsh types (Palmisano and Chabreck 1972).

4.1.1 RELATION OF HABITATS TO POPULATIONS

Populations exist, grow, and interact within the constraints of habitats. A habitat limits and molds a population through external forces. In turn, as interacting populations (the biotic components of the community) change, they modify the habitat. Three habitat characteristics are important for individual populations. First, the carrying capacity of a habitat depends on the magnitude of primary production of the community and on the trophic position of the population in question. Conceptually, a habitat has a carrying capacity for every species population that it supports. This carrying capacity can be managed by controlling primary production (e.g., increasing the amount of Olney's three-corner grass to allow muskrat populations to increase), by manipulating the trophic structure of a habitat (e.g., reduction of predators in an area often allows prey species to increase in numbers), and by reducing limiting factors (e.g., providing nesting boxes for wood ducks where natural cavities are few). Since components of a community interact, increasing the carrying capacity for one species generally has repercussions for other species, and could be detrimental to the community as a whole.

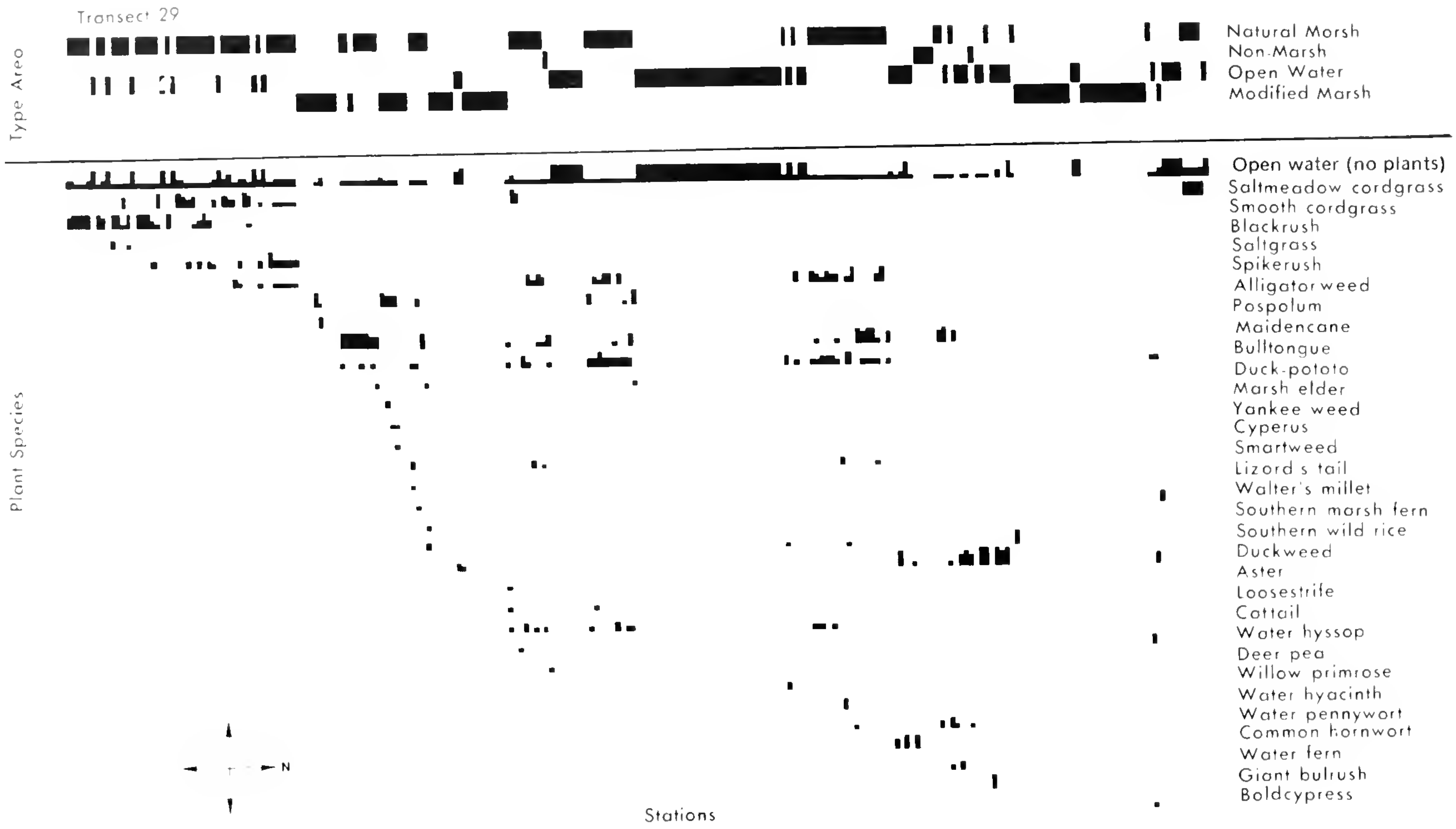


Figure 4-1. Distribution of plant species along a south-to-north 80-km (50-mi) transect in southeastern Louisiana. The distribution and percentage coverage of each species along the transect is indicated by the length and width of the black bar. (Data from Chabreck et al. 1968.)

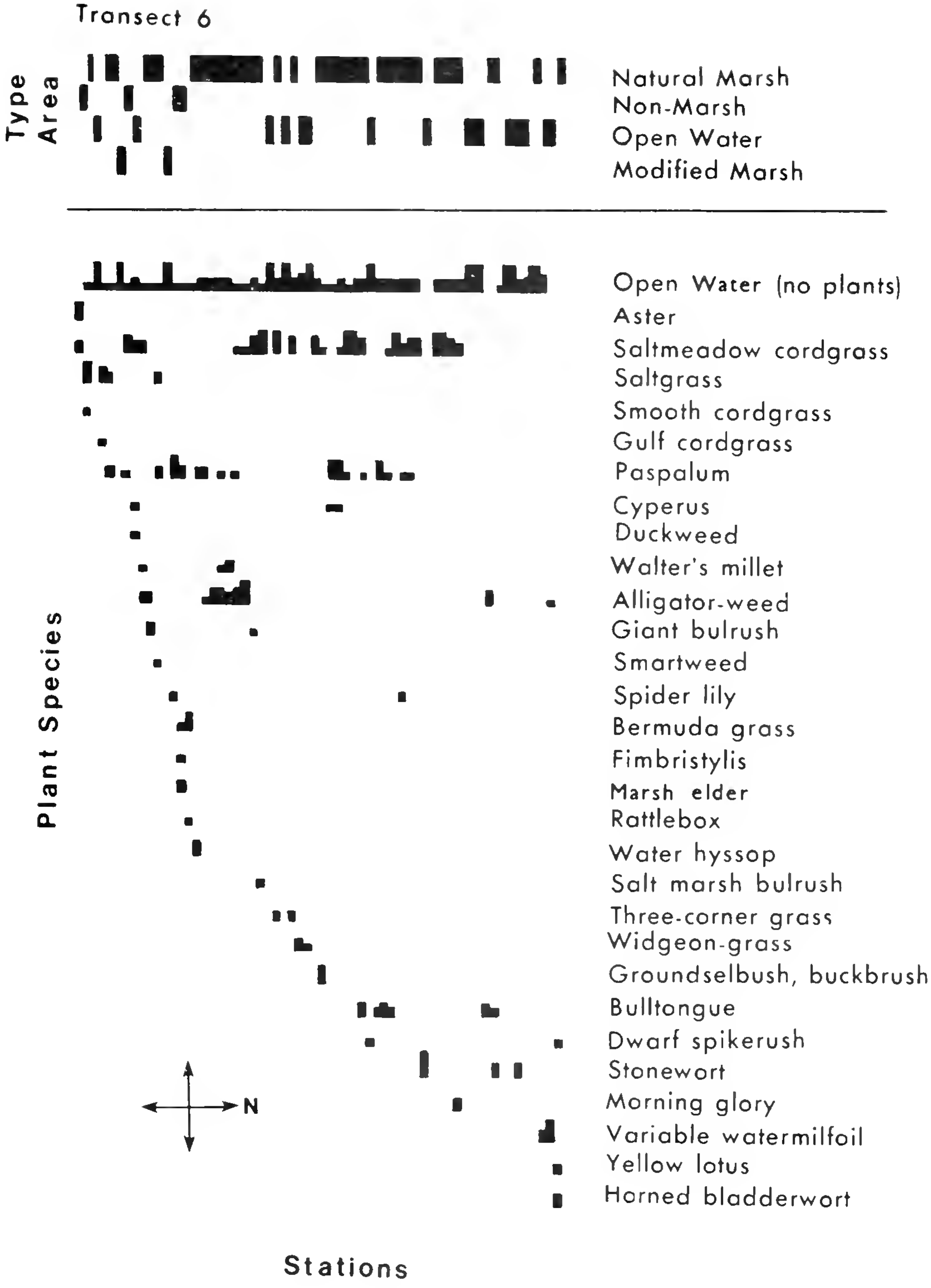


Figure 4-2. Distribution of plant species for four area types along a south-to-north transect in Calcasieu Basin. The distribution and percentage coverage of each species along the transect is indicated by the length and width of the black bar. (Data from Chabreck et al. 1968.)

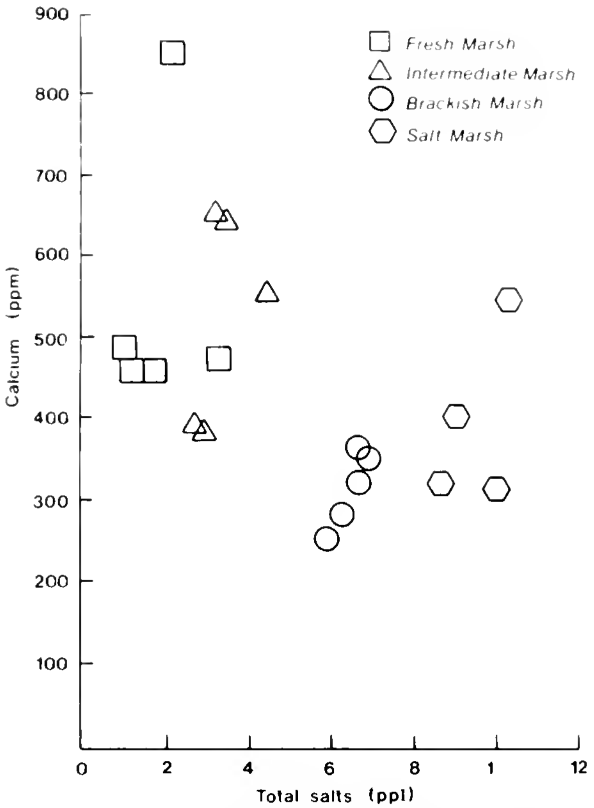


Figure 4-3. Comparison of soil calcium and total salt concentrations within four marsh types in coastal Louisiana (Palmisano and Chabreck 1972).

A second important aspect of a habitat is its areal extent. The habitat's area relates to the relative amount of space, food and cover available for a particular species. Some species, e.g., the river otter, occur in low densities and range over large areas. For these species, a large continuous area of habitat is necessary to maintain the population and its gene pool.

A third characteristic of a habitat that is important to individual populations is its interlinking with other habitats. Habitats are interlinked by populations that migrate from one to another. For instance, virtually all of the commercial and sportfish species in the Chenier Plain must use several habitats (nearshore Gulf, inland open water, and one or more wetland habitats) to complete their life cycles.

4.1.2 RELATION OF HABITATS TO BASINS

In part 3.0 habitats were discussed as components of basins and were considered as geographic units of defined area. Habitats receive sunlight, water, sediments and nutrients. With coupling among habitats they can be expected to produce a characteristic harvest of commercially important fishes, shellfishes and mammals, and sustain a given level of recreational use. Water unifies the basin, acting as a vehicle for transport of materials and organisms among habitats. Renewable resource potential was discussed as a function of areal habitat change, not as a result of changes in habitat quality.

In part 4.0 the emphasis changes to the biotic components of each habitat; the complex trophic structure, the major processes, and reactions of the habitat to external forces are presented. The discussion is intended to show how processes which lead to changes in habitat area and quality at the basin level can also lead to changes in habitat structure, function, and carrying capacity.

4.1.3 ORGANIZATION OF HABITAT SECTION

Wetlands appear to be the most important habitats in the Chenier Plain in terms of loss and vulnerability to change. They are therefore treated first, followed by aquatic habitats, beach and ridge habitats, upland forest habitat, and finally agricultural habitats. Within each of these groups, functional similarities far outweigh differences. Therefore, a general discussion of common characteristics within each group prefaces individual habitat treatments. Differences, especially in species composition, are considered in subsections on individual habitats.

4.2 WETLAND HABITATS

From the air wetlands appear as watery grasslands interspersed with countless lakes, ponds, and sinuous streams, along whose borders the vegetation is particularly lush. From low altitudes, different types of vegetation can be distinguished in broad bands, lying roughly parallel to the major water bodies and to the coast.

The five distinct natural wetland habitats are identified by their dominant vegetation (Penfound and Hathaway 1938; O'Neil 1949; and Chabreck 1970, 1972). These habitats function as they do, and occupy particular spatial relationships to each other, primarily because of the influence of two related hydrologic processes. Freshwater from rainfall and from up-river discharge flows seaward across the basin. Saltwater influenced by tidal currents and density gradients from the Gulf tends to oppose this flow. Depending on the topographic features of the basin, the mixing of fresh and saltwater results in different marsh zones (fig. 4-4). Each of these zones supports a characteristic flora.

Three additional points should be made. First, wetland habitat boundaries are often not distinct. Salt concentrations vary over a continuum, not abruptly, and vegetation zones also grade diffusely into each other and overlap much as an ecotone separates a field from a forest. Second, wetland habitats usually occur as an ordered series. Fresh marsh is not expected to be contiguous to salt marsh, rather, there is a transition through intermediate and brackish zones. This follows from the mixing processes that produce a gradual change in salinity across the basin. Finally, the habitat zones change dynamically through time in response to natural and culturally induced changes in the hydrologic regime. For example, as natural subsidence occurs, seawater encroaches over the land, and marsh habitat boundaries move slowly up the basin (Chabreck 1970). As the basin's hydrologic regime changes, all of the habitats are affected. In the Calcasieu Basin dredging of a deep ship channel has accelerated saltwater intrusion (part 3.6.5). In the Mermentau Basin, on the other hand, control structures have prevented saltwater intrusion and the basin is becoming progressively fresher (part 3.6.3).

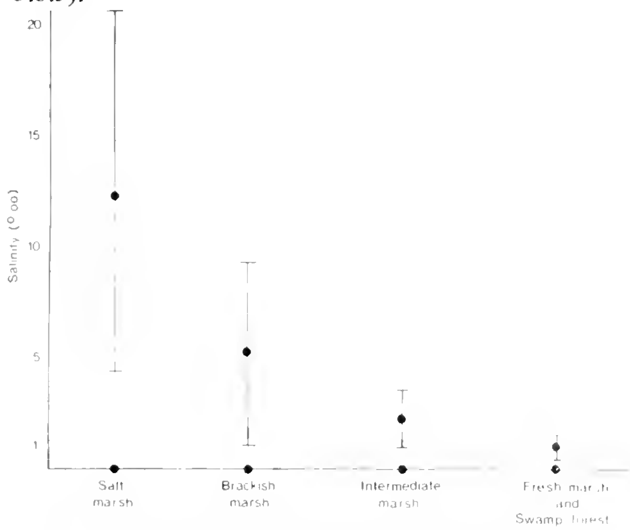


Figure 4-4. Water salinities (mean ± standard deviation) in five natural habitats in the Louisiana portion of the Chenier Plain (Chabreck 1972).

4.2.1 A FUNCTIONAL OVERVIEW OF WETLANDS

The structural and functional similarities of the natural wetland habitats far outweigh their differences. The trophic interactions in each habitat have much in common, although the animal species involved at each trophic level change with habitat. The flow diagram in figure 4-5 summarizes the interacting parameters characteristic of emergent wetlands. The many arrows crossing the system boundaries indicate the high degree of interaction between adjacent habitats. The whole system is shown as a net producer, since organic export to adjacent estuarine waters is characteristic of wetlands. The sun's energy is the ultimate source of all plant production, but the hydrologic regime (shown as H in the diagram), the available nutrients, and salts are the primary regulators of this production.

Three groups of plants are identified in the model. Most of the energy trapped is by the emergent vascular plants which dominate the marsh. The periodically inundated stems of these plants and the marsh floor support a vigorous growth of diatoms and other algae which contribute up to 10% of the net primary production (Gosselink et al. 1977). Submerged grasses (such as widgeongrass) and phytoplankton produce additional food. These three producer groups are distinguished by different rates of production, quality of production, and the relationship of production to biomass (turnover rate). In general, the algae, because of their high protein content, are a more nutritious food source to grazers than emergent grasses are, and have a more rapid turnover rate. This makes their contribution to the food web more important than their biomass would seem to indicate.

The food web shown in the model (fig. 4-5) includes a detritus compartment and three consumer groups. Because emergent grasses consist mostly of cellulose and other compounds that are not digestible by most consumers, they are eaten by a diverse group of scavenging animals only after the dead tissue is enriched by bacteria and other microbes. This is the most important food pathway in marsh habitats. However, grass seeds and tubers, submerged grasses, and many algae are consumed directly by insects, crustaceans, birds, and even mammals such as the muskrat and nutria. These scavengers and grazers, in turn, are prey for such carnivorous animals as hawks, some fish, and predaceous insects.

While the simple food web in the model is conceptually useful, in reality trophic relationships are not nearly so clear. For instance, puddle ducks apparently eat vegetation to store carbohydrates for migration, but switch to high protein animal diets at nesting time. Other trophic relationships are discussed in sections dealing with individual populations. For this overview it is sufficient to understand that several trophic levels exist, but that most food energy is processed through the detritus-scavenger pathway.

Because primary production is high, wetlands support large numbers of migratory and nonmigratory animals. These include commercially important shellfishes (shrimp, oyster, blue crab), finfishes (Gulf menhaden) and mammals (muskrat, nutria), as well as species prized by sportfishermen (spotted sea trout, redfish, flounder) and hunters (ducks, geese).

Other equally important marsh processes are not as closely related to the food web. These include (from Gosselink et al. 1974):

1. The value of the marsh as a storm buffer and flood water reservoir;
2. The sediment filtering and trapping action of emergent grasses and filamentous algae;
3. The ability of marshes to purify flood waters by removal of wastes, nutrients, and toxins.

4.2.2 ROLE OF HYDROLOGY IN WETLAND HABITATS

Wetland Habitats. The properties, distribution, and circulation of water are considered by many to be the most important controlling features of wetland habitats. Water is the vehicle for movement of biota into and out of wetlands. Water also controls marsh productivity and species richness, peat formation, organic export, and the inorganic nutrient flux into the marsh. Water level determines the accessibility of small marsh ponds to aquatic consumers and the usefulness of marshes to waterfowl. This section will document the importance of the fluctuating hydrologic regime that sustains wetland habitats.

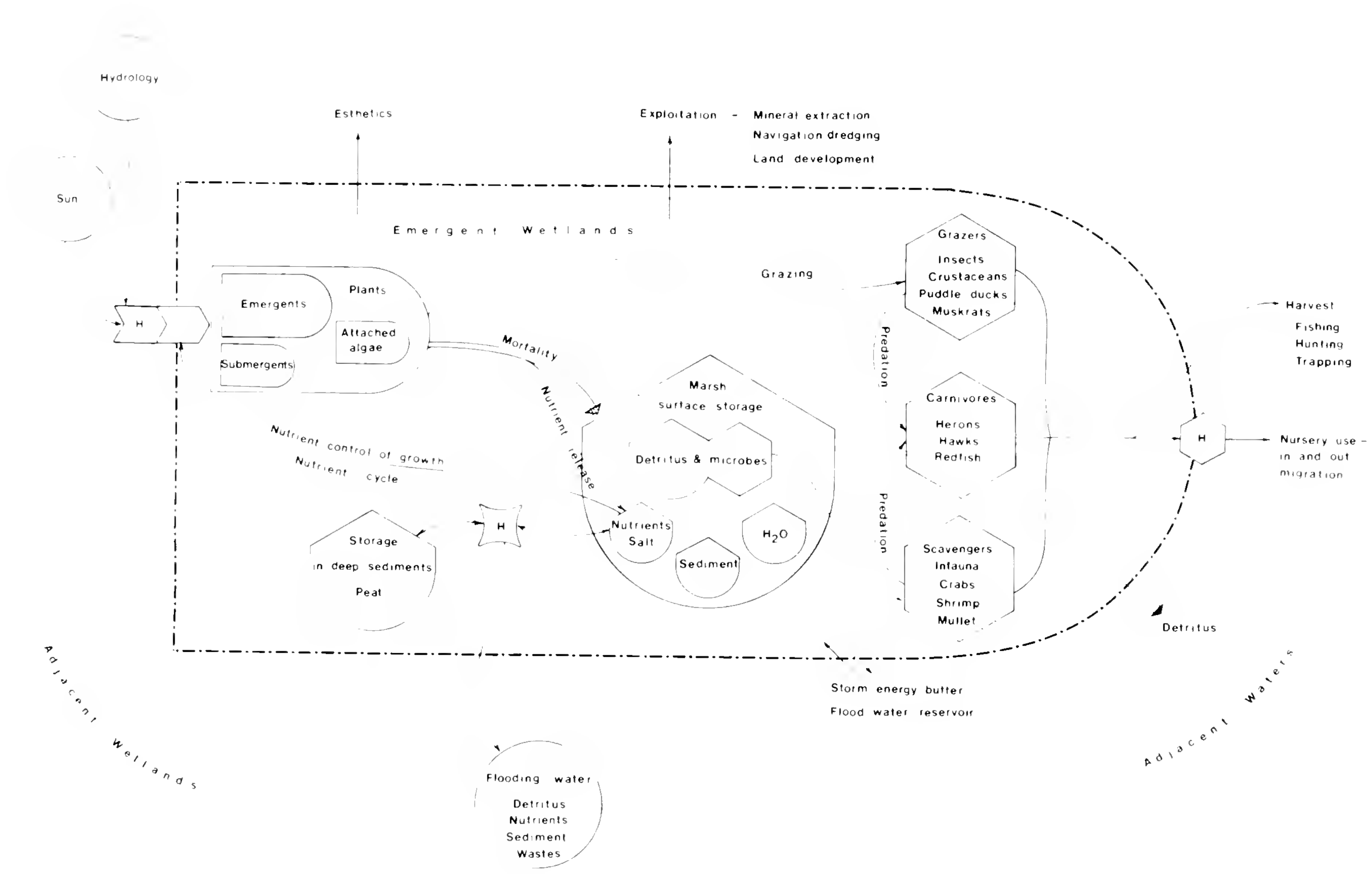


Figure 4-5. A model of a typical wetland system, showing major components and processes.

Production and Species Richness. Oxygen is an essential element in the metabolic processes controlling life. When wetland flooding (inundation) occurs, the amount of oxygen reaching the sediment surface is reduced. As the available oxygen in the sediments is depleted by benthic organisms, a complex series of chemical transformations take place, producing hydrogen sulfide, methane, and other toxic substances (DeLaune et al. 1976).

One unique feature of the marsh biota is the ability to tolerate these anerobic conditions through the evolution of specialized mechanisms. For instance, most marsh grasses have anatomical structures that enable atmospheric oxygen to diffuse through leaves and stems to roots (Armstrong 1975).

The relationship between plant success and the inundation regime is not known quantitatively. However, hydrological parameters (flooding frequency and duration, water depth, and current velocity) determine the sediment-carrying capacity and the level of nutrients flowing into a marsh. The inundation pattern in coastal wetlands varies across habitats. As the tidal influence decreases from salt to fresh marshes, the frequency of wetland inundation also decreases and the average duration of each flooding increases. However, the total yearly inundation time remains fairly constant across all habitats (part 3.3).

The high productivity of salt marshes has been attributed to the regular flushing with tidal waters that carry in nutrients and sediments, and carry out wastes (Schelske and Odum 1961). Recent studies in fresh and brackish wetlands, however, show that these irregularly flooded marshes can be as productive as salt marshes (Good et al. 1978). Fresh and brackish marsh plants appear to be adapted to long periods of root exposure to anoxic sediments, and apparently depend less on nutrients and sediments brought in by flooding waters and more on recycling of available nutrients than plants found in regularly flooded salt marshes.

Hydrology and Sedimentation. The process of sedimentation and the proportion of organic to inorganic material in marsh sediments is largely controlled by the hydrologic regime. Marshes act as traps for sediments which are carried by water flowing across them. As the water in adjacent streams rises and floods over the marsh surface, velocities slow and suspended sediments drop out. Knowledge of the sediment-trapping capacity of salt marshes, in particular, has been extensively used in Europe to build land in areas where high tidal energy results in large suspended loads (Zurr 1952, Dalby 1957).

As early as 1888, Dunbar (Coates 1972) described how harbors of New England filled with silt when the great marshes were drained and leveed. This occurred because the marshes were no longer able to trap silt, and because water currents in tidal passes were reduced as the intertidal volume decreased.

In addition to acting as a sink for suspended sediments (largely inorganic), marshes are also a source of organic detritus which can be incorporated into the marsh as sediment. The more vigorous the flooding action, the more organic detritus is exported from the marsh (Gosselink et al. 1977). As a result, the organic-inorganic mix of wetland sediments depends largely upon the hydrologic regime. High energy marshes accumulate inorganic sediments. If current velocities are slow and inundation periods long, as in intermediate, brackish, and fresh marshes, little inorganic sediment is brought in, detritus is deposited, and marsh sediments are peaty.

The rate of peat formation in the Chenier Plain varies greatly. A cross section of sediments across the Chenier Plain shows that the surface peat layer is seldom over 1.5 m (5 ft) thick and is generally underlain by silts and clays of the Pleistocene Terrace (Gould and McFarlan 1959). Radiocarbon dating of marsh peats has revealed deposition rates averaging from 0.3 to 1.2 mm/yr (0.01 to 0.05 in/yr) (Gould and McFarlan 1959). Most of the Louisiana Chenier Plain coastal marshes are subsiding, yet, the marsh surface stays at the same level relative to local water levels. This suggests that the rate of deposition is as great as the rate of subsidence and that water level and circulation play a vital role in determining what proportion of detritus contributes to peat. If the deposition rate becomes slower than that of subsidence, the frequency and duration of inundation increases, resulting in plant death and erosion of wetlands to open waters.

Export of Detritus. Recent estimates indicate that about 10% of the litterfall in swamp forests are exported (Butler 1975) compared to 30% of salt marsh production (Hopkinson 1973). If detritus export is assumed to be proportional to the frequency of inundation (a measure of the magnitude of flushing), it is possible to estimate the expected export from other marsh habitats. Figure 4-6 illustrates the hypothesized linear relationship between the frequency of flooding and organic export from wetlands. The coastal region is inundated almost daily by tides, but the more inland marshes, especially fresh marshes, are flooded by less frequent wind tides and during periods of high rainfall (Hopkinson 1973, Butler 1975, Byrne et al. 1976). As a result, less detritus is exported from these marshes than from salt marshes (table 4.1). Severe storms are also important in flushing wetlands, but no information is available about the magnitude of storm effects.

4.2.3 DYNAMICS OF ENERGY FLOW IN WETLANDS

Primary production, the conversion of solar to chemical energy by plants, sets an upper limit to the flow of energy through habitats. This chemical energy, fixed as plant tissue, is the energy available for the rest of the food web, so the potential for secondary production of fish, waterfowl, and furbearers is directly related to the magnitude of primary production. An examination of the energy pathway through the food web indicates the important components of the system and the seasonal dynamics of energy production.

Table 4.1. Estimates of organic export from wetlands.

Habitat	Primary production (t/ha/yr)	Exported % of net production	Magnitude ($g/m^2/yr$)
Salt marsh	22.7	30	680
Brackish marsh	27.6	13	360
Intermediate marsh	28.3	12	340
Fresh marsh	14.1	8	110
Swamp forest	9.8	10	100

Productivity. On the Gulf of Mexico coast, the year-round warm temperatures and the continuous nutrient subsidy from flooding waters combine to yield remarkably high production, judging from annual production of several important marsh plants in southeastern Louisiana (table 4.2). These yields far exceed those of other systems, even heavily fertilized agricultural crops such as sugarcane (fig. 4-7). Since on the Gulf coast many plants grow and die continuously throughout the year, the yield, i.e., the harvestable biomass at the end of summer, is only about one third of the total net production for most marsh species. Thus the large stand of plants covering the wetlands at the end of summer is not a true indicator of the real productivity of the system.

Table 4.2. Summary of annual net shoot production by six marsh plants (Gosselink et al. 1977).

Species	Production[a] (t/ha)	Ratio of production to peak biomass
Big cordgrass	11	1.4
Saltgrass	29	2.9
Blackrush	33	2.7
Smooth cordgrass	22	2.9
Saltmeadow cordgrass	42	3.0
Bulltongue	23	3.6

[a]Best estimate from several methods, rounded to nearest metric ton.

Control of Primary Productivity. Since primary production is the source of organic energy in an ecosystem, it is appropriate to examine the major controls of this production. While most dry land plants "saturate" with light (reach maximum photosynthesis rates) at about one-half of full sunlight, many marsh plants are adapted to increase their rate of energy capture as long as light intensity increases (Black 1971). These higher rates of energy capture are not

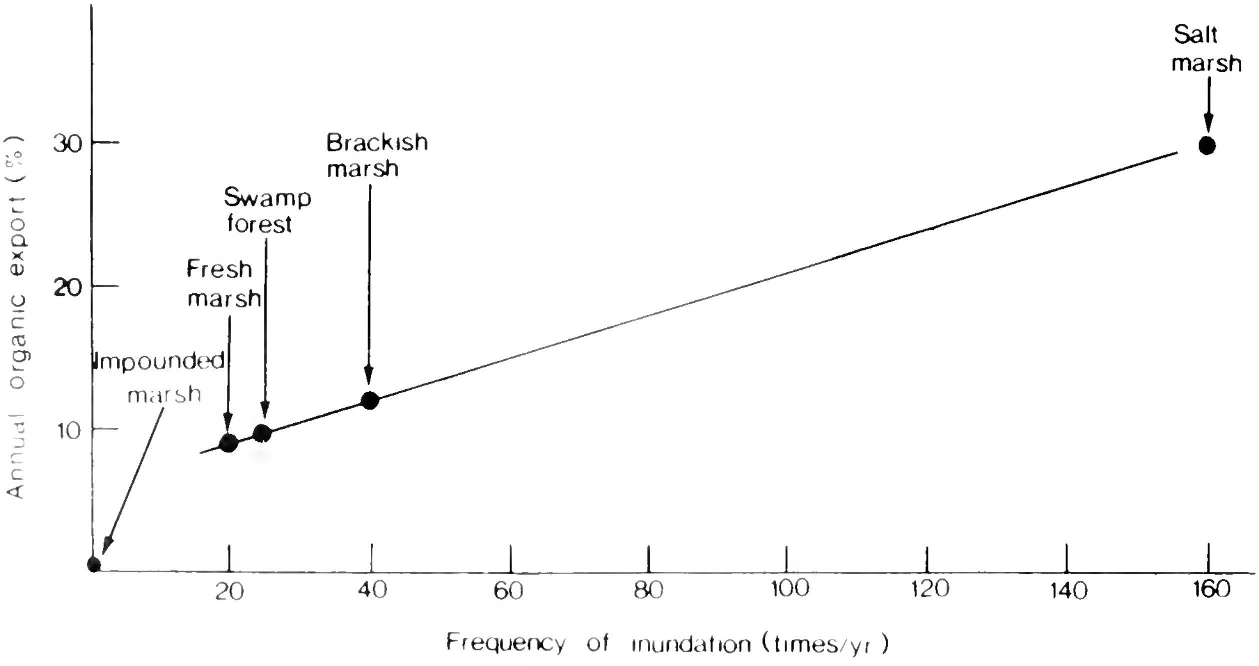


Figure 4-6. Hypothetical relationship between frequency of inundation and organic export from wetlands (inundation frequencies from Byrne et al. 1976, export rates from Day et al. 1973 and 1977).

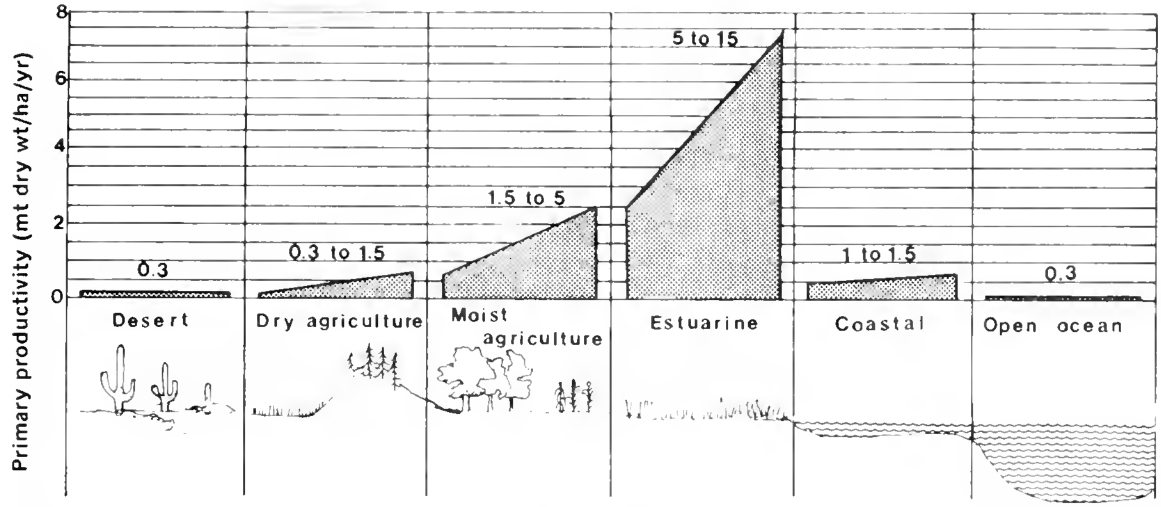


Figure 4-7. A comparison of primary productivity for different kinds of ecosystems (adapted from Teal and Teal 1969).

often obtained, however, since critical materials limit the maximum growth rate of the plants. The most common limiting materials are carbon dioxide, which enters the leaves directly from the air, and inorganic nitrogen and phosphorus which are taken up through the roots. Considerable research (Valiela and Teal 1972, Broome et al. 1975) shows that in the salt marsh habitat nitrogen is most often limiting (table 4.3). However, in freshwater lakes and streams, phosphorus is usually the limiting nutrient and this may also be true in the fresh and intermediate marsh habitats.

Recent evidence indicates that inorganic sediments (primarily clays and fine silts) are the major "new" source of nutrients in Louisiana marshes. DeLaune et al. (1977), for example, showed a strong linear relationship between soil density, which is proportional to the inorganic sediment content in the soil, and biomass of smooth cordgrass (fig. 4-8).

Since nitrogen is most often the limiting nutrient in coastal marshes, it is important to understand the normal sources and losses of this element. The diagram in figure 4-9 illustrates the marsh nitrogen cycle. The major source of nitrogen to plants is made available from stored nitrogen in the soil. It comes from inorganic sediments which are carried into wetlands by flooding waters, and from nitrogen dissolved in the water column. Most of this nitrogen is incorporated as an insoluble organic form in the sediments and becomes available to plants only after it is microbially transformed into ammonia [mineralization (3) on fig. 4-9]. Although the vegetation (4) absorbs significant amounts (5) for growth, the largest users of ammonia seem to be microscopic organisms (7), which transform plant detritus into a high protein bacterial biomass. The vast pool of atmospheric nitrogen gas (8) is not available to marsh grasses; however, certain microscopic organisms change it into a usable organic form [nitrogen fixation (9)]. This is a source of "new" nitrogen for the marsh system, but it is normally small in relation to available sediment nitrogen. In addition, other microorganisms in the

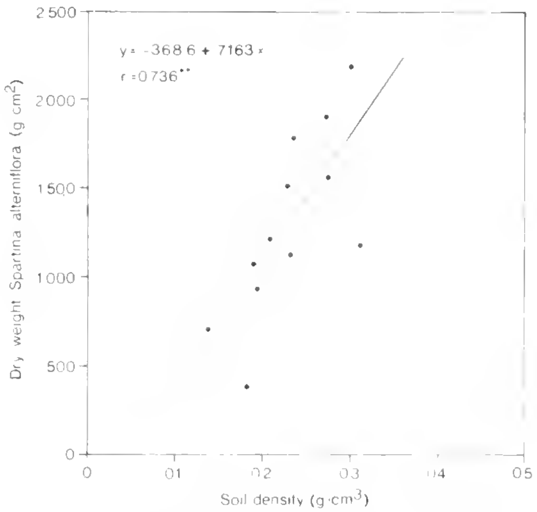


Figure 4-8. Relationship between soil density and growth of smooth cordgrass.

Table 4.3 Above ground yield of smooth cordgrass in September 1973 in a streamside location in Barataria Bay, Louisiana as affected by applications of nitrogen and phosphorus (Patrick and DeLaune 1976).

Treatment	Mean dry-weight yield (kg/ha)
Nitrogen (200 kg/ha)	19,160
Phosphorus (200 kg/ha)	16,560
Control (no N or P)	16,660

alternately oxidized-reduced environment of the sediment surface change ammonia to atmospheric nitrogen [denitrification (10)], where it is lost from the marsh system. Normally, this process also produces small amounts of nitrogen in comparison to the total nitrogen cycled. However, when the marsh is enriched with culturally derived nitrogenous wastes, denitrification becomes an important mechanism to reduce

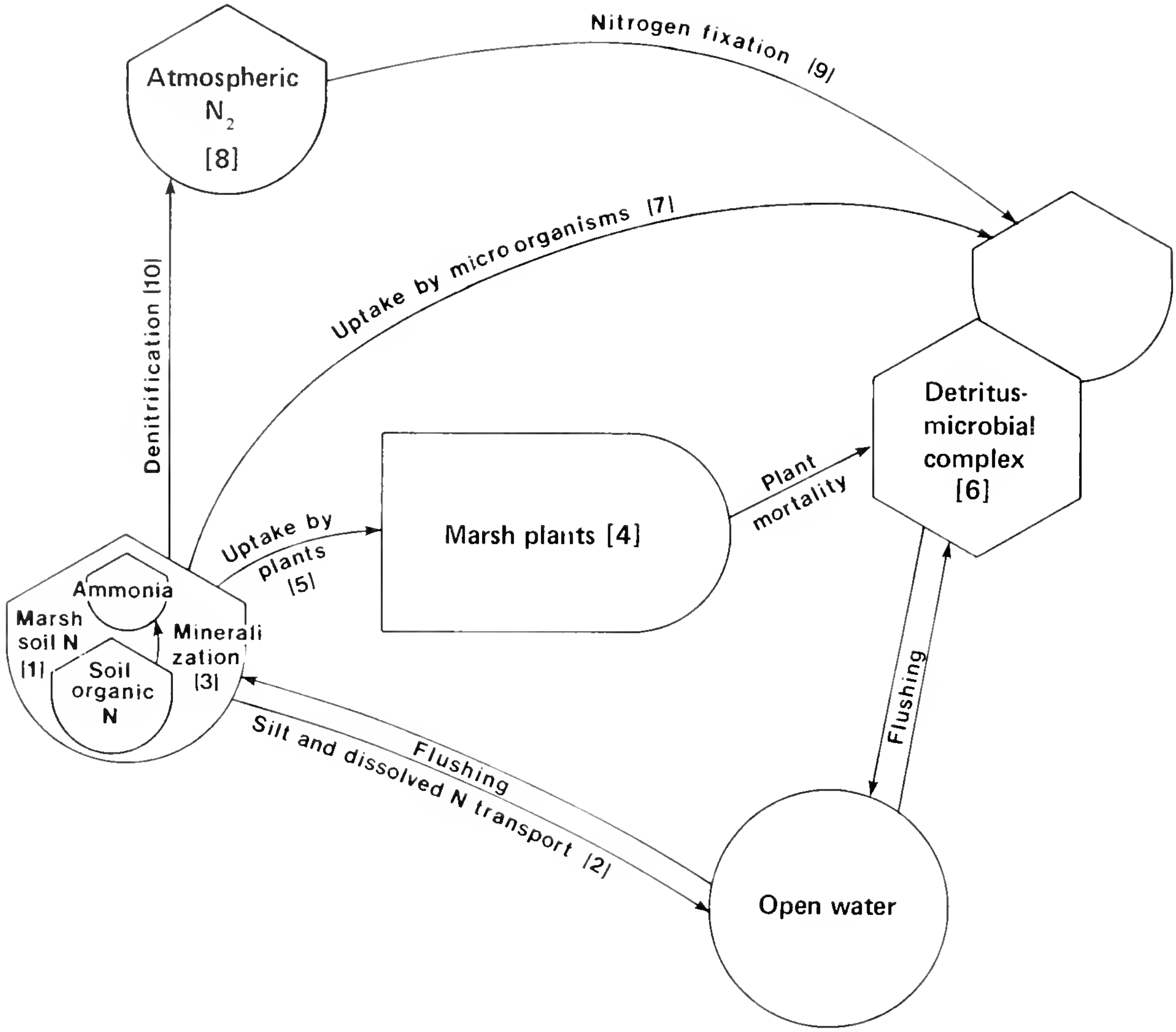


Figure 4-9. A model of the marsh nitrogen (N) cycle showing the major stores of N and interrelated processes (Hopkinson and Day 1977).

the total nitrogen supply (Valiela and Teal 1972). Normally, the growth rate of marsh grasses seems to be limited by the rate at which organic nitrogen in the sediment can be oxidized into ammonia (3). As this is a relatively slow process, the addition of inorganic nitrate or ammonia to the marsh often stimulates growth.

Aside from the nutritional value of specific inorganic elements to marsh plants, the total salt concentration in the root zone exerts a strong influence on plant growth. All of the major salt and brackish marsh plants appear to be inhibited by high salt concentrations. Even though they thrive in a moderately saline environment, growth is more vigorous for the same species in soils with lower salt content when competition from other species is eliminated. Thus the dominant species in the salt and brackish marsh habitats are not there because they are stimulated by the salt solution in which they grow, but because they tolerate moderately saline conditions better than fresh marsh species. This has been demonstrated by a number of individuals (Phleger 1971, Seneca 1972, Parrondo et al. 1977) whose results are shown in figure 4-10. Fresh marsh vegetation is particularly susceptible to salt intrusion since these species seem to be intolerant of even low salt levels.

The role of severe storms in the control of vegetation has often been ignored because of the difficulty of documentation. Hurricanes that strike the Chenier Plain are sufficiently intense to cause considerable short- and long-term changes in wetlands. The immediate effects have been difficult to ascertain. Day et al. (1977) reported that Hurricane Carmen in 1974 defoliated swamp forests in its path two months earlier than normal leaf fall. A large amount of organic carbon, nitrogen, and phosphorus was flushed from the swamp to the lower estuary (fresh, brackish, and salt marshes) by the accompanying torrential rains. Part of this material undoubtedly resulted from the early defoliation, but much visual evidence points to thorough flushing of stored detritus from the swamp floor which would not wash out under normal weather conditions. Short-term effects of Hurricane Camille on species composition in fresh and brackish marshes

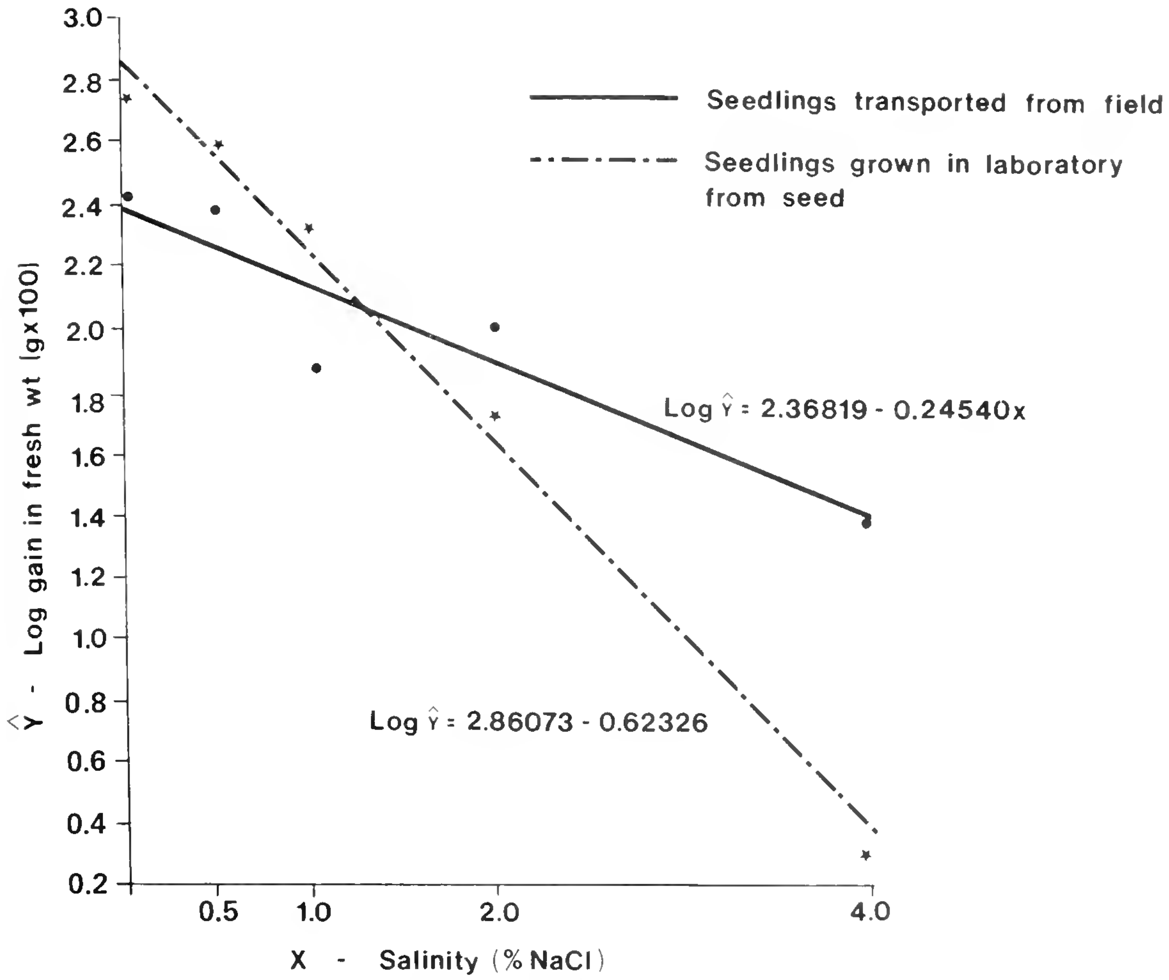


Figure 4-10. The inhibitive effect of salt on growth of saltmeadow cordgrass (Seneca 1972).

near the mouth of the Mississippi River were described by Chabreck and Palmisano (1973). They found that although this area was regularly flooded by fresh river water, the increase in salinity caused by the hurricane tide was ephemeral. The major effect of the hurricane seemed to have been widespread destruction of vegetation by wind and water, which uprooted and ripped apart stands of plants. Recovery of most species was rapid so that prehurricane levels of abundance were approached within a year. In the small lakes and ponds, however, the submerged and floating vegetation was slow to recover. Valentine (1977) described a long-term effect of Hurricane Audrey (1957) in sawgrass marshes of the Chenier Plain, apparently caused by increased soil salinity. Sediment salts became concentrated first directly from hurricane tides, then secondarily from the dry summers following. Initially, 161,874 ha (400,000 a) of sawgrass marshes were killed. The following year 86% of this area was open water. During the 1960, '62, '63, and '65 drought years, annual grasses and sedges became abundant. By 1972 bulltongue occupied 74% of the area and white water-lily occupied 11%. Other floating and submerged aquatics were also common. Sawgrass never reestablished itself in any extensive areas, perhaps because seed viability was very low. Secondary effects of these vegetation changes on duck food habits were dramatic. Prior to 1959 sawgrass seeds were an important component of duck diets. In the years immediately following the hurricane, duck stomachs contained primarily rice seeds, indicating heavy dependence on agricultural areas outside of the Chenier Plain. During succeeding drought years, when the marshes produced large quantities of annual grass seeds, large numbers of both ducks and geese were attracted to these habitats.

Seasonal Dynamics of Organic Production and Loss from Wetlands. Although each plant species has its own seasonal growth pattern, smooth cordgrass has been extensively studied and data from this species is used to show a typical wetland seasonal pattern of organic production, mortality, and export (fig. 4-11). Smooth cordgrass maintains a year-round growth rate of about 8 $g/m^2/day$ (Hopkinson et al. 1977). Mortality during spring and summer is low so that the

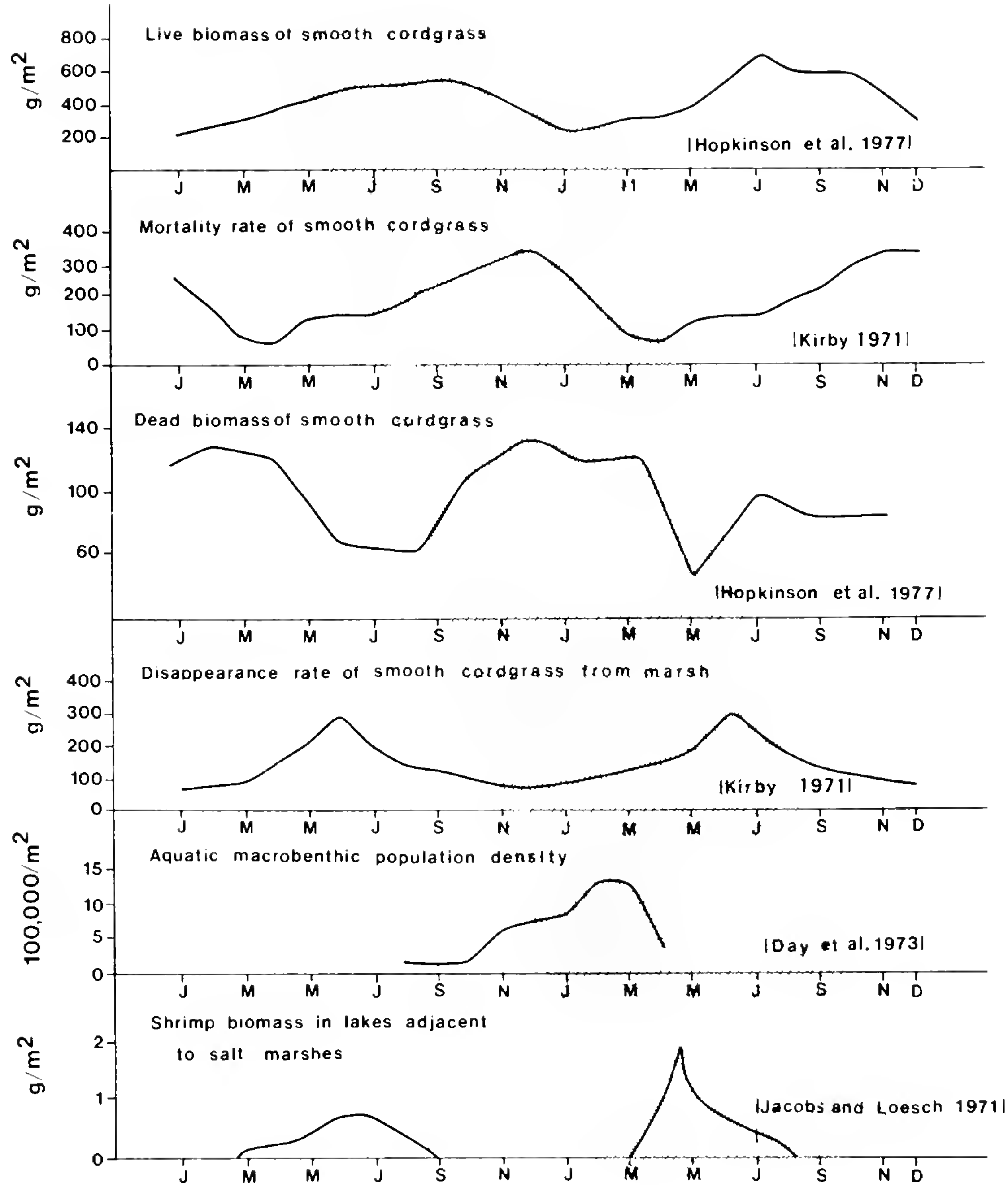


Figure 4-11. The seasonal flow of organic matter through the food chain (Turner 1977).

plant biomass increases to a maximum of about 700 g/m^2 in late August and September. Flowering begins at this time and subsequently most of the plants die, reducing the biomass to about 200 g/m^2 in January. As a consequence of winter senescence, the amount of dead grass increases rapidly to a peak in late winter. This material is broken down during the following spring and summer, and much of it is swept out of the marsh, as shown by the high rate of disappearance of detritus during April to July. The timing of the detritus pulse from the marsh corresponds with the arrival of migrating species from offshore such as shrimp that find a ready supply of food (Odum 1967). Thus plants produced in one year became available to consumers the following spring.

Energy Budget of Wetlands. The organic energy budget of an ecosystem accounts for the amount of organic energy fixed in plants by photosynthesis and the relative energy demand by different consumers. Unfortunately, detailed energy budgets have been constructed for very few ecosystems. In wetlands, only salt marsh budgets are well documented (Teal 1962, Day et al. 1973). Nevertheless, quantitative energy budgets for wetland habitats in Louisiana (fig. 4-12) have been estimated and give some indication of the relative importance of different wetland processes.

The following generalizations are drawn from these diagrams:

1. Direct grazing consumes a small proportion of plant production, although that proportion increases from salt to fresh marsh habitats as the diversity of grazers increases.
2. Consumer species of commercial interest probably directly consume much less than 1% of net primary production.
3. Most of the organic matter produced by the system (something over 90%) is processed through a detrital system (part 4.2.4).
4. A major proportion of primary production is respired to carbon dioxide by benthic and epiphytic organisms, primarily microbial.
5. Export and deposition of organic materials in marsh sediment are inversely related and together account for 20 to 40% of primary production. Export predominates where flushing action is strong; deposition where it is weak. In the swamp forest habitat a major portion of production is accumulated as wood.

4.2.4 THE DETRITUS-MICROBIAL COMPLEX

In wetland habitats little of the total plant production is consumed by grazers. Instead, plants die and the resulting detritus is modified by microorganisms before being consumed by other animals. In effect, the microorganisms are the first consumers in the detrital food web. Microorganisms feed on the lignins and cellulose of the dead plants, converting these compounds into microbial proteins, fats, and sugars (fig. 4-13).

During the process of enrichment, many small consumers ingest the detrital material, skim off the nutritious microorganisms, and egest the undigestible plant remains. These are recolonized and the process repeated (fig. 4-14; Fenchel 1970). This is true whether the detritus lies on the marsh surface or is carried by flood waters into adjacent water bodies.

Metabolic Rates. Part of the organic matter ingested by microorganisms is used to fuel their metabolic processes and is lost as heat. Estimates of this heat loss are summarized by Payne (1970), who concluded that a minimum of 40% of food energy is converted to heat during growth of the microorganisms. Gosselink and Kirby (1974) reported that conversion efficiencies of smooth cordgrass detritus to microbial biomass in laboratory cultures were as high as 60%, but in actual marsh conditions it was thought that a more realistic conversion rate was about 25%. The conversion efficiency varies, depending on the degree of aeration of the marsh surface, the flushing regime, the inorganic nitrogen available to the decomposers, and other factors. On the average, however, for every 4 g (0.14 oz) of detrital food assimilated by a consumer, some 3 g (0.11 oz) are lost as heat.

Although no data are available for other wetland habitats, Day et al. (1977) found that the total annual metabolic loss (benthic respiration) in salt marshes in Louisiana was about 600 to 718 g/m^2, while Teal (1962) found that the annual loss to microbial respiration was only 730 g/m^2 in a Georgia salt marsh.

Role of Benthic Organisms. Although microorganisms are the first to colonize the dead plant tissue, other benthic organisms are probably more important in breaking down this matter to fine particulate detritus. For instance, Fenchel (1970) showed that the degradation rate in marine turtlegrass beds was greatly increased when the leaves were exposed to amphipods. Detritus particles may be further reduced by grinding in digestive tracts of crustaceans (Odum et al. 1972). Crayfish are probably very important in breaking down leaf litter in the swamp forest habitat.

Summary. The deep layer of litter on the marsh surface should be recognized as an active biochemical factory (much like a cow's rumen), which transforms nutritionally indigestible cellulose to useful protein. The many small consumers living in this detritus are an important source of protein for animals higher in the food web. Events which impair the ability of these small consumers to transform litter have repercussions throughout the food web. For instance, regular flooding and draining of the marsh stimulates metabolism while continuous flooding results in oxygen depletion and slower decomposition rates (Day et al. unpublished).

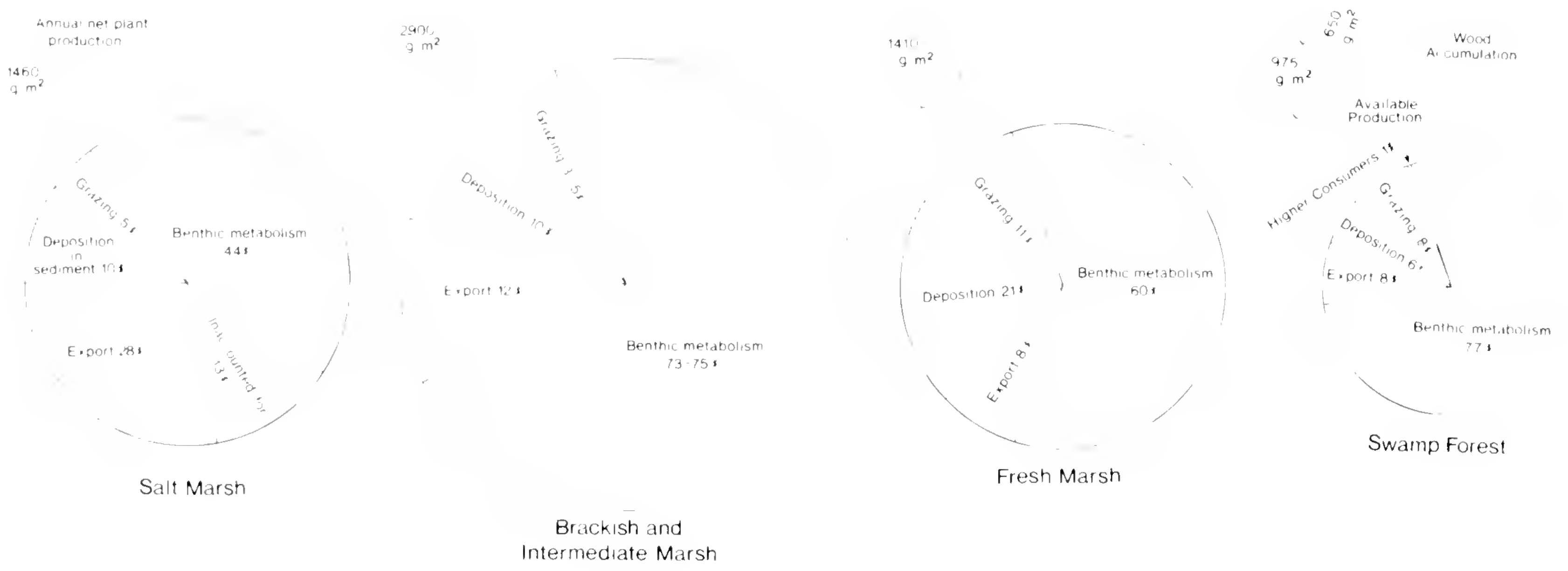


Figure 4-12. Estimated energy budgets of wetland habitats (the circle area is proportional to annual primary production in each habitat).

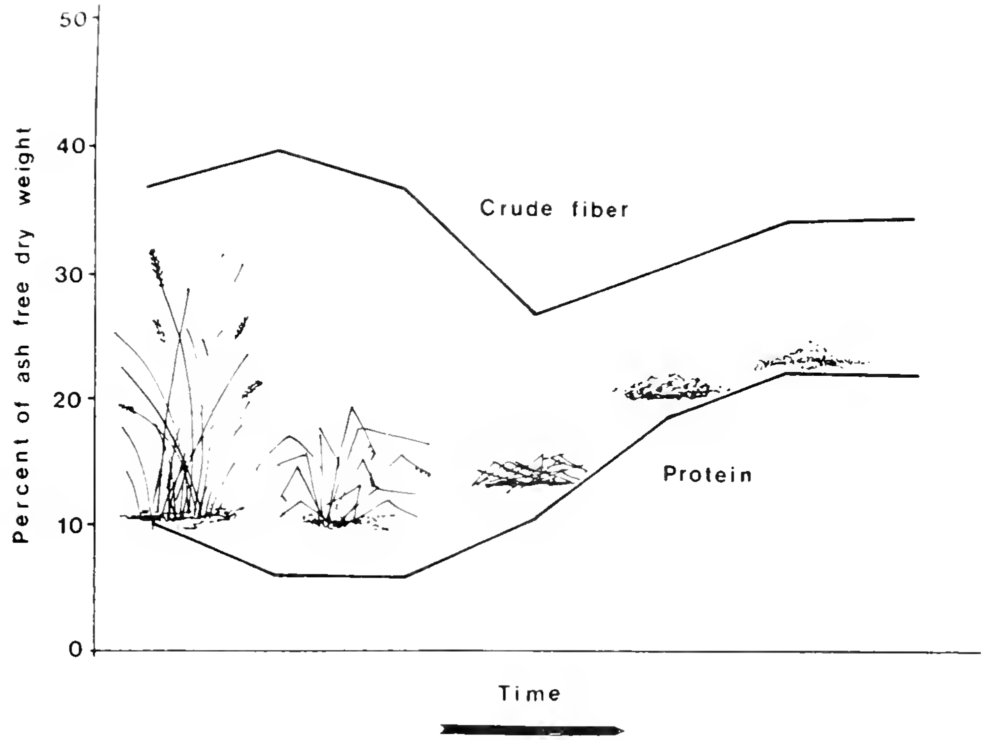


Figure 4-13. The food value of marsh litter as it decomposes. The protein concentration increases with time as the litter is fragmented and crude fiber is decomposed (adapted from Odum and de la Cruz 1967).

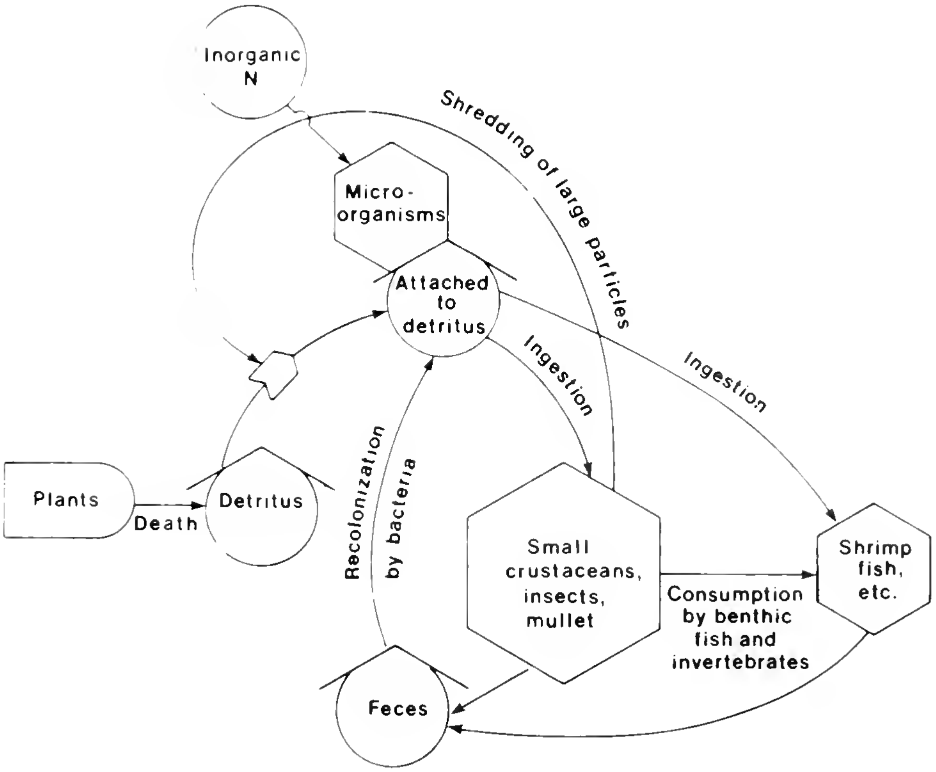


Figure 4-14. The microbial-detritus cycle for an estuary.

4.2.5 THE IMPORTANCE OF THE MARSH EDGE

The extensive interface between the marsh surface and the open water, especially in salt marsh and brackish marsh habitats, is a particularly important area (fig. 4-15). High production and a large biomass of many kinds of plants and animals are characteristic of the water-wetland transition zone. This is illustrated for plants (fig. 4-16) and macrofauna (fig. 4-17) in the marsh. Two features of the interface are particularly important for biota. Detritus carried off the marsh, and nutrients and silt carried onto it by high waters are concentrated near the interface. Thus, food and nutrients are in highest supply there. In addition, the irregular edge, thick plant growth, and eroded, exposed roots all provide protection from predators for many small animals.

The normal branching pattern of sinuous streams in tidal marshes maximizes the marsh edge/surface area ratio and contributes to the productivity of the marsh-estuarine system. In contrast, straight dredged canals with spoil banks on each side have a low edge/surface ratio. The edge present does not function as a normal marsh edge because the deep water on the canal side and the high spoil bank on the landward side prevent the normal exchange of water and organisms.

4.2.6 EXTENDED NURSERY FUNCTION OF WETLANDS

One major characteristic of wetland habitats is their degree of coupling with other habitats. The flooding waters provide a vehicle for passive transfer of nutrients, silt, and organic detritus. In addition to these passive transfers, active migrations of animals occur across habitat boundaries. For some species these movements are closely related to the seasons; for others, to diurnal cycles or to periodic inundation. Since many species are found in wetlands only during their juvenile stages, this role is commonly termed the "nursery function" of wetlands. In fact, use of wetlands by migrating species is much broader than the term "nursery function" indicates, as the following discussion shows.

For centuries man harvested fishes and shellfishes from offshore regions with little appreciation of the nursery role of estuaries. Recently, the importance of wetlands fringing these estuaries has been documented. These wetlands provide a more diverse system than the estuarine areas alone. Flooding waters encourage small fishes and shellfishes to forage into small marsh ponds and channels. Wagner (1973) found extremely high concentrations of small fishes in a marsh pond, as compared to the adjacent open waters

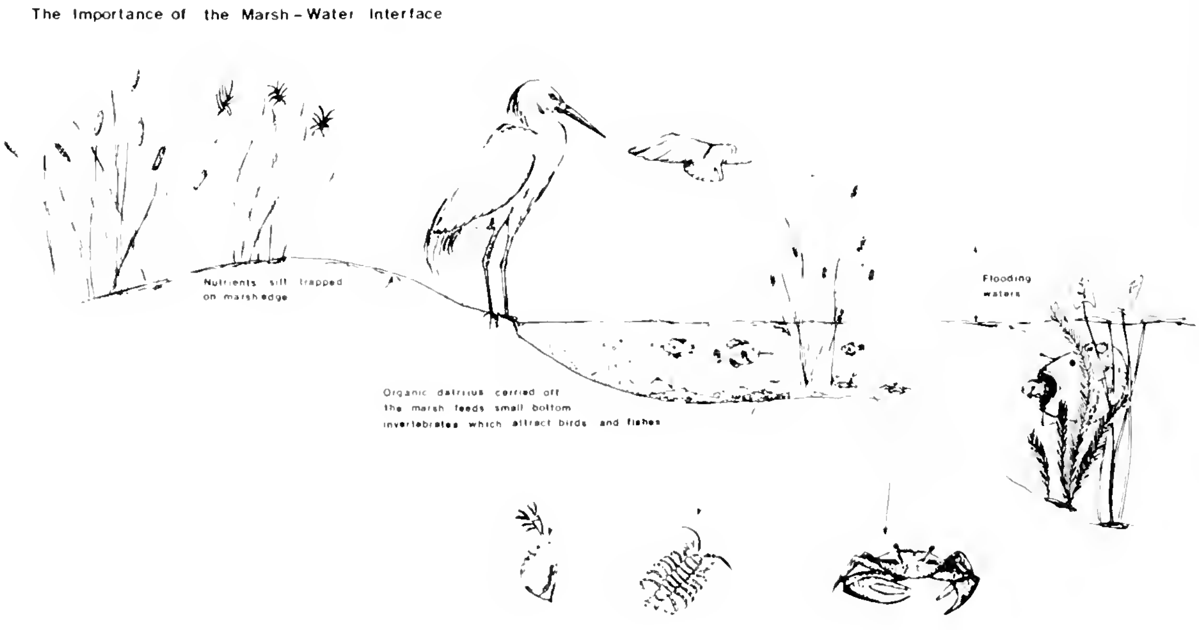


Figure 4-15. Important processes of the marsh-water interface.

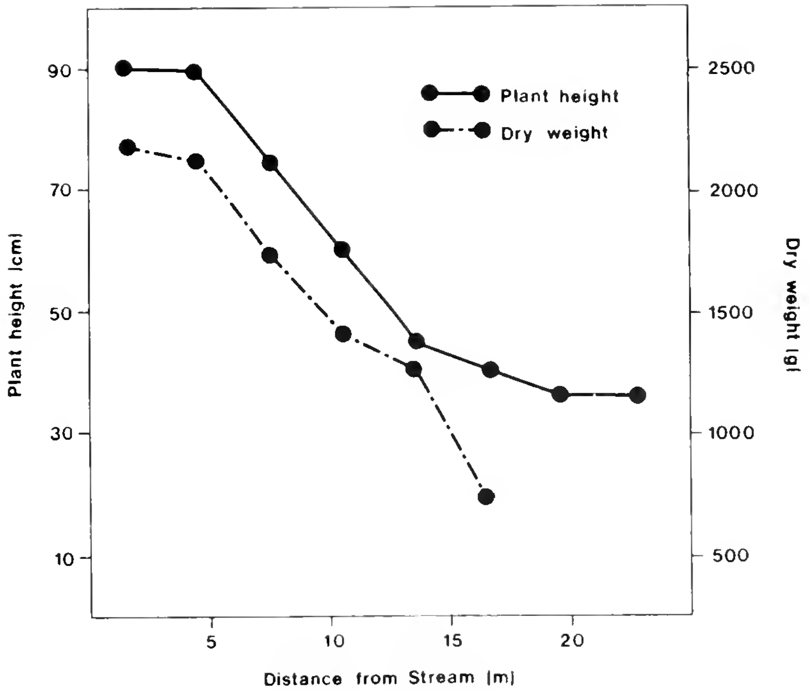


Figure 4-16. Relationship of marsh plant growth and distance of plant from stream edge (De Laune et al. 1976).

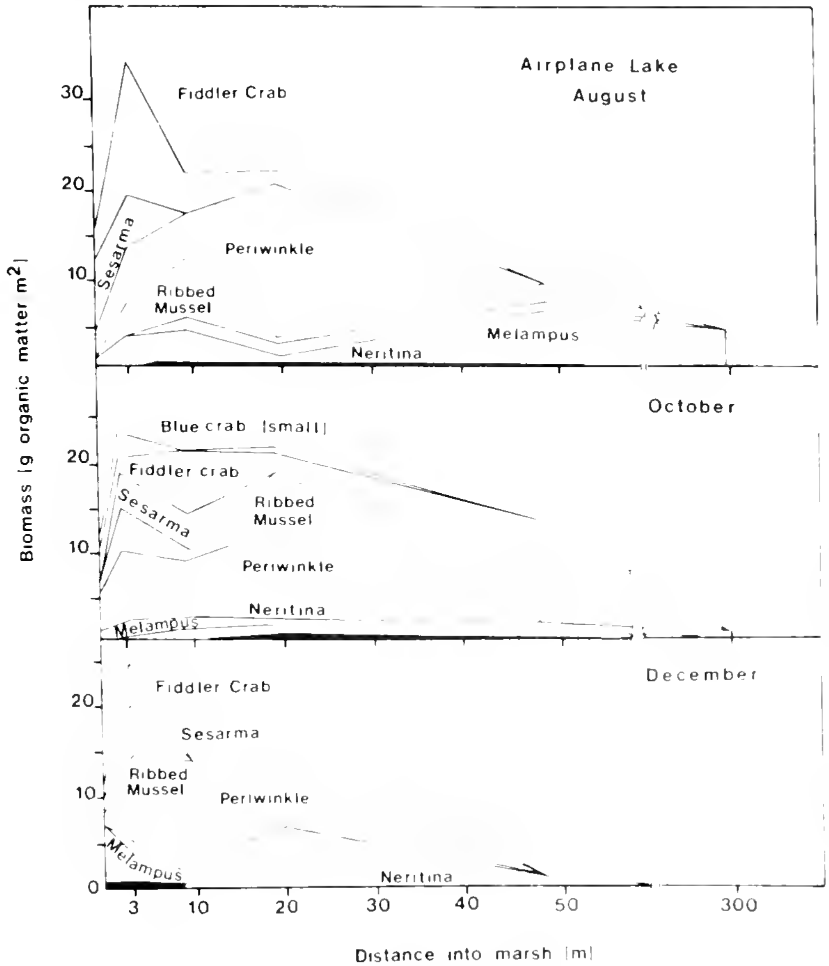


Figure 4-17. Relationship of macroinvertebrate biomass and distance of individuals from marsh-water interface (Day et al. 1973).

(table 4.4), and Butner and Brattstrom (1960) described the migration of killifish into the marshes on tidal cycles. Large redfish are often observed foraging in marsh ponds and tidal creeks so shallow that the dorsal fins of these fishes project out of the water.

In a recent study in southeastern Louisiana, Hinchee (1977) found that small Gulf menhaden, spawned offshore, moved through estuaries into fringing marshes and swamps for several months before they moved out into the estuarine waters as larger fish (fig. 4-18). The habitats used by the juvenile menhaden were fresh marsh and swamp forest habitats, indicating that the nursery function is not confined to saline tidal wetlands.

Table 4.4 Fish biomass in small marsh ponds compared to open estuarine waters of the Caminada Bay system, Louisiana (Wagner 1973).

Area	Fish biomass[a] (g/m^2)
Small enclosed marsh pond	46.1
Small marsh pond with deep channel to bay	13.8
Open water	1-6

[a]Pond fish determined by chemical toxin; fish in open water by trawl, gill net, and trammel net.

Perhaps the most dramatic evidence of the importance of the marsh as a food source and as a refuge for small organisms is the report by Turner (1977a), which showed that the harvest of shrimp is strongly related to the area of estuarine marshland (fig. 4-19). The relationship is much closer than that between shrimp harvest and the area of inland open water. It is also well documented that small shrimp migrate into inland waters and marshes where they pass through the juvenile stage before emigrating to the open Gulf (part 5).

Different bird species use wetlands as a nesting area in summer, as a wintering ground, or as a temporary stopover area during spring and fall migration. Shorebirds, wading birds, and many predatory birds feed in both open water and wetland habitats. The requirements of many such animals for different habitats, at different life history stages, underline the high degree of interaction among coastal communities, and show that the wetland-open water system must be considered and managed as a whole.

4.2.7 CONSUMERS

The previous sections have emphasized processes that are common to all wetlands. In different wetland habitats different species assume the same functional roles. The species that are characteristic of each habitat are discussed more fully in the following sections, but summary tables are included here for perspective.

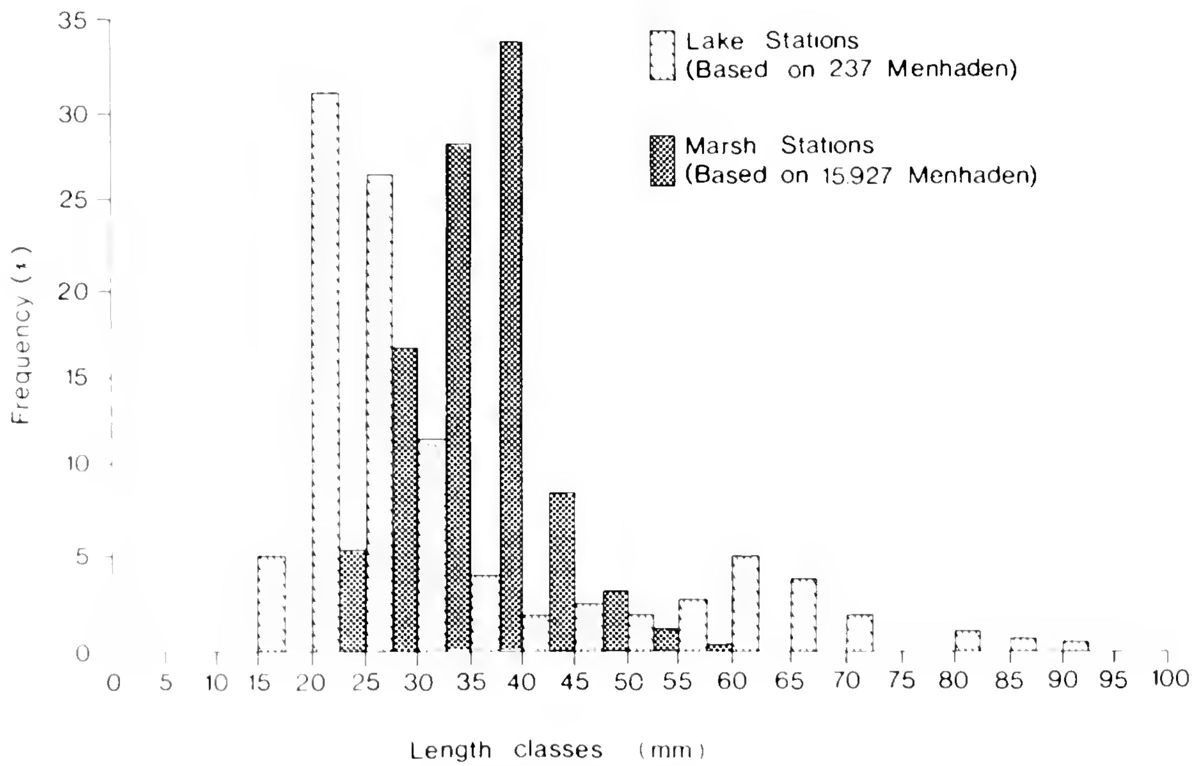


Figure 4-18. Length-frequency distribution of Gulf menhaden at marsh and lake stations in Lake Pontchartrain, Louisiana (Hinchee 1977).

The total number of consumer species reported to use different wetland habitats (table 4.5) generally increases as one moves inland from salt marshes to fresh marshes and is greatest in the swamp forest habitat. This trend probably reflects the decreasing salt stress, especially for mammals, amphibians, and reptiles, and the high niche diversity of the swamp.

4.2.8 NATURAL WETLAND VALUES

Wetlands are valuable to man in a number of ways:

1. Wetlands serve as habitats for birds, furbearers, and other wildlife important for both commerce and recreation. (Species of particular interest, e.g., muskrat, nutria, white-tailed deer, river otter, wading birds, and waterfowl are discussed in part 5).
2. Wetlands serve as nurseries for most fish and shellfish species of commercial and recreational interest. (Shrimp, menhaden, and sportfish are discussed in part 5).
3. Swamp forests are a source of timber particularly cypress which is valuable because of its resistance to decay.
4. Wetlands purify flooding water and buffer adjacent estuaries against large changes in upstream inputs of nutrients and wastes. Wetland sediments can reduce metals and organic toxins in flooding waters (Anonymous 1977). They perform valuable tertiary treatment in urban areas where sewage wastes are discharged into estuaries (Gosselink et al. 1974).
5. Natural wetlands have aesthetic value in addition to commercial and wildlife value.
6. On a global scale wetlands may be important in maintaining and controlling the normal cycles of nitrogen and sulfur (Deevey 1970). Both of these elements require the juxtaposition of oxidized and reduced sediment zones, a condition found in shallow coastal wetlands.
7. Wetlands buffer inlands from the damaging effects of hurricanes and other severe storms. They are significant floodwater reservoirs which reduce flooding in surrounding uplands.
8. Natural wetlands reduce maintenance dredging costs of deep water passes by trapping silt. (Impounded or drained wetlands cannot trap silt.) Additionally, scouring of passes decreases because water currents are reduced as intertidal volume decreases (Coates 1972).

Two factors that have made wetland management and preservation particularly difficult in the Chenier Plain are (1) the monetary return of the renewable resources of wetlands to the private owner is often very small compared to the value of the subsurface minerals; (2) most of the value of the renewable resources of wetlands accrues to society as a whole or some significant portion of it, not to the private owner.

The owner of wetland acreage in the Chenier Plain enjoys direct economic benefits only from trapping and from leasing his land to hunters. The combined actual return for these uses is under \$25/ha/yr (\$10/a/yr) (Robert Chabreck, Pers. Comm., School of Forestry and Wildlife Management, Louisiana State University, Baton Rouge). In contrast, extracted oil and gas may amount to thousands of dollars per acre. Thus, it is often difficult to convince the owner that sound ecological conservation practices are important.

The social value of renewable wetland resources is one to two orders of magnitude greater than the direct value to the private owner. For instance, in contrast to the \$25/ha/yr (\$10/a/yr) the owner might conceivably recover, the commercial and sportfishing value which accrues to another segment of society is around \$250/ha/yr (\$100/a/yr) and the tertiary sewage treatment services to a nearby metropolitan area may be valued at over \$2,500/ha/yr (\$1000/a/yr) (Gosselink et al. 1974).

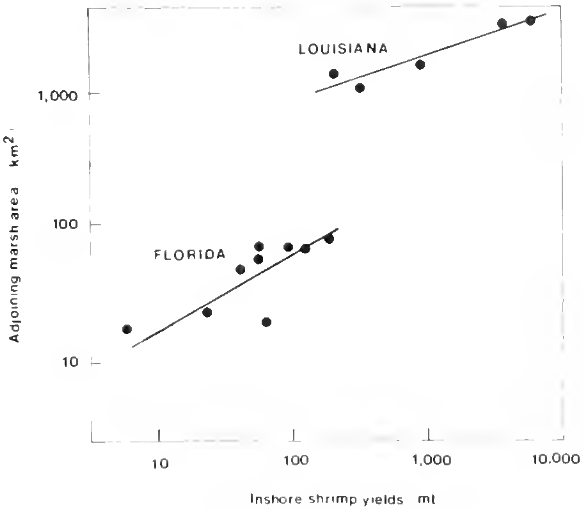


Figure 4-19. The relation of Louisiana and Florida inland shrimp landings to the area of marsh adjoining the estuary in which the shrimp were caught (Turner 1977a).

These two conflicts, between renewable and nonrenewable resources, and between private and public benefits, are the root of most of the environmental problems discussed in part 3. Understanding the way wetlands function, in particular their close coupling with adjacent uplands and estuarine areas and the Gulf of Mexico, and the importance of the integrity of the hydrologic system in a basin is the first step to intelligent management of resources.

4.3 SALT MARSH HABITAT

Salt marshes have been extensively studied and are probably the best understood wetland habitat, yet few studies have been conducted on the narrow salt marsh zone of the Chenier Plain. Studies in basins east of the Chenier Plain supply much of the pertinent data by inference.

Salt marsh habitat is not widespread in the Chenier Plain (fig. 4-20). Perhaps this is because the wetlands of this region have been cut off from the direct influence of Gulf waters by a relatively continuous beach and ridge complex. Tidal passes are few compared to the much more open eastern Louisiana subdelta region, and influx of saline waters is correspondingly restricted. As a consequence most of the inland wetlands are brackish to fresh, rather than saline.

Salt marsh habitats are, for the most part, a high-energy wetland habitat in the Chenier Plain. Tidal inundation is frequent, and sometimes occurs as often as twice a day. Compared to many salt marshes, salinities are rather low (about 12‰) with characteristically large daily and seasonal variability. Salinities are highest during late summer when rainfall is low and Gulf water levels are high (part 3.3). Conversely, during spring floods fresh water from overflowing rivers freshens the salt marsh.

4.3.1 PRODUCERS

Of the wetland habitats, the salt marsh supports the smallest number of plant species (table 4.6). In the Chenier Plain, saltgrass is the dominant species, while smooth cordgrass, blackrush, and saltmeadow cordgrass make up a smaller percentage of the total plant composition. The sea ox-eye daisy is found only at elevations above normal tidal action (spoil banks, for instance) and the saltwort, a halophyte, prefers highly saline sediments and grows in the upper reach of the tide where storms carry in salt, which is then concentrated by evaporation. Alligatorweed and bull-tongue are found at the interfaces with lower salinity marshes.

Table 4.7 shows estimated annual production for salt marshes in Louisiana to be about 2,200 g/m^2. This is extremely high production compared to most natural ecosystems. Epiphytes and benthic algae are also abundant (appendix 6.3). Primary productivity of epiphytes and benthic algae has not been measured in the Chenier Plain region, but Stowe (1972) determined seasonal rates for epiphytes on smooth cordgrass in Barataria Bay, Louisiana (appendix 6.3). His data indicate a net production peak during summer months and a minimum during winter months. However, absolute production levels were not high; gross production was 27 $g/m^2/yr$ for an inland community and 104 $g/m^2/yr$ along a stream bank. Over the year, respiration of the inland community exceeded production by a factor of three, showing that the epiphyte community is not self-sustaining, but depends on other organic sources in the marsh. Recent gas flux measurements indicate that production by the microbial components of a smooth cordgrass community was as much as 9% of the total community photosynthesis during the winter but less than 5% in the summer (Gosselink et al. in press). Emergent plants produce the bulk of the energy upon which animals of the salt marsh habitat depend.

Table 4.5 Numbers of vertebrate consumer species reported to use the different wetland habitats.

	Wetland habitat types					
Consumer species[a]	Salt	Brackish	Intermediate	Fresh	Swamp forest	Impounded
Amphibians	0	5	6	18	19	16
Reptiles	4	16	16	24	32	28
Birds						
Winter	44	40	43	40	23	59
Summer (feeding)	15	17	16	18	36	21
Year-round	19	15	16	14	11	6
Transients	22	17	16	16	15	1
Mammals	8	11	11	14	25	14
Total	112	121	124	144	161	145

[a]Many of these species use both marsh and open water habitats; many require large ranges for day to day movement and seasonal foraging for food.

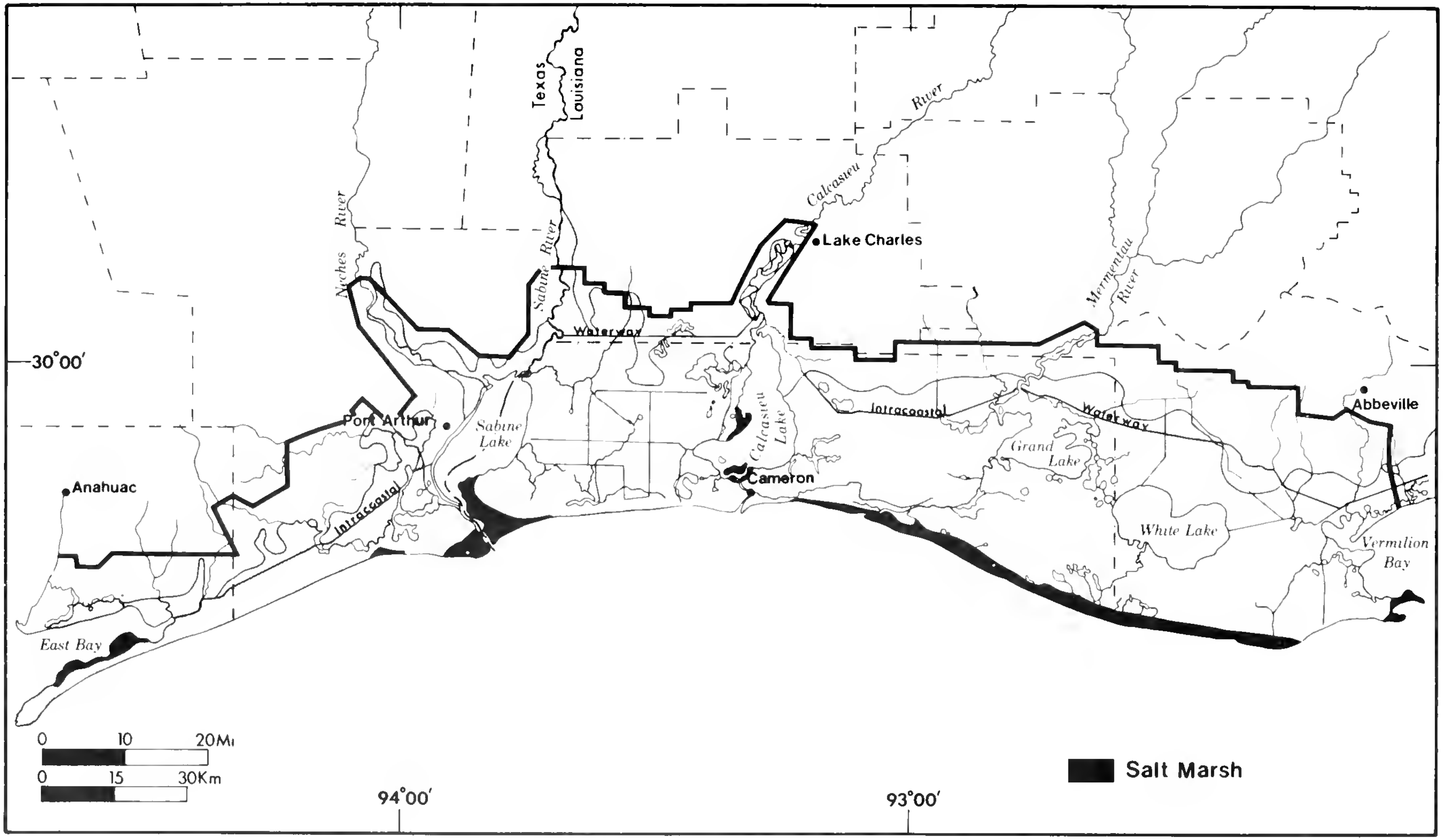


Figure 4-20. Distribution of salt marsh habitat in the Chenier Plain.

Table 4.6. Plant species present and their percent coverage in the salt marsh habitat in the Louisiana portion of the Chenier Plain by basin (Chabreck 1972).

Common name	Basin				
	Sabine	Calcasieu	Mermentau	Vermilion	Chenier
Saltgrass	32.50	70.00	- - -	- - -	50.63
Saltwort	25.00	- - -	- - -	13.33	- - -
Smooth cordgrass	22.50	16.67	- - -	20.00	7.50
Gulf cordgrass	1.00	- - -	- - -	- - -	- - -
Saltmarsh bulrush	- - -	- - -	- - -	13.33	5.00
Saltmeadow cordgrass	- - -	- - -	- - -	- - -	5.00
Sea ox-eye daisy	- - -	- - -	- - -	6.67	3.75
Alligatorweed	- - -	- - -	- - -	- - -	1.88
Bulltongue	- - -	- - -	- - -	- - -	1.88
Giant bulrush	- - -	- - -	- - -	- - -	1.88
Salt matrimony vine	- - -	- - -	- - -	- - -	1.25
Glasswort	- - -	- - -	- - -	- - -	1.25
Blackrush	- - -	- - -	- - -	20.00	- - -
Open[a]	19.00	13.33	- - -	26.67	20.00

[a]No plants.

Table 4.7 Estimated net primary production per square meter for the salt marsh habitat. Total net primary production is calculated as $\sum_1^n$ (percent coverage times net primary primary production)for n species.

Species	Net primary production ($g/m^2/yr$)	Coverage[a] (%)	Contribution to habitat net primary production ($g/m^2/yr$)
Saltgrass	2,900[b]	44.23	1,283
Smooth cord-grass	2,200[b]	12.31	270
Saltmeadow cordgrass	4,200[b]	3.08	129
Blackrush	3,300[b]	2.31	76
Alligatorweed	3,140[c]	1.15	36
Bulltongue	2,300[b]	1.15	26
Other[d]	- - -	15.92	451
Open area	- - -	19.85	- - -
Total net primary production			2,271

[a]Chabreck 1972

[b]Gosselink et al. 1977

[c]Boyd 1969

[d]Productivity assumed to be equal to the average for other species in the habitat

4.3.2 CONSUMERS

Less than 10% of the emergent vegetation of salt marshes is directly grazed (Smalley 1959). As in all wetlands, most consumers are detritus eaters. A list of the dominant species is included in appendix 6.3. Homopterans (leafhoppers), Orthopterans (grasshoppers), Dipterans (flies), and some Hemiptera (true bugs) are the major grazing insects of the salt marsh habitat. In one of the few studies of grazing insects in salt marshes, Smalley (1959, 1960) concluded that leafhoppers assimilated more than 6% of the annual primary production of smooth cordgrass in a Georgia salt marsh, while grasshoppers assimilated less than 1%.

Of the remaining primary consumers, most ingest a combination of detritus and epiphytic or benthic algae. Marsh snails (*Littorina irrorata*) are important detritivores that may ingest as much as 12% of the annual net production of smooth cordgrass, mostly as detritus, and are undoubtedly important animals at this trophic level (Alexander 1977).

Bacterial populations in salt marshes vary seasonally around 10^7 cells/g (2.83×10^8 cells/oz) of sediment. Hood and Meyers (1976) found that the bacteria are concentrated at the interface between the marsh and adjacent streams. These workers isolated 30 forms of bacteria from salt marshes, a low diversity compared to freshwater habitats. Of all the heterotrophic types isolated, 19% were found to be proteolytic, 1% cellulose degraders, and 10% chitinoclastic. Predominant genera were *Bacillus, Vibrio, Pseudomonas,* and *Achromobacter.*

Meiofauna and small macrobenthic forms are also important primary consumers in salt marsh sediments. These include such groups as copepods, amphipods, polychaetes, mites, insect larvae, and nematodes (appendix 6.3). Feeding habits of the latter group are not clear, since some nematodes feed on protozoa and some are strictly detritivores. The total amount of organic material ingested by nematodes is undoubtedly significant, since these minute animals commonly occur in six-figure densities in one square meter (10.8 ft^2) of marsh surface. The complex trophic relationships of the benthic community are discussed more completely in part 4.8, Aquatic Habitats.

The saline conditions of the salt marsh are hostile to many organisms which inhabit other marsh habitats. Nevertheless, most of the predatory species which use the salt marsh as a feeding ground include the same general forms and the same species that are found in intermediate and brackish marsh habitats. Spiders, insects, birds, and mammals are included in this category. Amphibians, with their highly permeable skin, seem to have no mechanisms for combating the drying effect of salt, and are not represented. Only four species of reptiles, including the American alligator, Mobile cooter, diamondback terrapin, and the Gulf salt marsh snake are found in this habitat (appendix 6.3).

Aquatic species such as the Gulf menhaden, shrimp, and blue crab use salt marsh extensively during high water periods, as do many small fishes such as killifish that have no direct economic importance. Organic materials transferred from marshes to the open Gulf by these latter species may be significant.

Spiders are reported to be the principal carnivores in smooth cordgrass communities (Marples and Odum 1964), outnumbering carnivorous insects (Barnes 1953; Davis and Gray 1966). Many parasitic insect pests inhabit the salt marsh habitat. Early discussions by Hine (1904, 1906) indicate that biting or sucking flies were abundant in Louisiana salt marshes at the turn of the century, causing damage to livestock. Wilson and Richardson (1969) mention that horseflies and deerflies are among the most damaging groups of insects that attack livestock in estuarine and alluvial areas of the state. Besides being irritants to livestock, they are known vectors of anaplasmosis, an infectious disease of cattle. Cattle, horses, deer, and rabbits are the only major hosts attacked by them. Birds, reptiles, and smaller mammals are apparently not essential hosts. Mosquitoes and other pests feed mostly on cattle, rabbits, and horses; other mammals, birds, and amphibians are rarely attacked (Schaefer and Steelman 1969).

Marsh alterations influence the populations of these invertebrates. Dukes et al. (1974a) found tabanid larvae in North Carolina salt marshes most abundant where living plants maintain uniform moisture conditions. Bailey (1948) observed that Massachusetts salt marshes that were ditched to control mosquitoes had greater expanses of suitable larvae habitats than natural marshes which were subject to drying and flooding. Additional studies of tabanid larvae (Duke et al. 1974b) in North Carolina indicate that as mixed vegetation increases, and smooth cordgrass decreases, the numbers of larvae decline. Thus, uniform stands of smooth cordgrass contain the greatest numbers of tabanidae. No comparative study in Louisiana's marshes has been made.

Species richness of birds in the salt marsh may not be as high as indicated (appendix 6.3), since most seabirds and wading birds primarily utilize areas peripheral to salt marshes. Population densities of waterfowl species are also generally low in this habitat (part 5).

Predation by mammals in the salt marsh is exemplified by the raccoon which feeds on practically anything, including fiddler crabs, snails, rail eggs, and plant material. Other mammalian consumers include the Virginia opossum, nine-banded armadillo, swamp rabbit, marsh rice rat, muskrat, and Nearctic river otter.

4.4 BRACKISH AND INTERMEDIATE MARSH HABITATS

Brackish and intermediate marsh habitats in the Chenier Plain probably serve the same function as salt marsh habitat in other coastal regions. This is because the area of salt marsh in the Chenier Plain is small relative to the areas of brackish and intermediate marshes. The estuarine water bodies along this coast are usually edged by brackish to fresh marshes; and at least in some areas (e.g., Galveston Bay, Texas, Parker 1965; Lake Pontchartrain, Louisiana, Hinchee 1977), these marshes are known to act as nurseries for migratory fishes and shellfishes. Figure 4-21 shows the distribution of brackish and intermediate marshes. They are the dominant wetlands in every basin except the Mermentau, which is nearly all fresh marsh habitat.

Unlike the fresh and salt marshes which are fairly distinct, the intermediate and brackish vegetation types overlap and boundaries are often diffuse transition zones. For this reason, and because the two habitats are similar, they are discussed together.

A broad band of brackish marsh habitat crosses the entire state of Louisiana. This marsh zone is the most extensive and productive of all wetland types. It also seems to be the most vulnerable to loss since the brackish marsh habitat is eroding and becoming open water at an alarming rate statewide (Craig and Day 1977).

The brackish marsh habitat has lower average salinities than salt marsh (5.1‰ compared to 12.4‰), but salinity varies widely and may reach 13‰ (Chabreck 1972). Tidal water level fluctuation is attenuated but present, and storm surges periodically raise water levels and increase salinities. However, sustained winds are probably the most important factor in marsh flooding (part 3.3). During periods of heavy rainfall, these marshes are flushed with fresh water. These conditions seem to favor the production of large amounts of organic matter, much of which is deposited in sediments to form peat.

The intermediate marsh habitat supports a transitional community of organisms which includes both marine and freshwater forms. Salinities average 2.2‰, but sometimes reach 6‰ (Chabreck 1972). Flushing frequency in the intermediate marsh habitat is reduced compared to that in salt marsh habitat, while peat production probably reaches a maximum in this environment.

4.4.1 PRODUCERS

The most common plant in the brackish and intermediate marshes is saltmeadow cordgrass. Vegetation in the intermediate marsh habitat is more diverse than that in the brackish marsh habitat (tables 4.8 and 4.9), probably because of the presence of a number of fresh marsh species such as bulltongue and common reed that can survive occasional flooding with brackish water. There is much open area in both marsh types with as much as 20 to 40% of the area being unvegetated.

Almost nothing is known about the primary productivity in brackish and intermediate marshes. No production studies of these marsh types include the Chenier Plain region. Annual production of saltmeadow cordgrass is the highest reported for any vascular plant in this country (Gosselink et al. 1977). Using production figures from a number of studies and the percent occurrence of each species, production in intermediate and brackish marshes was estimated to be about 2,800 $g/m^2/yr$ (tables 4.10 and 4.11).

Because winters are mild, growth occurs actively throughout the year and dramatic seasonal changes in standing crop do not result. Similarly, mortality occurs throughout the year, providing detrital consumers, waterfowl, and furbearers a ready food supply.

Large mats of dead grass accumulate in marshes dominated by saltmeadow cordgrass. These mats tend to smother other plant species and increase the dominance of saltmeadow cordgrass, which is not used extensively by waterfowl and furbearers. Management techniques such as marsh burning and water level control have been developed to maximize production of desirable plants for wildlife such as widgeongrass and Olney's three-corner grass. These techniques are discussed in part 4.7, Management of Chenier Plain Coastal Wetlands.

4.4.2 CONSUMERS

The brackish marsh habitat is the most saline area in which amphibians occur in appreciable numbers. Reptiles are represented by 16 species, fewer than in fresh marsh habitat, but four times more than in salt marsh areas. Some 79 bird species have been identified in the brackish marsh habitat, mostly migrants; but 16 species are year-round residents. The 11 species of mammals include several important furbearers and the endangered red wolf.

Intermediate marsh habitat has a vertebrate species richness almost identical to that for the brackish marsh. This similarity is, at least in part, because vertebrate species apparently do not distinguish between these two habitats. Among amphibians, the dwarf salamander probably reaches its gulfward limit within the intermediate marsh zone. The diamondback terrapin and Gulf salt marsh snake occur in the brackish marshes, while the stinkpot, Graham's water snake, and the garter snake are found in intermediate marshes. Among birds found in brackish marshes, the reddish egret, clapper rail, and great-tailed grackle rarely, if ever, inhabit intermediate marsh. The hooded merganser, common yellowthroat, and swamp sparrow, on the other hand, are found in intermediate marsh but seldom in brackish areas. Appendix 6.3 contains a list of representative vertebrates of the intermediate and brackish marsh habitats.

Herbivores and Detritivores. The size of the microbial population may be larger in brackish and intermediate marshes than in salt marshes. Benthic species richness (the majority of detritivores), however, is lowest in the brackish marsh habitat. Nematodes are abundant in sediments across the coast and may make up about 60% of the total number of animals found at the edges of brackish marshes. Polychaetes (segmented worms) are also abundant and represent a major food item for many predaceous finfishes and other carnivores. Ostracods and amphipods are also abundant (Farlow 1976, Thomas 1976).

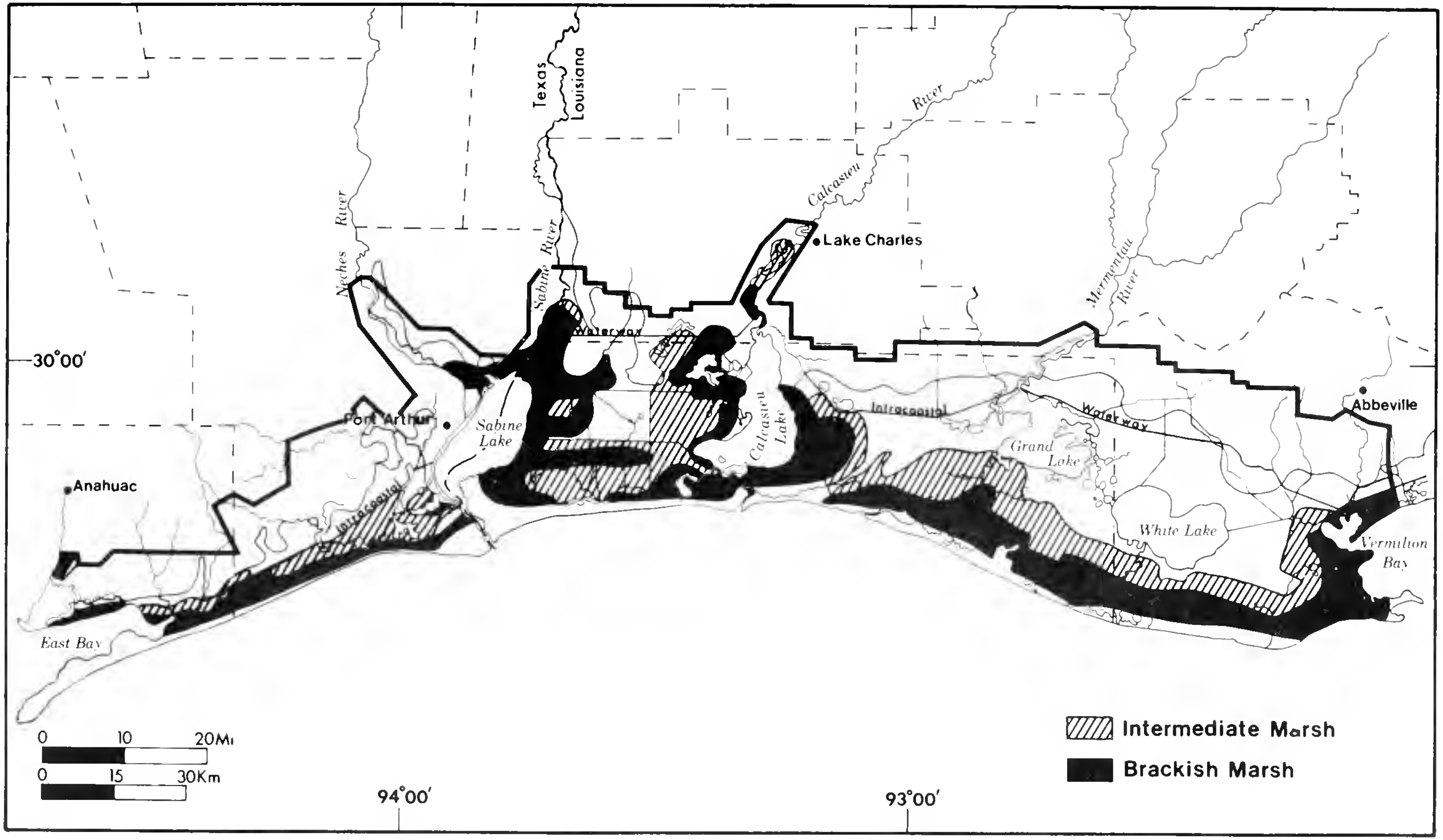


Figure 4-21. Distribution of brackish and intermediate marsh habitats in the Chenier Plain.

Table 4.8. Plant species present and their percent coverage for the intermediate marsh habitat in the Louisiana Portion of the Chenier Plain, by basin (Chabreck 1972).

Common Name	Basin				
	Sabine	Calcasieu	Mermentau	Vermilion	Chenier
Saltmeadow cordgrass	28.89	33.56	41.05	33.00	22.34
Muskgrass	8.25	3.13	---	---	---
Seashore paspalum	7.14	10.00	2.11	---	7.87
Giant bulrush	6.03	---	---	---	---
Olney's three-corner grass	2.86	5.63	---	---	---
Bulltongue	2.79	2.81	---	7.33	2.34
Sprangletop	2.76	---	1.58	---	2.34
Gulf cordgrass	1.59	---	---	---	1.28
Water hyssop	1.17	---	7.37	5.33	1.91
Common reed	---	5.94	---	3.00	5.96
Alligatorweed	---	4.06	---	---	8.30
Southern water hemp	---	2.19	---	---	---
Colorado River hemp	---	2.19	---	---	---
White water-lily	---	1.25	---	---	---
Walter's millet	---	---	---	8.33	5.53
Three-square bulrush	---	---	---	---	4.68
Flat sedge	---	---	5.79	2.00	3.83
Camphor-weed	---	---	---	1.00	2.47
Disc water-hyssop	---	---	---	---	1.70
Deer pea	---	---	---	1.00	1.49
Marsh purslane	---	---	3.68	---	1.49
Blue hyssop	---	---	3.16	---	---
Common water nymph	---	---	2.63	---	---
Saltgrass	---	---	2.11	---	---
Mudbank paspalum	---	---	1.05	3.33	---
Switchgrass	---	---	---	8.33	---
Morning glory	---	---	---	4.33	---
Blackrush	---	---	---	2.67	---
Other[a]	6.11	3.38	1.58	0.67	5.11
Open[b]	32.41	25.87	27.89	19.67	21.36

[a]Includes those plants covering less than 1% of the area.

[b]No plants.

Table 4.9 Plant species present and their percent coverage for the brackish marsh habitat in the Louisiana portion of the Chenier Plain by basin (Chabreck 1972).

	Basin				
Common name	Sabine	Calcasieu	Mermentau	Vermilion	Chenier
Saltmeadow cordgrass	26.33	35.28	---	49.11	37.08
Widgeongrass	6.73	10.00	---	2.67	---
Saltgrass	6.20	7.36	---	4.44	18.73
Olney's three-corner grass	6.08	1.06	---	7.78	---
Water hyssop	5.51	---	---	---	---
Seashore paspalum	4.41	3.58	---	2.22	---
Gulf cordgrass	1.63	---	---	---	---
Saltmarsh bulrush	1.02	1.25	---	1.33	2.89
Dwarf spikerush	1.02	---	---	---	3.81
Groundselbush	---	1.13	---	---	---
Walter's millet	---	---	---	---	1.43
Big cordgrass	---	---	---	---	1.43
Blackrush	---	---	---	2.89	---
Flat sedge	---	---	---	1.33	---
Roundleaf bacopa	---	---	---	1.33	---
Other[a]	3.59	1.13	---	2.00	5.30
Open[b]	37.47	39.21	---	24.89	29.33

[a]Includes those plants covering less than 1% of the area.

[b]No plants.

Table 4.10 Estimated net primary production per square meter for intermediate marsh habitat. Total net primary production is calculated as Σ_1^n (percent coverage age times net primary production) for n species.

Species	Net primary production (g/m²/yr)	Coverage[a] (%)	Contribution to total net primary production (g/m²/yr)
Saltmeadow cordgrass	4,200[b]	29.92	1,257
Bulltongue	2,300[b]	3.17	73
Common reed	2,400[b]	3.14	75
Alligatorweed	3,140[c]	2.72	85
Other[d]	---	34.90	1,335
Open area	---	26.35	---
Total net primary production			2,825

[a]Chabreck 1972

[b]Gosselink et al. 1977

[c]Boyd 1969

[d]Productivity assumed to be equal to the average for other species in the habitat.

Table 4.11. Estimated net primary production per square meter for brackish marsh habitat. Total net primary production is calculated as Σ_1^n (percent coverage times net primary production) for n species.

Species	Net primary production (g/m²/yr)	Coverage[a] (%)	Contribution to total habitat net primary production (g/m²/yr)
Saltmeadow cordgrass	4,200[b]	36.70	1,541
Widgeon-grass	5,840[c]	4.67	273
Saltgrass	2,900[b]	9.88	287
Other[d]	---	15.81	655
Open area	---	32.77	---
Total net primary production			2,756

[a]Chabreck 1972

[b]Gosselink et al. 1977

[c]Nixon and Oviatt 1973

[d]Productivity assumed to be equal to the average for other species in the habitat.

Insects are usually considered major consumers in all wetland habitats. No study has been made to verify this in the Chenier Plain region, but Farlow (1976) included data on insect diversity and density in Cameron Parish. Major herbivore-detritivore species that were collected included water scavenger beetles (*Hydrophilidae*) and weevils (*Curculionidae*).

Brackish and intermediate marsh habitats are important nursery areas for shrimp and Gulf menhaden. Herbivorous waterfowl, including the dabbling ducks that are prized by hunters, prefer intermediate marshes for feeding grounds, but also use brackish and fresh marshes extensively. Diving ducks are also found in brackish marshes and represent the most numerous group of waterfowl that over winters in the Chenier Plain.

Muskrats are herbivores that prefer brackish marshes to other habitat types (part 5). They are an important node in the food web of the marsh system, being preyed upon by the alligator, various snakes, hawks, and the mink.

Carnivores. Marsh birds in brackish and intermediate marsh habitats become extremely numerous during spring and summer. Wading birds seem to have a prominent role among the predators, obtaining their food from water bodies within the marsh. This group includes various egrets, herons, bitterns, and ibises. Some of these birds have an extremely varied diet and will eat practically any small animal. Dabbling ducks, which are primarily herbivorous, reach their greatest densities in the intermediate marsh habitat (part 5).

At least ten species of predaceous water beetles (Dytisicidae) are found in the intermediate marshes of the Chenier Plain. Of these, *Hygrotus* spp. and *Cybister fimbriolatus* are the most common (Farlow 1976). Dragonflies are highly predaceous, and several species prefer the intermediate marshes (Bick 1957), but their numbers decrease in the more saline areas. The most common insect collected by Farlow (1976) in intermediate marshes was the biting midge (Heleidae).

4.5 FRESH MARSH HABITAT

The broad band of fresh marsh extending across the Chenier Plain (fig. 4-22) is one of the major waterfowl habitats of the Gulf coast. The region's high rainfall and abundant freshwater flow from upstream, coupled with the continuous beach ridge barrier against saltwater encroachment, combine to make this broad expanse of freshwater wetlands.

Water levels in Louisiana freshwater marshes are controlled more by upstream flows, rainfall, and the direction of prevailing winds than by tidal effects. The total annual inundation time does not vary much across different marsh habitats, but the frequency of inundation (a measure of marsh flushing) is lowest in the freshwater areas. As a consequence much of the organic production of the emergent plants accumulates in place. This often gives rise to floating marshes, called "flotants." Flotants consist of a diverse mat of vegetation supported by organic detritus several feet thick held together by a matrix of living roots. This floating marsh is indistinguishable from other wetlands until trod upon. It often extends the true shoreline out into shallow adjacent lakes, forming a new shoreline and shrinking the lake. This kind of growth does not occur extensively in more energetic hydrologic regimes.

Because freshwater marsh sediments are waterlogged and poorly flushed, anoxic conditions are probably more severe in this habitat than in others. In more saline marshes, sulfate from seawater is reduced to sulfide, donating its oxygen for biological respiration. In fresh marshes sulfate availability is much lower. In the absence of sulfates, carbonates and carbon dioxide act as oxygen donors, with resulting methane formation.

4.5.1 PRODUCERS

The richness of the emergent flora increases dramatically in fresh marsh habitat (table 4.12), compared to more saline areas (Chabreck 1972). Maidencane is the dominant true fresh marsh plant species and it is seldom found in other wetland habitats. The ubiquitous saltmeadow cordgrass also flourishes here. Bulltongue and alligatorweed are common in this habitat, as well as in the intermediate marsh habitat.

Alligatorweed is an introduced species that has reached pest proportions. It grows in shallow marsh ponds and on the edges of bayous and sheltered lakes, as well as on the wetland surface. Recently, the alligatorweed flea beetle (*Agasicles hygrophila*) was introduced as a means of biologically controlling alligatorweed; it has apparently succeeded in holding this plant in check in certain areas (Don Lee, Louisiana Department of Wildlife and Fisheries, unpublished data).

One common plant association in the fresh marsh habitat is the maidencane association, which typically includes water hyacinth, duckweed, water lettuce, smartweed, bulltongue, soft-stem bulrush, and cattail as minor components. The number of such associations is greatest in the fresh marsh (Gosselink et al. 1976). This increased plant diversity is due, in part, to the presence of annuals. Brackish and salt marsh habitats are dominated by perennials, which form stable communities that change relatively little from year to year. In contrast, fresh marshes support a large number of annual grasses. The seed of some of these germinate in the spring and others in the fall. Most require a bare moist soil for germination. The dominant annual at a single location, therefore, often changes from season to season and from year to year, depending on the degree of competition from perennials and on marsh water levels during germination periods.

Little is known about the productivity of fresh marsh emergent plants. Whigham et al. (1978) have cataloged production from freshwater tidal wetlands

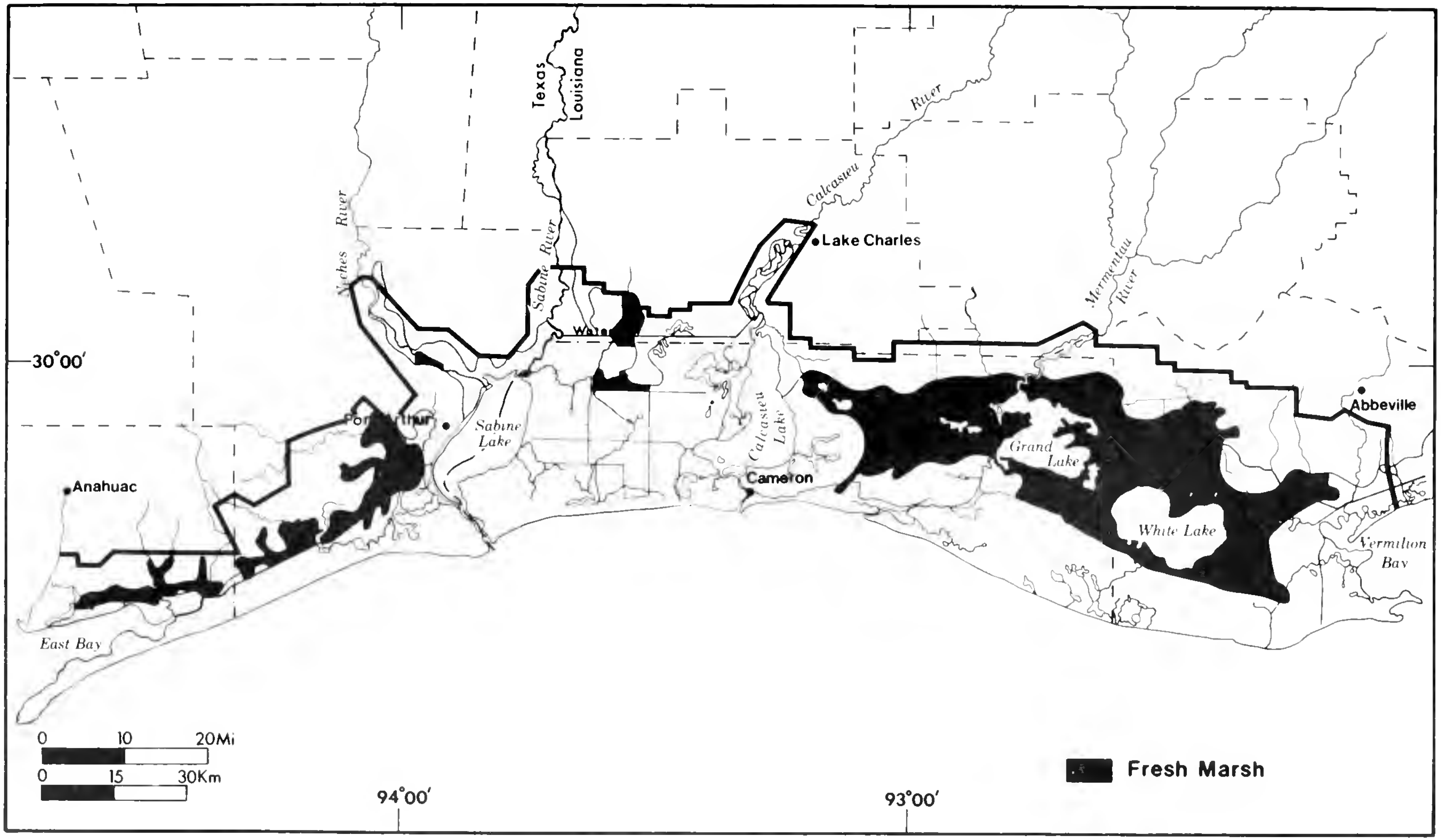


Figure 4-22. Distribution of fresh marsh habitat in the Chenier Plain.

Table 4.12. Plant species present and their percent coverage for the fresh marsh habitat in the Louisiana portion of the Chenier Plain by basin (Chabreck 1972).

Common name	Basin				
	Sabine	Calcasieu	Mermentau	Vermilion	Chenier
Bulltongue	21.00	---	19.30	22.40	8.26
Alligatorweed	11.00	20.00	5.88	---	14.78
Spikerush	8.00	1.67	4.67	3.60	---
Coontail	7.50	---	---	---	4.78
White water-lily	6.00	---	4.18	---	---
Horned bladderwort	4.00	---	3.76	---	---
Giant bulrush	3.00	3.33	---	---	1.74
Spiderlily	2.00	---	---	---	---
Maidencane	2.00	---	13.86	2.80	---
Slender pondweed	2.00	---	---	---	---
Soft rush	2.00	---	---	---	---
Seashore paspalum	---	9.67	---	---	---
Southern naiad	---	5.00	2.15	---	6.52
Bermuda grass	---	5.00	---	---	---
Walter's millet	---	3.67	---	1.6	1.30
Saltgrass	---	3.33	---	---	---
Water hyssop	---	2.50	---	---	---
Rattle bush	---	1.67	---	---	---
Smartweed	---	1.67	---	---	---
Saltmeadow cordgrass	---	13.33	3.17	26.00	22.61
Flat sedge	---	---	---	---	3.48
Three-square bulrush	---	---	---	---	3.48
Delta duck-potato	---	---	---	---	3.48
Muskgrass	---	---	3.65	---	---
Fanwort	---	---	2.36	---	---
Water-shield	---	---	2.20	---	---
Pondnut	---	---	1.56	---	---
Willow primrose	---	---	1.50	---	---
Sensitive joint vetch	---	---	1.18	---	---
Blackrush	---	---	---	12.4	---
Mudbank paspalum	---	---	---	3.2	---
Umbrella pennywort	---	---	---	2.4	---
Switchgrass	---	---	---	2.4	---
Bagscale	---	---	---	1.6	---
Other[a]	1.0	---	8.76	2.40	1.74
Open[b]	30.5	29.17	21.82	19.20	27.83

[a] Includes those plants covering less than 1% of the area.

[b] No plants.

in many locations and report that they can be as productive as salt marshes. An estimate of net primary production for fresh marshes in Louisiana, based on the measured productivity of selected plants is reported in table 4.13. The estimate of 2,200 $g/m^2/yr$ must be considered tentative. It is similar to the estimate for salt marsh and slightly less than the estimates for brackish and intermediate marshes.

In fresh and intermediate marshes, succulent broad-leaved plants like bulltongue dominate some areas. The leaves of these plants are shortlived; they die and decompose rapidly. These habitats are usually devoid of vegetation throughout the winter with little accumulation of organic detritus.

Table 4.13. Estimated net primary production per square meter for the fresh marsh habitat. Total net primary production is calculated as the $\sum_1^n$ (percent coverage times net primary production) for n species.

Species	Net primary production (g/m^2yr)	Coverage[a] (%)	Contribution to total net primary production ($g/m^2/yr$)
Bulltongue	2,300[b]	17.90	412
Alligator-weed	3,140[c]	4.19	131
Saltmeadow cordgrass	4,200[b]	7.21	302
Blackrush	3,300[b]	1.31	43
Other	---	---	1,344
Open	---	23.08	---
Total net primary production			2,232

[a]Chabreck 1972
[b]Gosselink et al. 1977
[c]Boyd 1969
[d]Productivity assumed to be equal to the average for other species in the habitat.

Epiphytic and epibenthic algae also occur in the fresh marsh habitat, but no information about their importance in the Chenier Plain marshes is available. Many of the same species, especially the large filamentous forms, are common in adjacent open waters (part 4.9).

4.5.2 CONSUMERS

Salt stress is reduced in the fresh marsh habitat and amphibian and reptilian species richness is greater than that for more saline habitats (appendix 6.3). Most reptiles live on elevated areas, including levees and spoil banks, rather than in the marsh proper. Bird species diversity is high and is generally comparable to that for other marsh habitats. The same species of mammals that use the intermediate and brackish marsh habitats are found in fresh marsh habitat. The nutria is the most abundant large herbivore in fresh marsh areas.

Insects are important functional components of freshwater wetlands, assuming many of the roles played by crustaceans in more saline environments. In a bulltongue community in southeastern Louisiana, Louton and Bouchard (1976) identified 40 insect taxa. The grazing pressure that these invertebrates put on marsh vegetation is not known, but studies by Hine (1904, 1906) indicated that insects caused considerable damage to marsh grasses in the Cameron area of southwestern Louisiana.

Amphipods and isopods are thought to be major consumers among the aquatic arthropods, which shred and ingest detritus fragments (appendix 6.3). As in other wetlands, bacteria and fungi are responsible for metabolic conversion of most of this detritus. Hood and Meyers (1976) isolated more bacterial types from fresh marshes than from more saline ones.

Practically nothing is known about either herbivorous or carnivorous (or parasitic) insects in marshes, although the density of biting flies and mosquitoes in some marsh areas makes them very important to man. Dragonflies and robberflies prey on all flying insects, including bees and wasps (Wright 1946). Their impact on the fly, mosquito, and gnat population is significant. Wright (1946) showed correlations between dragonfly populations and the swarming of mosquitoes and dog flies along the Florida coast. However, he further concluded that no effective control of these pest insects is accomplished due to their large numbers and the short life-cycle of the dragonfly (Wright 1946). Parasitism of Tabanid (horsefly) eggs by parasitic wasps, which reaches levels greater than 50% in the early summer, is also another factor which controls the number of flies in southern Louisiana (Jackson and Wilson 1966).

Aquatic predaceous insects are also significant in controlling mosquitoes and gnats. Beetles (Dytiscidae) have been singled out by several workers to have the best potential as aquatic insect predators (Bay 1974). When concentrated in small pools, dytiscid and hydrophilid larvae are important in killing mosquito larvae (Bay 1967). Hemiptera, the true bugs, are also effective in controlling mosquitos. Bay (1967) studied backswimmers (*Notonecta unfasciata*) that completely prevented emergence of mosquitos in field-situated tubs. Water scorpions (Nepidae) and giant waterbugs (Belostomatidae) will attack tadpoles, fishes, crayfishes, and salamanders. All of these insect groups are found in the fresh marshes and ponds of the Chenier Plain. Those predatory insects which are functionally most important, however, are the species which help to maintain a check on such grazing species as weevils and grasshoppers.

4.6 SWAMP FOREST HABITAT

A swamp is classically defined as a woody community where the soil is saturated or covered with water for one or more months of the growing season. Functionally, swamp forests are similar to marshes, although the woody vegetation in swamps gives it an added dimension of diversity and function not found in other wetlands. In the Chenier Plain region, the swamp forest habitat is not very common, occurring only among the upper floodplain regions of major streams (fig. 4-23). Two types of wetland forest are included in this habitat definition. One, the baldcypress-water tupelo forest, is the true swamp forest which tends to be flooded during most of the year. The other type is the alluvial forest which is flooded seasonally when river discharge is high. It grades from stands of baldcypress and tupelo to bottomland hardwood, and it is often characterized by rapidly growing pioneer species such as the black willow.

4.6.1 PRODUCERS

In the swamp forest system, there are several categories of plants, including trees, vines, and herbs. True swamp forests, in addition to baldcypress and tupelo, contain Drummond red maple, pumpkin ash, and a number of woody shrubs, such as Virginia willow and buttonbush. In the slightly drier areas, a more diverse community of swamp maple, tupelo, boxelder, cottonwood, and black willow is found. Along the natural levees of streams, sweet gum, overcup oak, bitter pecan, persimmon, hackberry, and cherrybark oak grow. The more common species of the swamp and bottomland hardwood forests are listed in Table 4.14. This information covers southeastern Louisiana, since no studies are available from the Chenier Plain. A more complete listing of trees, shrubs, vines, and herbs characteristic of the swamp forest habitat is given in appendix 6.3.

Table 4.14. Tree species found in swamp forests and bottomland hardwood forests in southeastern Louisiana (Conner and Day 1976).

Common name	
Drummond red maple	Deciduous holly
Tupelo	Bitternut hickory
Boxelder	Shumard red oak
Swamp cottonwood	Sweetgum
Baldcypress	Swamp privet
Rough-leaf dogwood	Nuttall oak
Black willow	Swamp red bay
American elm	Mock orange
Shagbark hickory	Laurel oak
Pumpkin ash	Elderberry
Water oak	Buttonbush
Hackberry	Carolina ash
Persimmon	

The most abundant forms of nonwoody vegetation in the swamp forest are climbing vines. Poison ivy, trumpet creeper, greenbriar, and peppervine are only a few of the types found.

Ferns and lichens are also common. Lichens are important in the fixation of atmospheric nitrogen. Herbs are not abundant on the swamp forest floor because of the long periods of inundation and the reduction of light by the forest canopy. In areas where flooding is infrequent the understory is more developed.

Seasonal flooding, as compared to continuous inundation with standing water, provides optimum conditions for tree growth and survival in the swamp forest habitat (Conner and Day 1976). For instance, in one greenhouse experiment, black-gum and tupelo seedlings grew better in tanks which had flowing water than did seedlings in tanks with stagnant water (Harms 1973). In another investigation, Broadfoot and Williston (1973) reported that diameter growth of principal tree species in a Mississippi swamp was 50 to 100% greater in flood years. They also reported that impoundment of rainwater from December to June increased hardwood diameter growth 25 to 90% depending on the species. These examples amplify the importance of the flooding requirement.

Primary production is lower in the swamp forest habitat than in marsh habitats, but in contrast to other wetlands, organic matter is accumulated in tree trunks and branches. Net primary productivity in a baldcypress-tupelo forest and in a bottomland hardwood forest in southeastern Louisiana have been calculated to be 1,140 and 1,574 g dry wt/m^2/yr, respectively (Conner and Day 1976). Of this, approximately one-half went into woody tissue. Some of the leaves, twigs, and herbs are consumed directly, but most fall onto the forest floor as organic litter, which is consumed through the detrital system (fig. 4-24).

Hurricanes have been a factor in the Louisiana coastal systems for thousands of years. Strong winds and heavy rains that are associated with hurricanes can cause early defoliation. Figure 4-24 shows an early litterfall peak in September 1973 that resulted from Hurricane Carmen (Day et al. 1977). A large pulse of organic carbon, nitrogen, and phosphorus was flushed downstream out of the swamp after the hurricane.

Timber Production. Cypress and tupelo logging was the first forest industry in Louisiana and has been, historically, the main reason for the high value put on swamp forests. However, information on logging of the virgin swamplands is virtually nonexistent (Norgress 1947, Mancil 1972). As early as the 1700's, some lumber was being shipped out of Louisiana, but it was not until 1890 that the boom in lumbering began. During the early phase of lumbering, logging was restricted to the lands adjacent to waterways. In the Chenier Plain, logs were floated down the Calcasieu and Sabine rivers. Lake Charles, in fact, became the

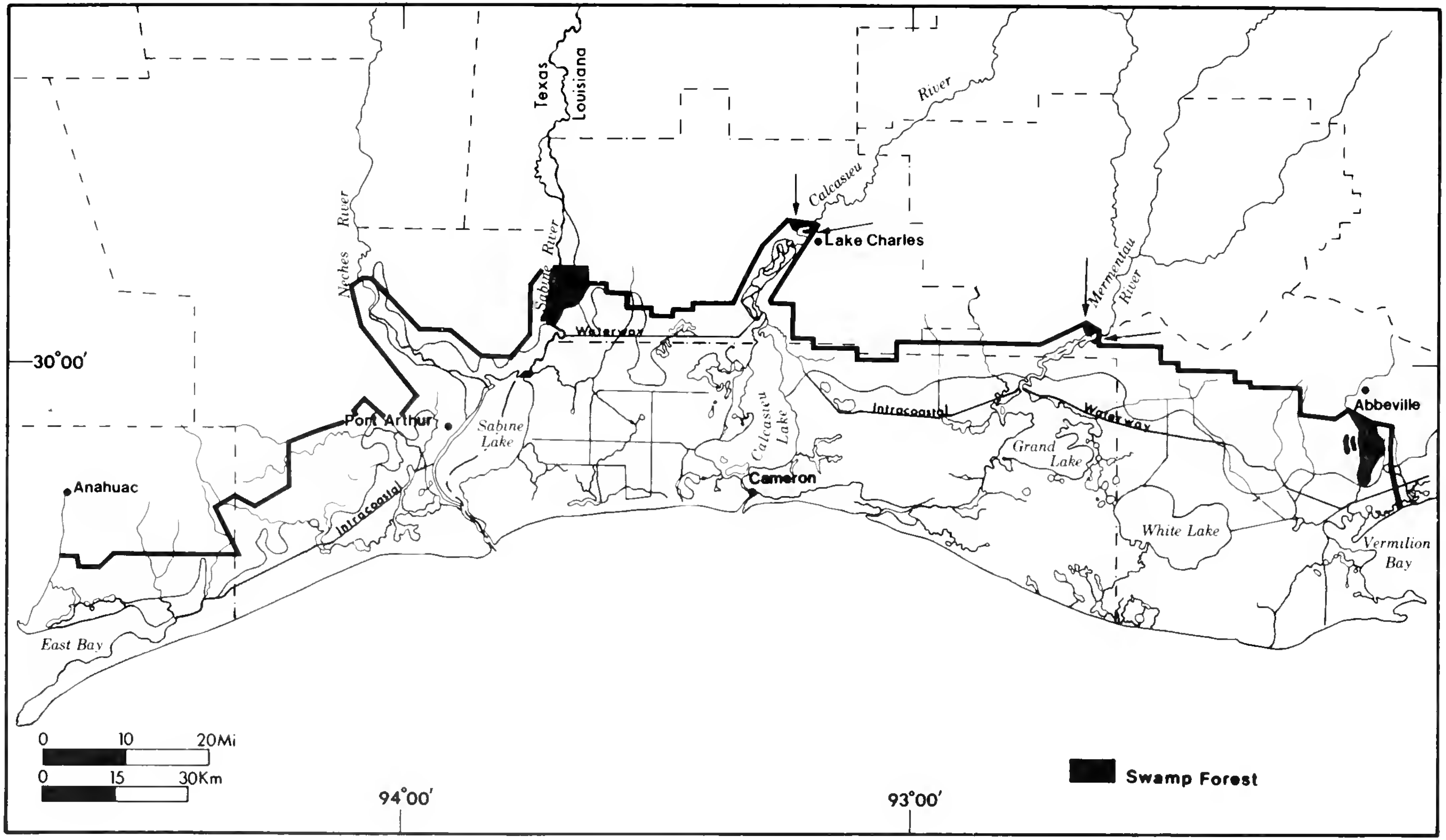


Figure 4-23. Distribution of swamp forest habitat in the Chenier Plain.

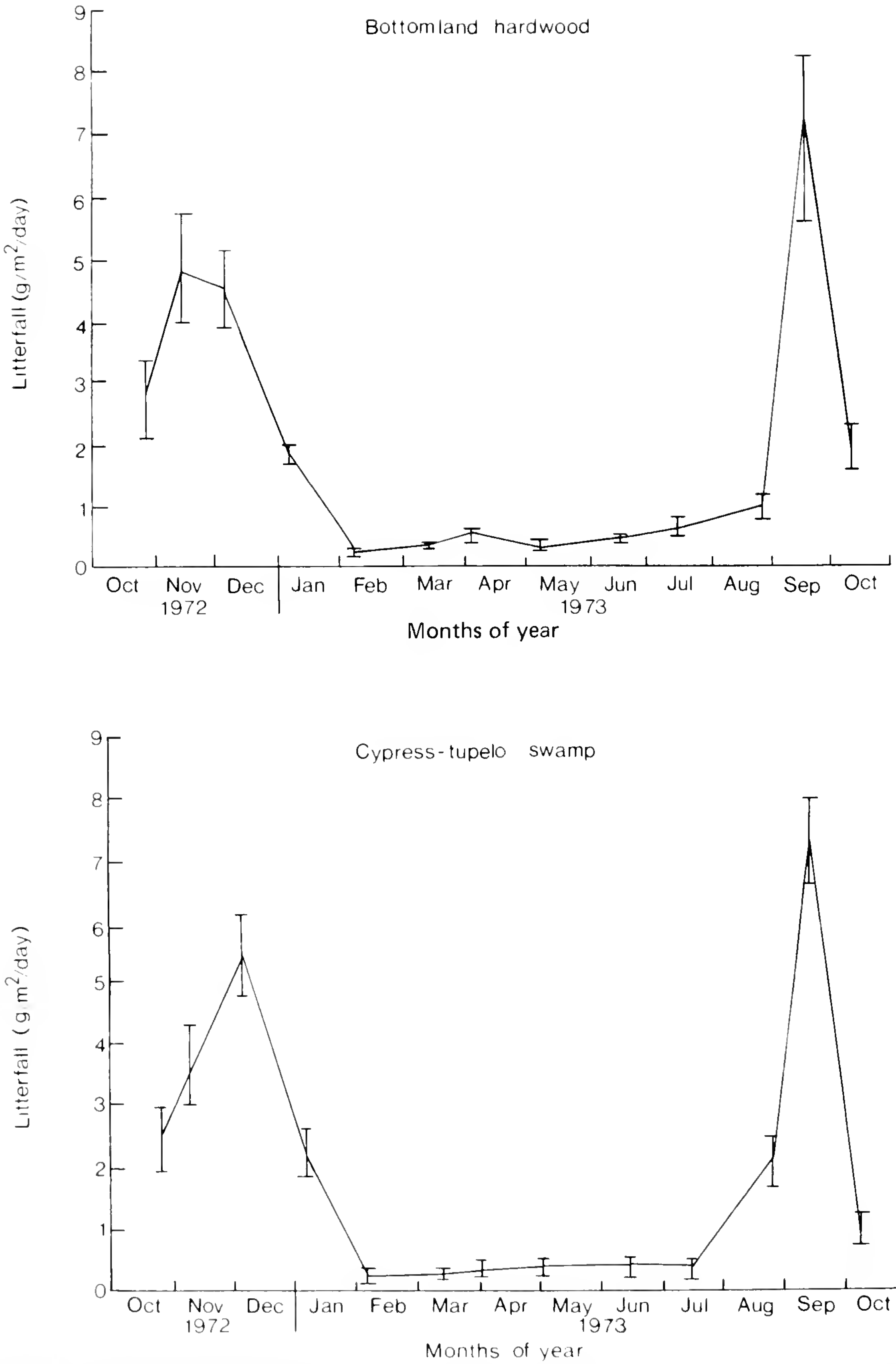


Figure 4-24. Litterfall in a bottomland hardwood forest and in a cypress-tupelo swamp forest in Barataria basin, Louisiana (Day et al. 1977).

first great center of logging and lumbering production in Louisiana (Stokes 1954).

Industrial lumbering was helped by the expansion of the railroad in Louisiana and the introduction of the steam logging engine and pullboat. The problem of timber removal was solved with these inventions. To utilize the new inventions, lumber companies dredged canals to the logging sites. A main canal was 8 to 9 m (25 to 30 ft) wide with access channels cut at right angles from the main channel. Among the access channels pullboats could be set to drag the timber from the swamp to the canal. The result was generally a north to south or east to west patchwork of connecting canals with fanshaped paths radiating outward from the canals (Davis 1975). This pattern can still be detected on aerial photographs. By 1925, virtually all virgin cypress had been removed from the forested swamps of the Chenier Plain.

4.6.2 CONSUMERS

The swamp forest habitat is spatially heterogeneous because of elevation differences and because of the perennial woody vegetation. Thus, niche space is available not only for aquatic species, but also terrestrial and arboreal species.

Amphibians and reptiles are represented by 18 and 32 species respectively (appendix 6.3). The number of bird species in the swamp forest habitat is exceeded only by the number of species found in rice fields and impounded marshes. Bird richness is rather low during the winter, but during spring and fall migrations it is relatively high. This reflects, in part, the seasonal nature of the habitat. The many deciduous trees support large numbers of herbivorous insects during the warmer months and insectivorous birds make up a considerable portion of the community at this time. Mammal species richness is relatively high, with species such as squirrels and bats present. Population levels of nutria, muskrat, and otter are unknown.

After the logging of the virgin baldcypress at the turn of the century, dense stands of tupelo developed. With an increase in the amount of tupelo came an increase in the forest tent caterpillar (*Malacosma disstria*). Eggs, laid in June on tupelo branches, hatch the following April. The caterpillars grow to about two inches while consuming the leaves and flowers on the tree. By early May the trees are often bare. In 1974, 202,343 ha (500,000 a) of tupelo forests in Louisiana were defoliated.

Reichle et al. (1973) reported that the timing of this insect's feeding spree is important to the survival of the tree. Early leaf production is supported by carbohydrate reserves, while later in the season, production depends on the photosynthetic biomass. Therefore, early spring foliage consumption may have a smaller effect on the total year's production than late defoliation. Even though the trees may not be killed, they are affected by this annual defoliation. Morris (1975) reported that studies in Alabama have shown five-year growth losses of 70% or more for tupelo stands defoliated each year.

This caterpillar defoliation was of little concern until recently because much of the tupelo forests were inaccessible. However, as the demand for tupelo wood increases, stumpage prices increase, and as new mechanized equipment is developed, the forest may need to be protected from the forest tent caterpillar to insure larger quantities of good quality wood (Morris 1975).

Other grazers in the swamp forest include deer, rabbits, squirrels, mice, and seed-eating birds. The swamp forest provides an optimum habitat for grey squirrels but is of only fair quality for deer. At times, it is extensively used by wood ducks and mallards. Swamp forests also harbor large numbers of wintering song birds (Coastal Ecosystems Management, Inc. 1975).

Important detritivores in the swamp forest habitat include insects, crustacea, microbiota, and fungi. From studies in the cypress swamps of Lafourche Parish, Louisiana, Thomas (1975) asserted that crayfish (*Procambarus clarkii*) are more important than amphipods in the breakdown of leaf litter. Cellulose-decomposing bacteria present in swamp sediments, likewise, play a key functional role in the mineralization of woody materials.

Carnivores in the swamp forest system include spiders and voracious insects, such as dragonflies and waterbeetles, that feed on other insects; reptiles, such as snapping turtles, snakes, and alligators; mammals ranging in size from bats and shrews to bobcats and otters; and insectivorous birds and raptors, especially barred owls. Less frequently seen birds such as the red-shouldered hawk, barn owl, and hairy woodpecker also inhabit these forests.

4.7 MANAGEMENT OF CHENIER PLAIN COASTAL WETLANDS

As long as humans have lived in the coastal zone they have used and modified its resources. They have built levees for flood protection, canals for navigation and mineral extraction, impoundments for agricultural and residential use, and they have discharged sewage and other pollutants into coastal waters and wetlands. These changes have occurred in addition to the natural processes of subsidence, erosion, deposition, and river meander that characterize this naturally dynamic area.

4.7.1 PRESERVATION OF THE ENVIRONMENT

As an objective for wetland management, preservation of the environment is the most restrictive. Its purpose is to preserve the environment in as natural a state as possible. In the Chenier Plain no wetland area is managed strictly for this purpose. However, Shell Keys National Wildlife Refuge located offshore of Vermilion Bay is managed for preservation. This refuge, established in 1907, is a 3.2 ha (7.9 a) island, used primarily as a nesting area for marine birds. No hunting, trapping, or disturbance of wildlife is allowed. The land is not to be altered by man in any way. Natural processes are allowed to proceed uninterrupted. There are no weirs, impoundments, shoreline stabilization projects, or marsh burning programs. Finally, economic activities such as mineral extraction or cattle grazing are prohibited.

4.7.2 PRESERVATION OF WILDLIFE

A slightly more active management objective is to preserve wildlife habitat and to improve that habitat where possible. In the Chenier Plain there are three areas managed to optimize this objective (table 4.15). Paul J. Rainey Wildlife Refuge and Game Preserve (10,522 ha or 26,000 a), located in the Vermilion Basin, is owned and managed by the National Audubon Society. The refuge is located west of State Wildlife Refuge and is bordered to the south by a seven mile beach on the Gulf of Mexico. State Wildlife Refuge (6,070 ha or 15,000 a), received by the State of Louisiana through gifts of donation, is situated directly west of Vermilion Bay. Rockefeller Refuge (34,800 ha or 86,000 a) was established in October 1920 by a Deed of Donation from the Rockefeller Foundation to the State of Louisiana. The refuge is located on the Gulf in the Chenier Basin. Both State and Rockefeller Wildlife refuges are administered by the Louisiana Department of Wildlife and Fisheries.

The management program for the three refuges consists of protection of all wildlife, and of alteration of the land for purposes of habitat improvement. Trapping of furbearers is allowed on Rockefeller and State Wildlife refuges. To improve wildlife habitat, the land may be managed by weirs and impoundments (Rockefeller Wildlife Refuge) and by such techniques as marsh burning (State and Rockefeller refuges). Rockefeller and Paul J. Rainey Wildlife refuges have extensive oil and gas activities that are supervised by refuge personnel. Access is denied in areas of ongoing research, and any public use of roads or canals in other areas is determined by refuge personnel. Spoil deposition is regulated and nonproductive drill sites must be returned to their former states (Joanen, unpublished). State Wildlife Refuge allows no oil or gas developments.

4.7.3 MANAGEMENT OF WILDLIFE HABITAT

A third management objective is habitat improvement and protection of selected species of wildlife. In the Chenier Plain the Sabine National Wildlife Refuge, Lacassine National Wildlife Refuge, Anahuac National Wildlife Refuge, J. D. Murphree Wildlife Management Area, and Sea Rim State Park are managed for this objective.

Sabine National Wildlife Refuge (57,809 ha or 142,849 a) was established in 1937 to protect and manage a large block of marshland important to wintering waterfowl. The refuge is located between Sabine Lake and Calcasieu Lake and extends just southeast of Calcasieu Lake in southwestern Louisiana. Lacassine National Wildlife Refuge, also in southwestern Louisiana, is situated northeast of Grand Lake. The 12,856 ha (31,768 a) making up this refuge were also set aside for wintering waterfowl. In these refuges the management program allows alteration of the land to improve habitat, selected wildlife preservation and protection, and controlled economic activities. Both refuges have permanently flooded, freshwater impoundments. Impoundments retain water on the marsh and, at Sabine, provide habitat diversity within the refuge. Controlled burning of marshlands is employed for the management of geese and furbearers. Hunting is restricted to the taking of ducks, geese, and coots with 12-gauge shotguns and steel shot. Trapping is also permitted for furbearers on both refuges. Management allows carefully controlled oil and gas extraction, cattle grazing, and leasing of land for agriculture. Both Sabine and Lacassine have oil and gas activities on the parts of the refuges where the mineral rights belong to another party. These activities are more controlled than general oil and gas extraction. The Lacassine Refuge management program generally limits oil and gas activities to the period from 1 April to 1 October. The Sabine Refuge management plan requires ring levees to be used at oil and gas well sites, and nonproductive wells to be plugged (Walther, unpublished). Both refuges allow cattle grazing. Grazing is allowed on Sabine Refuge from 15 October to 15 April. At the present time, Lacassine allows grazing year-round on specified sites.

Table 4.15. Refuges in the Chenier Plain

Refuge	Basin	Size (ha)	Primary management objective
Paul J. Rainey Wildlife Refuge and Game Preserve	Vermilion	10,522	Preserve and improve habitat
State Wildlife Refuge	Vermilion	6,070	Preserve and improve habitat
Rockefeller Wildlife Refuge	Chenier	34,800	Preserve and improve habitat
Sabine National Wildlife Refuge	Calcasieu and Sabine	57,809	Habitat improvement for waterfowl
Lacassine National Wildlife Refuge	Mermentau	12,856	Habitat improvement for waterfowl
Anahuac National Wildlife Refuge	East Bay	3,981	Habitat improvement for waterfowl
Sea Rim State Park	Sabine	6,117	Habitat improvement for waterfowl
J. D. Murphree Wildlife Management Area	Sabine	3,404	Habitat improvement for waterfowl

The J. D. Murphree Wildlife Management Area, located immediately south of the Port Arthur city limits, was established in 1958. Aside from maintaining a high quality marsh that is desirable to wintering waterfowl, refuge personnel are also concerned with developing marsh management techniques that will aid marshland property owners in the management of their own holdings. Hunting and fishing are allowed on the 3,404 ha (8,411 a) of brackish and freshwater marshes, which are only accessible by boat. The first trapping program is scheduled to go into operation during the 1978-79 trapping season (David S. Lobpries, Texas Parks and Wildlife Department, letter dated 8 August 1978). Oil and gas exploration is allowed and must conform to strict guidelines set by refuge personnel. Presently, no active oil or gas wells are on the area.

Anahuac National Wildlife Refuge, established in 1963, is located in the East Bay Basin. The 3,981 ha (9,837 a) of coastal wetlands is bounded on the east by Oyster Bayou, on the south by East Bay, and is situated inland about three miles from the Gulf. The refuge is managed primarily for migratory and wintering waterfowl, although the endangered American alligator and red wolf are also a major part of the management program (U.S. Department of the Interior 1976). Controlled marsh burning is employed for goose management and managed cattle grazing is allowed on some refuge lands on a year-round basis. Hunting and trapping are not permitted. Oil and gas exploration and production activities are allowed but are controlled by the refuge manager. Seismic operations are generally prohibited during the period from November through February when wintering waterfowl are present.

Sea Rim State Park consists of 6,117 ha (15,115 a) of beach and marshland in Jefferson County, 16 km (10 mi) west of Sabine Pass, Texas. The area is managed to preserve coastal estuaries and wetlands and to provide recreational activities associated with the Gulf beach (Texas Department of Parks and Wildlife 1978). Specific marshland units are managed for wintering waterfowl. Public hunting of waterfowl is allowed on specified areas, but trapping is not permitted. Oil and gas exploration and production activities are allowed and are monitored by park personnel.

4.7.4 MANAGEMENT FOR ECONOMIC RETURN

A final type of management objective is to receive an economic return. Individual and corporate land holders usually must justify their investment in terms of economic returns and they manage their holdings to maximize this. In the Chenier Plain this usually means extensive development for oil, gas, sulfur, and salt extraction. One land management practice is to construct a low levee along exposed shorelines of lakes and larger bayous to prevent erosion of wetlands to open water. This is done because mineral rights of land that has eroded to open water revert to State ownership.

Income is also derived from leasing of wetlands for cattle grazing, and hunting and trapping. Landowners often alter wetlands by constructing cattle walks and mud-boat ditches, and by burning vegetation to enhance the features for which the land is being leased.

4.7.5 USE OF WEIRS IN WETLAND MANAGEMENT

A weir is a submerged, low-sill dam placed in a natural marsh tidal channel to prevent complete drainage of ponds and tidal channels landward of the structure. It may be a solid, single level dam or it may have a stop-log structure that allows the sill depth to vary. The sill or stop-log gate is usually placed no less than 15 cm (6 in) below marsh surface elevation. However, the specific sill setting varies with the size of channel and area affected by the weir (Chabreck 1960). That is, if the affected area of wetland is large relative to the cross-sectional area of the drainage channel, the sill should be slightly lower than 6 in (15 cm).

Effects on Drainage and Water Level Fluctuations. Weirs prevent complete drainage of wetlands at low tide. Chabreck (1968b) determined that at a water level of 0.3 m (1.0 ft) below mean sea level (MSL) only 2.4% of weired pond bottoms on Rockefeller National Wildlife Refuge were exposed as compared to 84% of non-weired pond bottoms. Mean annual water level behind these weirs was 0.12 m (0.4 ft) higher than that for unaltered ponds. In a separate study Herke (1968) found that weirs in coastal Louisiana increased the area and duration of flooding.

Effects on Water Salinity and Turbidity. Weirs retain fresh rainwater in the marsh and thereby decrease water salinity. During periods of drought, weirs retard the intrusion of saltwater into wetlands. Chabreck and Hoffpauir (1962) found that average water salinity and turbidity were less than 10% lower behind weirs than in nonweired areas. Wengert (1972) found that weirs reduced the range of salinities from 1.5 to 12.1 ‰ in nonweired areas to 2.0 to 4.8 ‰ in weired areas.

Effects on Vegetation. Secondary effects of weirs on the abundance and relative distribution of plant species may be striking. Chabreck (1968b) reported that weired areas had four times more aquatic vegetation than nonweired areas. Over a nine-year period, spikerush increased and blackrush decreased in weired areas, a change not noted in similar nonweired areas. Herke (1968) also found that weirs stimulated the growth of rooted aquatics.

Effects on Movements of Aquatic Organisms. Weirs constructed in tidal channels restrict movements of fishes and crustaceans into and out of wetland areas. Herke (1971) found that weirs delayed recruitment of organisms, especially spot and shrimp which are associated with the bottom of channels; and delayed emigration of other bottom species and some surface species. Wengert (1972) concluded that weirs may decrease the total number of brown shrimp using the marsh as a nursery.

4.7.6 USE OF CONTROLLED BURNING IN WETLAND MANAGEMENT

Controlled burning of marsh vegetation is a technique of wetland maintenance widely practiced in the Louisiana coastal zone. An estimated 300,000 to 400,000 ha (750,000 to 1,000,000 a) are burned annually in the coastal marshes (Hoffpauir 1968). Burning generally takes place from mid-October to mid-February. A cover or wet burn is achieved when the water level is at or above the marsh soil at the time of the burning. A root burn is the result of burning during a dry period when the water level is below the marsh soil level. In marshes that have a peat soil overlaying a clay pan, a deep peat burn results from a fire during very dry periods.

Marsh burning is practiced by cattle ranchers, trappers, hunters, and State and Federal refuge personnel. Cattlemen burn to create growth of succulent vegetation favored by cattle. Trappers burn to remove dead vegetation, improve access, and create new growth of Olney's three-corner grass favored by muskrats. Since geese prefer young tender shoots of marsh vegetation, burning an area attracts geese for hunting purposes. Ducks are unable to feed on sawgrass seeds until the dense marsh vegetation is burned off (Lynch 1941). Regular marsh burning reduces the buildup of a vegetational mat and helps to control fires caused by lightning.

Environmental Impacts of Burning. Controlled burning of wetlands removes all or a fraction of the existing vegetation; releases plant material into the atmosphere, water, and soil in the form of smoke and ash; and exposes soil to erosion by wind, tidal waters, and rainfall.

Marsh burning does not change the plant species previously present, but it may change the percentage composition of those species. The effect of a burn on vegetation depends upon the type of burn (i.e., wet burn, root burn, or peat burn), which in turn depends upon the water level during, and subsequent to, the burn. A wet burn, with water levels at or above the root horizon, results in a return of the pre-burn vegetation but with a different percentage composition. For instance, in a dominantly saltmeadow cordgrass marsh, Hoffpauir (1968) noted the percentage of saltmarsh bulrush was increased because it had an initial faster growth rate than saltmeadow cordgrass. The marsh, however, remained dominantly saltmeadow cordgrass. When the water level was below marsh soil level, however, burning resulted in the replacement of the majority of saltmeadow cordgrass by Olney's three-corner grass and saltmarsh bulrush. This resulted because the roots of saltmeadow cordgrass were nearer the soil surface and, thus, were more easily damaged by the burn than the roots of the other two species.

A deep peat burn is possible only during dry periods. When the vegetation is burned, the peat also catches fire and burns down to the underlying clay pan. This results in the formation of a swale or shallow pond with no vegetation (Lynch 1941, Hoffpauir 1968). Hoffpauir (1968) found that the edge of a freshwater pond created by a deep peat burn was revegetated with spikerush, wild millet, and cattail within six months after the burn.

The water level subsequent to the burn will also affect the impact of the burn. If the water level covers the stubble or root system long enough to cause rotting, there will be no regrowth of vegetation (Hoffpauir 1968). Regrowth will be similarly inhibited if an extended drought occurs after a burn.

Hoffpauir (1961) found that in five of six burned areas in a brackish marsh in coastal Louisiana, calcium, phosphorus, chlorine, and the acid/alkaline balance (pH) increased in the soil and that calcium, phosphorus, sodium, potassium, manganese, chlorine, pH, and hardness increased in the water immediately following the burns. This resulted from the deposition of plant ash. If a burn is followed by high tides or heavy rainfall, these nutrients are leached from the soil and are no longer available for regrowth of marsh plants. Such leached nutrients, however, are available to phytoplankton in the adjacent inland open water habitat.

The time of year of a burn is an important factor in its impact. A burn in late spring will damage or destroy waterfowl and alligator nests. A fall or winter burn favors the regrowth of Olney's three-corner grass (Hoffpauir 1968). Burning during the spring will reduce total plant growth. A burn just prior to the spring growing season is beneficial in the perpetuation of the same stand of vegetation. A burn in summer and early fall exposes plant roots to snow geese which may "overgraze" the area.

The direction and velocity of wind affects the rate of burn which in turn affects the efficiency of the burn. The wind direction also determines the direction of the burn.

Burns that get out of control can cause serious irreversible damage to wetlands. A portion of the Calcasieu Basin marshes, southeast of Lake Calcasieu, became a permanent open water area because a change in the wind direction caused a deep burn from which the marsh never recovered.

4.7.7 PLANTING AND SEEDING

Experimental planting and seeding of marsh vegetation may improve habitat for selected consumer species (especially waterfowl) and may stabilize wetlands against erosion. Several different methods of planting and seeding have been used. The easiest is broadcast seeding over unprepared marsh or mudflats, or over marsh prepared by mechanical tillage, burning, chemical treatment, and/or water control. Seeds may be broadcast by hand, by a seed spreader, or by airplane.

Root stocks are planted, generally by hand, in either prepared, unprepared marsh, or on mudflats. Whole plants, usually aquatic species, may also be transplanted. Besides planting or seeding of the marsh proper, levees and dikes may also be seeded or sprigged with vegetation. Both Olney's three-corner grass and saltmarsh bulrush have been seeded and planted in brackish areas to improve the food supply for waterfowl and muskrats (Palmisano and Newsom 1967, Ross 1972). Yellow foxtail, wild millet, Japanese millet, and brown top millet are suitable for seeding in fresh marsh areas for duck food (Neely 1968). Smooth cordgrass is best suited for planting in a salt marsh (Larimore 1968). Levees may be seeded with bermuda grass or sprigged with saltmeadow cordgrass (Soil Conservation Service 1976).

Method of Preparation. Controlled burning removes the thick mat of organic matter to allow easier tilling or disking before planting or seeding. If the planting or seeding project is unsuccessful, the impact of burning is increased; without vegetative cover the soil is exposed to wind and tidal erosion, and oxidation. Chemical treatment has been used to destroy undesirable vegetation (Soileau 1968) but it is not an effective means of land preparation for seeding or sprigging in the marsh, as chemicals may also destroy or prevent growth of desirable vegetation. The vegetation may be turned by mechanical tilling. If the marsh is burned, the remaining organic matter may be tilled under the soil surface. Tilling is generally a "once over" type of soil break-up, whereas disking requires going over the area several times. Ross (1972) found tilling to be the best means of site preparation for marsh planting projects.

Water Manipulation. Levees, weirs, impoundments, and pumps may be used prior to planting or seeding to (1) provide an optimum water level for plant growth, (2) eliminate undesirable species, (3) retain water in ponds and channels for aquatic vegetation, (4) allow better seed germination, (5) drain an area for tilling and disking, or burning, and (6) drain an area to oxidize bottom sediments and firm them up to provide a better surface for plant attachment. Water manipulation greatly affects the success and impact of a planting or seeding project. All vegetation has an optimum range of salinity and water level. If this range can be met through water manipulation, the chances of success are increased.

Suitability of the Species. Planting and seeding projects are usually done to provide a food source for ducks, geese, or muskrats; and this determines the species of vegetation to be planted. The species must also be suited to the environment in which it is planted, especially with reference to salinity and water levels, and must be able to compete successfully with natural vegetation and other invader species. Plantings may fail because of competition from animals.

Excessive grazing of young grass shoots by cattle, geese, or muskrats, called an "eat-out," will destroy the vegetation or reduce its capacity to revegetate. Birds frequently eat the seeds before they germinate.

4.7.8 CATTLE GRAZING

To realize an economic return from wetlands, cattle are allowed to graze some two million acres of coastal marsh (Williams 1955). Grazing may occur year-round; however, mosquitoes and the chance of floods reduce this practice during the period from May to September.

Both fresh and salt marsh are grazed. Maidencane and southern wild rice are preferred forage in fresh marsh areas; the *Spartina* species, seashore paspalum, and saltgrass are grazed in the salt marsh.

Grazing in the marsh depends on the number and distribution of ridges. Cattle will graze up to one quarter mile from a ridge or levee (Williams 1952), and this area becomes severely overgrazed. Cattle walkways, or artificial ridges, placed 0.8 km (0.5 mi) apart allow grazing to be more evenly distributed. Cattle walkways are also used for bedding grounds, supplemental feeding, and retreats in case of high water.

Walkways are characteristic of the Chenier Plain, which has some 390 km (242 mi) of walkways (Soil Conservation Service estimate, unpublished), while the Mississippi Deltaic Plain, to the east, has only 16 km (10 mi) of walkways because natural delta marsh soils generally will not support the weight of cattle.

Environmental Impacts of Cattle Grazing. The impact of cattle grazing depends upon grazing pressure, the condition of the marsh range, the suitability of soils, the time of the year the marsh is grazed, and the use of cattle walkways. The following stocking rates on salt and fresh marsh ranges are recommended by the Soil Conservation Service:

Marsh in climax vegetation %	Salt marsh mid fall-late spring	Fresh marsh late winter-mid-summer
75 to 100	1.6 ha (4 a)/cow	1.2 ha (3 a)/cow
50 to 75	2.4 ha (6 a)/cow	1.6 ha (4 a)/cow
25 to 50	3.2 ha (8 a)/cow	2.4 ha (6 a)/cow
0 to 25	4.8 ha (12 a)/cow	4.0 ha (10 a)/cow

Chabreck (1968a) has identified three range types: high marsh consisting of firm, well-drained soils used as bedding ground; intermediate marsh consisting of fairly firm soil with slower drainage after rains; and low soft, poorly drained marsh normally covered with water that is several inches deep into which cattle sink up to eight inches. Cattle spend 50% of their time on high marsh, 30% on intermediate, and 20% on low marsh. Range types in the Chenier Plain marsh are mainly high and intermediate. In the low marsh the hooves of cattle destroy vegetation that may take several months to recover (Chabreck 1968a).

Intensity, and time of year of grazing, are both important to marsh utilization by wildlife resources. Light or moderate grazing removes dense stands of mature vegetation and encourages the growth of *Scirpus* sp., a preferred duck food (Chabreck 1968a). Tender, new grass growth resulting from moderate grazing, also benefits snow geese. Invader species that increase with overgrazing are blackrush, rattlebox, marsh elder and rattlebush, none of which is valuable to cattle or waterfowl. Snipe are often found in large concentrations on overgrazed marsh range during the winter months (Chabreck 1968a). Grazing in summer and early fall reduces seed production of annual grasses such as millet, bearded sprangletop, nutgrass, and fall panicum, which are favorite duck foods (Chabreck 1968a). Where smartweed occurs, grazing will improve the area for duck usage if the marsh is flooded in the fall and winter (Neely 1968).

4.7.9 IMPOUNDMENTS

Many species of wildlife are dependent upon wetland areas, and each year some of this land is altered by draining, filling, channelization, saltwater intrusion, and pollution. As a result, conservation interests have turned more and more to active management practices to maintain wildlife habitat at a high level of productivity (Chabreck 1977).

One technique that is widely used to conserve and improve wildlife habitat conditions is the construction of impoundments. In the Chenier Plain impounded marsh differs enough from natural wetlands that it has been identified as a distinct habitat in this study. Figure 4-25 shows the location and extent of impounded marsh. It comprises large areas of the Chenier, Mermentau, and Sabine basins, and composes 17.1% of the inland area of the Chenier Plain.

Impounded marshes are enclosed with a continuous levee for regulating or manipulating water depths. In the Chenier Plain three types of impoundments are recognized. The most common type is the fixed impoundment, which provides habitat for waterfowl, especially dabbling ducks. Some of these areas also provide considerable amounts of freshwater sport fishing. The Sabine and Lacassine National Wildlife refuges and the Rockefeller Wildlife Refuge are good examples of this type of impoundment. A second type of impounded wetland was originally constructed for agriculture. In pioneer days, farmers built levees around their fields to keep the water out. After finding that the impoundments were too expensive to maintain, the farmers abandoned them and they became shallow lakes. Management of continuously flooded areas for the purpose of waterfowl hunting began with the utilization of these abandoned agricultural areas (Ensminger 1963). The third type of impounded wetland includes areas that have been leveed and drained for pasture. This type is discussed in part 4.16, pasture habitat.

Studies indicate that plant species diversity is increased by the impoundment of wetlands (Chabreck 1960, 1962a). Large, almost pure stands of saltmeadow cordgrass can be drastically reduced or eliminated by continuous flooding with brackish water and fresh water respectively (fig. 4-26). The impoundment and subsequent reduction of dense cordgrass turf allows growing space for other species. An extensive list of plants recorded by Adams (1956) for the impounded marsh areas on Rockefeller Refuge is found in appendix 6.3.

Chabreck (1962a) reported that plants preferred by ducks make up 50% of the vegetation in the Rockefeller Refuge impoundments and less than 5% of the species in adjacent unimpounded areas. The greatest variety of high quality duck foods are produced in manipulated freshwater impoundments (fig. 4-26). In these impoundments, the water is drained during the spring or early fall to permit drying of the soil and germination of seeds from grasses and sedges. The impoundments are reflooded a few weeks after seed germination. As this management scheme for ducks coincides with crayfish production techniques, impoundments can be managed for both resources (Perry et al. 1970, Chabreck 1977).

Studies in southwestern Louisiana have reported that ducks prefer natural and impounded brackish marsh areas to similar fresh marsh areas during the fall season and prefer the reverse during the winter months (Palmisano 1972a, Chabreck et al. 1974b). This difference in habitat preference is thought to be related to the availability of food plants. Although 138 plant species occur in the large freshwater impoundment on Lacassine National Wildlife Refuge (Fruge 1974 unpublished data), Tamisier (1976) clearly demonstrated that teal and pintail used the impoundment primarily as a resting area and fed elsewhere.

The white-tailed deer and the American alligator also benefit from impoundments. Deer benefit not only from the permanent supply of freshwater and increased food supply but the levees provide the deer with travel lanes and cover. In Rockefeller Refuge, permanently flooded fresh water impoundments attract alligators. Although still listed as a "threatened species" in southwestern Louisiana, alligator numbers have increased enough so that controlled alligator harvests are conducted.

A list of representative vertebrate species inhabiting the impounded marsh habitat is found in appendix 6.3.

Although marsh impoundments have been widely used to improve habitat conditons, there are certain disadvantages to this type of management. Impoundments are costly to construct and maintain, and they can only be constructed in areas where the soil will support the weight of the levee. Without pumping facilities, unusually wet or dry years result in poor quality food production for wildlife. Impounded areas interact with adjacent wetlands and open water areas very little (except for waterfowl and other animal species that can actively come and go). That is, impounded areas have no appreciable function as nursery areas for aquatic organisms; and since the impounded areas are rarely drained, there is little export of organic production to adjacent systems. Most of the organic material accumulates on the bottom of the impounded marsh. Turner (1966) reported that in the Sabine National Wildlife Refuge the impounded marsh floor ranged from slightly below MSL to 0.6 m (2 ft) above. The impounded marsh bottom in Lacassine National Wildlife Refuge is reported to be 1.5 m (5 ft) above the surrounding marshes (Laurie Shiflett unpublished).

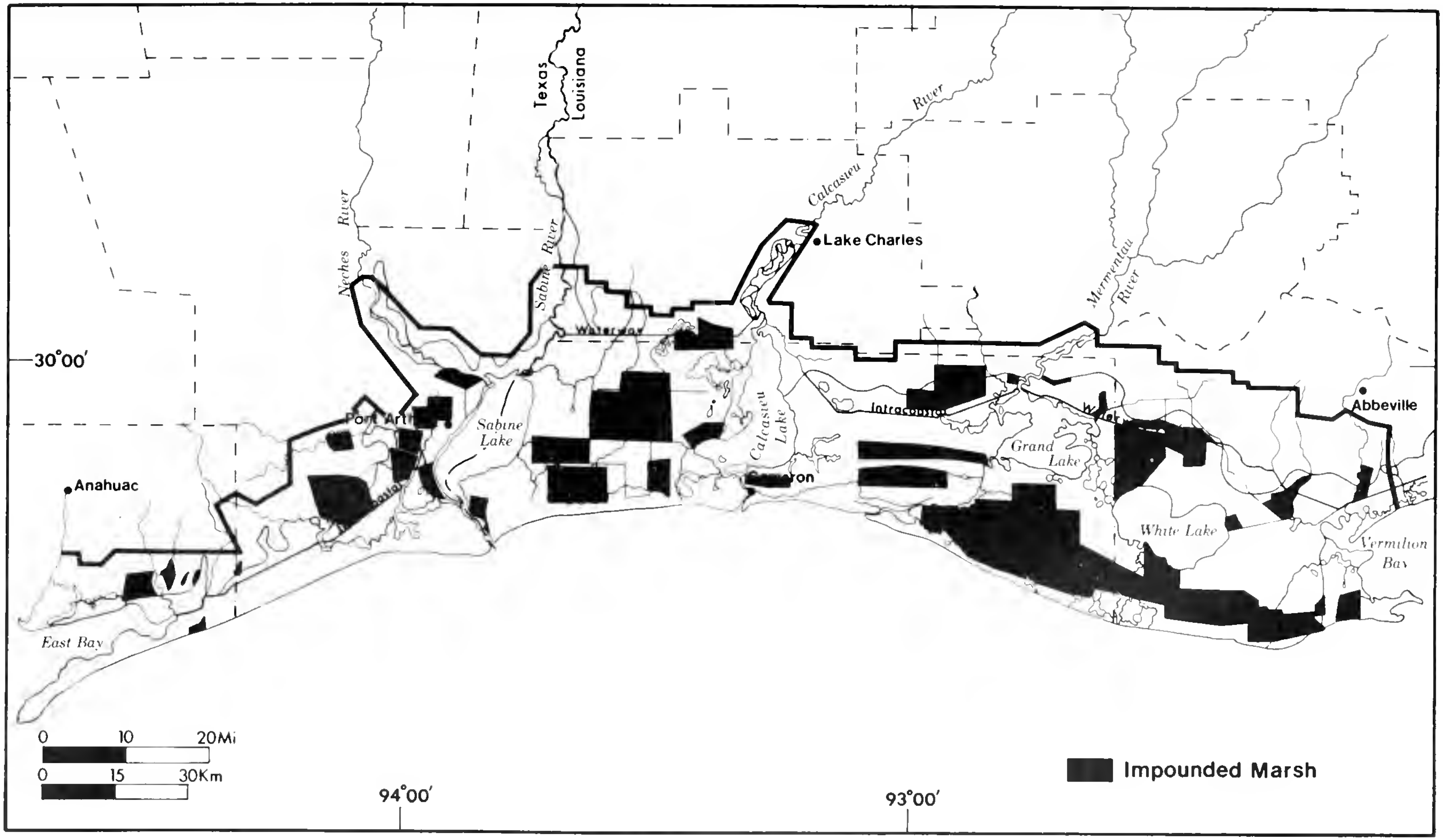


Figure 4-25. Distribution of impounded marsh habitat in the Chenier Plain.

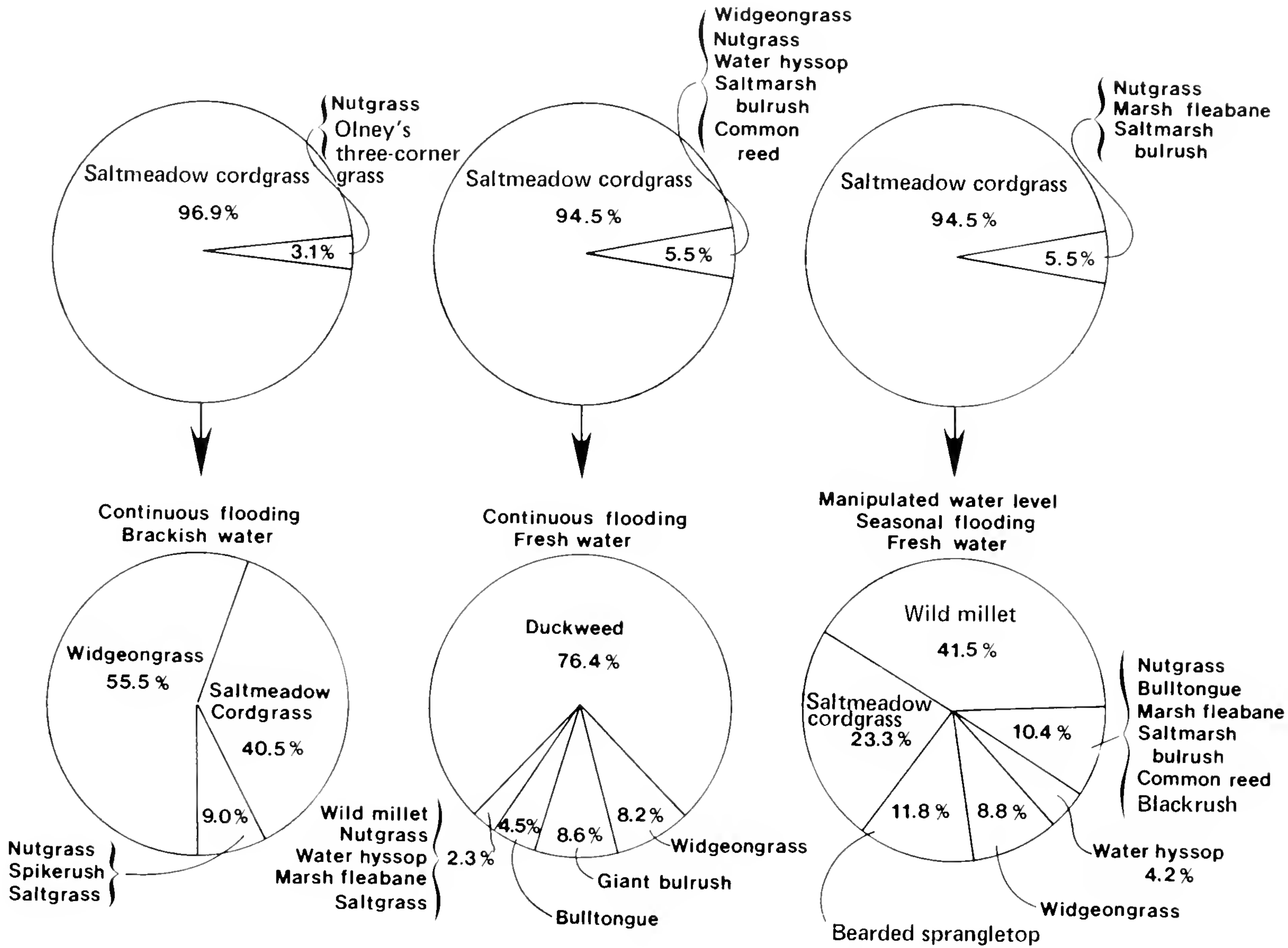


Figure 4-26. Effect of different impoundment management practices on the composition of marsh vegetation (Chabreck 1962a).

One other factor that should be considered is that other valuable species, such as furbearers, are not benefited by impoundments. Other management practices are carried out by landowners and refuge personnel to benefit these species.

4.8 AQUATIC HABITATS

This section considers the broad physical, chemical, and biological characteristics of the Chenier Plain aquatic system. This system comprises two habitats, divided at the barrier beach where inland waters flow through tidal passes to the Gulf. All water bodies landward of the beach and passes, including estuaries, rivers, drainage ditches, navigation canals, tidal creeks, bayous, lakes, and ponds collectively make up the inland open water habitat. Waters seaward of the beach and passes to a depth of 10 m (33 ft) constitute the nearshore Gulf habitat. While these two habitats differ descriptively and functionally, there is a strong physical, chemical, and biological interaction between them. For example, important commercial species (brown shrimp, white shrimp, blue crab, Gulf menhaden, Atlantic croaker) and others spend some part of their life histories in both habitats.

4.8.1 A FUNCTIONAL OVERVIEW OF AQUATIC HABITATS

Functionally, the interrelationships between hydrodynamic features, primary and secondary productivity, and food web interlinkages in the Chenier Plain aquatic system are complex (fig. 4-27). Much of this complexity is associated with the shallow waters. The bottom and the water column together afford many possibilities for specialization not found in either alone. In addition to plants and animals which occupy only the bottom (many invertebrates) or the water column (zooplankton), many organisms (fishes) use both parts of the system.

Phytoplankton are the major producers in the aquatic system. Benthic algae are important seasonally, especially in winter when the water is often clear. Little of the primary production is directly grazed; most of it dies, settles to the bottom, and becomes the base of a complex detrital food web. Benthic consumers predominate, from small crustacea in the sediments to large demersal fish which eat them. Birds feed in all areas along the shore, on intertidal mudflats, and along fringing marshes. Most nektonic species migrate between the nearshore Gulf and inland open water habitats.

Although productivity in the aquatic system is dependent upon solar energy, its magnitude is controlled by the hydrodynamic regime through nutrient and pollutant transport, turbidity, and the density of plankton. Indirectly, the production level and the integrity of the overall system determine the usefulness of the system to man through commercial harvests and sportfishing.

The Chenier Plain aquatic system model clearly conveys the idea that alteration or loss of one type of coastal aquatic habitat may directly or indirectly affect the endemic living resources of the entire system. The clear implication is that the nearshore Gulf, inland open waters, and wetlands must be maintained as an integral biological unit if the natural resources are to maintain their current characteristics.

4.8.2 ROLE OF HYDROLOGY IN AQUATIC HABITATS

The hydrodynamic characteristics of coastal aquatic habitats are a strong controlling factor affecting basic productivity, energy transfer, and the composition, abundance, and distribution of living organisms.

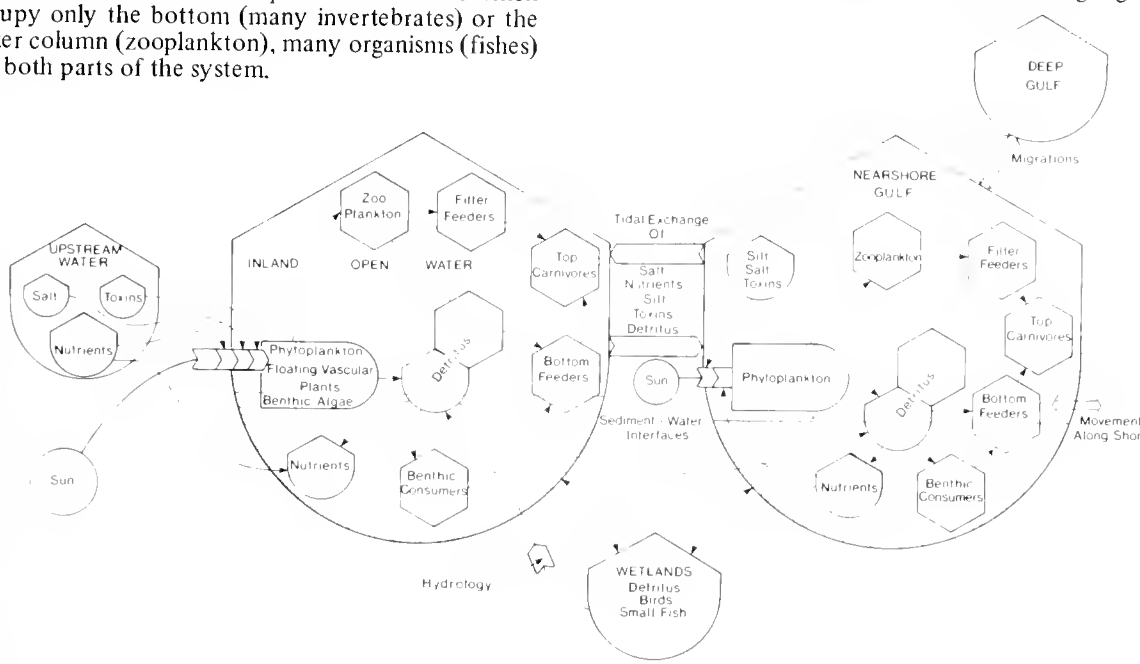


Figure 4-27. Conceptual model of energy flow and interrelationships between the inland open water and the nearshore Gulf habitats of the Chenier Plain.

Most of the effects are indirect, e.g., the hydrodynamics of the system modify other abiotic factors which in turn affect the biota. The major hydrodynamic features of the Chenier Plain are water circulation pattern, current velocity, water replacement rate, and turbidity.

Circulation patterns are affected by the topography of the area, flow volume, wind, and tides. These patterns determine the direction and movement of salts, dissolved organic compounds, nutrients, sediments, plankton, and contaminants. Current velocity affects size of suspended sediments, sediment load distribution, and strongly influences depositional and erosional patterns in inland open waters and the nearshore Gulf. The rate of water displacement is determined by flow volume and discharge rate which affect rates of nutrient replenishment and eutrophication. The volume and velocity of rivers, currents, and tides determine, in part, the degree of turbidity, the distribution of nutrients and contaminants, and indirectly affects the distribution of aquatic plants and benthic filter feeding organisms.

Circulation patterns and current velocities affect the distribution of living organisms. Larvae of oysters and other shellfishes are distributed almost entirely by prevailing currents. Many estuarine-dependent species, such as shrimp, spawn offshore, but their larvae are carried by currents into bays and estuaries which are their principal nursery grounds.

Currents are essential for carrying nutrients to clam beds and oyster reefs; consequently, the location or abundance of these forms is determined largely by the circulation pattern. Oyster reefs always build across prevailing currents (Hedgepeth 1953). Currents across fringing wetlands help transport nutrients and organic detritus throughout interconnecting aquatic habitats.

Water volume renewal relates the total volume of a body of water to the volumetric flow through it. The renewal time is a function of the inflow and outflow rate and the volume of the body of water. In general, the shorter the renewal time the more nutrients a body of water can receive without accumulating excessive nutrients.

The coastal waters of the Chenier Plain are kept in constant motion by the driving forces of wind, waves, tides, and atmospheric pressure gradients. Wave-driven currents control the circulation patterns in the immediate nearshore zone. Large volumes of freshwater from the typically abundant rainfall, as well as watershed runoff, mix with coastal salt waters to bring about density gradients and buoyancy effects that are important in the circulation of waters through tidal passes and estuaries.

A primary factor controlling the orientation and size of wave trains approaching the coastline, and consequently the overall circulation pattern, is the direction and intensity of the consistent winds along the Louisiana and eastern Texas coasts. Prevailing southeasterly winds with average velocities of 4 to 10 km/hr (2 to 6 mi/hr) in summer, and slightly higher in winter (Murray 1976), develop swells that contact the bottom of the smooth, gently sloping inner shelf and shoreface (Fisher et al. 1972). The resulting wave trains and currents control deposition and erosion along the coast (table 4.16).

There is an obvious lack of westerly winds throughout the year. As a result, local wind-driven currents are predominantly toward the west. Although winds other than the predominant southeasterly winds do occur, they are significantly less effective in generating waves, currents, and tidal effects.

Approximately 92% of the waves along coastal Louisiana are 0.9 to 1.5 m (3 to 5 ft) in height and have a period of 4.5 to 6.0 sec when wind speeds are greater than 10 km/hr (6.2 mi/hr) (Louisiana Superport Studies 1972). Seasonal variability of waves also is demonstrated. Waves greater than 2.4 m (8 ft) in height occur approximately 30% of the time during winter, as opposed to 2% of the time in midsummer.

The Chenier Plain coast is a low to moderate energy coastline in terms of offshore waves. During spring and summer the intensity of offshore waves is relatively low, but during fall and winter intensity increases two- to three-fold. The shallow slope of the Continental Shelf apparently attenuates offshore wave power sufficiently to yield the low energy environment of the coast.

Table 4.16. Annual wave climate summary for coastal Louisiana (Becker 1972).

Wave		Direction from which wave comes and proportion of time (%)[a]				
Height (ft)	Period (sec)	E	SE	S	SW	Subtotals
3.0	4.5	13.4	20.9	7.5	5.0	46.8
5.0	6.0	8.9	20.6	8.7	7.6	45.8
7.0	7.0	1.2	1.2	0.8	0	3.2
8.5	8.0	1.4	0.5	1.5	0.8	4.2
Subtotals		24.9	43.2	18.5	13.4	100.0

[a]The percentages cited are relative to portion of time during the year when wind velocities exceed 10 km/hr (6.2 mi/hr). Winds greater than 10 km/hr prevail during 43.3% of the year on the average.

Only winds associated with winter frontal passages or hurricanes produce large or sustained waves offshore. Hurricanes usually have a net drift toward the northwest. They can cause considerable modification to the shelf waters and generally push oceanic waters onto the shore and into estuaries. The intense wave action associated with hurricanes reworks the shelf sediments and can transport large quantities of sediments shoreward, which ultimately affects circulation by means of density gradients.

Tides along the western shelf, especially in the areas of the Sabine and Calcasieu lakes, are as high as 0.76 m (2.5 ft) and should produce significantly greater tidal currents than expected around the Mississippi Delta. Locally, significant tidal currents of 3.3 kn flood and 4.3 kn ebb develop in restricted passes in the Galveston Bay area, particularly between Galveston and West Bay and between Christmas Bay, Bastrop Bay, and West Bay (Murray 1976).

Turbidity (suspended solids) is closely related to current velocity, because the faster the current, the greater its potential for carrying sediment. Turbidity is of particular importance to primary productivity because nutrients needed by phytoplankton tend to be adsorbed onto suspended or precipitated clay particles. However, when water turbulence is increased, sediments are resuspended and nutrients are released into the water column and become available for plankton. The high turbidity that is observed in shallow inland and nearshore waters is primarily attributable to tidal flow and to local wave conditions which stir up and suspend bottom sediments. Primary productivity (rate of photosynthesis per unit water volume) in turbid waters is greater than in nearby clear waters in south-central Louisiana (Sklar 1976).

Although productivity may be enhanced by turbidity, excessive amounts or prolonged periods of high turbidity may be counter-productive. The depth of the water column that will sustain photosynthesis decreases with increased turbidity because of reduced light intensity.

Mudflats result from the net effect of sedimentary input from local rivers and the erosional forces of waves and longshore currents. When sedimentation exceeds erosion, mudflats may develop offshore of the beach. Alternatively, where the longshore sediment load is very small, severe storms may push the beach ridge back over the marshes behind them. This process also can result in exposed intertidal mudflats, which were former marshes.

4.8.3 THE IMPORTANCE OF SALINITY

Salinity is one of the major variables affecting the abundance and composition of aquatic life. Although a natural salinity gradient persists from land to the ocean, the extent of the gradient at any one time may vary depending upon the depth, rate of freshwater inflow, water circulation pattern, and tidal flow. For the Chenier Plain, the normal gradient may range from near zero salinity in and near river mouths and lakes to 5‰ to 15‰ in the mixing zones of the inland open waters, and 10‰ to 30‰ or higher in the nearshore Gulf waters.

Despite the tendency for a salinity gradient in these aquatic habitats, dynamic changes in salinity are relatively common. Floodwaters from rivers may reduce salinities over large areas, or strong winds and ocean currents may flush unusually large quantities of saltwater into systems. In some cases a saltwater wedge will penetrate inland open waters, expecially ship channels, and cause wide differences between surface and bottom salinities (Bowden 1967).

The significant flow of fresh turbid water from the Atchafalaya River into Louisiana coastal waters keeps the nearshore zone relatively diluted to the Texas border. During the flood season, the salinity levels along the entire open coast of the Chenier Plain may be as low as salinity levels in estuaries. The salinity pattern suggests slow shoreward movement of water in the lower saline layer and a circulation dominated by local wind effects in the upper brackish layer. Extreme changes in salinity may reduce or destroy some plant or animal populations.

4.8.4 ORGANIC DETRITUS DERIVED FROM ADJACENT WETLANDS

In the section on wetlands, it was emphasized that these communities produce vast quantities of detritus. Waters flooding these wetlands carry some of this detritus to inland open waters where it enters the food chain. The magnitude of export depends upon the abundance of detritus and flushing frequency, and its impact depends partly on the area of open water relative to the area of adjacent wetlands. The export of organic matter from adjacent habitats into Calcasieu Lake ranges from 1,100 kg/ha/yr (981 lb/a/yr) from fresh marshes to 7,300 kg/ha/yr (6,513 lb/a/yr) from saltmarshes (fig. 4-28). The open water productivity in situ for Calcasieu Lake is indicated in table 4.17. Figure 4-28 also suggests that inland open waters are themselves exporters of organic matter to the nearshore Gulf. This phenomenon, called outwelling, is considered an important reason for the high productivity of coastal waters compared to deep oceanic waters. The gradient of decreasing organic carbon concentrations from marshes through the bay to the Gulf (table 4.18) has been demonstrated for Barataria Bay, Louisiana, by Happ et al. (1977). Although outwelling has not been measured in the Chenier Plain, the data in figure 4-28 indicate that the phenomenon must occur. The magnitude of outwelling probably depends to some extent on the flow through coastal passes. Estimating an annual export of 100 kg organic matter per hectare of inland open water (89 lb/a) (a conservative estimate from Happ et al. 1977), one can predict that about 46,000 tonnes (50,706 tons) of organic material is flushed from the Calcasieu Basin into the nearshore Gulf habitat each year.

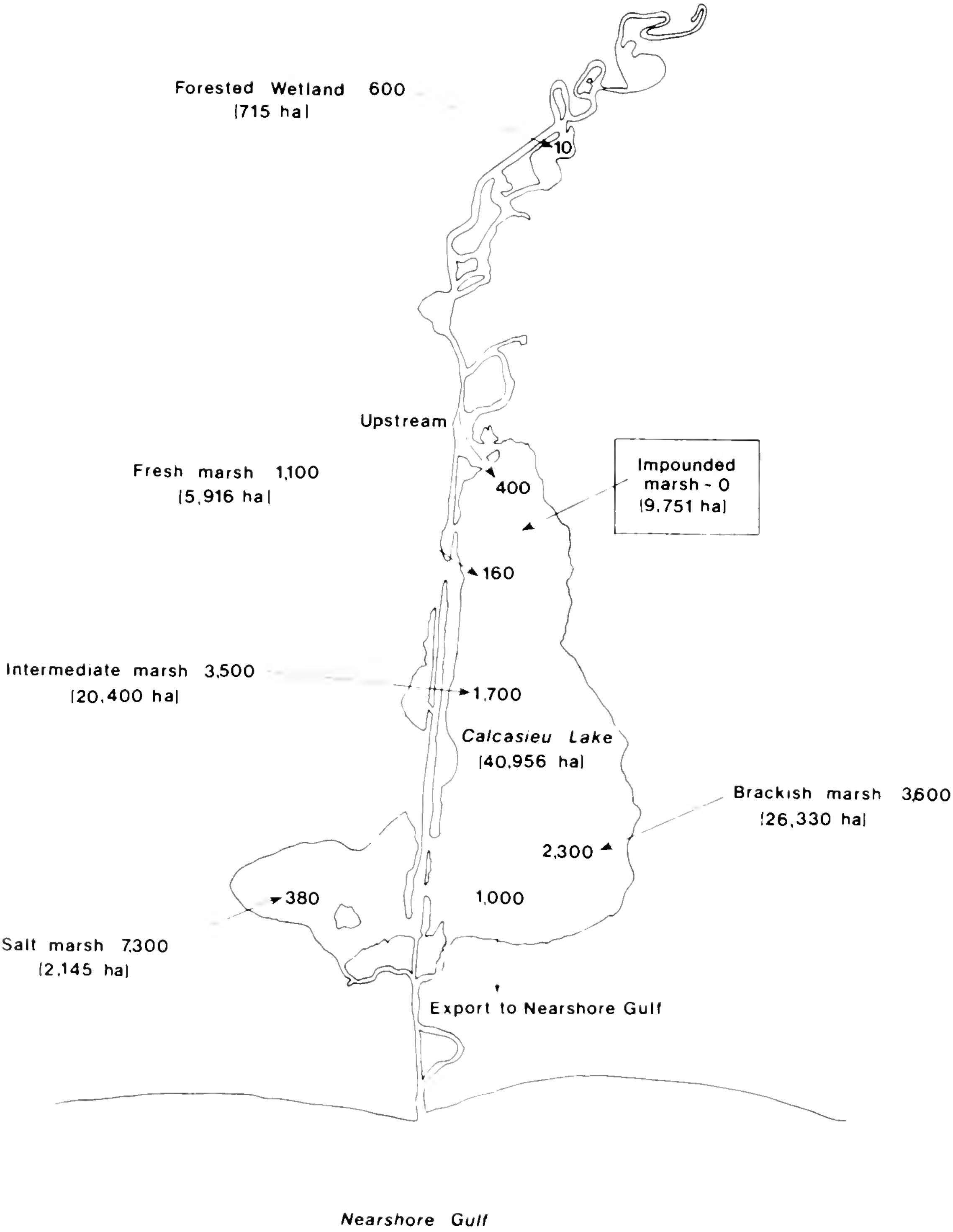


Figure 4-28. Estimated organic fluxes (kg/ha/yr) to aquatic habitats for Calcasieu Basin. The number at the source of each arrow is per hectare of that habitat. The number at the point of the arrow is per hectare of the recipient habitat. Organic material was assumed to be uniformly distributed in each habitat, although phenomena like the edge effect demonstrate that this is not true.

Table 4.17. Primary productivity (g dry wt/m^2/yr) in open water areas of Calcasieu Lake.

Area	Gross primary productivity	Net primary productivity	Net community productivity	Reference
Saline				
Phytoplankton	598	418		Day et al.
Benthos	698	488		1973
Total	1,296	906		
Saline[a]	1,122 ± 151		-57.5 ± 36	Allen 1975
Saline[a]	1,341 ± 162		19.2 ± 38	Allen 1975
Brackish[a]	1,396 ± 162		16.4 ± 38	Allen 1975
Intermediate[a]	1,369 ± 175		5.5 ± 38	Allen 1975

[a]Total phytoplankton and benthos.

Table 4.18 Average annual values (mg/l) of total organic carbon for four areas in Caminada and Barataria bays.

Areas	Locale	Total organic carbon
Marsh	Caminada	8.5 ± 0.2
Upper bay	Caminada	8.0 ± 0.3
	Barataria	7.1 ± 0.3
Lower bay	Caminada	5.9 ± 0.3
	Barataria	4.0 ± 0.3
Offshore	Southeast Louisiana	2.8 ± 0.1

4.8.5 ENERGY BUDGET OF AQUATIC HABITATS

Figure 4-29 shows the relative importance of different organic energy sources to the aquatic habitats and indicates the ways in which this organic matter is used. In the inland open water habitat, the three major sources of organic energy (phytoplankton, benthic algae, and detrital input from wetlands) are about equal in importance. The largest fraction of this organic production supports the benthic community. This evidence, as well as the predominance of benthic feeding organisms among the larger consumers (fish, birds), emphasizes the importance of the benthic community in shallow inland waters.

In the nearshore Gulf habitat the major organic producer is phytoplankton, but some supplemental input of detritus is contributed from the estuaries. Fishes, which feed primarily on small benthic animals, account for less than 5% of the total energy flow in this habitat.

4.8.6 THE DETRITUS SYSTEM AND THE BENTHIC COMMUNITY

Detritus has been defined in a biological sense as dead organic material, usually finely divided, which is used as a food source by many aquatic organisms. The process by which raw detritus becomes enriched by microorganisms and consumed by small crustacean scavengers was discussed in part 4.2, wetland habitats. Detritus is equally important in the shallow aquatic habitats of the Chenier Plain. It is ingested as suspended particulate material by filter-feeding animals such as the Gulf menhaden, or it can be eaten by deposit feeders such as shrimp, after it settles to the bottom.

Except for insects such as dragonflies, water surface bugs, and mosquitoes, many aquatic invertebrates spend their entire life cycle as benthos. These populations are usually most abundant near marsh interfaces; thus, the edges of inland open water bodies are particularly productive (fig. 4-30). Benthic productivity reaches a peak in early spring, providing a food supply for spring concentrations of shrimp and Gulf menhaden (fig. 4-31). The benthos tend to be concentrated near the surface sediment layer, with only a small fraction of the community found deeper in the sediment (fig. 4-32). Thus, the productivity of benthic invertebrates is primarily dependent on the surface area of bottom sediment and the physical conditions during the early spring season.

The importance of detritus feeders in the overall food web of estuarine waters was demonstrated for Lake Pontchartrain, Louisiana (Darnell 1961). The most common fishes and shellfishes (menhaden, mullet, and shrimp) in this system fed predominantly on detritus or on small benthic scavengers which themselves were detritus feeders. The bay anchovy was the only abundant estuarine fish that was not a detritivore, its diet was composed largely of zooplankton. The largest group of fishes occurring in the Chenier Plain consists of bottom-feeders and most fish are dependent upon the detrital system (appendix 6.3).

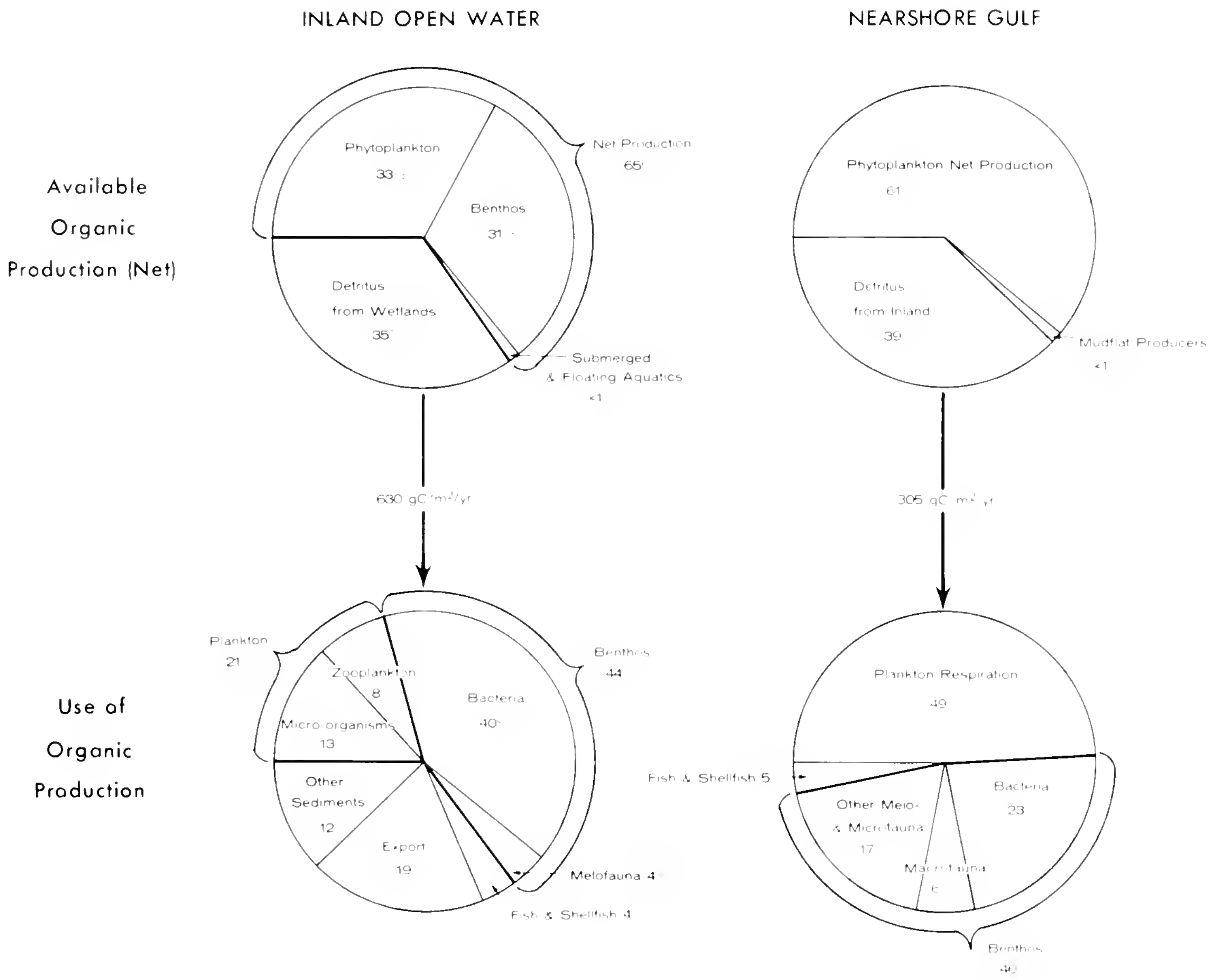


Figure 4-29. Sources of organic energy and its uses in inland open water and nearshore Gulf habitats.

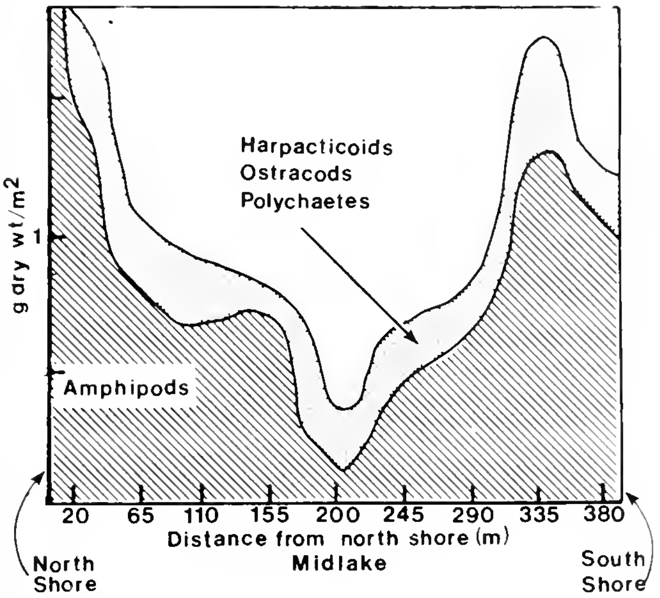


Figure 4-30. Distribution, in g/m^2 (dry wt), of major benthic groups from north shore to mid-lake to south shore of a small lake in southeastern Louisiana (Day et al. 1973).

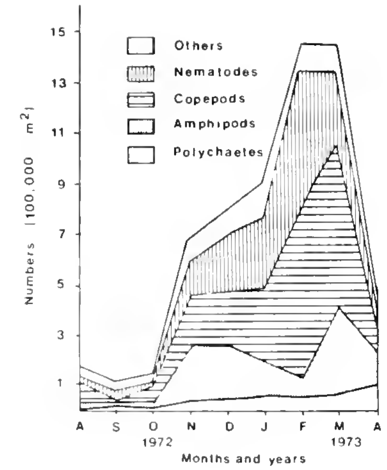


Figure 4-31. Monthly densities of benthic fauna from August 1972 to April 1973 in southeastern Louisiana (Day et al. 1973).

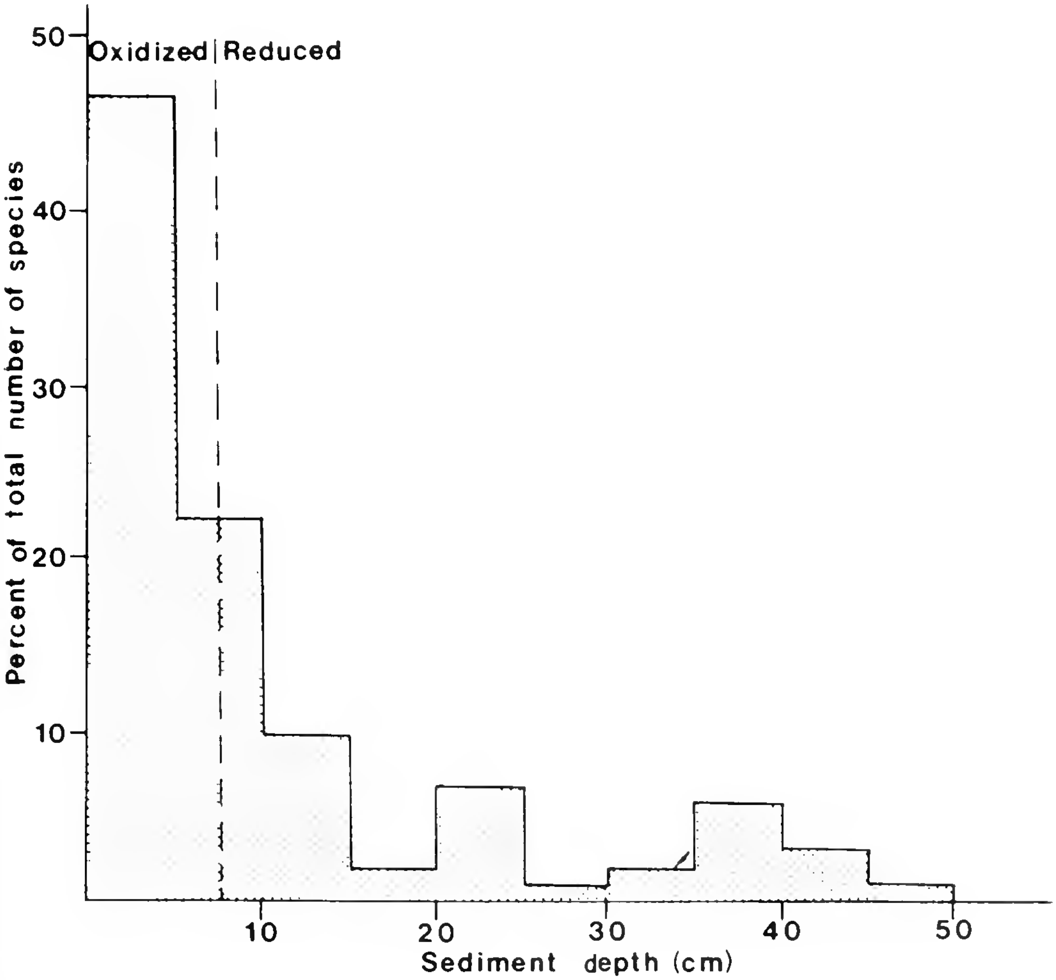


Figure 4-32. Relationship between sediment depth and relative number of benthic invertebrate species in the nearshore Gulf waters of Georgia (Smith 1971).

Benthic food supplies are used extensively. Any decrease in area and productivity of the benthic component will be accompanied by a decrease in dependent fisheries. For instance, the productivity and normal function of the benthic community are modified by hydrologic changes and dredging. Dredging resuspends sediments, nutrients, and toxins in quantities that benthic communities cannot tolerate. A common example is the smothering of oyster beds with sedimentary materials. On the other hand, some benefit may result from resuspending the shallow buried organic material which can then enter the food web.

4.8.7 PRIMARY PRODUCTIVITY

The capacity of a body of water to produce living organisms is usually determined by its primary productivity. Primary productivity is often measured by photosynthetic rates of phytoplankton, but photosynthetic rates of benthic algae and submerged aquatic plants also may be included. Primary productivity may be expressed as $gC/m^3/yr$ or as $g\text{-}cal/m^3/yr$.

Data for primary productivity of the Chenier Plain aquatic system or other similar areas in the northern Gulf generally are scarce and inconclusive. However, seasonal differences in productivity in inland brackish water and saltwater in Louisiana have been documented. In a one-year study, peak productivity, based upon photosynthetic rates of phytoplankton, benthic algae, and submerged aquatics, occurred in February to March and again in July to August (fig. 4-33). Cause for these peaks was not explained. In a study by Sklar (1976), phytoplankton productivity of the nearshore waters west of the Mississippi River failed to show a second peak (in the summer).

On the basis of Sklar's work (1976), turbid, river-influenced waters in the inland open water habitat tended to show higher productivity than the nearshore Gulf habitat.

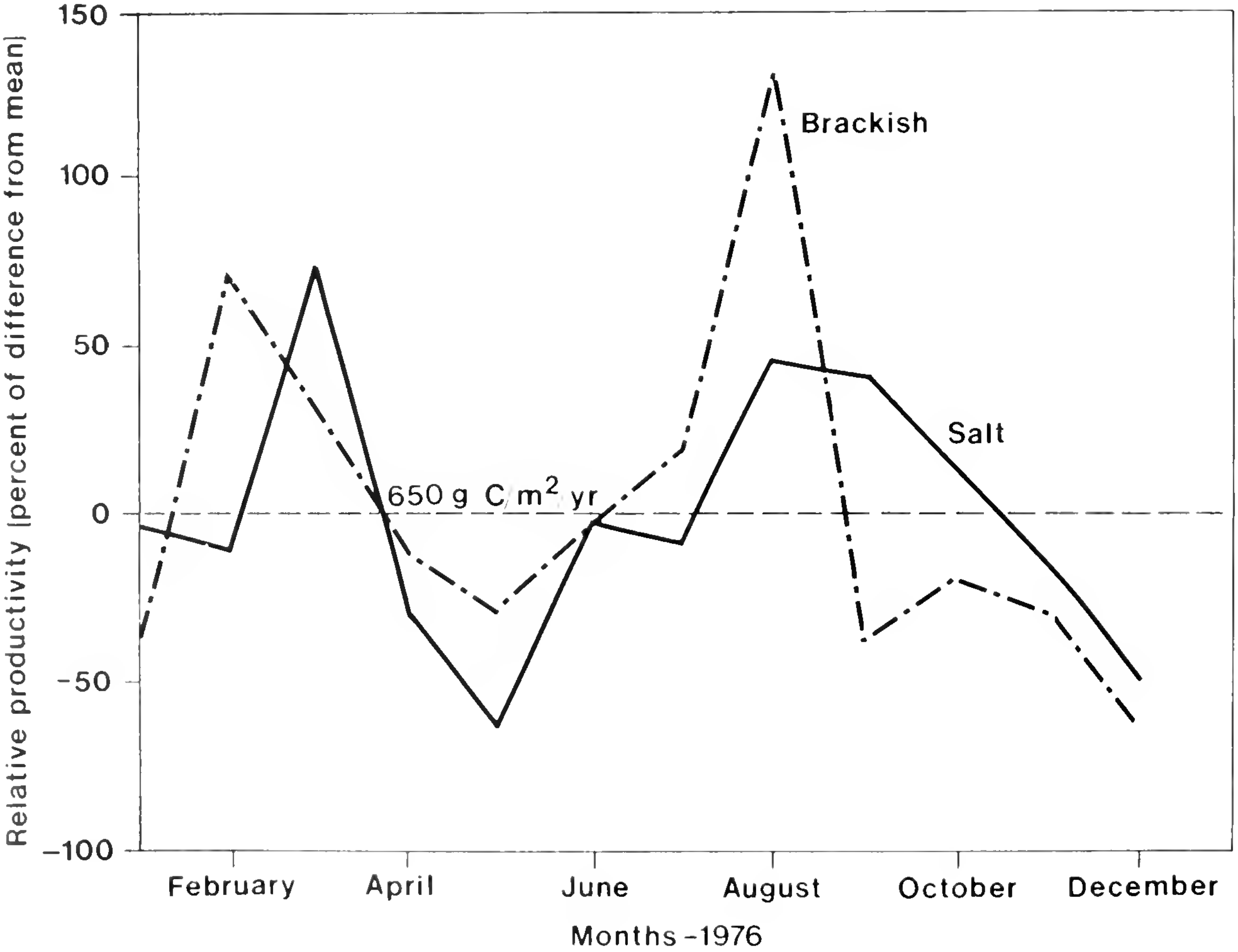


Figure 4-33. Monthly fluctuations of plant productivity in brackish and salt waters based upon deviations from the 1976 mean (Day et al. 1973, Allen 1975). Adapted by R. Beck, ERCO.

4.8.8 CONTROL OF PRODUCTION

Nutrients appear to be the major abiotic variable controlling the primary production rate, although salinity has an important effect on the kinds of phytoplankton present.

Saline sediments are typically rich in phosphorus (Pomeroy et al. 1965) and have a strong buffering ability for phosphorus, so nitrogen is more likely to be limiting in brackish and saline waters. Ryther and Dunstan (1971) documented this for Long Island Sound, New York. They found that about twice the amount of phosphate as can be used by the phytoplankton is normally present, whereas nitrogen is available in limiting amounts.

Addition of excessive nutrients, usually nitrogen and/or phosphorus, leads to an excessively eutrophic state. The high nutrient levels stimulate growth of a few algal species, which rapidly reach high population densities. Thus eutrophication is accompanied by dramatic changes in the composition of the community with a progressive deterioration of water quality, often anoxic conditions of sediments, advent of algal blooms, and the elimination of desirable (commercially important) fishes and shellfishes. Normally, algal blooms and oxygen problems associated with eutrophication occur in the warmer months of the year. This condition can occur in fresh, brackish, or saline waters. In fresh waters, blue-green algae such as *Microcystis*, *Anabaena*, *Anabaenopsis*, and *Spirulina* dominate. In brackish and saline waters the common blooming genera include such small coccoid algae as *Monodus*, *Nanochloris*, and *Stichococcus*.

The severity of eutrophication in a water body is strongly controlled by the flushing rate. Rapidly flushed areas can tolerate higher levels of nutrient inflow than can stagnant areas. Since coastal bays and lakes are usually inundated daily by tidal waters, they tend to be better flushed than freshwater areas and less subject to excessive states of eutrophication. Since inland Chenier Plain water bodies are usually very shallow (2 m or 6.6 ft), they are particularly sensitive to high nutrient loading levels. Craig and Day (1977) suggest a critical phosphorus loading level of 0.4 g/m^2/yr for Louisiana freshwater areas. They also cited permissible and dangerous loading levels of phosphorus and nitrogen from studies by Vollenweider (1968) and Brezonik and Shannon (1971).

4.9 INLAND OPEN WATER HABITAT

For the most part, the inland open water habitat is maintained by rainfall, the inflow of freshwater and sediments from rivers and runoff, and from tidal action and seawater inflow from the Gulf. The water bodies composing this habitat are shallow, seldom exceeding 3 m (10 ft), except for deep channels such as tidal passes and navigation channels. The area covered by this habitat type (fig. 4-34) is 2,008 km^2 (775 mi^2), 35% of the Chenier Plain aquatic system.

Shape and size of inland water bodies vary widely, since linear canals and rivers,as well as lakes and ponds,are included. The boundary between these water bodies and the surrounding wetlands is gently sloping, except where the water body is dredged and a spoil bank is formed. Salinities within the inland open water habitat vary from fresh to nearly full ocean strength, reflecting both proximity to the Gulf and the local hydrologic regime.

Generally inland open waters are somewhat turbid, emphasizing the importance of the interactions of fine bottom sediments, shallow depth, and turbulence. This turbulence is caused by wind-driven water currents, and sometimes by boat traffic. The water column is relatively homogeneous and well-mixed. During the summer, water temperature is usually high, often above 30°C (86°F), and the amount of dissolved oxygen sometimes can become dangerously low for aquatic animals.

4.9.1 PRODUCERS

The inland open water habitat provides a gradient of subhabitats that range from saline (up to 25‰) through brackish to freshwater. Plant communities associated with each subhabitat vary with salinity ranges.

In the saline areas of the inland open water habitat, the large proportion of water to wetland and the high frequency of marsh flooding by estuarine waters leads to a pronounced interaction between the aquatic and wetland habitats. The inland open water habitat is shallow and turbid with a muddy substrate. These conditions are unfavorable for the growth of large rooted aquatic plants and most of the primary production in these areas results from phytoplankton. Most numerous of the phytoplankton are the diatoms, coccoid blue-green algae, and coccoid green algae. Only one study (Denoux 1976) was found concerning phytoplankton in the Chenier Plain area, and it lists numbers of phytoplankton and not the types found there. Appendix 6.3 lists those phytoplankton found in inland open water habitat in southeastern Louisiana.

A few species of phytoplankton, such as *Nitzchia closterium*, are found across the whole salinity range into freshwater, but most freshwater species are seldom present where salinity is significant. The most numerous forms are diatoms and blue-green algae; the presence of the latter often reflects excessive eutrophic states.

Plant growth in brackish marsh areas shows a marked difference between summer and winter conditions. During the winter, tides and tidal currents are generally low in amplitude, and water bodies clear up allowing the growth of several macrophytes adapted to reduced temperatures. Large mats of filamentous green algae sometimes clog the less saline waterways. During the summer, higher turbidity levels restrict primary production to phytoplankton, except for the shallowest areas which are colonized by benthic diatoms (Bahr and Hebrard 1976).

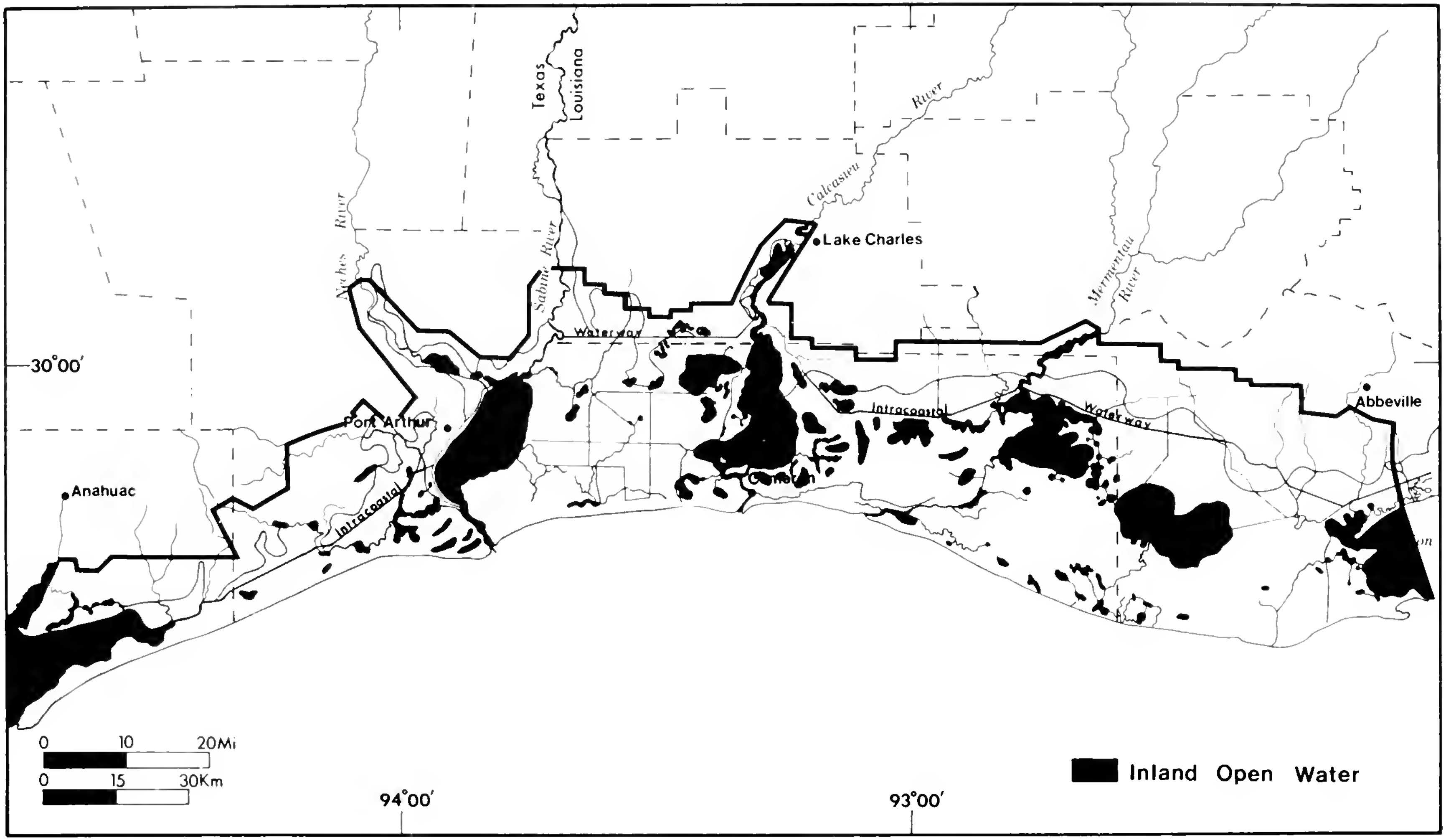


Figure 4-34. Distribution of inland open water habitat in the Chenier Plain.

The north coast of the Gulf of Mexico has been described as being a barren region for benthic algae (Taylor 1960); however, some macroscopic algae do exist. Since no data for the Chenier Plain study area have been found, the following information is based on studies in southeastern Louisiana. The most common genera in saline waters are *Enteromorpha* and *Ectocarpus* (table 4.19). These two forms are most abundant on the banks of streams and lakes and in quiet pools. They are found from early November to mid-April and early May, but peak abundance occurs in January.

Table 4.19. List of benthic marine algae from inland open water habitat of southeastern Louisiana (Day et al. 1973).

Chlorophyta
Blidingia marginata
B. minima
Chaetemorpha linum
Cladophora dalmatica
Enteromorpha clathrata
E. flexuosa
E. linza
E. ramulosa
Entrocladia testarum
Pseudendoclonium submarinum
Rhizoclonium kochianum
Phaeophyta
Ectocarpus intermedius
E. siliculosus
Giffordia mitchelliae
Rhodophyta
Bargia atropurpurea
Bostychia radicans
Erythrocladia subintegra
Erythrotrichia carnea
Polysiphonia subtillissima

Diversity of vascular plant species increases with decreasing salinity in the inland open water habitat. For brackish water bodies along the Louisiana coast, Chabreck (1972) reports a coverage of about 1% for rooted submerged aquatics. Common floating plants in inland freshwater bodies include water hyacinth, alligatorweed, duckweed, and waterlettuce. These plants only do well in quiet, slow-moving waters. When they are washed downstream from the freshwater areas into saline zones, the salt water kills them. Alligatorweed is reported in fresh marshes in the Calcasieu Basin at a frequency of 26% (Chabreck 1972). Both water hyacinth and alligatorweed are introduced species that have become major pests in coastal waterways.

4.9.2 CONSUMERS

Zooplankton identified in the inland open water habitat are listed in the appendix 6.3. Many of these were identified by Denoux (1976) for the Calcasieu Basin and by Gillespie (1971) for Sabine and Calcasieu passes and the lower Mermentau River.

Stickle et al. (1975) sampled a number of locations in the brackish parts of the Calcasieu Basin for benthic organisms. Sampling stations and the macroinvertebrates identified are shown in appendix 6.3. Freshwater benthic organisms are also listed in this appendix.

The inland open water habitat, as defined, ranges from highly saline to completely freshand, therefore, has a rather high vertebrate species richness. There are species of amphibians and turtles ranging from the saltwater diamondback terrapin to the southern painted turtle, a species that is confined to completely fresh water. Seven species of watersnakes are also represented. Wading birds and shorebirds occur primarily around the periphery of larger water bodies, while waterfowl use open water for feeding and/or resting. The southern bald eagle, an endangered species, nests near water and feeds on fishes. Mammals in this habitat are represented by four species of bats, the nutria, muskrat, otter, and, in areas near the coast, the Atlantic bottle-nosed dolphin. The West Indian manatee, an endangered species, has been periodically recorded in lower estuaries.

The finfish species richness is also somewhat higher in the inland open water habitat than in the nearshore Gulf. In addition to the majority of species which divide their time between the two habitats, there are a few species which are strictly estuarine (Gulf killifish, diamond killifish) and a number of species which are limited to fresh or nearly fresh water (bowfin, carp, smallmouth buffalo, and largemouth bass). In trawl and seine catches from 18 inland open water habitat stations in the Chenier Plain (Perret et al. 1971), the Gulf menhaden, the Atlantic croaker, and the bay anchovy were the most abundant finfishes. Perry (1976), reporting results of trawl and rotenone catches from the Rockefeller Wildlife Refuge (4 to 15.5‰ salinity), also found the Gulf menhaden to be dominant in numbers. Red drum was the dominant fish in terms of weight (fig. 4.35). Other common fishes were the bay anchovy, striped mullet, shad, Atlantic croaker, and southern flounder. Lists of representative finfishes and other vertebrate species, found in the inland open water habitat are in appendix 6.3.

4.10 NEARSHORE GULF HABITAT

Water bodies of the nearshore Gulf habitat are characterized by smooth, gently sloping bottoms, with occasional mudflats and sand ridges that are subject to relatively strong wind and wave action. The depth gradient runs roughly parallel to the coast; east to west variations occur because of differences of interaction with the river basins and because of the net westward drift of the longshore current. The area covered by the nearshore Gulf habitat (fig. 4-36) is 3,713 km^2 (1,434 mi^2), 65% of the Chenier Plain aquatic system.

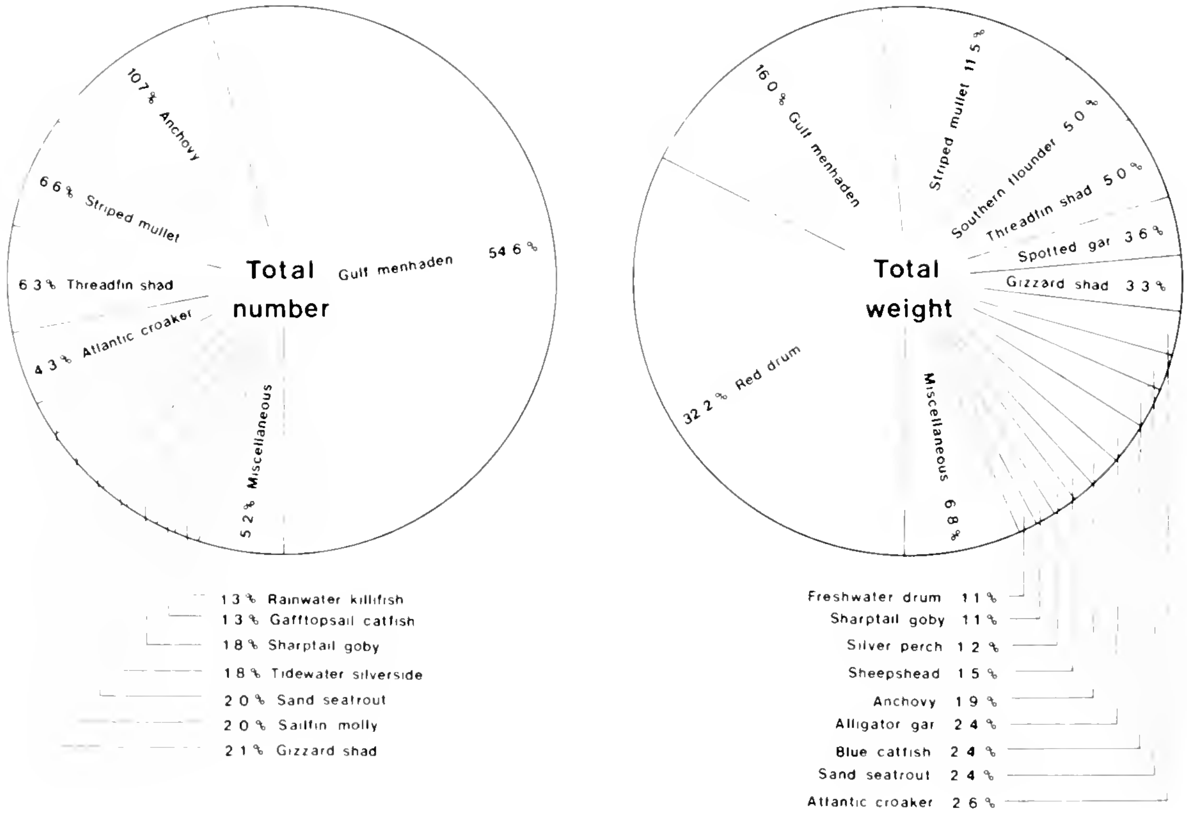


Figure 4-35. Percentage (numbers and weight) of fish species in rotenone and trawl samples from Rockefeller Wildlife Refuge, Louisiana (Perry 1976).

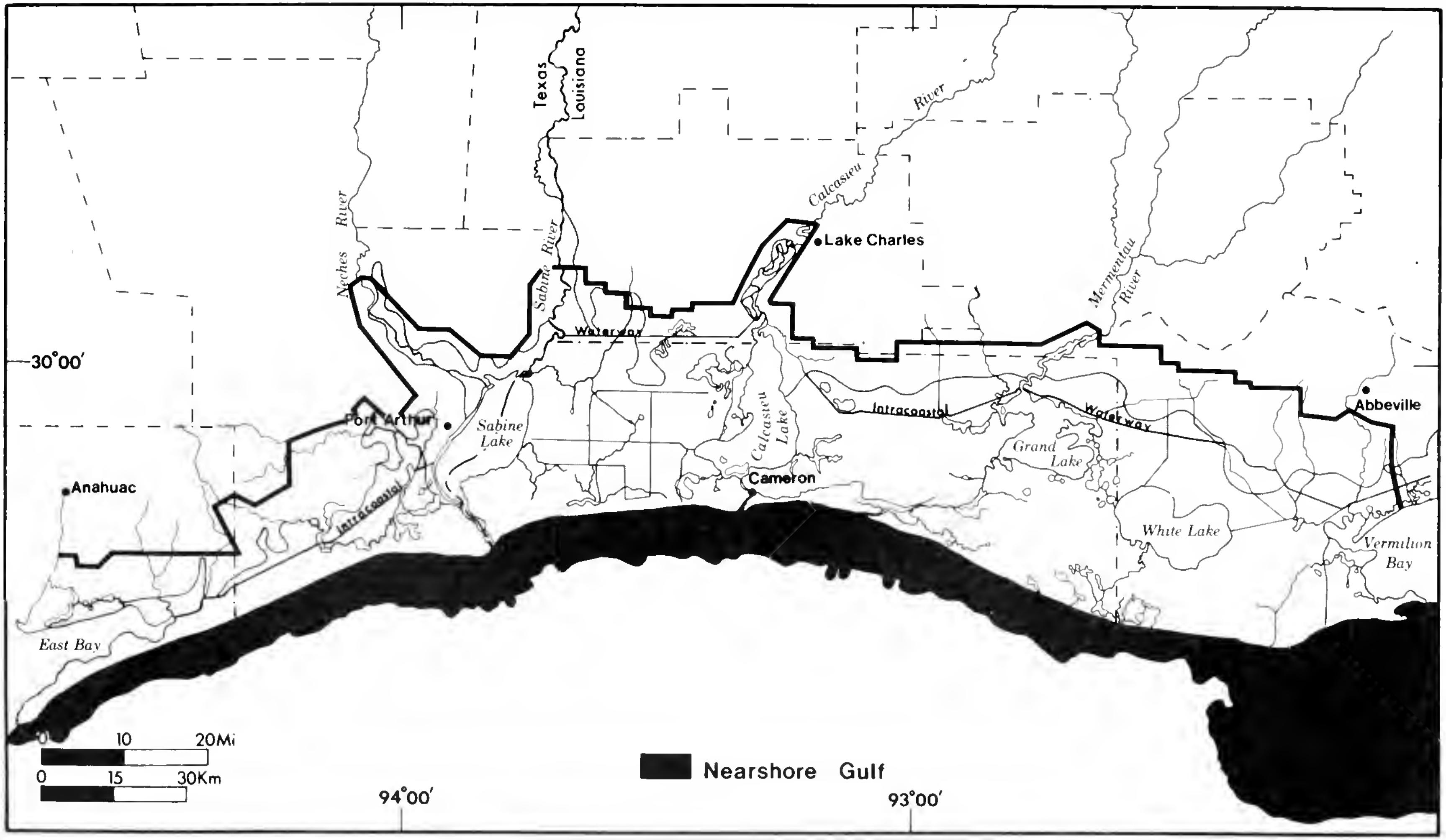


Figure 4-36. Distribution of nearshore Gulf habitat in the Chenier Plain.

The nearshore Gulf environment is generally more uniform than the inland open water environment. Salinity varies from 10 to 35‰, depending on freshwater inflow. Water temperatures are buffered by the deep oceanic waters and are more moderate than those of inland waters. The stirring of the water column by wave energy, the lower water temperatures in summer, and the living biomass effectively maintain sufficient dissolved oxygen for biological activities.

4.10.1. PRODUCERS

Phytoplankton studies of the Gulf of Mexico nearshore region are few. Selected areas have been surveyed (Freese 1952, Simmons and Thomas 1962) but much more work on taxonomy, ecology, and productivity needs to be done.

In a study along the southeastern Louisiana coast, Green (1976) found that the predominant species during the spring to summer months consisted of the dinoflagellates: *Ceratium*, *Exuviaella*, *Gonyaulaux*, and *Gymnodinium;* the diatoms: *Asterionella*, *Biddulphia*, *Coscinodiscus*, *Cyclotella*, *Lithodesmium*, *Navicula*, *Pleurosigma*, *Surirello*, *Skeletonema*, *Stauroneis*, and *Thallasiosira*. In the fall and winter, diatoms were the dominant phytoplankton (table 4.20).

Studies of benthic marine algae in Louisiana have centered on the Chandeleur Islands off the southeastern Louisiana coast. Kapraun (1974), however, has conducted field and culture studies of the seasonal periodicity and distribution of the benthic marine algae along the Louisiana coast including the Calcasieu region (table 4.21).

Of the species observed by Kapraun, most developed maximum growth in winter or early spring. *Polysiphonia subtilissima* exhibited the greatest abundance in the summer. *Giffordia mitchelliae*, primarily a tropical form, failed to develop as part of the summer flora; instead, it appeared inconspicuously at other times of the year. *Cladophora dalmatica*, *Ectocarpus intermedius*, *Enteromorpha clathrata*, and *E. ramulosa* formed extensive blooms during February and March on the mudflats flanking the Calcasieu River.

Table 4.20. Collections of phytoplankton by taxa and month from nearshore Gulf waters in southeastern Louisiana (Green 1976).

Species	Month M	J	J	A	S	O	D	J	F	M
Dinoflagellates										
Ceratium furca		x	x							
C. hircus	x	x	x							
C. sp.	x	x	x							
Exuviaella sp.			x	x						
Gonyaulaux monilata	x	x	x							
G. sp.		x	x							
Gymnodinium splendens	x	x		x					x	
Peridinium sp.		x	x							
Diatoms										
Asterionella japonica		x	x		x			x	x	x
Bacillaria sp.				x	x					
Biddulphia alternans				x	x	x	x			
Chaetoceros compressum			x	x						
C. peruvianum		x								
C. pelagicum					x					
Coscinodiscus spp.			x	x	x					
C. eccentricuis	x	x	x							
Cyclotella sp.	x	x	x	x						
Fragilaria sp.		x	x	x					x	x
Guinardia flaccida								x	x	
Hemidiscus sp.			x	x	x					
Lithodesmium undulatus		x	x							
Navicula sp.				x	x	x				
N. distans		x	x	x						
Nitzchia sp.						x	x	x		
Porosira stelliger	x	x								x
Pleurosigma sp.	x	x	x						x	x
Rhizosclenia fragilissma			x	x		x			x	x
R. alata				x	x		x	x		x
R. acuminata		x	x	x						
R. imbricata				x	x		x	x		x
Surirella gemma	x	x	x	x						
Skeletonema sp.	x	x	x						x	x
Stauroneis membranacea	x	x	x							x
Thallasiosira aestivalis	x	x	x							x
Blue-green Algae										
Oscillatoria-like		x	x							
Green Algae										
Chlorella-like									x	x

Table 4.21. Monthly relative abundance of benthic marine algae near the Calcasieu River jetty (Kapraun 1974).

Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Chlorophyta												
Blidingia marginata		C	C	C			R					
B. minima	C	C			C							
Chaetomorpha linum		R		C								R
Cladophora dalmatica	C	C	C	M	M	C	C	C	C	R	C	C
Enteromorpha clathrata	C	M	M	C		C		C	C			C
E. linza	M	M	M	M	C	C	C	R	C		C	C
E. ramulosa	C	C	M	M	C	C	C	R	C		C	C
Entocladia testarum	C	C								C		
Pseudendo clonium submarinum	C	C	C	C	C	C	C	C	C	C	C	C
Rhizodonium kochianum		C		C		C						
Rhodophyta												
Bangia atropurpurea	M	M	C	C	C			R	R		C	C
Bostrychia radicans	C	C	M	C	C		C	C		C	C	C
Erythrotrichia carnea					R							
Erythrocladia subintegra	R	R				R	C	R				
Polysiphonia subtilissima		R		C		C	C	C		C		
Phaeophyta												
Ectocarpus siliculosus	R									R	R	C
Giffordia mitchelliae	R									R	R	R

M = Maximum vegetative development.
C = Common.
R = Rare.

4.10.2 CONSUMERS

Zooplankton populations in the nearshore Gulf habitat were studied by Bouchard and Turner (1976) off Bay Champagne in southeastern Louisiana. A taxonomic listing is shown in appendix 6.3. According to these workers, salinity is a major influence in species distribution. Calanoid copepods, particularly *Acartia tonsa*, are the dominant zooplankton in saline and brackish water, Bouchard and Turner's study covered the period from October to March only, so seasonal differences are not clear; but in another study (Gillespie 1971), peak abundance of zooplankton was found to occur in coastal waters in April, August, and September (fig. 4-37).

Zooplankton abundance generally follows the cyclic pattern of phytoplankton abundance; however, zooplankton peaks lag behind those of phytoplankton by about one month. This lag is expected since zooplankton depend heavily upon phytoplankton for food.

Penaeid shrimp dominate the nektonic invertebrate macrofauna throughout the summer, fall, and winter. Five species of penaeid shrimp are commonly found,but white and brown shrimp are by far the most abundant. In addition, several non-penaeid shrimp and several species of crab are common (table 4.22).

Benthos collected with a grab sampler along the southeastern Louisiana coast were dominated by polychaetes (fig. 4-38) on all collecting dates except in December (Ragan 1976). Population density seems to decrease with water depth (fig. 4-39). A taxonomic list of benthos described by Ragan (1976) is included in appendix 6.3.

Excluding fish, vertebrate species richness is lowest in the nearshore Gulf habitat. There are no amphibians, and the reptiles are represented by sparse populations of four species of sea turtles. Two of these, the Atlantic hawksbill and the Atlantic loggerhead, are on the endangered species list. Birds using the nearshore Gulf habitat are primarily fish-eating species. There are often very large concentrations of overwintering lesser scaup in the immediate offshore area. The only mammal which regularly occurs in the nearshore Gulf habitat is the Atlantic bottlenosed dolphin. Although there are records of other dolphins and whales from the Gulf, most of these mammals are found in deep water.

Table 4.22. Benthic macroinvertebrates of the Louisiana nearshore Gulf habitat (Perret et al. 1971).

Taxonomic classification	Common name
Mollusca	
Loliginidae	
Lolliguncula brevis (Blainville)	Squid
Crustacea	
Cymothoidae	
Livoneca ovalis (Say)	Isopod
Penaeidae	
Penaeus setiferus (Linnaeus)	White shrimp
P. duorarum (Burkenroad)	Pink shrimp
P. aztecus (Ives)	Brown shrimp
Xiphopeneus kroyeri (Heller)	Seabob
Trachypeneus constrictus (Stimpson)	Roughneck shrimp
Sergestidae	
Acetes americanus (Ortman)	Netclingers
Alpheidae	
Alpheus heterochaelis (Say)	Big-clawed snapping shrimp
Palaemonidae	
Palaemonetes vulgaris (Say)	Grass shrimp
Squillidae	
Squilla empusa (Say)	Mantis shrimp
Paguridae	
Pagurus longicarpus (Say)	Hermit crab
Portunidae	
Callinectes sapidus (Rathbun)	Blue crab
Xanthidae	
Menippe mercenaria (Say)	Stone crab
Panopeus herbstii (Edwards)	Common mud crab
Ocypodidae	
Uca pugnax (Smith)	Fiddler crab

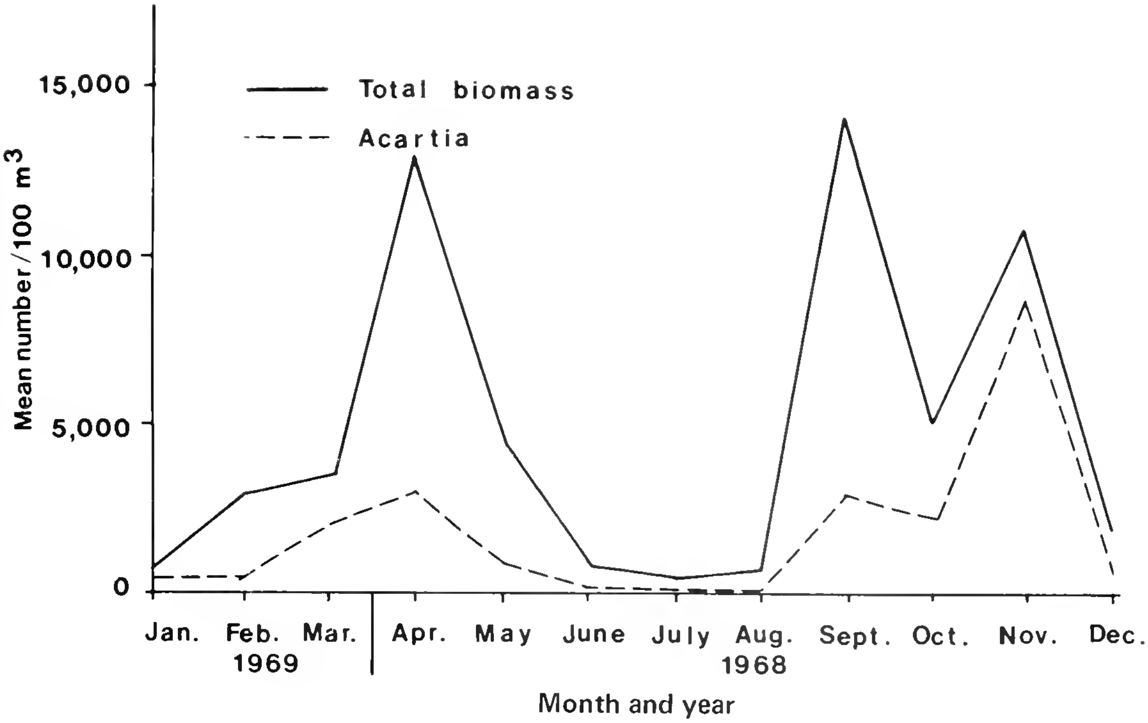


Figure 4-37. Monthly variation in density of total zooplankton and of *Acartia* in estuarine waters of Louisiana from April 1968 through March 1969 (Gillespie 1971).

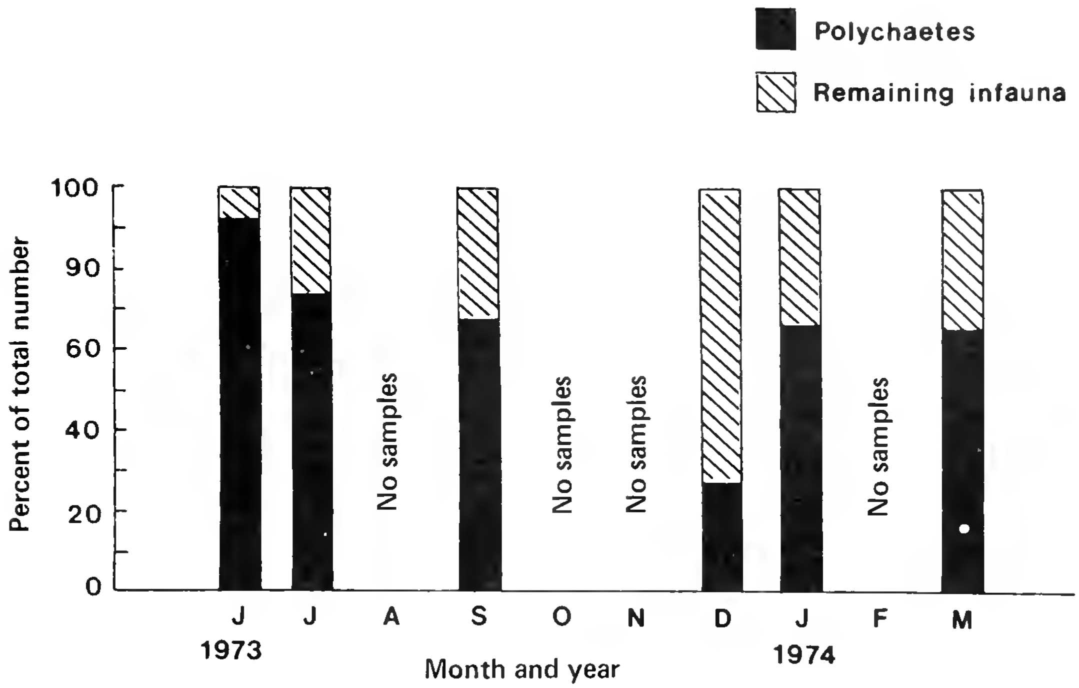


Figure 4-38. Proportion of polychaetes in the total infauna in grab samples collected in June 1973 through March 1974 along the southeastern Louisiana coast (Ragan 1976).

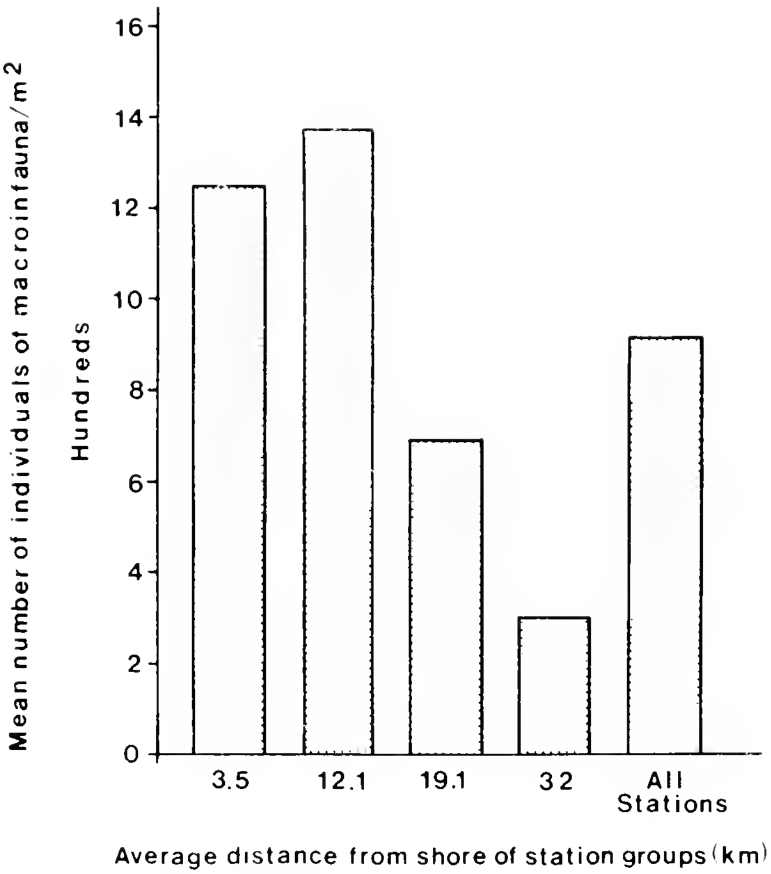


Figure 4-39. Relationship between mean density of macroinfauna and the average distance from shore in Louisiana (Ragan 1976).

The number of finfish species in the nearshore Gulf habitat is less than the number found in the inland open water habitat, probably because of the greater physical diversity of the latter habitat. Studies of shallow waters, less than 5 m (16 ft), along the beach indicate that bay anchovy and sea catfish dominate these areas (Loesch 1976). Sea catfish, Atlantic croaker, cutlass fish, and bay anchovy were the dominant species at depths from 5 to 30 m (16 to 98 ft) (Ragan and Harris 1976).

4.11 BEACH AND RIDGE HABITATS

Two related habitats in the Chenier Plain, easily distinguished from all others, are the beach and ridge habitats. Beaches represent the geological precursors of cheniers; both formations are basically linear bodies of sand. Included as ridge habitat are natural cheniers and stream levees, Pleistocene outcroppings, artificial levees, and spoil banks.

4.11.1 A FUNCTIONAL OVERVIEW OF BEACH AND RIDGE HABITATS

The total combined area of beach and ridge habitats in the Chenier Plain is small compared to that for surrounding habitat types (fig. 4-40). However, the ecological influence of these habitats extends far beyond their boundaries (fig. 4-41). One major function of the beach habitat is to serve as a storm barrier. As elevated features, beaches control the flow of water between the Gulf and the inland open water habitat. Cheniers and other inland ridges also serve this function and control patterns of water circulation inland as well. Beach and ridge habitats provide major routes of travel for terrestrial animals, and they are important refuges for all kinds of animals during floods and seasonal migrations. Since cheniers provide limited areas of high land in the midst of wetlands, they are heavily exploited by man for residential, agricultural, and industrial purposes.

4.12 BEACH HABITAT

The beach habitat has a structure and function that is quite unlike that of other coastal habitats. The area of this habitat type is small (table 4.23) in comparison to other types, but it is relatively constant. The functional importance of beach habitat is related to the controlling influence this habitat has on surrounding areas, rather than on its own biological productivity and species diversity.

Plant production in this sandy environment is limited by availability of nutrients and freshwater. Organic material carried onto the beach by wave action is the major source of food for small beach consumers. Migrating organisms (especially birds), which often use the beach habitat as resting or nesting areas, feed predominantly in the Gulf and in adjacent wetlands.

Table 4.23. Area of beach habitat in the Chenier Plain by basin.

Basin	Area (km^2)	Percent of basin
Calcasieu	8.40	0.6
Vermilion	4.00	0.5
Chenier	15.40	1.6
Mermentau	0	0
Sabine	21.20	0.7
East Bay	12.60	1.5
Total	61.60	

4.12.1 PHYSICAL PROCESSES

The major physical function of beaches is to buffer the inland area against marine processes. Along the Chenier Plain coastline, the amount of coarse-grained materials is highly variable. Such material, largely shell, is virtually absent along the eastern sections of the coast, but accumulates to a thickness of several feet along the western sections. Where beach accretion is insignificant, marshes are exposed to direct wave attack.

During stormy periods sediments are moved shoreward by waves and currents, and the suspended materials create highly turbid conditions in the nearshore waters. Upwash and backwash action of waves along the coast move these sediments onto the beach. When sufficient energy is available, onshore winds blow sediments to the upper back-berm, forming dunes. In this process, sorting and redistribution of the original beach sediments occurs. The smaller fraction is removed either offshore or inland, the larger fraction remains on the beach, and medium-sized materials are transported to form dunes.

The accretion of beach ridges at river mouths is evidence of sediment supplied from estuaries. Although dams and other water control structures have diminished riverine sediment supplies in the Chenier Plain, quantities of sediments are flushed out of the estuaries during storms and floods. Occasional severe storms spread beach sands widely, permitting wave action to cut back the coast.

4.12.2 PRODUCERS

Vegetation of the beach habitat is a mixture of typical halophytic marsh plants and beach plants characteristic of subtropical areas. On beaches along the Rockefeller Wildlife Refuge in the Chenier Basin, Chamberlain (1959) found saltmeadow cordgrass, and camphorweed growing from the highest elevation of the beach, about 1.5 m (5 ft), back into the adjacent salt marshes. The salt marsh species, saltgrass and smooth cordgrass, grew out from the marsh to within about 8 m (26.4 ft) of the beach crest, in a zone also

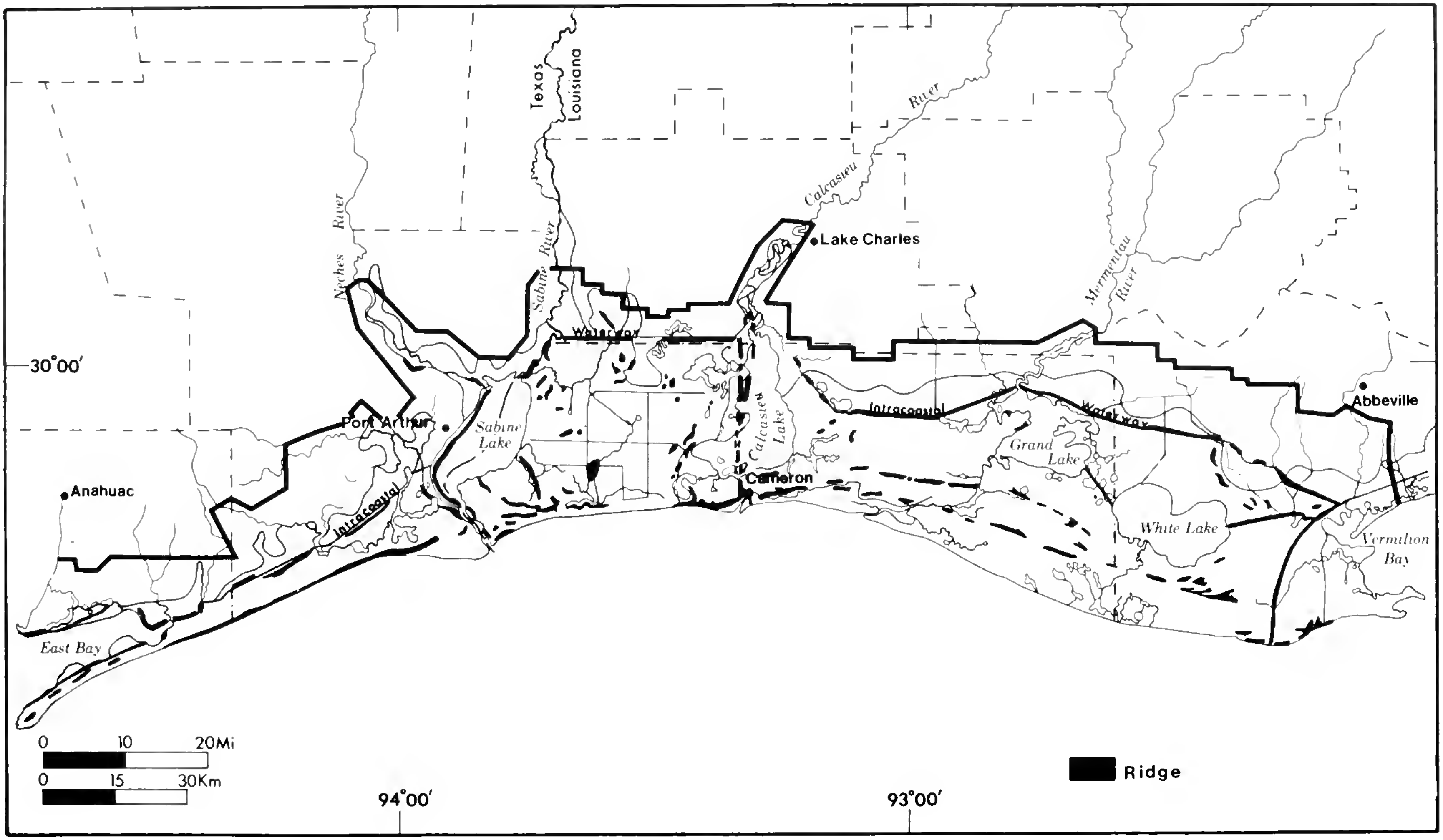


Figure 4-40. Distribution of ridge and beach habitats in the Chenier Plain.

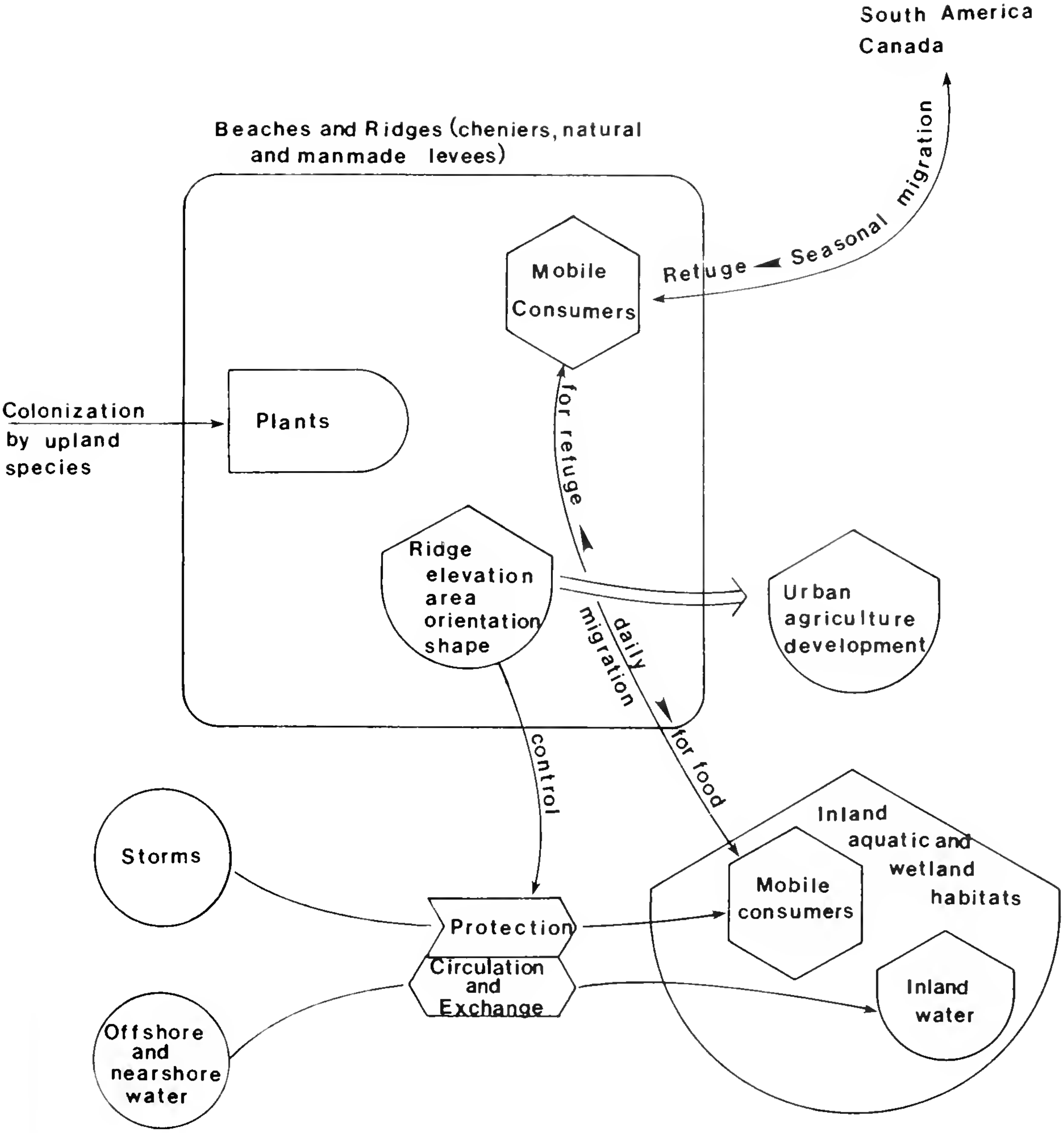


Figure 4-41. Diagrammatic model of the beach and ridge habitats showing the functional relationship of these habitats to other surrounding Chenier Plain habitats.

occupied by sea ox-eye daisy, saltwort, and poor man's pepper. Several meters further inland heliotrope, frogfruit, and aster grew just above the marsh elevation.

One important function served by beach plants is the stabilization of sand dunes. As plants grow, they interrupt air flow and cause windborne particles to be deposited. Their roots secure the dunes and help bind loosely-packed sand grains together (Oertel 1975). Stabilization of sand dunes as a management practice is widespread, although it is not practiced along the Chenier Plain beaches. A general discussion of dune stabilization practices is, however, included in appendix 6.3.

4.12.3 CONSUMERS

In most beach communities, minute detritivores and predators occupy the lower forebeach in the spaces between sand grains. These microbes and small animals (predominantly crustacea) are supported by organic carbon which filters into sand grains from Gulf waters. Stirring of the beach sediments by the surf insures an adequate oxygen supply for respiration. Shore birds, such as plovers, sandpipers, and willets utilize these small animals as a food source. Small fishes consume small crustaceans, as well as larger benthic macrofauna such as coquinas and other bivalves.

Reptiles and amphibians are scarce in the beach habitat; only the Gulf coast toad, Woodhouse's toad, and six-lined racerunner are found there. Fish-eating birds, such as the American white pelican, herons, egrets, gulls, and terns are well represented, and there are about 25 species of shorebirds. These birds often concentrate on mudflats during low tides. Some seabirds nest on remote sections of beach (e.g., laughing gull and least tern), several species of swallows feed in the air over beaches, and other land birds, including grackles and the Savannah sparrow, use the area. Of the birds of prey that may occur on beaches, the osprey and merlin are listed by the National Audubon Society as having declining populations. The endangered peregrine falcon also occurs in this habitat during migration. Only three mammals, the Virginia opossum, nine-banded armadillo, and Northern raccoon occur in the beach habitat. A listing of representative vertebrate species which occupy the beach habitat is found in appendix 6.3.

4.13 RIDGE HABITAT

Since natural relief in the Chenier Plain is rare, even a relatively low surface feature can be enormously beneficial. Therefore, the importance of the ridge habitat relates to its elevation rather than to its relatively small area (table 4.24).

Cheniers represent the largest and longest of the elevated coastal areas, rising 3 m (10 ft) above mean sea level and extending for many miles. Their orientation is uniformly east and west. Large cheniers are often forested with live oaks. They are used by man for residential and agricultural purposes and serve as avenues for the movement of terrestrial animals into wetland areas. Cheniers and ridges support a rich assortment of plants and animals, and provide roosting and nesting sites for migrating birds.

Natural stream and man-made levees are generally perpendicular to the coast, while spoil banks are constructed in all directions. These artificial ridges are much younger and generally smaller than cheniers and are colonized by vines, herbs, willow trees, Chinese tallow trees, and various shrubs. Since these man-made levees and spoil banks are usually constructed with soils taken from adjacent wetlands or canals, they are highly organic and shrink and settle with time. If dug in a straight line (as they usually are), canals or borrow pits can affect the surrounding wetlands by draining water and nutrients rapidly into the inland open water habitat. Sometimes canals and barrow pits are dug in a staggered fashion to allow cattle access to adjacent marshes.

4.13.1 PRODUCERS

Cheniers are well above normal tidal influence and support a variety of trees, shrubs, and small plants (table 4.25). Historically, cheniers have supported live oak forests, but many of these forests have been

Table 4.24. Area (km^2) of natural and artificial ridge habitat in the Chenier Plain by basin.

	Basin					
Habitat	Calcasieu	Vermilion	Chenier	Mermentau	Sabine	East Bay
Natural						
Cheniers		9.3	24.1	28.6	70.4	31.7
Levees	80.6	1.3	8.7	0.7	8.6	15.2
Pleistocene islands	——	0	0	10.6	21.8	0
Total	80.6	10.6	32.8	39.9	100.8	46.9
Artificial						
Spoil banks	33.1	15.9	34.2	86.4	93.1	23.1

cleared to produce pasture and farmland. On the more heavily grazed cheniers, the vegetation consists primarily of chickasaw plum, prickly pear cactus, and salt cedar (Palmisano 1967).

Table 4.25. Natural vegetation of the cheniers in the Louisiana portion of the Chenier Plain (Palmisano 1967, 1970).

Common name
Trees
Live oak
Hackberry
American elm
Drummond red maple
Baldcypress
Water locust
Prickly ash
Persimmon
Water oak
Understory
Palmetto
Blackberry
Haws
Buttonbush
Deciduous holly
Chickasaw plum
Groundsel tree
Saltmeadow cordgrass
Grape
Black willow
Salt cedar
Prickly pear cactus

Plant communities on man-made levees and spoil banks include a wide range of species, many of which are primary invaders on disturbed sites. The most common plants include marsh elder, groundsel tree, bermuda grass, saltmeadow cordgrass, saltgrass, common reed, and blackberry, and the overstory trees, willow and Chinese tallow. On Rockefeller Wildlife Refuge, Spindler and Noble (1974) found that groundsel tree and saltmeadow cordgrass were dominant on spoil banks, while saltmeadow cordgrass, bulltongue, giant bulrush, sawgrass, common reed, and Walter's millet were prevalent in adjacent wetlands.

On these elevated areas the composition of herbaceous and shrubby vegetation reflects the salinity of the spoil. As salts are leached from spoil sediments, trees invade and plant communities change. Eventually, there is a convergence toward the climax community of old cheniers.

4.13.2 CONSUMERS

The ridge habitat, as defined, includes not only forested cheniers, but spoil banks and natural and man-made levees in all stages of succession. The physical diversity of this habitat type is reflected by a high species richness (appendix 6.3). The ridge habitat is not only inhabited by species typical of forest or shrub associations but also by marsh species which use elevated areas for nesting, basking, or other activities. Spoil bank areas would be expected to support fewer animal species than would cheniers, because they are less diverse vegetatively and are more exposed to flooding.

Populations of various terrestrial salamanders, toads, and treefrogs occur in the ridge habitat. Reptiles including box turtles, lizards such as the six-lined racerunner and *Eumeces* skinks, the prairie kingsnake, the rough earth snake, and the pygmy rattlesnake are all characteristic of upland habitats. However, the alligator and a variety of aquatic turtles and snakes move from inland lakes and wetland habitats onto ridges, levees, and spoil banks to nest, bask, and hibernate.

Bird species richness is greater for the ridge habitat than for other habitat types in terms of summer residents, year-round residents, and migratory transients. The relatively high number of breeding birds (summer and year-round residents) may be related to the heterogeneity of the ridge habitat. Ridges are often the only forested islands in a sea of wetlands and they provide nesting sites for typical forest birds, as well as for birds from marsh or agricultural habitats. Some beach-inhabiting species may also find suitable nesting sites on new spoil banks. Wading bird rookeries are often located on forested cheniers or old levee sites.

Typical terrestrial mammals that occur on Chenier Plain ridges include the white-tailed deer, Northern raccoon, swamp rabbit, least shrew, nine-banded armadillo, gray and fox squirrels, marsh rice rat, cotton mouse, eastern wood rat, coyote, gray fox, and bobcat.

Use of ridge habitats by migrating birds. More than 60 species of land birds that spend the winter months in Central and South America return to North America in spring by flying directly across the Gulf of Mexico (Lowery 1945, 1951). These species are listed in appendix 6.3.

The spring migration period in coastal Louisiana extends from late March to mid-May (Hebrard 1971). Trans-gulf flights occur somewhat erratically in March and then on a regular, almost daily basis from the first week in April through the second week in May. Each species has its own seasonal pattern. Birds that nest in southern Louisiana generally appear first in the spring, followed by those species that nest in more northern latitudes.

Most of these birds are nocturnal migrants, generally migrating all night and feeding during the day. This is illustrated in the temporal pattern of their departure from the northern coast of Yucatan (fig. 4-42). Most birds depart in the hours before midnight and, owing to the 772 km (480 mi) distance of the Gulf crossing, are still over water at dawn and must continue flying until they reach land. Figure 4-43 shows the hour to hour change in densities of arriving trans-gulf migrants on the northern Gulf coast under conditions of moderate southerly winds, the most frequent condition during the peak period of spring migration. Peak arrival time may be shifted to an earlier hour when southerly winds are stronger and may be delayed when winds are northerly (Gauthreaux 1971).

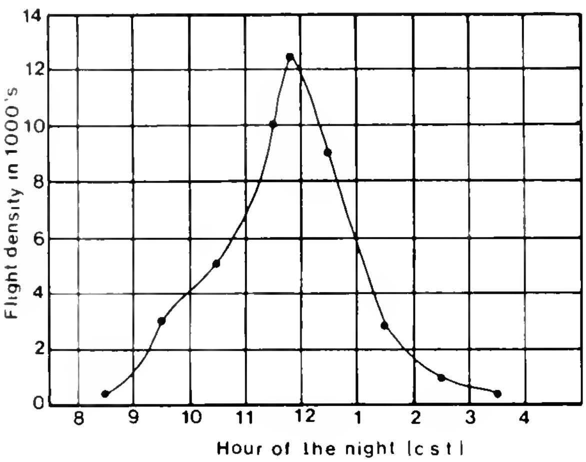


Figure 4-42. Flight densities at different departure times for land birds that migrate from the northern coast of Yucatan to southern Louisiana.

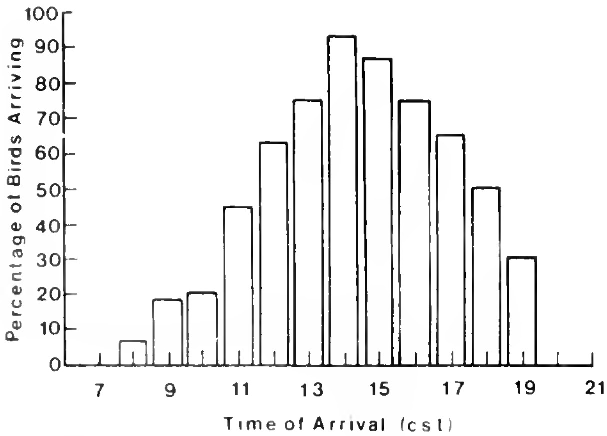


Figure 4-43. Percentage of land birds arriving in southern Louisiana from the coast of Yucatan during different hours of the day.

In spite of the rigors of a Gulf crossing, most trans-gulf migrants do not usually alight on the first available land, but overfly the coastal marshes and put down in an extensive forested zone about 56 km (35 mi) north of the coastline in the Chenier Plain (Lowery 1945). Radar studies by Gauthreaux (*in* McIntire et al. 1975) revealed that in fair weather with southerly winds only about 10% of the migrants landed south of Lake Charles. However, under conditions of strong northerly winds and thunderstorms that often accompany a spring frontal passage, as many as 60 to 80% of individuals in a trans-gulf flight might alight in isolated coastal woodlands such as are found on cheniers. At such times these woodlands temporarily support tremendous densities of land birds, and the presence of these areas may be extremely important to the survival of many individuals.

Orientation patterns of all migrants were studied by Able (1972) who utilized weather radar facilities at Lake Charles. He found that trans-gulf migrations per se were relatively infrequent during the fall migration season (August, September, October). Instead, flights were oriented to the southwest, along the Louisiana and Texas coasts. These coastal flights can result in concentrations of land birds in small woodlands on coastal ridges as great as, or greater than, those resulting during the spring trans-gulf migrations.

4.14 UPLAND FOREST HABITAT

The upland forest habitat in the Chenier Plain is usually designated as a pine and hardwood forest. This name is synonomous with the term "loblolly pine-shortleaf pine type" described by Walker (1962). The pine and hardwood community occurs on acidic soil that is primarily clay or loam. This forest also colonizes disturbed soils and disposal areas (Parker et al. 1975). It can be cultivated on suitable sites and managed for specific tree species. The faunal composition of this forest is altered by changes in the age classes and species composition of plants. Upland forest habitat occurs extensively in Texas and Louisiana, but it occupies only about 1.7% of the Chenier Plain ecosystem (fig. 4-44).

4.14.1 A FUNCTIONAL OVERVIEW OF THE UPLAND FOREST HABITAT

The forest community (fig. 4-45) is characterized by a high biomass of standing vegetation and surface litter material (2 on fig. 4-45), which provides refuge (8) for many animals. The contribution of organic matter (6) to bordering wetlands (3) is probably low and is influenced by rainfall (9), which exports litter and nutrients from the forest community. Gross primary production and the synthesis of vegetational structure (2) is a function of solar energy (1) and nutrient inputs (4) from the atmosphere and the earth's crust. Plants (2 and 6) are consumed by herbivores or incorporated into soil litter with its associated decomposers. These first level consumers (herbivores) are in turn utilized by higher level consumers (carnivores), many of which move between upland and wetland areas. Adverse conditions (5)

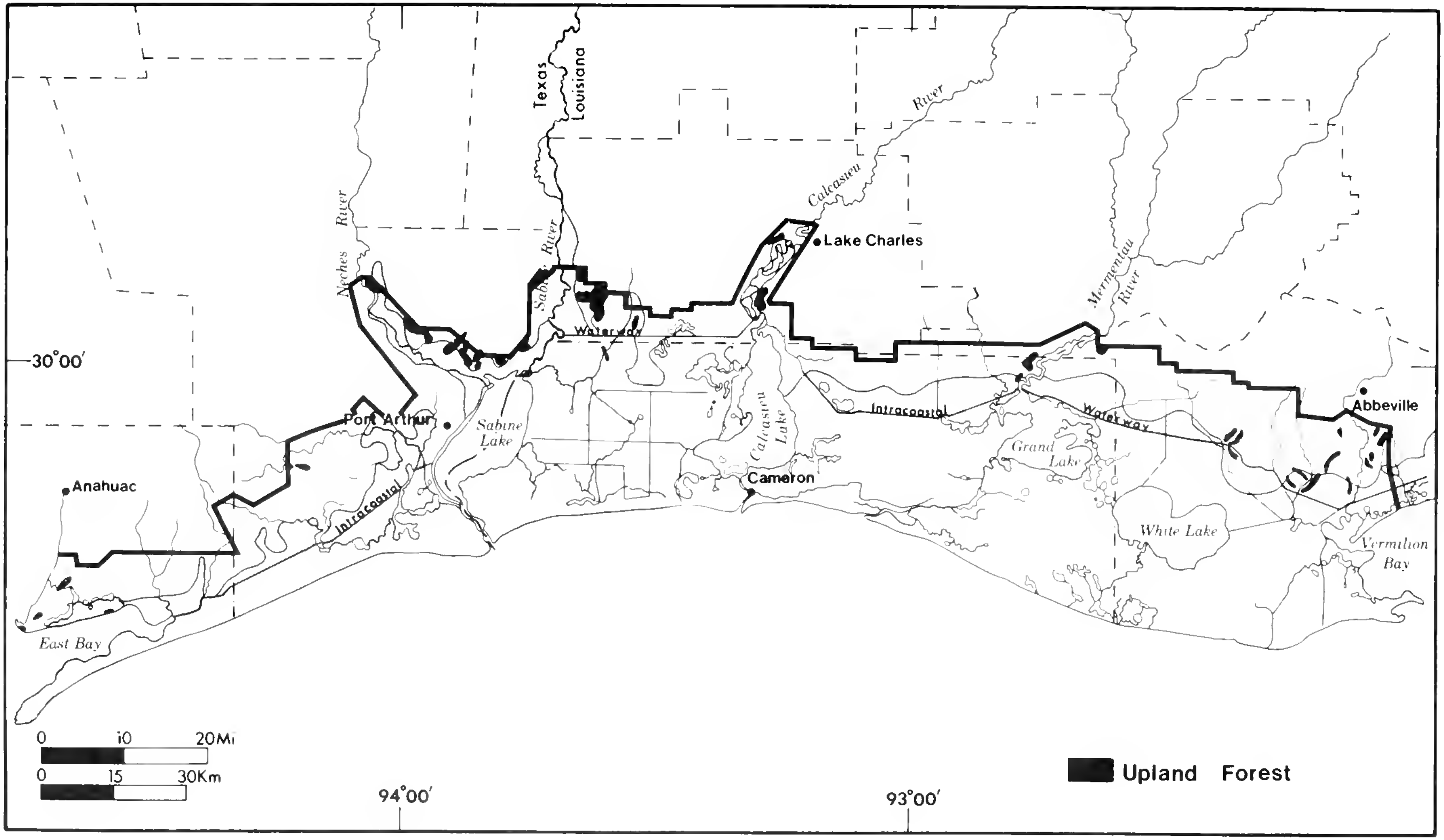


Figure 4-44. Distribution of upland forest habitat in the Chenier Plain.

resulting from natural catastrophes or man-induced changes can affect these movement patterns. Man can alter the upland forest habitat by indiscriminately harvesting its resources (7).

4.14.2 PRODUCERS

The upland forest habitat includes pine and hardwood components. The major pine species are loblolly, shortleaf, longleaf, and slash. These pines are found in association with such hardwoods as water oak, American elm, sweetgum, and southern magnolia. Table 4.26 provides a more complete list of the major hardwood species and other understory plants.

The distribution of pine species in the upland forest habitat is related to soil moisture. Longleaf and shortleaf pines are found on dry ridges, while loblolly occurs on moist sites. The latter becomes the first dominant tree species in the succession of this forest type. Young stands of loblolly pine can grow 0.6 to 0.9 m/yr (2 to 3 ft/yr), but generally attain 22.5 to 25.5 m (75 to 85 ft) over a period of 50 years (Walker 1962).

Oak and hickory seedlings begin to dominate 20 to 30 years after pines become established (Barrett and Downs 1943). During this stage in the forest succession, the shaded and undisturbed forest floor is a poor seedbed for pines but not for hardwoods (Walker 1962, Wenger 1968). As older pines die from such causes as wind and lightning damage, insect infestations, and diseases, openings in the canopy occur that are not closed by adjacent pine crowns. Instead, the small shade-tolerant hardwoods in the understory fill these vacancies. This process usually begins about 75 to 100 years after pine establishment and the replacement of pines by hardwoods is complete within 200 to 300 years. The climax of this natural succession is a forest of mixed hardwoods with no remaining pines. However, both natural and human processes retard development of this mixed hardwood forest. Fire is frequent enough to set back succession to a pine-dominant stage (called a fire disclimax), and the practice of clearcutting is usually followed by replanting with pine seedlings. Hence,climax stands of mature hardwoods are nonexistent in the Chenier Plain.

Table 4.26. List of hardwood and understory species in the loblolly pine-shortleaf pine type forest (Parker et al. 1975).

Common name	
Eastern red cedar	Blackgum
Water oak	Tupelo
Overcup oak	Water ash
Burr oak	American beauty berry
Willow oak	Blackberry
Swamp hickory	Palmetto
Southern hackberry	Rough-leaf dogwood
American elm	Boxelder
Sweetgum	Spanish moss
Southern magnolia	Paspalum
Sycamore	Scribner panicum
Blackcherry	Indiangrass
Texas sugarberry	Smutgrass
Water locust	Poison ivy

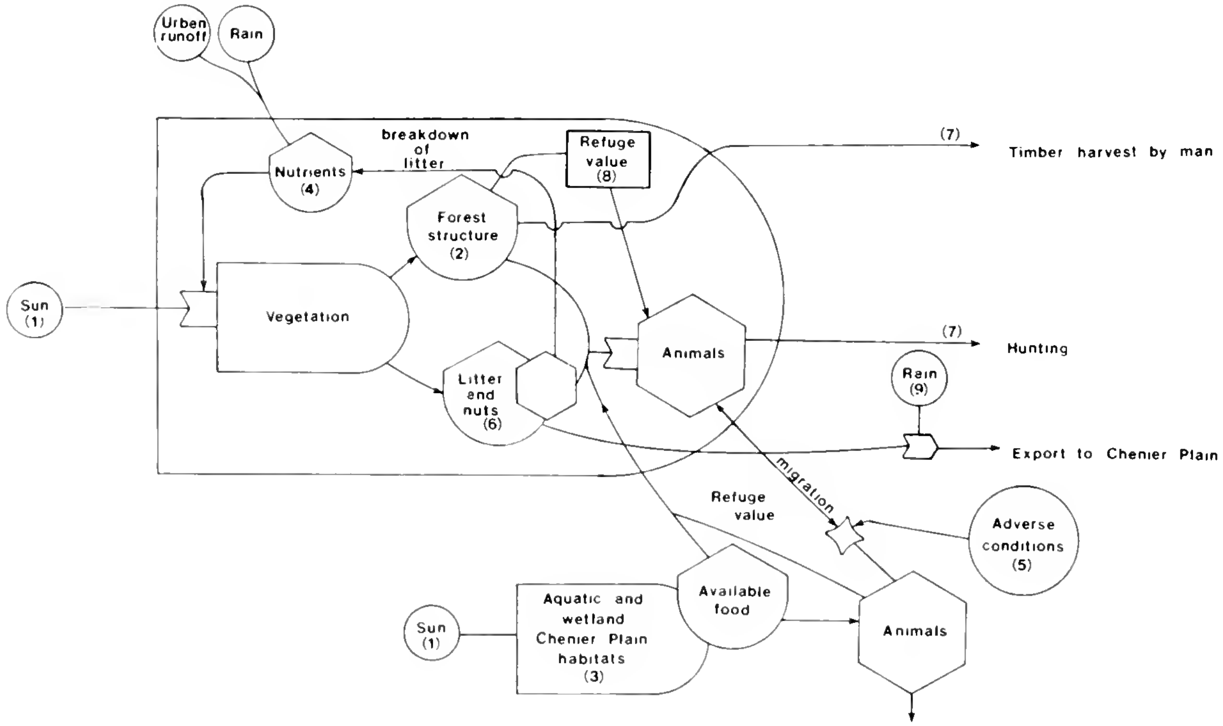


Figure 4-45. Conceptual model of energy flow and interrelationships between upland forest and aquatic habitats in the Chenier Plain.

4.14.3 CONSUMERS

Vertebrate species composition in the upland forest habitat is similar to that of the swamp forest habitat, with the omission of most aquatic or semi-aquatic forms. Eleven species of amphibians include terrestrial salamanders and arboreal frogs, as well as terrestrial frogs and toads. There are fewer species of reptiles here than in the swamp forest habitat. A variety of birds, including raptors and song birds, occur in the upland forest habitat. Mammals found in the upland forest habitat are similar to those found in the swamp forest habitat, except for the absence of aquatic furbearers such as the nutria, otter, and muskrat. Lists of representative vertebrates found in the upland forest habitat are found in appendix 6.3.

The loblolly pine-shortleaf pine type forest usually supports a limited white-tailed deer population, moderate squirrel populations, and low numbers of bobwhite quail (Parker et al. 1975). However, certain areas where the number of hardwoods is significant can support increased numbers of deer and squirrels.

The upland forest habitat supports a large number of insect species. Several of these, including the southern pine beetle, Ips engraver beetle, hickory bark beetle, and various oak borers, cause considerable damage.

4.14.4 IMPACTS OF FORESTRY PRACTICES

In upland forests along the Gulf coastal plain, mechanized site preparation practices pose a threat to soil and water quality (McClurkin and Duffy 1975). Even though data are scarce, logging experience and agricultural engineering show that the use of heavy equipment in these practices compacts and destroys forest soil structure. This reduces the amount of infiltration of water and increases surface runoff. Exposed soils are subject to increased erosion. Where large volumes of fresh organic matter are incorporated into the soil, as through clearcutting, there is a drastic increase in the carbohydrate to nitrogen ratio. Acids released during decomposition of this excess material leach nutrients from the soil. Since little biomass is left after clearcutting to take up these nutrients, they may substantially change the water quality of nearby streams (McClurkin and Duffy 1975).

Of all forestry practices, fertilization has the greatest potential for causing changes in water quality. If fertilizers are not taken up by the existing vegetation, they may leak into shallow ground-water aquifers, drainage ditches, or streams. Eutrophic conditions result when fertilizers accumulate in ponds or in downstream wetlands.

Grazing may significantly modify the upland forest habitat. Cattle destroy young seedlings, and heavily grazed areas are subject to extreme erosion along cattle trails and where herbs and grasses have been overcropped.

4.15 AGRICULTURAL HABITATS

Rice fields and pastures, the dominant agricultural habitats in the Chenier Plain, make up about 16% of the area (fig. 4-46). The extent of these habitats varies from 3.6% in the Chenier Basin to more than 20% in East Bay and Mermentau basins. Rice fields and pastures have slowly and steadily increased at the expense of natural areas.

The relative proportion of rice fields to pasturelands varies widely from year to year as market conditions fluctuate and crops are rotated for optimum production. The most common practice is to plant half the farm with rice and use the other half as pasture for beef cattle. A preferred practice is to graze the land for 2 to 4 years before replanting rice. This rotation of rice and cattle increases the organic matter in the soil, the available nitrogen, and other plant nutrients (Black and Walker 1955).

Agricultural systems differ considerably from natural systems for the following reasons:

1. Agriculture requires large fossil fuel inputs for cultivation, fertilization, water level regulation, harvesting, and curing.
2. Agricultural habitats are necessarily highly simplified; most producers and consumers are eliminated in favor of selected organisms.

Eutrophic and toxic effects result when fertilizers and pesticides enter natural water bodies and wetlands. Some pesticides or their products can remain in these habitats for years. For example, the fire ant poison Mirex, applied to a Mississippi experimental plot at 1.0 lb/a in 1962, was still present in 1974 at a level of one part per million (Carlson et al. 1976).

Agricultural habitats, on the other hand, can benefit some wildlife species (especially waterfowl) by providing alternative food sources. This benefit becomes increasingly important as natural areas are reduced.

4.15.1 FUNCTIONAL OVERVIEW OF AGRICULTURAL HABITATS

The basic components and functions of the agricultural habitats in the Chenier Plain are illustrated in fig. 4-47. Rice field and pasture habitats are readily interchangeable. The major agricultural producers, rice plants and pasture grasses, are dependent upon sunlight, but production levels are dependent on cultivation and harvest techniques, fertilizer and pesticide applications, and the availability of fossil fuels to operate machinery. Plants are used to feed cattle or are harvested for human consumption. In addition, both habitats are used by a variety of mammals, birds, reptiles, amphibians, and crustaceans. Crayfish cultivation is sometimes practiced along with rice production. Both rice fields and pastures are subject to runoff of rainwater which can carry with it significant levels of nutrients and/or toxins.

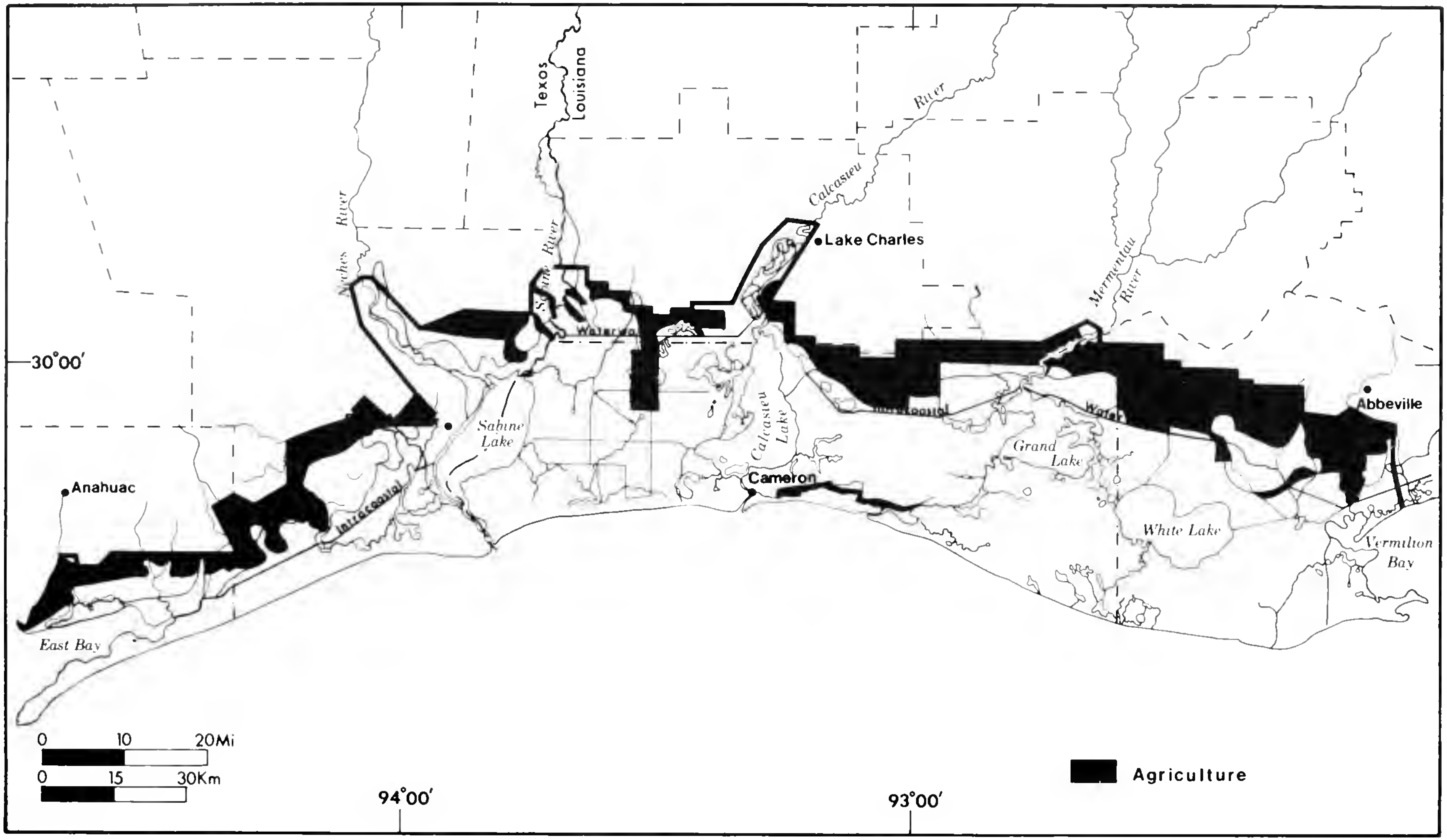


Figure 4-46. Distribution of rice field and pasture habitats (agriculture) in the Chenier Plain.

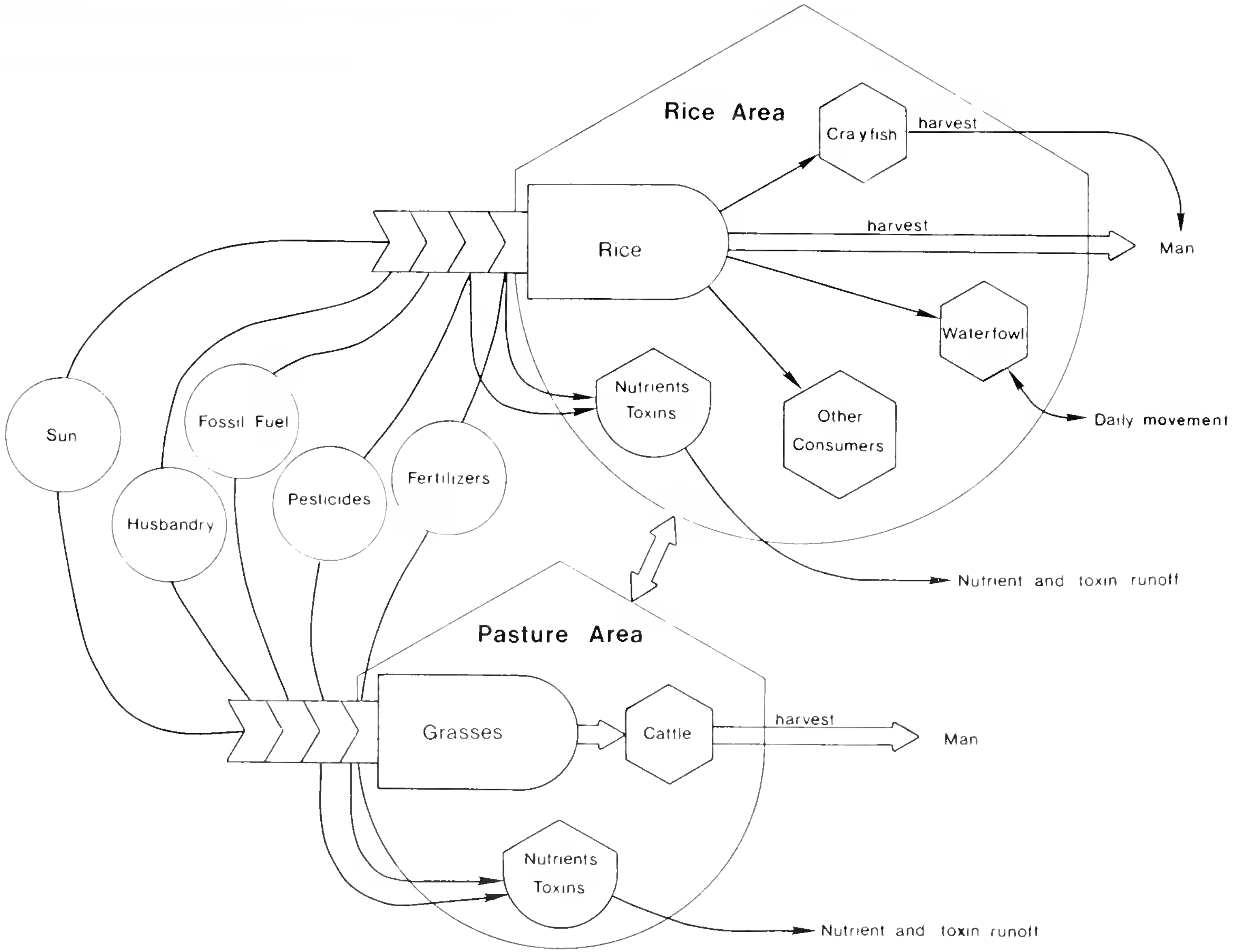


Figure 4-47. Conceptual model showing basic components and functions of agricultural habitats.

4.16 PASTURE HABITAT

Pasturelands constitute almost 10%, 901 km^2 (348 mi^2), of the Chenier Plain region. Much of the pasture habitat was created by impoundment and drainage of natural wetlands. Artificial cattle walks have additionally allowed cattle access to natural wetland areas. These cattle walks permanently destroy the marsh area over which they are constructed and result in the loss of additional marsh areas from which construction materials are dredged. More importantly, they disturb natural water flow and allow cattle to graze and trample adjacent marsh areas, contributing to further wetland deterioration.

4.16.1 PRODUCERS

Plants characteristic of unimproved pasturelands in the Chenier Plain include butterweed, swamp and curly dock, cranesbill, chickweed, goldenrod, and wood sorrel (Bonck and Penfound 1945). These same species are also present in pasture areas that have been improved by planting and fertilizing forage crops. Improved pasture areas are generally planted in fescue grass, vasey grass, rye grass, Dallis grass, and smut grass (Robert Murry, Per. Comm).

4.16.2 CONSUMERS.

Cattle are the dominant herbivores in the pasture habitat and consume the bulk of net primary production. However, a diverse natural fauna is also found here (appendix 6.3). The pasture habitat includes enough small ponds and low areas to support 11 species of amphibians.

On drier sites, reptiles such as the ornate box turtle, six-lined racerunner, prairie kingsnake, rough earth snake, and pygmy rattlesnake may be found. Noteworthy is the lack of water snakes, although the cottonmouth may be abundant here. Among waterfowl, the white-fronted goose and Canada goose probably reach peak abundance in this habitat type. Most of the other birds found in the pasture habitat are those typical of open country, such as the eastern meadowlark and American kestrel. The endangered red wolf, the coyote, the spotted and striped skunks, and the house mouse are examples of mammals found in Chenier Plain pasturelands.

4.17 RICE FIELD HABITAT

Rice farms occupy sites that were formerly tall grass prairie or fresh marsh areas. Prairie rice became commercially important in Louisiana in the late nineteenth century (Kniffin 1968). Presently, rice cultivation occurs in about 6.4% of the total area, or 603 km^2 (233 mi^2) of the Chenier Plain. Since it is rotated with cattle grazing, the exact acreages of land devoted to rice production change each year. Other crops grown in the Chenier Plain, including soybeans and corn, occupy less than 1% of the total area, about 81 km^2 (31 mi^2).

The rice field habitat is underlain by poorly drained depressional soils with silty clay loam to clay surface layers and clay subsoils. Poor drainage limits profitable production of row crops (Woolf and Vidrine 1976).

4.17.1 CONSUMERS

In spite of intense cultivation, many wild consumer species live or feed in rice fields. Amphibian species richness is high, exceeded only by the swamp forest habitat where arboreal niches are available. Water snakes and the prairie kingsnake, a species characteristic of more elevated areas, reflect the aquatic-terrestrial nature of the rice field habitat. In a partially flooded or drained state during fall, winter, and spring, rice fields provide ideal habitat for many species of shorebirds and wading birds, as well as geese and ducks. During the summer, rice fields provide nesting habitat for species such as the fulvous tree-duck, mottled duck, purple gallinule, and common gallinule. Birds, such as the house sparrow, red-winged blackbird, and European starling, feed on waste grain. Winter populations of the red-tailed hawk are also found here. Mammals are similar to those found in the fresh marsh and/or pasture habitats. Introduced rodents such as the Norway rat and house mouse are also present and are usually associated with human dwellings.

Several studies on waterfowl feeding habits have demonstrated the importance of rice to the wetland areas. Singleton (1951) found that rice made up almost 40% by volume of all foods eaten by waterfowl on the eastern Texas coast. Dillon (1958) found mostly rice and plants associated with rice culture among the stomach contents of ducks taken in the fresh marshes of Cameron and Vermilion Parishes. Chamberlain (1959) reported that rice fields north of Rockefeller Refuge supported large numbers of mallards and pintails throughout the wintering period. Valentine's (1961) report on the feeding habits of ducks in the area of Lacassine National Wildlife Refuge suggests that seed-producing marsh annual grasses are preferred over rice. During wet years, when marsh annuals are not abundant, rice becomes the important food resource for these waterfowl.

Appendix 6.3 lists vertebrate consumers that utilize rice fields and includes available information on their food habits.

Table 4.27. Common and scientific names of most vascular plants listed in the Chenier Plain Characterization (Correll and Correll 1975, Montz 1975).

Common name	Scientific name
Alligatorweed	*Alternathera philoxeroides*
American beauty berry	*Callicarpa americana*
American elm	*Ulmus americana*
Aster	*Aster* spp.
Bagscale	*Sacciolepsis striata*
Bahia grass	*Paspalum notatum*
Baldcypress	*Taxodium distichum*
Banana waterlily	*Nymphaea mexicana*
Bearded sprangletop	*Leptochloa fascicularis*
Beggarweed	*Desmodium* spp.
Bermuda grass	*Cynodon dactylon*
Bicolor lespedeza	*Lespedeze bicolor*
Big cordgrass	*Spartina cynosuroides*
Bitternut hickory	*Carya cordiformis*
Bitter pecan	*C. aquatica*
Blackberry	*Rubus* spp.
Blackcherry	*Prunus serotina*
Blackgum	*Nyssa sylvatica*
Black mangrove	*Avicennia germinans*
Blackrush	*Juncus roemerianus*
Black willow	*Salix nigra*
Blue hyssop	*Bacopa caroliniana*
Boxelder	*Acer negundo*
Brown top millet	*Panicum ramosum*
Buckbrush	*Baccharis halimifolia*
Bulltongue	*Saggittaria falcata*
Bulrush	*Scirpus* spp.
Bur oak	*Quercus macrocarpa*
Butterweed	*Senecio glabellus*
Buttonweed	*Diodia virginiana*
Buttonbush	*Cephalanthus occidentalis*
California bulrush	*Scirpus californicus*
Camphorweed	*Pluchea camphorata*
Carolina ash	*Fraxinus caroliniana*
Carpet grass	*Axonopus* spp.
Cattail	*Typha* spp.
Cherrybark oak	*Quercus falcata* var. *pagodaefolia*
Chickasaw plum	*Prunus angustifolia*
Chickweed	*Cerastium* spp.
Chinese tallowtree	*Sapium sebiferum*
Chufa	*Cyperus esculentus*
Clover	*Trifolium* spp.
Cocklebur	*Xanthium* spp.
Colorado River hemp	*Sesbania macrocarpa*
Common hornwort	*Ceratophyllum echinatum*
Common lespedeza	*Lespedeza* spp.
Common reed	*Phragmites communis*
Common water nymph	*Najas quadalupensis*
Coontail	*Ceratophyllum demersum*
Cottonwood	*Populus deltoides*
Cranesbill	*Geranium* spp.
Curly dock	*Rumex crispus*
Cyperus	*Cyperus* spp.
Dallis grass	*Paspalum dilatatum*
Deciduous holly	*Ilex decidua*
Deer pea	*Vigna luteola*
Delta duck-potato	*Sagittaria platyphylla*
Delta threesquare	*Scirpus deltarum*
Dichondra	*Dichondra* spp.
Disc water-hyssop	*Bacopa rotundifolia*
Dock	*Rumex* spp.
Doveweed	*Croton* spp.
Drummond red maple	*Acer rubrum* var. *drummondii*
Duck lettuce	*Otellia alismoides*
Duck potato	*Sagittaria latifolia*
Duckweed	*Lemna perpusilla*
Eastern red cedar	*Juniperus virginiana*
Elderberry	*Sambucus canadensis*
Fall panicum	*Panicum dichotomiflorum*
Fanwort	*Cabomba caroliniana*
Fescue grass	*Festuca* spp.
Fimbristylis	*Fimbristylis* spp.
Flat sedge	*Cyperus odoratus*
Foxtail grass	*Setaria glauca*
Frogfruit	*Phyla* spp.
Giant bulrush	*Scirpus californicus*
Giant reed	*Arundo donax*
Giant ragweed	*Ambrosia trifida*
Glasswort	*Salicornia bigelovii*
Goldenrod	*Solidago* spp.
Goosegrass	*Eleusine indica*
Grape	*Vitis* spp.
Greenbriar	*Smilax* spp.
Groundseltree (bush)	*Baccharis halimifolia*
Gulf cordgrass	*Spartina spartinae*
Gulf spikerush	*Eleocharis cellulosa*
Hackberry	*Celtis laevigata*
Haw (hawthorn)	*Crataegus* spp.
Heliotrope	*Heliotropium* spp.
Horned bladderwort	*Utricularia cornuta*
Honeysuckle	*Lonicera* spp.
Japanese millet	*Echinochloa crusgalli* var. *frumentacea*
Jointvetch	*Aeschynomene* spp.
Laurel oak	*Quercus laurifolia*
Leafy three-square	*Scirpus robustus*
Live oak	*Quercus virginiana*
Lizard's tail	*Saururus cernuus*
Loblolly pine	*Pinus taeda*
Longleaf pine	*P. palustris*
Loosestrife	*Lysimachia* spp.
Maidencane	*Panicum hemitomon*
Marsh elder	*Iva frutescens*
Marsh purslane	*Ludwigia palustris*
Millet	*Echinochloa* spp.
Mock orange	*Styrax americana*
Morning glory	*Ipomoea* spp.
Mudbank paspalum	*Paspalum dissectum*
Muskmelon	*Cucumis melo*
Needlerush	*Juncus roemerianus*
Nutgrass	*Cyperus rotundus*
Nuttall Oak	*Quercus nuttallii*

Continued

Table 4.27. (Concluded)

Oats	*Avena sativa*
Olney's three-corner grass	*Scirpus olneyi*
Overcup oak	*Quercus lyrata*
Palmetto	*Sabal minor*
Panic grass	*Panicum*
Parrot's feather	*Myriophyllum brasiliense*
Paspalum	*Paspalum* spp.
Pennywort	*Hydrocotyle* spp.
Peppervine	*Ampelopsis arborea*
Persimmon	*Diospyros virginiana*
Pickerelweed	*Pontederia cordata*
Poison ivy	*Rhus toxicodendron*
Pokeweed	*Phytolacca americana*
Pondnut	*Nelumbo lutea*
Pondweed	*Potamogeton* spp.
Poor man's pepper	*Lepidium virginicum*
Prickly ash	*Zanthoxylum virginiana*
Prickly pear cactus	*Opuntia compressa*
Pumpkin ash	*Fraxinus tomentosa*
Rattan	*Berchemia scandens*
Rattlebox	*Ludwigia alternifolia*
Rattlebush	*Sesbania drummondii*
Red maple	*Acer rubrun*
Rough-leaf dogwood	*Cornus drummondii*
Roundleaf bacopa	*Bacopa rotundifolia*
Ryegrass	*Secale cereale*
Salt cedar	*Tamarix gallica*
Saltgrass	*Distichlis spicata*
Saltmarsh bulrush	*Scirpus maritimus*
Salt matrimony vine	*Lycium carolinianum*
Saltmeadow cordgrass	*Spartina patens*
Saltwort	*Batis maritima*
Sawgrass	*Cladium jamaicense*
Scribner panicum	*Panicum scribnerianum*
Sea ox-eye daisy	*Borrichia frutescens*
Seashore paspalum	*Paspalum vaginatum*
Sedge	*Sedum* spp.
Sensitive joint vetch	*Aeschynomene indica*
Shagbark hickory	*Carya ovata*
Shortleaf pine	*Pinus echinata*
Slash pine	*P. elliottii*
Shumard red oak	*Quercus shumardii*
Slender pondweed	*Potamogenton pusillus*
Smartweed	*Polygonum punctatum*
Smilax	*Similax* spp.
Smooth cordgrass	*Spartina alterniflora*
Smutgrass	*Sporobolus* spp.
Soft rush	*Juncus effusus*
Softstem bulrush	*Scirpus validus*
Southern hackberry	*Celtis occidentalis*
Southern magnolia	*Magnolia grandiflora*
Southern marshfern	*Thelypteris palustris*
Southern naiad	*Najas guadalupensis*
Southern water hemp	*Acnida cuspidata*
Southern wildrice	*Zizaniopsis miliaceae*
Spanish moss	*Tillandsia usneoides*
Spider lily	*Hymenocallis* spp.
Spikerush	*Eleocharis* spp.
Sprangletop	*Leptochloa fascicularis*
Stoneseed	*Lithospermum* spp.
Swamp cottonwood	*Populus heterophylla*
Swamp dock	*Rumex verticillatus*
Swamp hickory	*Carya leiodermis*
Swamp privet	*Forestiera acuminata*
Swamp red bay	*Persea palustris*
Sweetgum	*Liquidambar styraciflua*
Switchcane	*Arundinaria tecta*
Switchgrass	*Panicum virgatum*
Sycamore	*Platanus occidentalis*
Texas sugarberry	*Celtis laevigata*
Three-square bulrush	*Scirpus americanus*
Trumpet creeper	*Campsis radicans*
Tupelo	*Nyssa aquatica*
Umbella pennywort	*Hydrocotyle umbellata*
Variable watermilfoil	*Myriophyllum heterophyllum*
Vasey grass	*Paspalum urvillei*
Virginia willow	*Itea virginica*
Walter's millet	*Echinochloa walteri*
Water ash	*Fraxinus caroliniana*
Water fern	*Azolla caroliniana*
Waterhemp	*Acnida* spp.
Water hyacinth	*Eichornia crassipes*
Water hyssop	*Bacopa monnieri*
Water lettuce	*Pistia stratiotes*
Water locust	*Gleditsia aquatica*
Watermelon	*Citrullus vulgaris*
Water oak	*Quercus nigra*
Water pennywort	*Hydrocotyle ranunculoides*
Water primrose	*Ludwigia* spp.
Watershield	*Brasenia schreberi*
Water tupelo	*Nyssa aquatica*
Waterweed	*Elodea canadensis*
Water willow	*Decodon verticillatus*
Wax myrtle	*Myrica cerifera*
White dutch clover	*Trifolium repens*
White waterlily	*Nymphaea odorata*
Widgeongrass	*Ruppia maritima*
Wild grape	*Vitus* spp.
Wild millet	*Echinochloa crusgalli*
Wild plum	*Prunus* spp.
Willow	*Salix* spp.
Willow oak	*Quercus phellos*
Willow primrose	*Ludwigia leptocarpa*
Witchgrass	*Panicum capillare*
Wood sorrel	*Oxalis* spp.
Yankeeweed	*Eupatorium capillifolium*
Yellow foxtail	*Setaria glauca*
Yellow lotus	*Nelumbo lutea*

5.0 Chenier Plain Animal Species

5.1 INTRODUCTION

Part 5 presents a brief description of some of the more common or important animal species that inhabit the Chenier Plain. More detailed information is available from the cited references.

5.2 MAMMALS

5.2.1 SWAMP RABBIT (*Sylvilagus aquaticus*)

The swamp rabbit thrives best in habitats that provide a good mixture of resting, travel, and escape cover (Bryant 1954). Pastures, levee banks, swamps, marshes, and shrub-covered fields provide such cover (Bryant 1954, Hastings 1954, Lowery 1974b). During periods of high water, swamp rabbits need access to elevated areas. Saltmeadow cordgrass lightly intermixed with wax myrtle less than 1.2 m (4 ft) high is suitable habitat for the species in the Chenier Plain (Gould 1974).

The home range (2 to 8 ha or 5 to 19 a) for swamp rabbits varies seasonally (Lowe 1958, Hunt 1959, Gould 1974). The species is normally active during the early morning and late evening hours (Gould 1974).

Daily food consumption of the swamp rabbit is about 1 kg (2.5 lb) of vegetation (Richardson 1963). A variety of herbaceous and woody plants are eaten (Svihla 1929, Bryant 1954, Toll et al. 1960, Croft 1961, Richardson 1963, Sullivan 1966, Lowery 1974b). Important plant foods reported for Louisiana swamp rabbits include white dutch clover, bermuda grass, carpet grass, foxtail grass, bahia grass, dallis grass, giant ragweed, cocklebur, beggarweed, dichondra, bicolor lespedeza, common lespedeza, goosegrass, vasey grass, and buttonweed (Bryant 1954).

There are no reports which indicate that a specialized habitat is necessary for mating. Nesting occurs in relatively dry, undisturbed areas. Nests are slight depressions in the ground filled with a mixture of grass and fur.

The major factor affecting swamp rabbit populations is habitat destruction by livestock overgrazing, land clearing operations, and clean-farming practices (Hastings 1954, Sims 1956).

5.2.2 COTTONTAIL (*Sylvilagus floridanus*)

An area where a mixture of cropland, grassland, woodland, and brush are about equally represented is good cottontail habitat (Hastings 1954). Such areas, however, are few in the Chenier Plain and the cottontail rabbit is not abundant. According to Ted Joanen (pers. comm. January 1978, Rockefeller Wildlife Refuge, Grand Chenier, La.), the species has never been observed on any of the cheniers.

Cottontails are most active during the early morning and late evening hours. They occupy a home range which varies in size from 0.2 to 3 ha (0.6 to 8 a), depending on seasonal changes in habitat (Bruna 1952). No data are available on daily and seasonal movements for this species on the Chenier Plain.

The cottontail consumes about 1 kg (2.4 lb) of vegetation daily (Richardson 1963). Preferred foods are the same as those reported for the swamp rabbit (Bryant, 1954).

No specialized breeding or nesting areas have been reported for cottontails. Lowery (1974b) described the nest as a small depression in the ground filled with a mixture of grass and fur, usually in a dense grass clump beneath a stand of taller vegetation.

Overgrazing by livestock, land clearing, and clean-farming decrease the amount of suitable habitat, thereby reducing rabbit numbers.

5.2.3 MUSKRAT (*Ondatra zibethicus*)

Suitable muskrat habitat must provide food, water, and sites for constructing burrows or lodges. In the Chenier Plain, these conditions are best provided in brackish marsh, and in rice-growing areas (Arthur1931, O'Neil 1949, Palmisano 1972b).

In marshes, muskrats will build a lodge from marsh vegetation. They will often construct underground burrows in levees or bayou banks. The lodges or burrows form the central area of activity from which animals disperse at night for feeding. In favorable habitat where Olney's three-corner grass is abundant, the species occupies a small home range. In southwestern Louisiana, tagged muskrats were recaptured within 100 m (328 ft) of their home site after one year (O'Neil 1949).

Movements other than those associated with feeding have been noted. Juvenile muskrats leave their den when they are sexually mature and travel several kilometers before establishing a new home site (O'Neil 1949). In rice-growing areas, muskrats often vacate burrows in adjacent irrigation canals and construct lodges in flooded rice fields (O'Neil 1949).

Properly managed impounded marshes can also provide excellent muskrat habitat. Over 25,000 muskrats were trapped from a 400 ha (988 a) impoundment containing Olney's three-corner grass near the western shore of Vermilion Bay during the 1976-77 season (R. G. Linscombe, pers. comm. Louisiana Wildlife and Fisheries Department).

Muskrats consume about one-third of their weight in food each day (O'Neil 1949). Marsh populations of Chenier Plain muskrats feed predominantly on Olney's three-corner grass, whereas populations living in rice fields consume mostly rice and crayfish during spring and summer, and rushes, cattail, clover, and maidencane during the winter (O'Neil 1949).

A dense and vigorous plant community is necessary to support a large muskrat population, and when the population increases beyond the growth capacity of the plants, 'eatouts' (large areas devoid of vegetation) occur. When eatouts become severe, the muskrat population may collapse.

No special reproductive requirements have been reported for muskrats; they are monogamous, and are sexually active year-round. The gestation period is 26 to 28 days, and up to 5 or 6 litters may be produced each year. The average litter size is 4, and a lodge or burrow may contain as many as 3 litters in different stages of development (O'Neil 1949).

The presence of preferred food plants is no assurance that an area is suitable muskrat habitat. Many areas in the Chenier Plain have an abundent growth of preferred plants, but do not support muskrats, whereas other areas with lower quality food plants do support muskrat populations (O'Neil 1949). This observation suggests that some factor other than food is regulating Chenier Plain muskrat populations. For example, excessive flooding and drying of marshes are known to affect muskrat abundance adversely (O'Neil 1949). Diseases and parasites reduce muskrat numbers when muskrat numbers are high. Commercial trapping has not been demonstrated to greatly affect Chenier Plain muskrat populations (O'Neil 1949).

5.2.4 NUTRIA (*Myocastor coypus*)

Nutria are usually active during the early morning and late evening hours and at night (Chabreck 1962b). In Chenier Plain marshes, activity takes place within a circular home range of about 0.78 km^2 or 0.30 mi^2 Adams 1956, Kays 1956).

Nutria living in the vicinity of agricultural areas often move into these areas to feed on crops. Evans (1970) studied nutria in sugarcane fields in southwestern Louisiana and found that only about 10% of the nutria using these fields actually made their homes there and only 50% of these remained year-round.

Nutria were introduced into Louisiana in 1938 and populations increased rapidly. Within a period of 20 years,the animals dispersed across the Chenier Plain (Davis 1960, Lowery 1974b). Although no systematic studies have been made of nutria populations in different habitat types, Palmisano (1972a) analyzed trapping records and concluded that greatest population densities occurred in fresh and intermediate marshes. Brackish marshes carried lower populations but still produced a sizable harvest. Salt marshes support considerably lower nutria populations than the other marsh types.

Large numbers of nutria feed in rice fields during the rice-growing season. The animals move into rice fields from adjacent fresh marshes. Most return to the marsh after the rice has been harvested. Nutria that remain in rice-growing areas during the winter months occupy irrigation canals, drainage ditches, and impoundments (Evans 1970).

Swamp forests, where water is readily available, usually support nutria. Under favorable conditions, swamp forests will produce population densities similar to those of coastal marshes (Palmisano 1961, Nichols 1974).

Nutria feed chiefly on plants and consume 1 to 1.5 kg (2 to 3 lb) of vegetation per day. Preferred plants in fresh and intermediate marshes are pickerelweed, cattail, southern wild rice, alligatorweed, sawgrass, pennywort, giant bulrush, and spikerush. In brackish marshes, they feed heavily on Olney's three-corner grass, big cordgrass, saltmeadow cordgrass, and leafy three-square. Important foods in salt marshes are smooth cordgrass and saltgrass (Atwood 1950, Palmisano 1961). Submerged pond plants such as pondweed, southern naiad, and parrots' feather are also consumed.

Nutria reproduce year-round. The gestation period is from 130 to 134 days and females will often breed two days after young are born (Atwood 1950). Of 224 adult females examined on Rockefeller Refuge, 91% were pregnant (Kays 1956). The number of embryos ranged from 1 to 11 and averaged 5. In studies elsewhere on the Chenier Plain, Atwood (1950) and Harris (1956) examined different nutria populations and found that the average number of embryos ranged from 4 to 6. Harris (1956) noted that 5% of the total embryos were in the process of resorption, and the percentage of resorbed embryos seemed to be associated with increased nutria populations and dwindling of the food supply.

The rapid spread of the nutria throughout the Chenier Plain after its release in 1938 indicated that the species adapted well. The extent to which diseases and parasites have increased since that time has not been studied in detail, but it is likely that diseases and parasites have become increasingly important as limiting factors. Lowery (1974b) reported that 80% to 90% of the nutria in Louisiana are infected by the nematode *Strongyloides myopotami*, which restricts reproduction and causes mass mortality.

The alligator is the main predator, other than man, and apparently consumes large numbers of nutria (Lowery 1974b). Valentine et al. (1972) reported that nutria are the major food of large alligators on the Chenier Plain. The young nutria are also eaten by turtles, gar, snakes, and birds of prey.

Severe freezes which occasionally strike the Chenier Plain sometimes cause high mortality. Young animals are more seriously affected than adults. Greatest losses occur where shelter in bank burrows or dense vegetation is sparse.

Annual harvest of nutria for fur over the past several years has been about equal to recruitment, so that fall populations have remained fairly static. Increased harvest rates coupled with losses due to predators, to diseases and parasites, and to habitat destruction from increased saltwater intrusion and marsh drainage could result in serious population declines.

5.2.5 COYOTE (*Canis latrans*)

The coyote is found in a variety of habitats, but seems to prefer early successional stages of vegetation that are fairly open with a large amount of ' edge ' (Young and Jackson 1951, Schwartz and Schwartz 1959, Krefting 1969, Lowery 1974b, O'Neil and Linscombe 1976). Coyotes have been observed in sugarcane fields, rice fields, pastures, upland forests, bottomland hardwoods, swamp forests, fresh and brackish marshes, forests on cheniers, and in transitional areas between wetland and agriculture habitats. Optimum habitat contains permanent sources of freshwater, and an abundance of prey species and seasonal fruits.

Little is known about the daily and seasonal movements of coyotes in the Chenier Plain. According to Larry J. Dugas (925 Iberia Street, New Iberia, La. 70560), who has been monitoring coyote activity in southwestern Louisiana since 1972, individuals and groups move over several square miles during a day or a season. Dugas observed both daytime and nightime movement, although activity was greatest at night.

Coyotes are omnivores that are highly adaptable to seasonal changes in the availability of food. Knowlton (1964) stressed that coyotes utilize the most abundant and convenient food source available. Wilson (1967) reported small rodents and rabbits as the number one and two foods consumed by Louisiana coyotes. In the Chenier Plain, Dugas (unpubl.) found that rabbit, nutria,and bird remains occurred most frequently in scat samples collected during the winter months.

Mating occurs wherever an estrous female accepts a breeding male. Dens are usually used for bearing and rearing young. Den sites vary and may be found in banks, hillsides, stubble fields, plowed fields, dense thickets, drainage pipes, dry culverts, hollow logs, under railroad trestles and deserted buildings, or in enlarged dens of other mammals (Schwartz and Schwartz 1959, Lowery 1974b, O'Neil and Linscombe 1976). Dens are usually located near water. Both parents care for the young (Young and Jackson 1951, Schwartz and Schwartz 1959, Laycock 1974, Lowery 1974b). Pups are weaned after 8 weeks (Schwartz and Schwartz 1959, Lowery 1974b). Both parents feed the young up to the age of 12 weeks.

Man's attempt to eradicate the coyote is an important limiting factor for the species (Schwartz and Schwartz 1959, Krefting 1969).

5.2.6 NORTHERN RACCOON (*Procyon lotor*)

Raccoon movement patterns are affected by food availabilty and tidal changes. Fleming (1975) reported that in the summer raccoons in the Chenier Plain use canal levees more than any other area when crayfish are abundant and readily accessible. During the winter, raccoons feed largely on fish along the bayou edges. In Florida marshes, Ivey (1948) found that feeding was heaviest during low-tide intervals, when a variety of food items were exposed on mud banks and beaches.

Average home ranges (74 to 100 ha or 183 to 247 a) in the Chenier Plain vary seasonally (Fleming 1975). The raccoon is found in all wetlands and adjacent upland habitats. Highest densities are in marshes and swamp forests (O'Neil and Linscombe 1976).

Raccoons are often found resting on canal levees, elevated banks of bayous, ponds, and lakes, and on the limbs and in cavities of trees. Of 426 resting sites examined by Fleming (1975) on Rockefeller Refuge, 50% were near open water, 28% were on levees, and 22% were in open marsh areas. Resting areas are often located in dense stands of common reed during summer, and in cordgrass during cooler months.

The raccoon is an omnivore. Fleming (1975) reported the following foods for raccoons in the Chenier Plain: crayfish, fiddler crab, blue crab, shrimp, palmetto, peppervine, hackberry seeds, liveoak acorns, muskmelon, pokeweed, giant reed, dragonflies and beetles, swamp rabbit, passerine birds, reptile eggs, shad,mullet, and minnows. Crustaceans are the major food items. Fruits are consumed mostly in the fall, and fish most often during the winter.

Denning sites are usually necessary for the successful bearing and rearing of young. Dens may be located in dense stands of vegetation and in cavities of trees. Urban (1969) reports that abandoned muskrat houses are used as dens by raccoons in Florida marshes. The young, born in the spring, are weaned at 10 weeks of age and remain with the female until winter (Johnson 1970, Lowery 1974b).

Loss of den sites from land clearing operations is a major limiting factor to raccoon populations in some areas (Schwartz and Schwartz 1959). Raccoon populations also fluctuate in response to the prevalence of disease and parasites (O'Neil and Linscombe 1976).

5.2.7. NEARCTIC RIVER OTTER (*Lutra canadensis*)

Otters have a home range of 80 to 160 km (50 to 100 mi) of shoreline (Schwartz and Schwartz 1959). They travel more during the mating season than at any other time (Wilson 1959). Families appear to live within an area of about 23 km^2 (9 mi^2) according to Wilson (1959). Otters occasionally travel overland from one water body to another.

Otters are mostly nocturnal, but occasionally are active during the day. They remain active all year and are not inhibited by weather changes (Schwartz and Schwartz 1959).

The primary types of habitat utilized by the river otter are swamps, streams, and marshland in coastal areas (St. Amant 1959). Favorable habitat includes tidal flats, freshwater streams, ponds, and small, open-water lakes. Coastal habitats produce 80% of the annual otter fur production for Louisiana (O'Neil and Linscombe 1976).

The otter requires a year-round permanent water supply to survive. Appropriate sites for dusting and sunning, interspersed with aquatic feeding areas, are essential to the species. The tidal areas of the intermediate to brackish marshes are optimum otter feeding grounds (G. Linscombe, pers. comm January 1978, Louisiana Department of Wildlife and Fisheries, Baton Rouge, La.). The preferred habitats of otter in Mississippi are deep-water swamps adjacent to, or closely connected with, a large lake (Yeager 1938).

Spoil deposits and levees are utilized for denning areas. Thick mats of marsh grass and heavy vegetation on levees, ridges, and spoil banks provide resting cover and shelter.

The otter feeds prmarily on aquatic animals. Foods include crayfish, fishes, crabs, salamanders, frogs, snails, turtles, snakes, shrimp, clams, water beetles, and larvae of aquatic insects, as well as earthworms, muskrats, rails, waterfowl, rats, mice, and carrion (St. Amant 1959, Schwartz and Schwartz 1959, McDaniel 1963, O'Neil and Linscombe 1976).

Courtship and mating activities take place in water (Liers 1951). Dens are located in banks and levees, old muskrat houses, old nutria burrows, in hollow logs, roots, and stumps, and even in thickets of vegetation such as common reed (Yeager 1938, Schwartz and Schwartz 1959, Wilson 1959, Lowery 1974b, O'Neil and Linscombe 1976). Bank dens generally have an entrance beneath the water surface. The entrance way leads to a nest chamber above the high-water level and the chamber may have a bare floor or a slight accumulation of leaves and grass (Schwartz and Schwartz 1959, O'Neil and Linscombe 1976).

New-born young are helpless for 5 to 6 weeks (Liers 1951). They are weaned at four months but usually remain with the mother until nearly full grown. The male parent may assist in caring for young after they leave the den (Schwartz and Schwartz 1959, Lowery 1974b).

With the conversion of wetlands to agricultural and urban areas, otter habitat has dwindled in the Chenier Plain. Drainage of marsh habitats through dredging activites is detrimental to otter populations.

5.2.8 WHITE-TAILED DEER *(Odocoileus virginianus)*

White-tailed deer are relatively common in the Chenier Plain. Largest populations are found in the fresh and intermediate marshes. The species rarely occurs in salt marshes, except in areas with abundant high ground nearby (Self et al. 1974). Potential density of deer is estimated at 1 deer/12 ha (30 a) in fresh marshes, 1 deer/134 ha (330 a) in brackish marshes, and 1 deer/2,892 ha (7,140 a) in salt marshes (letter dated 26 June 1972 from J. B. Kidd, Louisiana Department of Wildlife and Fisheries, Baton Rouge, La.).

Home range for white-tailed deer is about 2.6 km^2 (1 mi^2). Deer are normally crepuscular, but may feed nocturnally under heavy hunting pressure. Seasonal movements are responses to changing climatic conditions, food, cover and water availability, hunting pressure, and breeding habits. White-tailed deer movement patterns in the Chenier Plain have not been documented.

Interspersion of habitat types is important for this species. The wide variety of plants in fresh marshes contributes to its high carrying capacity for white-tailed deer (Self 1975). Chabreck (1972) identified 118 plant species in the Louisiana coastal marshes, of which 93 species (79%) were found in fresh marshes. Levees and spoil banks in marsh areas provide a major portion of the escape cover, travel lanes, and resting grounds for deer (Self et al. 1974). These elevated areas increase habitat diversity and support plant communities different from adjacent marshes (Self et al. 1974). Glasgow and Ensminger (1957) reported that after extensive canal digging, white-tailed deer became more numerous. The increase in number of deer was attributed to the increased acreage of elevated land and the drainage of adjacent marshland. During adverse weather conditions such as floods and hurricanes, white-tailed deer heavily utilize these higher elevations for food and cover.

Vegetation supplies much of the water requirements for the deer (Lay 1969); however, Hosley (1956) reports that at least one source of fresh water is necessary. Alligator holes are important reservoirs of freshwater during periods of drought in the Everglades (Loveless and Ligas 1959).

Glasgow and Ensminger (1957) reported that deer of southwestern Louisiana marshes preferred deer pea, millet, spikerush, and water hyssop. Joanen et al. (1972) listed alligatorweed as one of the most important deer foods in the fresh marsh habitat. Doveweed, stoneseed, panic grass, and new sprouts of Gulf cordgrass are utilized on the Aransas National Wildlife Refuge in Texas (Halloran 1943).

Major browse species on coastal ridges are elderberry, smilax, blackberry, rattan, deer pea, aster, red maple, wax myrtle, black willow, alligatorweed, various sedges, and other aquatic and semiaquatic weeds (letter dated 10 August 1976 from J. W. Farrar, Louisiana Department of Wildlife and Fisheries, 400 Royal Street, New Orleans, La.).

Self et al. (1974) and Short (1975) reported that a wide variety of foods were utilized by white-tail deer from May to mid-September, but the number of species of plants available became less numerous from September to mid-February. Their diet is limited to foods that are available within the travel range because white-tailed deer do not necessarily move out of an established territory to areas with greated availability of food (Lay 1969).

Does randomly select areas isolated from other deer to give birth (Michael 1965, White et al 1972). During the first month, new-born fawns remain hidden in heavy cover and are cared for and fed by the doe, often only twice a day (Jackson et al. 1972). In the Chenier Plain, the heaviest cover for fawns is found on elevated areas.

Clearing and draining of bottomland forests for agricultural purposes has reduced the abundance of traditional white-tailed deer habitat. In some areas free-ranging livestock compete with deer for food and space (McMahan 1966). Saltwater intrusion into fresh marshes from dredging operations may reduce preferred food types of white-tailed deer. In coastal areas, illegal hunting, reduced cover, and free-ranging dogs sometimes limit the abundance of deer (Chabreck, R. H., pers. comm., December 1977, Louisiana State University, School of Forestry and Wildlife Management, Baton Rouge).

5.3 BIRDS

5.3.1 AMERICAN WHITE PELICAN (*Pelecanus erythrorhynchos*)

The American white pelican is a common winter resident of the Chenier Plain as well as of the entire Gulf coast. Largest numbers are present from October to April, but flocks of up to 1000 may be present along the coast in summer (Lowery 1974a). Nesting has not been confirmed in Louisiana, but there have been some recent unconfirmed nesting sites reported. Some scattered nesting occurs in southern Texas (Lowery 1974a, Palmer 1962).

In the Chenier Plain area, daily movements largely consist of flights from resting areas to nearby feeding areas. Feeding occurs largely in the early morning and late evening, especially during the incoming tide (Palmer 1962).

Pelicans rest and feed largely in shallow open waters such as lakes and fresh water impoundments, or in coastal bays and inlets (Imhof 1976, Palmer 1962). Flocks may feed occasionally in salt or brackish marshes. They often rest on beaches and sandbars (Palmer 1962). Pelicans usually feed simultaneously in a tight flock. The flock often encircles a school of fish and herds it into shallow water where they are easily caught. Imhof (1976) reports that Gulf menhaden, a commercially important species, comprised 90% of the diet of white pelicans along the Gulf coast.

The American white pelican nests primarily in the northwestern United States and southwestern Canada. Great Salt Lake in Utah and Pyramid Lake in Nevada are two well-known nesting areas. They breed on relatively bare islands that are remote from man's activities (Palmer 1962).

White pelican numbers are apparently decreasing because of the loss of suitable nesting habitat and their intolerance to human disturbances. Individuals are sometimes killed by hunters and fishermen (Palmer 1962). White pelican colonies often break up during severe weather (Hildebrand and Blacklock 1969).

5.3.2 OLIVACEOUS CORMORANT (*Phalacrocorax olivaceus*)

The olivaceous cormorant is a permanent resident in the Chenier Plain, which is the northernmost part of its range. In the United States, it is native only in coastal Texas and southwestern Louisiana (Palmer 1962, Oberholser 1974). It currently breeds in the Chenier Plain, as has the double-crested cormorant (*Phalacrocorax auritus*) a rare winter resident (Lowery 1974). The olivaceous cormorant is a bird of fresh and brackish water habitats (Palmer 1962). The species does not occur where suitable perching sites do not exist (Morrison and Slack 1977). In Louisiana, the olivaceous cormorant is found almost exclusively in the Chenier Plain. Eight colonies have been reported for southwest Louisiana (Portnoy 1977). Seven of these, representing 99.5% of the birds, were in the Chenier Plain.

Cormorants feed under water, almost entirely on fish (Palmer 1962). They often feed in flocks and individuals work in unison to herd fish into compact schools. Sometimes thousands of birds gather where food is plentiful. In addition to fish, cormorants feed on frogs, tadpoles, and dragonfly nymphs (Oberholser 1974). In the Chenier Plain, social feeding, apparently on schools of small fish, has often been observed (Hamilton, R., pers. comm., School of Wildlife and Forestry, Louisiana State University, Baton Rouge).

Olivaceous cormorants commonly nest in the tallest trees or shrubs in fresh or brackish marshes or in swamp forests, often mixed with colonies of herons, egrets, ibises, or spoonbills (Portnoy 1977). All cormorant colonies reported for the Chenier Plain were in fresh-water habitats (Portnoy 1977). Two of these were located in swamps, two on spoil banks, and three in marshes. Trees were used for nesting in two colonies and woody shrubs were used in the other five. In the Chenier Plain, most nesting occurs from April to June (Palmer 1962, Portnoy 1977). Nests are constructed in living or dead branches 1 to 7 m (3 to 23 ft) above water, or on bare ground if woody sites are lacking. Both sexes feed the young 3 to 8 times daily. Boat-tailed grackle and raccoon are major predators of eggs and young (Palmer 1962).

Cormorants occur largely where fish are abundant. They are not tolerant of extensive human interference (Palmer 1962). Numbers have fluctuated in Texas since 1945. A population crash in the 1960's may have been related to low reproductive success caused by high levels of pesticide and polychlorinated biphenyl (PCB) residues in adults. Olivaceous cormorants are now increasing in numbers in Texas and southwestern Louisiana, as the levels of residues decrease. Other fish-eating birds in Texas showed similar population changes in association with residual pesticide levels (Morrison and Slack 1977). Habitat loss has also caused a significant decline in numbers of olivaceous cormorants (Morrison and Slack 1977, Oberholser 1974). Part of the recent increase in numbers of breeding cormorants is due to establishment of several Audubon Society refuges.

5.3.3 GREAT BLUE HERON (*Ardea herodias*)

The great blue heron is a relatively uncommon permanent resident of the Chenier Plain. Post-nesting dispersal is common (Byrd 1978). Daily movements consist of flights between nesting or roosting sites and feeding areas.

The great blue heron is the largest wading bird that resides in the Chenier Plain. It utilizes a variety of habitats, including shallow water of ponds, lakes, marshes, streams, and bays (Palmer 1962).

Long legs and a large bill enable the great blue heron to feed in deeper water and on larger food items than most other wading birds. Food from 189 heron stomachs collected in the United States consisted of nonsport fish (43%), sport and commercial fish (25%), unidentified fish (4%), aquatic insects (8%), crustaceans (9%), amphibians and reptiles (5%), mice and shrews (5%), and other matter (2%) (Palmer 1962). In Southern Louisiana, their diet included 67% fish, 10% shrimp and crabs, and 5% small mammals (Day et al. 1973). Parents regurgitate food material for nestlings. Feeding may occur up to 10 times per day during the first week, and decrease to 4 times per day during the fledgling period (Pratt 1970).

Pesticide contamination in California and Iowa has caused nesting failure (Konermann et al. 1978). Pratt (1977) found that great blue herons sometimes were preyed upon while nests were untended. Human activity near nesting colonies has reduced nesting success (Werschkul et al 1976, English 1978).

5.3.4 GREEN HERON (*Butorides virescens*)

Although green herons are common in the Chenier Plain during spring, summer, and fall, few remain throughout the winter. They are most abundant from mid-March to mid-November (Lowery 1974a). Green herons nest singly or in small colonies near suitable feeding areas, and do not fly far to feed.

Green herons usually nest in woody vegetation near open water. They nest and feed in both fresh and salt marshes and along margins of streams.

Green herons usually wait, often perched on an overhanging branch or along a stream bank, for prey to approach. Most food is obtained near the surface of the water. Palmer (1962) found that their diet included fishes (45%), crustaceans (21%), insects (24%), and other small organisms.

Green herons usually nest solitarily (Palmer 1962). A few individuals may nest at the edges of large heronries composed of other species. Initial clutch size varies from 3 to 6 eggs, but second clutches usually are smaller. Incubation lasts approximately 20 days, with both parents participating. Young are fed 2 to 3 times a day and become independent at about 30 to 35 days (Palmer 1962).

Further loss of swamp forest in the Chenier Plain would reduce green heron populations.

5.3.5 LITTLE BLUE HERON (*Florida caerulea*)

The little blue heron nests in the Chenier Plain area and is abundant from mid-March to mid-October (Lowery 1974a). Post-nesting dispersal from the colony is common (Palmer 1962, Byrd 1978). Daily movements consist primarily of flights to and from nesting, resting, or feeding areas. During the breeding season, in North Carolina, daily flights may be as far as 15 km (9.3 mi) (Parnell and Soots 1978).

In Texas and Louisiana, small numbers of little blue herons feed and nest along bays and estuaries, but densities are highest in fresh marsh habitat. Ninety-seven percent of the nests in coastal Louisiana are located in fresh marshes (Portnoy 1977). Less than 1% of these nests occur in the Chenier Plain. In rice field areas, this species frequents levees in search of food (Palmer 1962).

Little blue herons feed in shallow water along shorelines. They stand motionless or move very slowly and capture prey by a rapid thrust of the bill (Palmer 1962). They often feed in more densely vegetated areas than other herons. In one study, of 46 stomachs examined, 45% contained crustaceans, 27% fish, 17% insects, and 9% frogs, snakes, and turtles (Palmer 1962).

Little blue herons usually nest in swamp forests, often in close association with snowy egrets. Nests are usually clumped in relatively tall vegetation. The species will nest on herbaceous vegetation if woody species are unavailable. Little blue herons nest earlier in salt marshes than in fresh marshes (Portnoy 1977). Renesting sometimes occurs. Incubation usually begins after the second egg is laid (Maxwell and Kale 1977).

Suitable nesting sites may be limited in some areas because of competition with the cattle egret (Hildebrand and Blacklock 1969). In Alabama, eggshell thickness was correlated with concentrations of both DDE and dieldren in the eggs (Biskup et al. 1977). Thin-shelled eggs are more easily broken by the setting parent, thus limiting the number of young herons which survive.

5.3.6 CATTLE EGRET (*Bulbulcus ibis*)

The cattle egret is primarily a summer resident in the Chenier Plain, but increasing numbers of birds are wintering there. Daily movements consist of flights from roosting or nesting areas to nearby feeding areas.

Cattle egrets often feed in association with cattle. These birds feed primarily on insects, land snails, earthworms, ticks, spiders, frogs, toads, snakes, and lizards.

Cattle egrets frequent more terrestrial habitat than do other herons, but nest most commonly in fresh marshes, to a lesser extent in salt marshes. They often nest later than other herons in mixed-species colonies (Jenni 1969). At Miller's Lake, Evangeline Parish, peak nesting is mid-July (Ortego et al. 1976). Clutch size averaged 3.5 in Florida (Jenni 1969). Because incubation begins at the onset of laying, hatching of the young is staggered. The smallest nestlings sometimes starve. Nestlings fledge at about 50 days of age (Palmer 1962).

During migration, this species is observed along road shoulders, in vacant lots, or even on lawns (Palmer 1962). Rice field-pasture rotation is especially suitable habitat for cattle egrets in central Louisiana (Ortego et al. 1976). Although the availability of nesting habitat may be limited in some areas, the recent general increase in the number of cattle egrets indicates that plentiful habitat is available. For example, nesting mortality of only 8% was documented in Florida (Jenni 1969). An increase in pasture habitat in the Chenier Plain could be beneficial to this species.

5.3.7 REDDISH EGRET (*Dichromanassa rufescens*)

Reddish egrets are year-round residents, but their numbers are lower in winter than in summer (Palmer 1962, Lowery 1974a). Daily flights to and from resting and feeding areas or nesting areas are typical. Reddish egrets are rarely seen far from the Gulf or large coastal estuaries. They are found in more saline areas than any other wading bird of the Chenier Plain.

Reddish egrets hop and run actively after prey in shallow, often muddy water. Food consists mostly of fishes, frogs, tadpoles, and crustaceans (Bent 1927, Palmer 1962).

Portnoy (1977) found no reddish egrets nesting in the Chenier Plain, but a few nests were found in black mangrove communities in southeastern Louisiana. Human disturbances, as reported by Anderson (1978), sometimes cause nesting failures.

5.3.8 GREAT EGRET (*Casmerodius albus*)

Great egrets reside year-round on the Chenier Plain, but numbers are relatively low in the winter. Post-nesting dispersal is common (Byrd 1978). Daily movements consist of flights to and from resting or nesting grounds to foraging areas. During nonnesting seasons, great egrets at Avery Island, Louisiana, return to roost about 1 hour before sunset and leave individually after sunrise (Weise 1976). Small groups fly to or from nesting colonies throughout the day during the nesting season. At Avery Island, these flights were often longer than 3 km (2 mi) (Weise 1976). In North Carolina, they averaged at least 15 km (9 mi) (Parnell and Soots 1978).

The great egret, because of its white color, large size, widespread distribution, and abundance, is one of the most conspicuous birds of the Chenier Plain. Like most herons, it feeds primarily in shallow water. This species is larger and has longer legs than most herons; consequently, it often is found in deeper water than the other species. The great egret uses all the aquatic habitats of the Chenier Plain.

Great egrets usually do not feed in large groups, but in Mexico, Gladstone (1977) found feeding assemblages of 125 to 150 birds. Food includes insects, crabs, crayfish, a variety of fishes, frogs, toads, snakes, lizards, rodents and small birds.

Great egrets are especially conspicuous at their nests, which are frequently atop the highest woody vegetation or highest site in the area (Portnoy 1977). In mixed-species colonies they tend to nest in open or exposed areas (Burger 1978, McCrimmon 1978). Portnoy (1977) found 10 colonies in the Louisiana Chenier Plain, which represented 19.4% of the breeders in the study area. Great egrets nest early, with the peak of incubation occurring in late March. Incubation begins after the first egg is laid (Maxwell and Kale 1977).

Imhof (1976) reported that this species is declining because of habitat destruction, water pollution, and insecticide contamination. Nestling mortality is often due to competition among the nestlings for food (Pratt 1970). In California, nesting success has recently decreased, probably because of organochlorine poisoning (Ohlendorf et al. 1978).

5.3.9 SNOWY EGRET (*Egretta thula*)

Snowy egrets are present year-round in the Chenier Plain, but most of the breeders migrate south during the winter (Lowery 1974a). Post-nesting dispersal, as far as 320 km (198 mi), is common (Ryder 1978). Daily movements consist of flights between feeding areas and resting or nesting areas. In the breeding season in North Carolina, these flights probably average at least 15 km or 9 mi (Parnell and Soots 1978).

Although snowy egrets are most abundant in impounded and natural fresh marsh areas of Louisiana, they can be found in all aquatic and marsh habitats, especially near the coast, where they feed on small fishes, crustaceans, and worms (Palmer 1962). They feed in shallow open water, actively pursue prey, and often exhibit specialized feeding behavior (Jenni 1969).

The species nests early in the spring in fresh and salt marshes (Palmer 1962) or, rarely, in brackish marshes. Snowy egrets usually build nests at lower levels in woody vegetation than do great egrets (Portnoy 1977, Burger 1978). Incubation begins after the first egg is laid (Maxwell and Kale 1977).

Like all aquatic birds, snowy egrets are threatened by chemical contamination of aquatic habitats.

5.3.10 LOUISIANA HERON (*Hydranassa tricolor*)

The Louisiana heron is primarily a bird of salt marshes, but it occasionally uses fresh marshes. It is predominanatly a summer resident species in the Chenier Plain. The few individuals that remain throughout the winter are inversly related in number to the severity of the winter weather. Daily movements consist mostly of flights between resting or nesting areas and feeding areas. In North Carolina, these flights probably average 15 km (9 mi) in the nesting season (Parnell and Soots 1978). Young are fed 4 to 5 times a day (Rodgers 1978).

Louisiana herons eat insects, fishes, amphibians, and other small aquatic organisms (Imhof 1976). Bent (1927) reports that Louisiana herons eat more fish than other wading birds. They are primarily solitary feeders and will often stand in water up to their bellies when feeding. As with other waders, they are opportunistic feeders.

Louisiana herons construct nests in woody vegetation, but will also nest on elevated herbaceous vegetation or on the ground (Palmer 1962). They frequently nest in mixed-species colonies where the plant canopy is open. They often nest on the periphery of colonies at lower levels in the vegetative cover. McCrimmon (1978) studied nesting requirements and found that those of the Louisiana herons were distinct from other species except for the little blue heron. This may be due to inability to compete with other species for more central sites (Maxwell and Kale 1977). About 7% of the nesting population in Louisiana is located in the Chenier Plain (Portnoy 1977). Renesting occurs and incubation begins after the first (Rodgers 1978) or second (Maxwell and Kale 1977) egg is laid.

Chemical contamination in food chains and the destruction of nesting and feeding habitat by human activities is threatening this species.

5.3.11 BLACK-CROWNED NIGHT HERON (*Nycticorax nycticorax*)

In the Chenier Plain, most night herons are found in salt marshes; however, Palmer (1962) reported that the species may be found in almost any wading-bird habitat.

This species is abundant in the Chenier Plain from early March to late September (Lowery 1974a) and less abundant in winter. It is not known if individuals present in winter are permanent residents or migrants from more northern breeding areas. Post-nesting dispersal is common (Byrd 1978). The black-crowned night heron feeds primarily at night and roosts during the day. Its nocturnal habits help to reduce competition with other species. Daily movements consist primarily of flights of individuals or small flocks between feeding areas and resting areas. In North Carolina, these flights probably average 15 km (9 mi) (Parnell and Soots 1978).

The black-crowned night heron's diet includes worms, insects, crustaceans, mollusks, fish, amphibians, and reptiles. This species occasionally consumes the eggs and young of other nesting herons (Palmer 1962).

Black-crowned night herons nest in mixed colonies with other herons, but usually closer to the ground and in heavier vegetation (Burger 1978). Approximately 8% of the Louisiana breeding adults reported by Portnoy (1977) occurred in the Chenier Plain.

Loss of breeding habitat and the presence of chemical contaminants in ecosystems has had a detrimental effect on black-crowned night heron numbers (Ohlendorf et al. 1978). In the Great Lakes area, this species may have been adversely affected by high PCB levels (Gilbertson et al. 1976).

Common crows and fish crows actively preyed upon black-crowned night heron nests in several New Jersey heronries (Burger and Hahn 1977). The crows could not successfully rob the actively defended nests of other species in these mixed-species colonies. Thus, it is an advantage for night herons to nest in mixed-species colonies (Burger and Hahn 1977).

5.3.12 YELLOW-CROWNED NIGHT HERON (*Nyctanassa violacea*)

Although this species primarily inhabits fresh marshes and swamp forest habitats in the Chenier Plain, it also occurs in salt or brackish marshes. Food consists largely of crustaceans; in the Chenier Plain crayfish are the major food item.

Although listed as a permanent resident by Lowery (1974a), this species rarely winters in the Chenier Plain. Migrants begin to leave in September and begin to return in March. Daily movements consist of flights from roosting and nesting areas to feeding areas. This species is less nocturnal than the black-crowned night heron.

Yellow-crowned night herons nest high in trees in loosely formed colonies. They rarely colonize with other species. In the Chenier Plain, clutch size is probably 3 to 5 eggs, and both sexes incubate. The incubation period is unknown, but young leave the nest approximately 2 months after the eggs are laid (Palmer 1962).

Draining of swamps has a detrimental effect on this species. In Louisiana, the larger nestlings are eaten by local residents.

5.3.13 LEAST BITTERN (*Ixobrychus exilis*)

The least bittern is primarily a summer resident in the Chenier Plain. Occasionally, a few remain through the winter. Highest densities occur in April through September (Lowery 1974a). Because breeders maintain territories that include both feeding and nesting areas, daily movements are somewhat limited. Territories often are about 0.8 ha (2.0 a) in size (Palmer 1962).

Least bitterns are more common in fresh marshes than in salt marshes. They generally occur in the densest marsh vegetation (Palmer 1962) where they consume a variety of foods. Of 93 stomachs analyzed by the U.S. Biological Survey, 40% contained freshwater fishes; 10% contained crustaceans, mainly crayfish; and 33% contained insects.

Nests are usually located in dense stands of cattail, bulrush, or similar vegetation. The least bittern nests singly and has a clutch of 4 to 5 eggs. Incubation lasts 17 to 18 days and both sexes participate.

Drainage of marshes and the use of pesticides have adversely affected this species in some areas (Palmer 1962).

5.3.14 AMERICAN BITTERN (*Botaurus lentiginosus*)

Although this species is listed as a year-round resident by Lowery (1974a), it is primarily a migrant and winter resident in the Chenier Plain. It is present in highest numbers from October to May. Birds nest singly, but several individuals may nest in the same vicinity. Nests and roosts are near feeding areas and daily movements are not extensive.

The American bittern is found principally in fresh marsh habitat, but it sometimes is found in fields of tall grass (Palmer 1962). In the Chenier Plain, it is also regularly found in the brackish marsh habitat.

American bitterns consume a variety of foods. A survey of 133 stomachs by U.S. Biological Survey found 20% fish (primarily noncommercial), 19% crayfish, 23% insects, 21% amphibians, 10% mice and shrews, 5% snakes, and 2% miscellaneous invertebrates.

The American bittern is not known to nest in the Chenier Plain.

5.3.15 WOOD STORK (*Mycteria americana*)

Wood storks migrate into the Chenier Plain after nesting elsewhere, principally in southern Florida. Many stay throughout the summer; others only pass through. Wood storks are present from March through November with maximum numbers from June through September (Lowery 1974a). They feed and rest in groups. Individuals often rest in trees for hours. They soar overhead in large circles, commonly between 9 a.m. and 3 p.m. They fly at least 15 to 25 km (9.3 to 15.5 mi) from roosting to feeding areas (Palmer 1962).

Wood storks are primarily freshwater residents. They feed in prairie ponds, swamp forests, flooded pastures, inundated fallow fields, borrow ditches, and the shallow shorelines of rock pits. An ebb tide or falling water level is preferred for feeding (Palmer 1962).

A variety of foods is consumed, including minnows, crustaceans, mollusks, reptiles (young alligators, snakes, small turtles), tadpoles and frogs, small mammals, insects, plants, and seeds (Palmer 1962).

The draining of marshes and drought, fire, lumbering, and land clearing has caused severe population declines of wood storks in some areas of the U.S.

5.3.16 WHITE-FACED IBIS (*Plegadis chihi*)

The white-faced ibis is a permanent resident of the rice fields and coastal marshes of the Chenier Plain. Daily movements consist of flocks of this rather nomadic feeder flying between feeding and resting or nesting areas. Each parent makes six or more trips per day to feed young (Palmer 1962). The species often occurs in large flocks and flies in a characteristic "V" formation. Individuals alternately flap and glide in flight. The white-faced ibis is spreading its range eastward from Texas; it has apparently occupied the former range of the glossy ibis (*P. falcinellus*).

Palmisano (1971) found few white-faced ibises in fresh marshes, but none in the salt marshes in southwestern Louisiana. Sometimes it also is found in rice fields and pastures (Lowery 1974a).

This ibis feeds by probing with its bill. Important foods include crayfish and insect larvae (Belknap 1957).

Less than 1% of the Louisiana white-faced ibis nest in the Chenier Plain (Portnoy 1977), although Palmer (1962) indicates that this area could be the center of abundance. Belknap (1957) reported that the species nests near the ground in reed and buttonbush growth in association with other wading birds. Portnoy (1977) also found them nesting in black mangroves. In mixed colonies that are associated with short vegetation, this species tended to nest on the ground (Burger 1978). The white-faced ibis normally begins nesting in May.

A die-off of white-faced ibis in the Texas Chenier Plain in 1974 was reported to be due to eggshell thinning caused by excessive concentrations of DDE, dieldrin, and aldrin. Its very specific nesting behavior makes this species particularly vulnerable to human disturbance and wetland loss (Burger and Miller 1977).

5.3.17 WHITE IBIS (*Eudocimus albus*)

The white ibis is common in the Chenier Plain from late March to late September. Some individuals overwinter. Daily movements consist of flights to and from feeding areas and resting or nesting areas. Large flocks flying to and from feeding areas are common. Birds may fly over distances of 100 km (62 mi) (Palmisano 1971).

The white ibis is abundant in coastal marshes and freshwater swamps and is primarily a nonvisual, tactile forager (Kushlan 1977). Foods include worms, insects, crustaceans, arthropods, mollusks, fish, amphibians, and reptiles.

The white ibis nests in colonies, often in association with other species. Nests are constructed in trees or shrubs, or on the ground. Portnoy (1977) found few nests of this species in the Chenier Plain.

There have been recent pesticide-related die-offs in Texas and similar die-offs may also be occurring in Louisiana.

5.3.18 ROSEATE SPOONBILL (*Ajaia ajaja*)

The roseate spoonbill is a year-round resident. Its northernmost distribution is in Louisiana, where it nests exclusively in the Chenier Plain (Palmer 1962). In Texas, the species nests along the coast from the Chenier Plain southward. As with other waders, daily movements consist primarily of flights between resting or nesting areas and feeding areas. Neither the pattern nor the length of these flights is known.

Roseate spoonbills feed primarily in open areas, but they nest and roost in woody vegetation. In the Chenier Plain, they are most abundant in fresh marsh habitat, but occasionally inhabit brackish and salt marshes and pastures. This species feeds by sweeping the bill sideways through the water. The diet is composed primarily of small fishes, but crustaceans, insects, and mollusks are also eaten (Palmer 1962).

Portnoy (1977) found three nesting colonies in Louisiana; two were in marsh habitats and one was on a site formed of dredged material. All birds observed were nesting in woody shrubs. The species requires isolated nesting areas far from human disturbance (Anderson 1978).

In addition to pesticides and destruction of habitat, exceptionally cold weather often causes spoonbill mortality. Nesting birds are highly sensitive, and if disturbed they may abandon their nests for the season (Anderson 1978).

5.3.19 RED-TAILED HAWK (*Buteo jamaicensis*)

In the Chenier Plain, red-tailed hawks are winter residents that arrive in early November and stay until late March (Lowery 1974a). Daily movement consists of flights from roosting areas to hunting perches, and occasional flights between hunting perches. Red-tails are somewhat territorial in winter (Brown and Amadon 1968). The winter territory of six red-tails in Michigan ranged from 1.6 to 5 km (1 to 3 mi) (Craighead and Craighead 1956).

Red-tailed hawks are found in a wide variety of habitats, but usually reside where fields and forests are intermingled. In the Chenier Plain these hawks occur primarily in areas north of the coastal marshes or occasionally on levees in the marsh. Red-shouldered hawks (*B. lineatus*) are usually more common than red-tailed hawks in swamp forests.

The food of red-tailed hawks is primarily rodents, rabbits and insects (Imhof 1976). Lowery (1974a) examined 65 stomachs of red-tailed hawks collected near Baton Rouge and found cotton rats (*Sigmodon hispidus*), rice rats (*Oryzomys palustris*), harvest mice (*Reithrodontomys fulvescens*) and house mice (*Mus musculus*) exclusively.

Red-tailed hawks are not yet known to nest in the Chenier Plain but the species has extended its range from northern Louisiana into central Louisiana. As with other raptors, there may have been some recent reproductive failures due to chlorinated hydrocarbons. Red-tails are frequently shot even though they are protected by the Migratory Bird Treaty Act.

5.3.20 MARSH HAWK (*Circus cyaneus*)

Marsh hawks are common residents in the Chenier Plain, but do not nest there. Migrants usually arrive in early September and some of these are present until late May (Lowery 1974a). There are indications that the species nests in Texas and Louisiana (Lowery 1974a, Oberholser 1974). The marsh hawk is more active during twilight periods than most hawks and can often be seen flying over marshes or prairies of the Chenier Plain. While hunting, they often fly more than 160 km (100 mi) in a day (Brown and Amadon 1968). The marsh hawk is more conspicuous than most hawks when hunting because it flies low while searching for prey. They may roost communally, but leave individually at dawn (Craighead and Craighead 1956). In winter, this species has a home range from 16 ha (40 a) to more than 1 mi^2 (Brown and Amadon 1968).

Marsh hawks feed over marshes, tidal flats, fields, pastures, meadows, and prairies (Oberholser 1974). They roost and nest on the ground and eat mammals, snakes, frogs, insects, and other birds (Brown and Amadon 1968).

5.3.21 KING RAIL (*Rallus elegans*) and CLAPPER RAIL (*R. longirostris*)

King rails and the clapper rails are common permanent residents of the marshes of Louisiana and Texas. King rail numbers increase in winter as northern miggrants arrive (Lowery 1974a). Because rails are secretive and, therefore, difficult to observe, little is known about daily movements. Telemetry studies of clapper rails revealed that movements are restricted to small areas with a radius of only 37 m (121 ft). Movement occurs throughout the day and is more extensive in winter (Sharpe 1976).

These two large rails are similar in appearance, but differ ecologically. The king rail is primarily a freshwater species whose distribution corresponds closely with that of the muskrat. The king rail breeds in fresh marshes and rice fields, whereas the clapper rail breeds primarily in salt marshes. The two species may coexist in brackish marshes (Meanley 1969, Lowery 1974a).

King rails feed mainly on crustaceans, especially crayfish, and aquatic insects, but will also eat fish, crickets, and seeds of aquatic plants. King rails feed in areas of dense plant cover or in narrow, open areas where their cryptic coloration blends in with the marsh background. They usually feed most heavily at dawn and dusk (crepuscular), and at low tide (Meanley 1969).

Clapper rails frequent areas of dense cordgrass or needlerush. They are primarily crepuscular and feed at low tide, mainly along tidal flats and muddy shores of bayous and tidal creeks. Food consists mostly of crustaceans, especially crabs (up to 90% fiddler crabs), snails, and other shellfishes (Sanderson 1977). Bateman (1965) found that, in addition to fiddler crabs, squareback crabs and periwinkle snails make up the bulk of the diet. The fall diet is primarily small crabs and snails.

In Louisiana, the king rail nests over a 7- to 8-month period, beginning in March. The species produces several broods and each clutch contains 10 to 12 eggs. Sanderson (1977) reported a hatching success of 75%, but 50% of the young died during the first week of life. King rails nest on the ground or slightly above the ground, usually in buttonbush (Imhof 1976).

Clapper rail nesting begins in February or early March, peaks in mid-April to mid-July, and continues into September. Density is about two to three nests per hectare, primarily in taller cordgrass (greater than 55 cm or 21 in) (Oberholser 1974, Sharpe 1976). Nests are located on elevated sites (15 to 25 cm or 6 to 10 in) near secondary and tertiary tidal creeks.

Many nests are destroyed by high water or predation. The most common predator is the raccoon. Fish crows and gulls also take eggs and young (Blandin 1963, Imhof 1976, Sharpe 1976, Sanderson 1977).

Hunting pressure on both species is light. The most serious problem facing the species is habitat destruction (Sanderson 1977). In southeastern Texas, king rail numbers have been greatly reduced, primarily where mercury-based fungicides are used on seed rice (Oberholser 1974).

5.3.22 PURPLE GALLINULE (*Porphyrula martinica*) and COMMON GALLINULE (*Gallinula chloropus*)

Louisiana is the most northerly wintering area for purple gallinules (Sanderson 1977). Most birds begin arriving in eary April and leave by late October (Lowery 1974a). It is resident in all of Louisiana during the summer, but its winter range is restricted to the southern parishes. It is most abundant in the Chenier Plain from early April to mid-November (Lowery 1974a), although small numbers remain throughout the winter months (Bell and Cordes in press).

Both species are territorial and diurnal. Their daily movements are usually restricted to local areas.

Gallinules occur in ponds, lakes, swamps, canals, rice fields, and marshes (Lowery 1974a, Oberholser 1974, Olsen 1975, Sanderson 1977, Bell and Cordes in press). Imhof (1976) reported that common gallinules are more tolerant of saline habitats than are purple gallinules, although the greatest numbers of both species are found in fresh marshes (Sanderson 1977, Bell and Cordes in press). Population densities in the large freshwater impoundment on Lacassine National Wildlife Refuge were estimated to be 0.8 common gallinules/ha and 1.2 purple gallinules/ha during August (Bell and Cordes in press).

Emergent vegetation is a major requirement of nesting habitat (Oberholser 1974, Bell and Cordes in press). On Lacassine National Wildlife Refuge, purple gallinules nested in maidencane and common gallinules nested in bulltongue (Bell and Cordes in press).

Gallinules consume a variety of foods, including southern wild rice, wild millet, flowers of the white waterlily, various grasses, insects, mollusks, and worms (Oberholser 1974, Imhof 1976, Sanderson 1977, Bell and Cordes in press). Common gallinules are also known to feed on carrion (Guillory and LeBlanc 1975). Bell and Cordes (in press) reported that common gallinules fed in deeper water and over greater areas than purple gallinules. During severe weather, both species often seek shelter in dense stands of vegetation. Predators of the gallinules include large mouth bass, alligator, bowfin, gar, and snapping turtles (Bell and Cordes in press).

5.3.23 AMERICAN COOT (*Fulica americana*)

Coots are common in Louisiana from early September to late April and are most abundant in winter (Lowery 1974a, Imhof 1976). By mid-October, about 650,000 coots have migrated to Louisiana. Peak numbers of American coots that winter in Louisiana range from 635,000 to 1,639,000. There are about 4,944 km^2 (1,909 mi^2) of habitat available for nesting and 18,210 km^2 (7,031 mi^2) for migrating and wintering populations in Louisiana (Sanderson 1977). About 11,219 km^2 (4,375 mi^2) are available for all categories of habitats in Texas.

Coots occur mostly in marshy areas, ponds, and streams in the summer, and in coastal bays, lakes, and lagoons in the winter (Oberholser 1938).

Seventy-five percent of the diet of the American Coot is composed of plants (Jones 1940). Food includes leaves and seeds of aquatic plants such as duckweek, widgeongrass, pondweed, spikerush, sedges, and grasses, as well as waste grain (Sanderson 1977, Imhof 1976). In summer, animal material composes an important part of their diet and includes insects, mollusks, fish, crustaceans, worms, spiders, and other water animals (Sanderson 1977, Imhof 1976). Food is taken from the water surface or along the shoreline (Jones 1940). Ortego et al. (1976) observed coots feeding in open water near emergent aquatic vegetation. Chicks feed on insects and eggshells found in the nest (Sanderson 1977). During migration coots gather in areas where food is available.

The American coot does not usually nest in southwestern Louisiana. Nests have been found on Lacassine National Wildlife Refuge in Cameron Parish and Avery Island in Vermilion Parish. Sanderson (1977) noted that coots nest most frequently on fresh water. In Texas, the American coot nests in muddy, reedy, and grassy margins of pools, lakes, sloughs, rivers, and creeks (Oberholser 1974). Prime nesting habitat, according to Sanderson (1977), consists of 50% open water and 50% emergent aquatic plants such as bulrush and cattail. Nests of the American coot are situated over water. A clutch consists of 8 to 12 eggs that are incubated for 21 to 22 days (Sanderson 1977, Jones 1940). Muskrat houses may be used as nest sites in lieu of the more common floating nests. Coots may renest (Sanderson 1977), and nesting territories are actively defended (Jones 1940).

Because the nest is often located over, or floating on water, the birds are relatively secure from predators. Young, however, are eaten by bass, turtles, and snakes (Imhof 1976). Effective waterfowl management is highly beneficial to American coots.

5.3.24 AMERICAN WOODCOCK (*Philohela minor*)

Few American woococks nest in Louisiana (Lowery 1974a), but the largest winter concentrations in the

United States occur here. Woodcocks are common in Louisiana from mid-October to mid-February (Lowery 1974a), with highest numbers occurring around the second week in December. Birds that winter in Louisiana are probably from areas west of the Appalachian Mountains (Sanderson 1977).

Woodcocks winter in all parts of Louisiana except in the coastal marshes (St. Amant 1959). They frequent piney woods and prairies, but most woodcocks occur in bottomland hardwoods (Evans 1976), where fertile alluvium and moist, sandy soils predominate (Pursglove and Coster 1970). The main factor controlling the use of the southwestern Louisiana prairies and coastal marshes is the lack of cover (St. Amant 1959). Fringe areas of highlands are excellent habitat. During extremely cold weather, the prairies and coastal areas of southwestern Louisiana are used extensively by woodcock (St. Amant 1959, Sanderson 1977).

Woodcock have three general habitat requirements: (a) forest openings for singing and nocturnal roosts; (b) fertile, generally poorly drained soils with many earthworms; and (c) vegetation for diurnal and nocturnal cover (Sanderson 1977). In winter, birds prefer alluvial floodplains with a brushy understory. Favorable habitat includes shadowy, secluded places with moist soils that are conducive to probing (Oberholser 1974, Sanderson 1977). Daytime cover is dense thickets composed of shrubs, briars, and vines (Glasgow 1958, Britt 1971, Oberholser 1974). Feeding sites are often associated with switchcane, blackberry, and honeysuckle (Dyer 1976). Areas used at night are small, open areas surrounded by an overhead cover of tall weeds, grass, or crops, and may be located as far as 5 to 6 km (3 to 4 mi) from daytime cover (Glasgow 1958). Wet ditches in dry pastureland, old fields, or harvested croplands are also used extensively at night. Controlled burning of night nesting areas may be beneficial under some conditions (Ensminger 1954).

Earthworms compose 50% to 90% of the diet of the American woodcock, which also includes beetles, fly larvae, and occasionally, plant material (Britt 1971, Sanderson 1977). When the soil is dry and probing is difficult, the birds will eat grubs, slugs, and ants (Oberholser 1974). Dyer and Hamilton (1974) noted three major feeding periods throughout the day: (a) early morning; (b) midday; and (c) sunset. During extremely cold weather, thousands of birds are forced into the coastal marshes and occupy all available habitat (St. Amant 1959). Many birds are found along the coast and on cheniers at this time.

Migration of the woodcock to the northern nesting grounds begins in late January or early February (Sanderson 1977). Although nesting occurs mainly in the northern states, it has been documented on the Chenier Plain of Texas (Oberholser 1974).

In the Chenier Plain, woodcocks are limited by the availablility of suitable habitat. Any loss of forested land will further reduce available habitat. Wintering habitat is being lost to stream channelization, dam projects, land clearing for urban and industrial purposes, clean farming, pine plantations, clearing of pastureland, and clear-cutting of our forests (Sanderson 1977).

5.3.25 COMMON SNIPE (*Capella gallinago*)

The common snipe occurs on the Chenier Plain from early October to late April (Lowery 1974a) and often occupies the same wintering grounds year after year (Naney 1973). Local movements in winter are correlated with fluctuations in water level (Perry 1971). Migration to northern areas begins about mid-March (Sanderson 1977). Snipe feed in early morning and late afternoon (Oberholser 1974). Little feeding occurs at night (Owens 1967).

Rice fields and coastal marshes provide suitable habitat for common snipes (Booth 1964, Tuck 1965, Perry 1971) in the Chenier Plain. Excellent wintering grounds include coastal marsh and fallow or cultivated rice fields (Owens 1967). Tuck (1965) found that the interface between prairie and marsh is attractive to snipe because large areas of pastures are highly productive (Hoffpauir 1969). In south central Louisiana, ditches and pond edges having weeds and sedges interspersed with bare ground, disked land, and burned areas offer excellent snipe habitat (Owens 1967). In Texas, snipe use shallow rain pools, prairies and pastures, mowed or plowed fields, fresh or salt marshes, roadside ditches (Oberholser 1974) and canal edges (Olsen 1975). Shallow, flooded fields with both inundated land and exposed rises are preferred by snipe (Neely 1959).

The diet of the common snipe includes 80% animal material (e.g., insects, earthworms, crustaceans, arachnids, and mollusks) (Neely 1959, Oberholser 1974, Sanderson 1977). Snipe eat sedge, smartweed, sawgrass, bulrush, witchgrass, and wild millet. Most of these plants occur naturally on wet fields (Neely 1959). Owens (1967) suggested that plants may be incidental in the diet. Due to periodic application of commercial fertilizers, ricelands provide nutrients to snipe. Some food is picked up from the ground surface, but snipe usually concentrate in areas where they can probe (Owens 1967). Neely (1959) found that snipe utilize closely cropped fields for feeding. They will not use areas with tall vegetation. Snipe feed in areas containing exposed and inundated land (Owens 1967) and in wet, organic soils with dense cover (Tuck 1969) and often roost in areas similar to those where they feed (Perry 1971).

Nesting occurs in the northern tier of states. The common snipe lays four eggs that are incubated for 19 days in nests on the ground.

5.3.26 LAUGHING GULL (*Larus atricilla*)

Laughing gulls are more abundant in summer than winter in the Chenier Plain. They are most abundant in nearshore Gulf waters, along beaches, and in salt marshes. They nest in colonies that usually are located in smooth cordgrass or on barrier island beaches (Portnoy 1977). Nests are usually in isolated locations. Laughing gulls usually feed in shallow water, but may feed in open water or scavenge on land. Large numbers of gulls often follow fishing boats. Groups often roost on sand spits at low tide.

Laughing gulls eat a large variety of animal matter obtained on or near the water surface Oberholser (1974) reported that crabs, small fishes, and shrimp are important food items and stated that there is a preference for foods containing a relatively large proportion of fat or animal oils. This species does not frequent garbage dumps as much as do other gulls. This species occasionally consumes eggs or young of other birds nesting nearby.

Laughing gulls usually use sticks or grass for nesting material, but sometimes will merely scrape a depression in sand or shell substrates. Nests are usually concealed among low, dense shrubs or clumps of grass. The nesting season extends from April to August and peaks in mid-May (Portnoy 1977). Hildebrand and Blacklock (1975) stated that mortality of young is always high, sometimes close to 100%.

Suitable nesting locations are rare in the Chenier Plain. Traditional nesting sites should be protected if possible. At Brigantine National Wildlife Refuge, New Jersey, Montevecchi (1977) found that eggs of laughing gulls were preyed upon by fish crows (*Corvus ossifragus*), common crows (*Corvus brachyrynchos*), and herring gulls (*Larus argentatus*). Herring gulls also preyed on laughing gull chicks. Barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), and marsh hawks (*Circus cyaneus*) were also responsible for chick and adult mortality.

5.3.27 FORSTER'S TERN (*Sterna forsteri*)

Forster's terns are primarily a migratory species, but there are some individuals present all year, especially on the coast. This species breeds and nests in colonies. Individuals move unknown distances from the colonies to feed.

Forster's terns often nest in small groups on sandy, open beaches, lagoons, and inlets. They seem to frequent all marsh types, but usually nest in salt marshes (Portnoy 1977). Colonies are usually located where the marshes contain a large number of open-water pools. They usually nest in the open, either on or adjacent to the tidal wrack. They feed by diving into the water and catching fish near the surface. Foraging areas need to be productive, and the water should be clear enough for the terns to see their prey.

Forster's terns feed primarily on small fish, but also eat other small aquatic animals near the water surface (Oberholser 1974). This species frequently eats aquatic insects, and sometimes flying insects.

Forsters' terns usually nest in colonies on islands in a marsh. Nests usually are located on driftage or other firm substrates where marsh vegetation is absent. Nests are sometimes placed on muskrat houses. The majority (63%) of the nests found by Portnoy (1977) were in salt marshes; 35% were found in brackish marshes; and only 1.1% in fresh marshes. Only 0.5% of the nests were found on coastal beach and 0.8% on spoil islands. This species nests earlier than other waterbirds in Louisiana (Portnoy 1977). Most nesting occurs between March and July.

A shortage of suitable isolated nesting sites may limit the distribution of this species. Portnoy (1977) reported one colony of 2,750 incubating adults which abandoned their nests after some of its members were shot. Because of this bird's position in the food web, they may occasionally accumulate excessive concentrations of contaminants.

5.3.28 LEAST TERN (*Sterna albifrons*)

The least tern is primarily a summer resident that migrates to the Chenier Plain in late March or early April and remains until late October. There are a few scattered winter coastal records of birds (Lowery 1974a). In the Chenier Plain, least terns usually nest in proximity to feeding areas, and daily movements therefore are not extensive.

Least terns require a flat, essentially bare area for nesting, and open, shallow water nearby for feeding (Portnoy 1977). This species is distributed primarily along the coast (Oberholser 1974), but it also occurs along large open bodies of water such as bays, estuaries, and major rivers.

Most food is obtained in shallow water (Oberholser 1974), and consists primarily of small fishes caught by skimming the surface or diving (Bent 1921).

Least terns nest largely on sandy beaches close to civilization (Oberholser 1974). In Texas (Hildebrand and Blacklock 1969) and Louisiana (Portnoy 1977), it commonly nests on newly formed dredged-material islands. This species usually does not nest in colonies with other waterbirds (Oberholser 1974). Four of the five colonies Portnoy (1977) found in the Chenier Plain were on a beach and one was on spoil. Eighty-five percent of the nests were near salt water, often on sand. Incubation peaked in early May (Portnoy 1977).

In the past, populations of least terns were decimated by market hunters. Collected specimens were used primarily as decorations. The protected status of this species has allowed its numbers to increase. Historically, least terns nested on sandy beaches. Proximity to occasional activities of man is no great hindrance. If refuges are established on a beach, this species can nest successfully. (There is such a refuge near Biloxi, Mississippi.) Exceptionally high tides also can wash away beach nests. This species will use fresh spoil areas for nesting; however, plant succession soon makes spoil areas unsuitable.

5.3.29 ROYAL TERN (*Thallasseus maximus*)

This resident species lives along beaches for most of the year, but in winter it flies short distances into bays and bayous (Lowery 1974a).

Royal terns usually inhabit beaches or the edges of larger estuaries and lagoons. Few are found inland. They obtain food by diving for millet, menhaden, anchovies, croakers, shrimp, and crabs.

Royal terns nest in every major lagoon or bay in Texas (Hildebrand and Blacklock 1969), usually on sandy islands or bars along the coast (Oberholser 1974), and frequently in colonies with other species. Portnoy (1977) found 97% of the nests on coastal beaches and only 3% in salt marshes. The shortage of suitable beaches that are not subject to flooding and that are relatively free from human disturbance is the main factor limiting royal terns in the Chenier Plain.

5.3.30 CASPIAN TERN (*Hydroprogne caspia*)

Caspian terns are permanent residents in the Chenier Plain. During spring and fall, additional migrants occur along major rivers and lakes of the region, as well as along the Gulf shore. Daily movements are probably not extensive. Individuals tend to congregate in small flocks near feeding areas.

This tern is distributed farther inland than are royal terns (Oberholser 1974). Caspian terns are definitely more partial to the marshes than the beaches (Lowery 1974a) and require open water for feeding. Oberholser (1974) reported that Caspian terns feed on medium-sized fishes such as mullet; they also feed on shrimp and other aquatic life. Although they dive to obtain food and will sometimes completely submerge, most food items are taken from the surface.

Caspian terns in Louisiana nest in colonies on bare ground in salt marsh habitat, or on unvegetated offshore islands (Portnoy 1977). In Texas, they nest in colonies on sandy or gravelly islands (Oberholser 1974) or on barren spoil islands (Hildebrand and Blacklock 1969). Lack of suitable isolated nesting areas may be one factor affecting Caspian terns in the Chenier Plain. In the Great Lakes area, high PCB levels may have adversely affected reproduction of this species (Gilbertson et al. 1976).

5.3.31 BLACK SKIMMER (*Rynchops niger*)

Black skimmers, permanent residents in the Chenier Plain, are largely restricted to the coastal zone. Inland observations are usually associated with hurricanes or other severe weather (Oberholser 1974). Black skimmers nest or rest near their foraging grounds and often feed at night. Tidal influence is more important than time of day in controlling foraging time (Erwin 1977). Young were fed an average of 0.43 times per hour in North Carolina.

Black skimmers are conspicuous flocking birds that frequent beaches and bars near the shallow Gulf or in estuaries. They forage along shallow mud flats, tidal streams, and marsh edges (Erwin 1977). Food includes small fishes, shrimp and other crustaceans (Oberholser 1974). Erwin (1977) found that skimmers in North Carolina fed primarily on small fishes.

Individuals that are feeding fly with their specialized lower mandible skimming the water surface, and grab food as the mandible makes contact.

Black skimmers nest in colonies on sandy beaches, flats, or shell-covered ridges (Oberholser 1974). In North Carolina, they nest on open sand beaches on natural islands or small spoil islands (Erwin 1977). In Louisiana, the largest colonies are on barrier beaches, but many nest on shell berms in salt marshes. All nesting sites are located near shallow water (Portnoy 1977). Colonies may be easily disturbed, and colony sites often differ from year to year (Erwin 1977). Nests are scrapes in sand or shell (Portnoy 1977) and may be destroyed by storm tides (Hildebrand and Blacklock 1969). Black skimmers do not nest abundantly in the Chenier Plain. Other species in the Chenier Plain, such as least terns, often nest in association with black skimmers. In Louisiana, incubation begins in late May, but most incubation occurs in late June and early July (Portnoy 1977). Both sexes participate in incubation, which begins after the first egg is laid. Clutch size is 3 to 4 eggs. Incubation period is 23 days.

In the Chenier Plain, availability of suitable isolated nesting sites may be a limiting factor. Because of low fledging success in North Carolina and the fact that the first-hatched chick is almost invariably the only one to survive, Erwin (1977) argued convincingly that the black skimmer is often food-limited. Destruction of nests by storm washouts sometimes is overcome by renesting.

5.3.32 MOURNING DOVE (*Zenaida macroura*)

Mourning doves in Louisiana exhibit three patterns of movement: (a) flocking and migration of locally reared birds; (b) arrival and departure of northern-reared birds; and (c) local shifting of winter concentrations due to food availability and weather condtions (St. Amant 1959, Sanderson 1977). During the fall, birds from north Louisiana are found throughout southwestern Louisiana and Texas (St. Amant 1959). In winter, birds from northern states intermingle with local birds.

Mourning doves are highly adaptable and common in many habitats, (Oberholser 1974). This species thrives in almost all terrestrial habitats, including beaches. Mourning doves also are associated with agricultural areas because of the waste grain and weed seeds found there (St. Amant 1959). Mourning doves are common at all times of the year in Louisiana (Lowery 1974a).

In the South, doves eat corn, peanuts, sorghum, millet, rice, grass seeds, and weeds. Waste grain and weed seeds are eaten largely in fall and winter (St. Amant 1959). Some insects are consumed during the nesting season.

Most nesting occurs from April to June, but in Louisiana, nesting may occur all year. Oberholser (1974) confirmed that nesting occurs in the Chenier Plain of Texas. Mourning doves may make four to six attempts at nesting but only two or three of these may be successful (Lowery 1974a, Sanderson 1977). Any available tree is used for nesting (St. Amant 1959). Nesting habitat includes woodland edges, shelterbelts, church and cemetary sites, cities, farmlands, and orchards. Nests are flimsy platforms that hold two eggs (Sanderson 1977). Incubation lasts 14 days.

Pasture and rice lands in southwestern Louisiana produce excellent dove food. Intensive agriculture sometimes may have a detrimental effect on mourning dove populations (Sanderson 1977). In Texas, a decline in the number of doves has been attributed to drought and trichomoniasis (Oberholser 1974).

5.3.33 BARN OWL (*Tyto alba*)

Barn owls reside in the Chenier Plain throughout the year. Young birds disperse over a wide area in response to food shortages (Sparks and Soper 1970). Barn owls become active and reportedly fly many miles while hunting during the night (Presst and Wagstaffe 1973). They return to roost before sunrise (Karalus and Eckert 1974). Adults usually nest in late winter and late summer, producing two broods per year (Karalus and Eckert 1974).

Barn owls flourish in warm, open or semi-open lowlands such as prairies, meadows, marshes. and seashores (Oberholser 1974), often in proximity to man. They usually nest or roost in isolated structures such as old buildings or in clumps of trees (Karalus and Eckert 1974).

Barn owls eat mice, rats, shrews, rabbits, and birds, especially European starlings and house sparrows (Oberholser 1974). Mice make up more than half of their diet (Karalus and Eckert 1974). Frogs, snakes, lizards, fishes, crayfish and insects also are eaten.

Barn owls require appropriate structures in which to nest. These include isolated buildings and hollow trees. When these structures are not available, barn owls will nest in abandoned crow or hawk nests, or even occasionally in holes in the ground. Nests usually contain 3 to 7 eggs, but up to 14 have been found. Both parents incubate the eggs. Incubation begins after the first egg is laid and lasts approximately 33 days. The young hatch on different days, and the oldest have an advantage in obtaining food from the parents (Karalus and Eckert 1974, Oberholser 1974).

Survival of the young barn owls depends upon available food supply (Karalus and Eckert 1974). Frequently barn owl abundance corresponds with cyclic abundance of rodents (Sparks and Soper 1970). Use of agricultural chemicals may be a factor in the decline of barn owls in agricultural areas.

5.3.34 COMMON SCREECH OWL (*Otus asio*)

Screech owls are nocturnal predators and have been known to range at least 1.6 km (1 mi) to feed. They inhabit open woodlands, especially those adjacent to grain fields, meadows, and marshes. They often roost in tree cavities (Karalus and Eckert 1974). Screech owls may also be found in young second-growth forests or in scrub forests.

Screech owls eat rodents, amphibians, reptiles, small birds, and insects. Small birds are consumed in largest quantities during the nesting period (Karalus and Eckert 1974). This owl requires hardwood tree cavities for nesting and in the Chenier Plain, the removal of hardwood stands has probably greatly reduced the abundance of this species.

5.3.35 GREAT HORNED OWL (*Bubo virginianus*)

Great horned owls are year-round residents of the Chenier Plain. Although primarily nocturnal, they are sometimes active on overcast days. The species apparently maintains the same range throughout the year. Craighead and Craighead (1956) found an average of one pair of birds for each 16 km^2 (6 mi^2) in Michigan.

Great horned owls occur primarily in areas of hardwood trees intermingled with fields and marshes. In the Chenier Plain, it occurs regularly in the chenier forests (Karalus and Eckert 1974). It consumes large quantities of mammals, especially rabbits, skunks, rats, and mice (Lowery 1974a). They may also prey on other owls (Karalus and Eckert 1974).

Great horned owls require hollow trees or other appropriate structures, such as abandoned crow or eagle nests, for nesting purposes. Habitat loss is a major factor in the reduction of this species.

5.3.36 CANADA GOOSE (*Branta canadensis*)

The Canada goose was once abundant on the Chenier Plain where wintering populations numbered over 100,000 birds (Singleton 1953, Belsom 1974). Wintering populations began a rapid decline during the late 1940's, and by the early 1950's, they numbered less than 15,000 (Singleton 1953, Smith 1961, Belsome 1974). Now only a few thousand birds over-winter in the Chenier Plain.

Migrant Canada geese usually arrive in the Chenier Plain in early October and small groups continue to arrive throughout the fall and winter with peak numbers present in January. Canada geese migrate from the Chenier Plain in the spring to a vast breeding area extending from the midwestern states to the southern edge of Hudson Bay. Paired birds remain together for life. The male stands guard while the female incubates the eggs (Bellrose 1974).

In the Chenier Plain the Canada goose is found predominantly in the rice fields and pastures. This species uses upland sites more than do other waterfowl.

The few flocks that winter south of the rice belt occupy low marsh ridges and cheniers that are grazed by cattle (Lynch 1967).

Breeding flocks of resident Canada geese have been established at several locations on the Chenier Plain. A flock at Rockefeller Refuge contains about 2,000 birds and annual production is about 600 young. Geese from this flock have moved to new areas and nesting birds have been observed as far as 65 km (40 mi) from the refuge. Egg predation, mainly by raccoons, appears to be a limiting factor (Chabreck et al. 1974a).

5.3.37 WHITE-FRONTED GOOSE (*Anser albifrons*)

The white-fronted goose is an early migrant to the Chenier Plain. A few birds begin arriving in late September, but the majority do not arrive until mid-October. The white-fronted goose is typically a bird of western flyways, and the Chenier Plain is on the eastern edge of its range (Smith 1961). Prior to 1952, most birds on the Chenier Plain occupied the Texas portion of the area and fewer than 3,000 were found in Louisiana. The species gradually began an eastward shift, and by 1959 the wintering population in Louisiana had increased to 12,000 birds; by 1975 the population had increased to 50,000 (Smith 1961, Bateman 1975a). Spring migration from the Chenier Plain begins in early March, and most birds depart by late March (Smith 1961).

At one time, white-fronted geese on the Chenier Plain were considered "marsh geese". They fed almost entirely in shallow marshes along the landward edges of coastal lagoons and in "sea rim" marshes adjacent to beaches. Feeding areas in marsh habitats have now been largely abandoned in favor of agricultural lands (Lynch 1967). The geese often rest in shallow fresh marshes adjacent to the coastal prairie and make frequent flights into rice fields and pastures to feed. Some geese spend the entire winter in agricultural areas. Major concentrations are found near the Gulf in former wetland habitats which have been leveed, drained, and turned into pasture.

White-fronted geese in agricultural habitats usually eat rice, but they also graze on the succulent parts of green plants growing in rice fields and pastures. Seeds seem to be preferred, but stems and blades of marsh grasses also are eaten (Glazener 1946).

White-fronted geese breed north of the Arctic Circle. Paired geese remain together for life and the male assists in rearing the young.

5.3.38 LESSER SNOW GOOSE (*Chen caerulescens*)

Although white and blue phases of the lesser snow goose occur on the Chenier Plain in about equal numbers, the blue phase outnumbers the white phase by 5:1 in all of Louisiana. The ratio is reversed in Texas (Smithey 1973). Historically, most of the individuals arrived in the Chenier Plain during the last 2 weeks of October, but recent studies indicate that birds are deviating from this pattern and many flocks do not arrive until December (Smithey 1973).

Lesser snow geese move about considerably on the wintering grounds. Although large flocks of several thousand birds may remain in one general area throughout the winter, small groups and family units frequently move from flock to flock and show little respect for flock integrity (Schroer and Chabreck 1974). The main migration of lesser snow geese from the Chenier Plain begins in mid-February, and by late March most have departed.

Historically, the lesser snow goose wintered in coastal lagoons and brackish marshes. Within the past few decades, however, many geese have abandoned the coastal marshes, and now winter in rice fields and pastures. This trend first developed in Texas but is now evident throughout the Chenier Plain (Lynch 1967).

The traditional food of the lesser snow goose is Olney's three-cornered grass. Periodic marsh burning has perpetuated the grass and added new feeding areas for the geese. They also feed on saltmeadow cordgrass and saltgrass that grow in association with three-corner grass. The birds are classified as "grubbers" that uproot and eat rhizomes and other tender parts of marsh plants (Glazener 1946, Lynch 1967).

In coastal farmlands geese display a different feeding behavior by resorting almost entirely to grazing on sprouted rice, spikerush, and other green plants in rice fields and pastures. Considerable controversy arose when the lesser snow goose shifted to the coastal prairie. The birds there began to destructively feed on winter ryegrass. The extension of the goose hunting season into February largely eliminated this problem (Linscombe 1972).

Snow geese nest in the far north, mostly on Baffin Island, Southampton Island, and along the western and southern shores of Hudson Bay. Once paired, the birds remain together for life (Bellrose 1974, Smithey 1973).

5.3.39 FULVOUS TREE-DUCK (*Dendrocygna bicolor*)

Fulvous tree-ducks are summer residents of the Chenier Plain. They begin arriving from wintering areas in Mexico during March, but the greatest influx takes place in mid-April. Upon arrival in the Chenier Plain, they concentrate in the fresh marshes and remain there for several weeks before dispersing into rice fields and pastures for nesting (McCartney 1963).

During late summer the birds begin forming flocks which gradually increase in size. These flocks feed in rice fields and cause some depredation. They begin departing from the breeding area in September and again concentrate in the fresh marshes. In October they depart for wintering areas in Mexico. By mid-November the fall migration is nearly completed (Smith 1961, McCartney 1963).

Fulvous tree-ducks use fresh marshes for only a brief period after their spring arrival and before their fall departure. During this time they occupy shallow flooded areas. During the breeding season, fulvous tree-ducks feed in rice fields, flooded rice stubble, wet pastures, small inland marshes, fish ponds, and crayfish ponds (Lynch 1943, McCartney 1963).

The major food of the fulvous tree-duck is rice, although they feed on various grass and sedge seeds growing in association with rice. When feeding in marshes, the birds also select seeds of grasses and sedges such as wild millet, paspalum, and cyperus. Animal material makes up only a small portion of the bird's diet (Meanley and Meanley 1959, McCartney 1963).

Fulvous tree-ducks usually form a pair bond when one year old and, unlike most ducks, they remain paired for life. Nesting begins in late May and extends to late August. On the Chenier Plain, the species nests almost entirely in rice fields. Clutch size averages between 12 and 15 eggs; both parents are thought to incubate the eggs (McCartney 1963).

5.3.40 MALLARD (*Anas platyrhynchos*)

The mallard is widely distributed throughout Texas and Louisiana in various habitats, and is the major waterfowl of the Chenier Plain. The mallard is considered a late migrant and, unlike many other dabbling ducks, few mallards pass through the Chenier Plain enroute to other areas. Mallards begin arriving in large numbers in mid-November, gradually increase in abundance during early winter, and reach a peak in mid-January (Smith 1961).

Winter abundance is influenced largely by the severity of cold weather in the north. The winter of 1974-75 was considered mild, and the January 1975 mallard population in southwestern Louisiana was only 154,000 (Bateman and Linscombe 1975). On the other extreme, the winter of 1976-77 was much colder and the January 1977 mallard population numbered 787,000 in southwestern Louisiana (Bateman et al. 1977).

The mallard is an adaptable species that is found in coastal marshes, rice fields, flooded pastures, or flooded bottomland hardwoods. The species will often use one habitat as a feeding area and another as a rest area. Dillon (1957) found that mallards fed in rice fields at night in the Chenier Plain, then flew to marsh areas 8 to 16 km (5 to 10 mi) away to rest.

Mallards typically eat seeds, and select feeding areas where the seeds of wild plants or agricultural crops are abundant and readily available. Mallards prefer to feed in waters less than 50 cm (19.5 in) deep. Resting areas may be deeper, but mallards are secretive and prefer marshes with small ponds of less than 0.5 ha (1.2 a) or flooded areas with abundant plant cover. Although mallards are occasionally found in brackish marshes, greatest concentrations occur in fresh and intermediate marshes. Preferred mallard foods in rice fields of the Chenier Plain are the seeds of rice, paspalum, and wild millet (Dillon 1957). Food in fresh and intermediate marshes consists largely of grass and seeds of millet, panic grass, cyperus, spikerush, and bulrush. Brackish marsh plants used most often are saltgrass, spikerush and bulrush (Chamberlain 1959).

Courtship and pair formation take place during the wintering season among mallards using the Chenier Plain. However, the birds migrate northward for nesting and brood rearing.

5.3.41 MOTTLED DUCK (*Anas fulvigula*)

The mottled duck is a year-round resident of the Chenier Plain and breeds and winters there. Large coastal areas may be utilized by this species in and out of the Chenier Plain area (Singleton 1953, Smith 1961).

In a study by Weeks (1969), two male and two female mottled ducks were equipped with radio transmitters over a period of 5 to 38 days. Their home ranges were found to be between 42 and 132 ha (105 and 327 a). He felt that the home range was an underestimate because of the short time period involved.

Although mottled ducks occupy a wide range of habitats in the Chenier Plain, they prefer fresh and slightly brackish marshes. Other favorite habitats are shallow marshes along the margin of saline and brackish bays and lagoons, and freshwater ponds and streams in row-crop agricultural areas (Singleton 1953).

Studies of mottled duck distribution (Singleton 1953) indicate that marshes of the Chenier Plain are heavily used during the summer and fall, and rice fields are heavily used during the winter and spring. Observations in the Louisiana portion of the Chenier Plain suggest that habitat use varies only slightly during the annual cycle. The use of brackish marshes increases somewhat during late summer because they serve as staging areas following the post-nuptial molt (Weeks 1969). Rice fields may be used during late summer as the crop matures. Linscombe (1972) reported problems with rice crop depredation by mottled ducks.

The food of mottled ducks in the Chenier Plain is diverse. According to Singleton (1953), insects and fishes were the main foods. Important plant foods were wild millet and rice. Stomachs from ducks killed in salt marshes in Aransas County, Texas, contained 90% widgeongrass. Bent (1923) found that mollusks, crustaceans and insects accounted for 40% of the mottled ducks's diet, while Smith (1973) found only 7% of the gizzard contents to be of animal origin. Some of this difference may be explained by the trend towards greater use of domestic rice during the past 50 years. Bent did not mention rice specifically as a food source, but Smith found that rice was the major component of the gizzard contents.

Hatchlings feed mainly on insects (Singleton 1953). Suitable feeding areas often include open water with emergent and submergent aquatic vegetation.

Mottled ducks usually select one of three types of nesting areas (Singleton 1953). One type is a coastal marsh containing dense stands of saltmeadow cordgrass on slight ridges well above high tides. A second type is inland prairies, including ungrazed areas such as abandoned fields, roadsides, levees and other sites having dense cover. A third type is rice fields, either fallow or in production. Only lightly grazed or completely ungrazed fields are used. A few nests are located on levees, but most are constructed in heavy patches of stubble. Nests in stubble are poorly concealed compared to those in dense saltmeadow cordgrass. Nest distance from permanent or semipermanent water bodies was as far as 300 m (984 ft.).

Flooding of nests is often a serious problem. Losses are greatest after a dry spring when the ducks nest on low sites that are flooded by heavy rainfall. During high water ducks nest on higher sites.

Although coastal marshes used by nesting ducks have undergone changes during the past few decades, Lynch (1967) felt that no great harm to mottled ducks has resulted. The building of oilfield roads, cattle walkways, and canals in the marshes of the Chenier Plain seemed to have benefited rather than hurt nesting ducks by providing flood-proof nest sites and drought-proof rearing ponds.

Although nesting does not peak until April, pair formation takes place in early winter, and nesting may begin as early as February (Singleton 1953). Clutch size varies from 7 to 14 eggs and the incubation period is about 26 days. Nest abandonment is common among mottled ducks. Females that are disturbed early in egg-laying (less than 5 eggs) will usually abandon the nest but they renest readily. Singleton (1953) reported that one pair built 5 nests and laid 34 eggs in one season. Usually one brood is reared each year.

Singleton (1953) observed 108 nests over a 4-year period (1949 to 1952) and reported that slightly over 25% of the nests were successful. Nests or eggs were destroyed in rice fields mainly by raccoons, opossums, dogs, cattle, and humans. As a part of the same study, mortality in 115 broods up to 8 weeks of age was found to be 38%.

5.3.42 GADWALL (*Anas strepera*)

The gadwall, often referred to as 'gray duck' by hunters, is a winter resident of the Chenier Plain, although a small segment of the population may migrate to the tropics in unusually dry years. Approximately 90% of the population of the Central and Mississippi flyways winter in Gulf coast marshes. About 40% winter in the Chenier Plain (Smith 1961).

The first major flight of gadwalls into the Chenier Plain takes place between mid-October and the first week of November. The peak migration is during the last week of October. Numbers gradually decline until mid-November, then stabilize somewhat through the remainder of the winter. The November decline possibly reflects some migration farther southward.

Gadwalls feed primarily on submerged aquatic plants. Migrants arriving in October concentrate in large flocks on shallow lakes in brackish marshes containing dense stands of widgeongrass (Chabreck 1978). The birds then disperse to other marsh lakes as food supplies become depleted.

Gadwalls show a strong preference for vegetative parts of aquatic plants, including leaves and succulent stems. Although seeds are consumed, they may often be taken as a source of grit rather than food. This was likely the case in Kimble's (1958) study in Cameron Parish, where sawgrass made up 62% of the gizzard contents of gadwalls. He also found that widgeongrass composed 27% of the contents and other plant foliage made up 9%. Smith (1973) found the gadwall's diet to consist of 35% waterweed, 33% spikerush, 22% algae, and 10% aquatic plants.

Gadwalls begin pair formation and courtship during late winter in the Chenier Plain, but nesting and brooding take place in the great plains and the lakes of western mountains (Johnsgard 1975). Gadwalls nest later than other dabbling ducks, and occasionally hens do not enter the postnuptial molt until after the fall migration to the Chenier Plain (Chabreck 1966b).

5.3.43 NORTHERN PINTAIL (*Anas acuta*)

Pintail migrants first arrive in the Chenier Plain in mid-September. Numbers rapidly increase through October and November and peak in December. Many flocks depart for wintering areas in Mexico and Central America. The exodus results in lower populations during midwinter, but the southerly migrants begin returning by late January, and Chenier Plain populations again increase (Smith 1961). The pintail is a mobile, wide-ranging species that shifts readily from area to area on wintering grounds.

Early migrants are attracted to large shallow lakes with abundant stands of aquatic plants. Brackish lakes containing widgeongrass are favored areas in the Chenier Plain. In December and January, fresh and brackish marshes with dense stands of annual grasses and sedges are preferred feeding areas for the pintail. They usually feed in water less than 30 cm (12 in) deep. After feeding, pintails fly to rest areas where they concentrate in large flocks (Tamisier 1976).

Grasses compose the bulk of the pintail's diet. Ninety-eight percent of the content of crops from birds taken in the vicinity of Creole were grass seeds (Bardwell 1962). Animal material made up less than 1% of the diet.

Most pintails wintering on the Chenier Plain are paired prior to spring migration. Nesting and brood rearing take place mostly in the prairie pothole region of southern Canada.

5.3.44 GREEN-WINGED TEAL (*Anas crecca*)

The Chenier Plain is a major wintering area of the green-winged teal. Birds begin to arrive in late September, but the major flights do not arrive until late October (Smith 1961). Populations continue to increase through November and peak in mid-December. There is some evidence that a segment of the green-winged teal population migrates farther southward, causing population declines in late December and January. By February, the trans-Gulf migrants begin returning to the Chenier Plain from the south, and populations temporarily increase. However, other birds begin the northward migration by mid-February and populations decline again (Smith 1961).

The green-winged teal is one of the smallest North American waterfowl. Preferred feeding habitats are large open flats of 5 to 10 ha (12 to 25 a), with water less than 10 cm (4 in) deep. Habitats include fresh to brackish marshes, but large flocks are frequently found in rice fields. Green-winged teal move from daytime resting areas at dusk to feeding areas, and return to the resting areas at dawn (Tamisier 1976).

This duck often concentrates in great flocks, at times exceeding 100,000 birds (Smith 1961). Prior to implementation of the Federal point system for duck shooting,the green-wing was seldom shot because hunters preferred bigger ducks; however, the point system probably placed greater hunting pressure on the green-winged teal than on any other species in the Chenier Plain.

Seeds of annual plants are favorite foods. The bird will often feed heavily on plants with very small seeds such as spikerush and waterhemp.

The green-winged teal does not breed on the Chenier Plain. The species migrates northward in the spring to breeding areas in the Dakotas, Minnesota, and the prairie region of Canada and Alaska.

5.3.45 BLUE-WINGED TEAL (*Anas discors*)

Before 1957, the blue-winged teal was largely a transient in the Chenier Plain and large concentrations were present only in the fall and spring while birds were migrating. However, marsh changes associated with Hurricane Audrey in June 1957 and an extremely high nutria population that competed for the available food supply altered the migration patterns of the blue-wing. For several years, a large portion of the population remained throughout the winter on the Chenier Plain (Smith 1961). This pattern continued for several years and was reinforced by high production of annual plant growth during prolonged summer droughts during the early 1960's. Since then,the migration pattern has reverted largely to that followed prior to 1957. The departure of the blue-winged teal to more southerly wintering areas during the fall and their return in the spring meant that a major segment of the population was absent during the winter season.

Habitat preferences of the blue-winged teal closely parallel those of the green-winged teal. Migrants that begin arriving on the Chenier Plain in late August use mainly fresh to brackish marshes and feed on the leaves and seeds of aquatic plants and associated invertebrates. Blue-wings also use areas where seeds from early crops of annual plants are available and water depths are favorable. Shallow ponds in brackish marshes, which dry up in early summer and produce dense stands of marsh purselane, are a favorite late summer habitat. Birds continue to use such areas until they migrate to tropical wintering areas.

Late winter habitats are fresh and intermediate marshes and rice fields with preferred water depths less than 20 cm (8 in). The marshes contain an abundance of seeds of annual plants from the previous growing season (Chabreck 1978).

The diet of blue-winged teal in one study was mostly insects and mollusks, whereas rice composed almost 60% of the blue-wings' diet in Texas (Bennet 1938). Kimble (1958) examined the gizzards of blue-winged teal from Cameron Parish and found that seeds made up over 75% of the contents, mostly from sawgrass and California bulrush. The seeds and leaves of widgeongrass made up almost one-fourth of the food items and consisted of seeds and leafy material in about equal amounts. Animal matter made up less than 1% of the gizzard contents.

Although the major nesting area of blue-winged teal is the prairie region of the north central states and south central Canada, a small segment of the population nests in the Chenier Plain (Lowery 1974a). The number of resident breeders is usually very low, and most people are not aware of the birds' presence. In some years, such as 1958, large numbers remained and nesting blue-wings or broods were conspicuous (Lynch 1967).

Most nesting takes place in early spring, when 8 to 12 eggs are laid in down-lined nests of grasses and reeds on the margin of ponds and sloughs (Lowery 1974a). Some nests are constructed on cheniers and pastures considerable distances from water.

5.3.46 NORTHERN SHOVELER (*Anas clypeata*)

Shovelers migrate into the Chenier Plain in mid-September and substantial numbers are present by mid-October. Many of the birds make only brief stopovers before continuing to move to southerly wintering areas. Concentrations do not usually peak until March when migrants returning from the south join those flocks which overwintered on the Chenier Plain. Many birds remain until mid-April and some remain well into May before migrating northward (Smith 1961).

Although the greatest concentrations of shovelers are found in freshwater and brackish ponds, some occupy areas of higher salinity than most other dabbling ducks(Smith 1961). Preferred habitat, regardless of water salinity, consists of marsh interspersed with open water less than 10 cm (4 in) deep (Chabreck 1978).

Shovelers are relatively small ducks with a spatulate bill with comb-like lamellae around the perimeter, which are used to strain food from water (Johnsgard 1975). Shovelers tend to prefer shallow, turbid water and feed mostly on small crustaceans, which comprise about 30% to 40% of their diet. Favored plants are pondweed, vegetative parts of bulrush and other rushes, and sometimes even rice (Smith 1973).

Many shovelers begin courtship and pair formation on the Chenier Plain before migrating north in late spring. The western portion of the prairie pothole region in Canada is the main nesting area.

5.3.47 AMERICAN WIGEON (*Anas americana*)

The American wigeon migrates to the Chenier Plain in early fall, usually late September through October (Smith 1961). During years when habitat conditions are unfavorable, many birds remain only a short period on the Chenier Plain, then continue migration to tropical wintering areas. Wigeons migrate north through the Chenier Plain in April.

Wigeons are "pond ducks" that feed mainly on green vegetation. They are partial to sheltered coastal waters containing submerged aquatic plants and they often pilfer scraps of pondweeds from surfacing ducks and coots (Lynch 1967). Early migrants concentrate in large groups on widgeongrass ponds in brackish marshes of the Chenier Plain. As food supplies there become depleted, wigeons feed in freshwater ponds, along lake shorelines, and in pastures (Chabreck 1978). Wigeons prefer aquatic plants and algae, but also eat grass, seeds, and animal material (Bellrose 1974, Smith 1973). Hard seeds are concentrated in the gizzard for grit.

Courtship and pair formation is usually completed in the Chenier Plain. Their large nesting range coincides with that of both the mallard and gadwall, and extends northwest to the Bering Sea in Alaska (Bellrose 1974).

5.3.48 WOOD DUCK (*Aix sponsa*)

Wood ducks constitute only a minor portion of the waterfowl in the Chenier Plain. Wintering populations consist of both resident and migrant birds. Migrants begin arriving in October, reach peak concentrations during November, and depart in February and March for northern nesting areas (Smith 1961).

Wood ducks are predominantly found in freshwater environments, mostly flooded timber or marsh ponds near wooded areas. The roosting area is usually a secluded pond with low overhead cover, often composed of buttonbush.

Wood ducks feed by dabbling. They select seeds and vegetative parts of aquatic plants, plus fruits and nuts of trees and shrubs. Brooding areas usually contain dense growths of submerged aquatic plants, and emergent plants along the shoreline. These plants harbor insects which are the major food of the ducklings (Johnsgard 1975).

This species is a cavity nester and usually selects a hollow tree near water. Cavities range from 10 cm to 2 m (4 in to 6 ft) deep. The down-lined nest may be constructed at heights up to 15 m (50 ft). The species readily utilizes artificial nesting structures, and local populations can be greatly increased by supplying artificial nesting sites. The number of natural cavities available for nesting is a limiting factor to the species (Bellrose 1974).

5.3.49 REDHEAD (*Aythya americana*)

Only a small portion of the redhead population that migrates down the Mississippi and Central Flyways winters on the Chenier Plain. Large flocks do, however, winter in the Chandeleur Islands area and Laguna Madre area of southern Louisiana (Smith 1961, Singleton 1953). Redheads arrive on the Gulf coast in late October and November and remain there for the winter (Smith 1961). Northward migration in the spring begins in early February, and by mid-March most birds have departed.

In the northern Gulf, redheads commonly inhabit offshore waters; however, in the Chenier Plain, the species limits its activities to inland open waters and impounded marshes. Although redheads are divers, they often use shallow marsh ponds, and feed by tipping. They feed primarily on aquatic plants, and winter in areas where these plants are readily available.

Redheads nest in the Dakotas and throughout the prairie pothole region of southwestern Canada. Hens often lay eggs in the nests of other redheads or even other waterfowl. The foster parent then hatches the eggs and rears the young (Bellrose 1974).

5.3.50 RING-NECKED DUCK (*Aythya collaris*)

Ring-necked ducks begin arriving on the Chenier Plain in mid-October. Populations gradually increase during the fall and reach a peak in late December and early January. The species begins the northward migration in February, but the major exodus does not take place until mid-March (Smith 1961). This species is found mostly on freshwater lakes that contain submerged aquatic vegetation. Largest concentrations of these ducks in the Chenier Plain occur at Lacassine National Wildlife Fefuge (Smith 1961).

Ring-necked ducks feed on succulent parts of aquatic plants. Seeds of species such as watershield, bulrush, and pondweed are also eaten by the birds. Animal material, mainly mollusks, make up about 25% of the diet (Johnsgard 1975).

These birds are common nesters in the Great Lakes region and across midwestern Canada (Johnsgard 1975).

5.3.51 CANVASBACK (*Aythya valisineria*)

Small flocks of canvasbacks begin arriving on the Chenier Plain in early November, continue to arrive throughout the winter, and reach highest numbers in January; however, no more than a few thousand birds usually overwinter. Spring departure begins in February and is completed by late March (Smith 1961).

The coastal lagoons of Louisiana and Texas were once a major winter concentration area for canvasbacks, but numbers gradually dwindled to the point where the bird is rarely seen there. Canvasbacks are excellent divers and frequent lakes that support stands of submerged and floating-leaf plants.

Canvasbacks prefer plant materials, but also eat many forms of animal life when available (Bellrose 1974). Canvasbacks traditionally wintered on Fearman Lake in Vermilion Parish and fed on banana waterlily but the plant gradually disappeared from the lake and the canvasbacks moved to other wintering sites

The canvasback nests in northern United States and Canada. Marsh drainage there causes a serious loss of nesting habitat.

5.3.52 LESSER SCAUP (*Aythya affinis*)

The Chenier Plain and its offshore waters is a major wintering area for lesser scaup. The species arrives in the Chenier Plain in late October and forms flocks of several thousand birds each in the Gulf of Mexico 1 to 10 km (0.6 to 6 mi) offshore. These combined flocks number nearly 250,000 birds, of which an estimated 2% may be greater scaup. Scaup remain offshore throughout most of the early winter and usually move to inland waters in January. During some years the scaup will remain offshore until spring migration in March (Chabreck et al. 1974b).

The lesser scaup is typically a bird of large open bodies of water, but at times it is found on small marsh ponds. This species freely utilizes fresh, brackish, and saltwater habitats. An excellent diver, it occasionally feeds offshore in water over 6 m (20 ft) deep.

The diet of lesser scaup consists largely of animal material. Harmon (1962) examined 32 birds collected 5 to 7 km (3 to 4 mi) offshore from Cameron Parish and found that 99.8% of the food eaten was surf clam (*Mullinia lateralis*). Kimble (1958) examined 13 lesser scaup killed on inland waters in Cameron Parish and found that 75% of the diet was composed of animal material, mainly small fish, clams, snails, and shrimp.

Lesser scaup wintering on the Chenier Plain have a nesting range which extends from the Dakotas northward through the Canadian prairies into Alaska. The species is greatly affected by marsh drainage.

5.3.53 HOODED MERGANSER (*Lophodytes cucullatus*)

Migrant hooded mergansers begin arriving on the Chenier Plain in mid-october, but the major influx does not take place until November. Largest numbers of birds are present in mid-December. They begin departing in January and by March most have left the area (Smith 1961).

This species occupies marsh ponds and lakes. A larger relative, the red-breasted merganser, limits its activities to coastal bays and the Gulf of Mexico. Hooded mergansers are often found on small ponds, bayous, and canals and frequently occur in swamp forest habitat (Smith 1961). They consume a variety of aquatic animals, but feed largely on fish. They catch their prey by diving and by pursuing it underwater. Because of their diet, they are often referred to as 'fish ducks' and are generally avoided by hunters (Lowery 1974a).

Most hooded mergansers are migratory, however, a few birds remain on the Chenier Plain to nest. They nest in tree cavities and often compete with wood ducks for nest sites (Lowery 1974a). The shortage of nesting sites sometimes is limiting to reproduction in the Chenier Plain.

5.3.54 LIMITING FACTORS FOR WATERFOWL

The drainage of marshes is the major limiting factor affecting mallards and other migratory waterfowl in the Chenier Plain and in the nesting grounds of the upper great plains of the U.S. and in Canada. Severe weather conditions and drought also are factors affecting nesting success and the size of fall populations in any one year.

Hunting removes a sizable portion of the fall population, but the length of the hunting season and bag limits are carefully regulated to help assure an adequate nesting population the following summer.

Disease outbreaks occur periodically in waterfowl on the Chenier Plain, but are usually localized and involve only a small number of birds. The major disease is botulism and losses of up to 500 ducks have been reported (Crain and Chabreck 1960). The disease usually occurs in late summer and mottled ducks have been the main species affected.

Parasites are common in most species of ducks and geese, but no mortality has been reported for the Chenier Plain. *Sarcocystis rileyii*, a sporozoan, occurs in a high percentage of the resident adult duck population of the Chenier Plain; however, no adverse effects have been noted among parasitized birds (Chabreck 1964b).

Lead poisoning in waterfowl, caused by ingestion of lead shot, is a major problem throughout most of North America. Spent shot accumulates on feeding areas as a result of decades of hunting. Shot ingested by ducks and geese during feeding concentrates in the gizzard and is gradually eroded by the digestive processes. Lead salts are released and then absorbed into the bird's blood, often causing paralysis and death (Bellrose 1974). The death of 2,000 snow geese in rice fields north of Lacassine National Wildlife Refuge in 1973 was attributed to lead shot poisoning (Bateman 1975b). Soft iron shot is gradually being substituted for lead and should greatly reduce waterfowl losses in the future.

Predators capture some waterfowl on the Chenier Plain, but most adult birds taken are probably cripples. Mottled ducks lose many eggs to raccoon predation (Singleton 1953). Chabreck and Dupuie (1976) reported alligator predation on nesting Canada geese. Some ducks are taken by avian predators.

In the Chenier Plain, habitat loss has had some adverse effect upon wintering waterfowl. Palmisano (1972a) found that ducks primarily used fresh marsh habitat; therefore, marsh drainage or saltwater intrusion would reduce its value for ducks. Special management has been implemented on refuges and private duck clubs to curtail saltwater intrusion and prohibit excessive drainage. Draining marshes to create pastures for cattle reduces the habitat available for ducks (Chabreck et al. 1974b), however, habitat conditions are often improved for geese (Chabreck 1968a).

5.4 AMPHIBIANS AND REPTILES

5.4.1 AMERICAN ALLIGATOR (*Alligator mississipiensis*)

McNease and Joanen (1974) found immature alligators 1 to 2 m (3 to 6 ft) long on Rockefeller Refuge to be consistently more active than adults. Longest daily movements, up to 2.6 km (1.6 mi), occurred in spring for both males and females. Minimum activity occurred in autumn and winter, although immature animals moved about during winter warm spells.

Greatest movement of adult females occurs in the spring (April and May), in deep water areas (Joanen and McNease 1970). Average minimum size of the home range during spring for three females was 3.2 ha (7.8 a).

Adult males actively move about during all seasons except winter, making good use of the network of canals and bayous that are common in the marshes of the Chenier Plain. The minimum daily movements for 14 individuals for spring, summer, and autumn averaged 735 m (2,411 ft) (Joanen and McNease 1972a). The longest daily movement recorded was 8.5 km (5.2 mi). Largest seasonal ranges were recorded during the summer. During the winter, animals spend the majority of the time in marshes.

With the possible exception of some portions of the State of Florida, the Chenier Plain supports the highest concentration of American alligator within a 10-state region, and the population is still increasing.

Alligator densities vary from one marsh habitat to another. Density estimates for fresh, intermediate, and brackish marsh habitats in Cameron and Vermilion Parishes were 1 animal per 2 ha (5 a), 1 animal per 3.2 ha (8 a), and 1 animal per 8.1 ha (20 a), respectively (Nichols et al. 1976). Salt marsh habitat is not preferred by alligators; Chabreck (1971a) reported that small alligators found in salt marsh were weak and consumed less food than those from freshwater areas. Impounded and drained wetlands are also of limited value to alligators (Palmisano et al. 1973).

The alligator population is segregated to some degree. Chabreck (1965, 1966a) found that young alligators that hatched in areas of dense vegetation remained near the nest and did not depart from the mother's den until the spring of their second year. Those reared in bank dens along waterways dispersed in the spring of their first year. McNease and Joanen (1974) reported that immature females preferred natural marsh areas throughout the year, but they also used flooded impoundments during the spring. Deep water areas provided by canals and bayous were preferred in summer, autumn, and winter. Immature males preferred impounded areas in spring, but used deep water areas in summer and autumn. The intermediate marsh habitat was preferred by both sexes of immature alligators in this study. Throughout the summer and autumn, nesting females remained in the vicinity of their nest and den sites, which are often located some distance from deep water areas. Joanen and McNease (1970) reported that females with well-established marsh dens wintered in them, but spent more time in bayous, canals and lakes during the spring. Adult males preferred open waters and ventured into dense marshes only during the wintering season, except for temporary visits to the dens of adult females during the breeding season in May.

Alligators are opportunistic carnivores. They will take whatever they can catch and swallow. Fogarty and Albury (1968) reported that young Florida alligators fed heavily on one species of snail. A food habit study by Giles and Childs (1949) on Sabine National Wildlife Refuge showed that crustaceans were the most important food source for immature alligators. Chabreck (1971a) found the major freshwater food of young alligators measuring 0.9 to 1.7 m (2.9 to 5.6 ft) in length was crayfish. Alligators from more saline habitats fed heavily on blue crabs. McIlhenny (1934) reported herons, turtles, gar, and snakes, in that order of abundance, in the stomachs of five adult alligators from Avery Island in southwestern Louisiana. Valentine et al. (1972) found crustaceans and fishes to be the most important food source for alligators of all sizes. The recent abundance of nutria in the Chenier Plain region probably has provided an additional source of high-quality food for large alligators.

Some game birds are also eaten by alligators. Valentine et al. (1972) reported mottled ducks, coots, and clapper rails in stomach contents. Kellog (1929) and McIlhenny (1939) presented evidence of predation on young and adult ducks. Chabreck and Dupuie (1976) reported predation by adult alligators on Canada goose nests.

Water is one of the most important requirements for successful reproduction by alligators. Observations made by Joanen and McNease (1971) on Rockefeller Refuge suggested that deep open-water areas were necessary for courtship activities during early April to early June. Nesting occurred with increasing marsh water levels (Joanen and McNease 1975). Marshes with water salinities of less than 10‰ are preferred nesting areas (Chabreck 1971b).

Temperature is another important factor in alligator reproduction. Joanen (1969) reported that the greater the average temperature for March, April, and May, the earlier the onset of nesting.

In the past, the most effective management practice has been to restrict the kill of alligators. Protection is still an important management strategy, but there are other ways a land manager may enhance an alligator population (Chabreck 1971b). The maintenance of open water areas during the spring breeding season will provide courtship areas and increase reproduction (Joanen and McNease 1970, 1972a, 1975). Impoundments are used by immature alligators until late spring. Drawdowns should coincide with the exit of alligators from these areas, beginning no earlier than mid-May.

Alligators prefer marsh with water salinities of less than 10 ‰ (Chabreck 1971b). Saltwater intrusion is particularly detrimental to young alligators (Joanen and McNease 1972b). Structures which stabilize water levels will decrease nest loss by flooding and reduce the effects of drought. Weirs may be desirable for stabilizing water levels (Chabreck and Hoffpauir 1962). Marsh drainage should be avoided altogether and shading vegetation should be retained (Spotila et al. 1972).

A strictly regulated harvest has become an integral part of alligator management in some portions of the Chenier Plain region. In addition to providing economic benefits to the people of the area, a harvest serves to regulate the numbers of animals. In some places, animals are so abundant that they are rapidly becoming a nuisance and a hazard. The 1970 session of the Louisiana State Legislature enacted laws setting up the framework for an alligator harvest. By 1972, a harvest plan had been developed, and in the late summer of that year, the plan was implemented. Palmisano et al. (1973) provided a thorough analysis of the first experimental harvest program. The harvest regulations are designed to be selective for adult males and regulate the harvest according to the abundance of alligators within marsh types.

Nichols et al. (1976) developed a model simulating the dynamics of a commercially harvested alligator population inhabiting the privately owned coastal marshland of Cameron and Vermilion parishes. The model takes into consideration all known aspects of the alligator's life history. They believe that under existing habitat conditions, a base population of 100,000 animals could be maintained for at least 20 years when subjected to an annual differential (selective for adult males) harvest rate slightly greater than 5%.

Most of the privately owned marshes of Cameron Parish (112,660 ha or 278,270 a) have had an alligator season since 1972 (excluding 1974). Portions of Vermilion (106,600 ha or 263,302 a) and Calcasieu parishes have been opened to alligator hunting in subsequent years. This harvest apparently had no detrimental effect upon the alligator population (Palmisano et al. 1973).

Marsh water levels are critical to the Chenier Plain alligator population. High water during June, July, and August is a major cause of egg mortality. Nichols et al. (1976) reported that egg mortality from flooding begins with marsh water depths in the nests of 27 cm (10.5 in) and virtually all nests are destroyed at a depth of 46 cm (18 in).

Drought increases mortality through dessication, predation, and cannibalism, and magnifies the effect of illegal hunting by concentrating many animals in easily accessible water bodies. Lack of open water for courtship during the spring breeding season results in reduced reproduction (Joanen and McNease 1970, 1972a, 1975).

Salinity limits the distribution of alligators in marsh habitats. The species has a low salt tolerance and is generally restricted to areas having salinities less than 10 ‰ (Chabreck 1971b). Salt water intrusion is particularly detrimental to young animals in some areas (Joanen and McNease 1972b).

5.4.2 WESTERN COTTONMOUTH (*Agkistrodon piscivorus*)

Most published reports on movements are concerned with overwintering congregations, water fluctuation responses, road-crossing observations, or feeding aggregations. In south Louisiana, cottonmouths may congregate on or near higher ground (cheniers, levees, spoil banks) during colder months or during spring or hurricane flooding. They usually disperse when warmer weather arrives or when flood waters recede.

Large assemblages may also be encountered around shallow marsh or swamp pools during warm summer nights. In traveling Chenier Plain Route 82 from Pecan Island to Cameron, Louisiana, it is not uncommon to see a dozen or more individuals crossing the road, night or day. Duck hunters in Sabine National Wildlife Refuge reported snakes moving into vegetation near their blinds, apparently for sunning purposes. Keiser (1974a, 1976a) noted responses to water fluctuations and to overwintering sites in the Atchafalaya wetlands. Arny (1948) reported movements in adjustment to seasonal changes in water levels and observed cottonmouths frequenting 'drift' along ridges during high water. These snakes dispersed over the marshes with the lowering of water levels during the summer. More detailed comments on daily and seasonal movements are found in Barbour (1956), Wright and Wright (1957), Burkett (1966), and Wharton (1969).

Cottonmouths may be found in most of the Chenier Plain habitats. They may be expected in and adjacent to rivers, bayous, swamps, marshes, marsh ponds, tidal ditches, and the Intracoastal Waterway. They are also found along chenier levees and spoil banks, within woodlands of various vegetational types, and in poorly drained areas and water-filled ditches of agricultural and urban areas. Cottonmouths are commonly associated with bodies of water, but they may wander overland for considerable distances. They are encountered occasionally in brackish habitats, but only rarely in or near waters of higher salinity. They are known to utilize animal burrows (those of crayfish and armadillos) and to submerge below the waterline in these burrows. They will also bask in bushes and trees over the water, sometimes moving as high as 2 to 3 m (6 to 10 ft) above the waterline.

Published locality records of cottonmouths in the Chenier Plain are not common. Burt and Burt (1929) noted a specimen from Vidor in Orange County, Texas. Brown (1950) included these species on his list of Texas coastal prairie species and reported three in Jefferson County. Burkett (1966) remarked that he had "twice observed cottonmouths crawling into crayfish burrows along the Gulf Coast of Texas . . ." Raun and Gehlbach (1972) and Werler (1970) showed distribution records for Orange, Jefferson, Chambers, and Galveston Counties in eastern Texas. For the Louisiana Chenier Plain, Penn (1943) reported 25 cottonmouths taken on six successive days in August of 1940 near Hackberry (Cameron Parish). Penn considered them to be "... exceedingly abundant along the marsh bayou ridges," and described the ridges as "... sand and shell ridges, locally known as 'cheniers,' with live oak and palmetto ..." Liner (1954) cited six specimens from Vermilion Parish, but gave no specific localities. Giles and Childs (1949) and Valentine et al. (1972) reported cottonmouths in the stomachs of alligators taken on Sabine National Wildlife Refuge. Keiser (1976a) found Atchafalaya Basin cottonmouths in almost any aquatic related habitat, including cottonwood-willow-sycamore forests, cypress-tupelo lowland forests, upland deciduous hardwood forests (on Belle Isle), rarely flooded and frequently flooded bottomland hardwood forests, levees, various forb and grass complexes, sand bars, mud flats, treeless ridges and spoil banks, tidal ditches, freshwater marshes, bayous, canals, shallow woodland streams, woodland pools and ditches, isolated ponds (farm and marsh), freshwater lakes, and on floating hyacinth mats. Keiser did not find them in the open waters of Atchafalaya Bay or the Atchafalaya River, but specimens were observed on shorelines peripheral to these aquatic habitats. Arny (1948), in a report on the herpetozoans of Delta National Wildlife Refuge, noted cottonmouths 'in all the main types of communities from the river [Mississippi] to the Gulf.' Specific habitats mentioned included ridges, willowless marshes, alligatorweed, muskrat rows, Gulf side of a mangrove ridge, and piles of drift.

Cottonmouths rarely utilize high salinity habitats. Wharton (1966) states, 'Cottonmouths apparently enter salt water only by accident or following disturbance by man; thus the sea as a food source is not utilized directly.' Since established freshwater populations may exist on Gulf islands (e.g., Marsh Island, Chandeleur Islands) and in coastal areas immediately adjacent to saline waters, occasional saltwater transients can be expected. Furthermore, individuals rafting on debris, hyacinth mats, etc., may easily be transported into situations unfavorable for extended survival. Regardless of these exceptions, it is apparent that there is an inverse correlation between population levels and salinity levels in Chenier Plain aquatic habitats.

Most natural habitats in the Chenier Plain sustain suitable escape cover. Vegetated higher ground (e.g., cheniers, levees, and spoil banks) provide cover during cooler months and protection during flooding and hurricanes. Animal burrows such as those of armadillos and crayfishes are often utilized as escape routes and overwintering sites. Logs, piles of boards, and other debris, if remaining in place for several months, will often attract these snakes in considerable numbers. Keiser (1976a) recommended cottonmouth management based, in part, on cover-high ground relationships.

The cottonmouth will eat almost any flesh, including carrion. It has been termed an 'opportunistic omni-carnivore' by Burkett (1966). Fishes, amphibians (particularly frogs), reptiles (mainly lizards and snakes), birds, small mammals, mollusks, and arthropods are readily consumed. Cannibalism has been reported. Conflicting reports exist concerning whether or not gravid females will feed in the wild. Cottonmouths forage for food by day and by night, and they will capture prey under water, on the surface of water, on land, and even in trees and bushes (Barbour 1956).

The cottonmouth feeds on a wide range of animals. Penn (1943) found two young cottonmouths in the stomach of an adult. Keiser (1976a) found sunfish, frogs, water snakes, and shrews in Atchafalaya Basin specimens. Fish were the most abundant prey items found by Kofron (1976).

Cottonmouths normally inhabit reasonably permanent bodies of freshwater, at low elevations in subtropical climates.

5.4.3 SNAPPING TURTLE (*Chelydra serpentina*)

Virtually nothing is known about the daily and seasonal movements of snapping turtles in the Chenier Plain. Liner (1954) reported juvenile and adult turtles moving into highways and being killed by automobiles in southwestern Louisiana.

Studies done in other parts of the country indicate that the species is highly mobile at times. An early study in Illinois (Cahn 1937) indicated that individuals move considerable distances overland during the summer, and that these journeys were not necessarily associated with nesting or with the drying of ponds. Cagle (1944) reported that both seasonal and forced migration occurred in the species. Distances traveled by 107 turtles in marshes of South Dakota ranged from 0 to 6.03 km (0 to 3.75 mi) and averaged 1.61 km (1 mi) in a period of from 1 to 3 years (Hammer 1969). Evidence suggests that adult turtles utilize the sun as a directional guide during overland travels (Gibbons and Smith 1968). Other papers on movements of snapping turtles include those of Carr (1952), Tinkle (1959), Gibbons (1970), Froese (1974), Froese and Burghardt (1975), and Ewert (1976).

Little is known concerning the distribution and habitat requirements of Chenier Plain snapping turtles. Penn (1943) termed these turtles 'common' in the marshes of Sabine National Wildlife Refuge near Hackberry, Louisiana, but Cagle and Chaney (1950) failed to capture specimens in 408 trap hours at the Sabine Refuge or 456 trap hours in the marshes of Lacassine Refuge. Brown (1950) included snapping turtles on his list of Texas Coastal Prairie Region species, but his species discussion mentioned only one locality ('Orange' in Orange County). Liner (1954) noted a single specimen from Vermilion Parish, Louisiana, but gave no specific locality data. Map 42 of Raun and Gehlbach (1972) indicates records for Orange and Jefferson Counties on the Texas Gulf coast.

Ernst and Barbour (1972) noted: 'The snapping turtle is one of the more aquatic species of turtle. It spends most of its time lying on the bottom of some pool or buried in the mud in shallow water with only its eyes and nostrils exposed. The depth of the water above the mud is usually comparable to the length of the neck. The turtle also hides beneath stumps, roots, brush, and other objects in the water and in muskrat lodges or burrows.' Engels (1942), Carr (1952), and Ernst and Barbour (1972) noted utilization of brackish tide pools by this species, and that adult turtles prefer deeper waters and younger turtles prefer shallower waters.

While certain authorities (Ernst and Barbour 1972; Froese 1974) have commented on or studied problems relating to cover requirements, almost nothing is known of the minimum needs for given individuals, populations. or activities. Most authors agree, however, that some sort of 'cover' is necessary or at least preferred by these turtles.

Ewert (1976) discussed sunning and sunning sites. Froese (1974) provided very limited data on substrate and cover preferences of juveniles.

Ernst and Barbour (1972) reported that snapping turtles consume insects, crayfish, fiddler crabs, shrimp, water mites, clams, snails, earthworms, leeches, tubifex worms, freshwater sponges, fishes (adults, fry, and eggs), frogs and toads (adults, tadpoles, and eggs), salamanders, snakes, small turtles, birds, small mammals, algae, and aquatic plants. Lagler (1943) recorded fishes, other vertebrates, invertebrates, carrion, and plant material in snapping turtle diets. Alexander (1943) reported that plant material composed 36.5% (by volume) and animal material 54.1% (by volume) of the contents of 470 stomachs from Connecticut specimens.

Feeding usually takes place under water. Ernst and Barbour (1972) reported that young snapping turtles actively forage for food while older individuals tend to lie in ambush for their prey. Burghardt and Hess (1966) considered early stage food imprinting to be important in the feeding behavior.

Information on reproduction of turtles in Louisiana is scarce. Arny (1948) reported a large number of nests along the ridges, particularly the pass ridges of the Mississippi River Delta, but no nests along the waterways adjacent to the Gulf. He found very heavy nest predation, especially by raccoons. Keiser (1976a) noted elimination of snapping turtle nesting grounds in the Atchafalaya River Basin by encroachment of hunting camps and summer homes.

This is an omnivorous species associated with a variety of aquatic habitats. Few papers deal with limiting factors at the level needed for adequate management, although Hammer (1969) provided useful insights. Water is obviously critical as specimens only occasionally travel on land. They do not sun themselves as often as most other aquatic turtles. Waters of higher salinity levels may not be suitable, although snapping turtles do occasionally live in brackish watters. Soft substrates are preferable to hard bottoms. Submerged vegetation, debris, or logs are required for cover. Rainfall and seasonal temperature variations are particularly important during breeding and nesting periods. Virtually nothing is known of specific limiting factors for Chenier Plain populations.

5.4.4 BULLFROG (*Rana catesbeiana*)

Bullfrogs apparently prefer waters with the shallow wooded shorelines with brush and stumps, driftwood, or matted roots of a fringe of willow trees (Wright and Wright 1949). Smith (1961) reported that bullfrogs inhabit almost any type of permanent water, such as lake, pond, river, and creek. Collins (1974) wrote that it is restricted to permanent lakes, rivers, streams, and swamps where deep water is available and that this frog apparently spends the winter months burrowed in mud beneath the water of lakes and rivers. Fitch (1958) found that dispersal from drying ponds usually takes place at night or during periods of high humidity. Johnson (1977) gave these comments: 'This is Missouri's most aquatic species of frog. Bullfrogs spend most of their time in or very near aquatic habitats such as lakes, ponds, rivers, large creeks, sloughs, and permanent swamps and marshes. They may enter caves at times.' Carr (1940) summarized North Florida habitats of bullfrogs as follows: '. . . Widely distributed, but most highly concentrated in woods ponds with emergent brushy vegetation (willow, button bush, waterwillow), lakes, ponds, and streams in which cover grows to the water's edge; pools along the courses of intermittent swamp streams.'

Arny (1948) noted bullfrogs in ponds and southern wildrice marshes at the Delta National Wildlife Refuge in southern Louisiana. He found recently metamorphosed young under boards on Octave Pass, but located none along the Mississippi River ridge or in saline areas. Tinkle (1959) reported bullfrogs in a swamp at Sarpy Wildlife Refuge in St. Charles Parish. Liner (1955) considered this species common in swamps and bottomland hardwoods, and scarce in the highland woods of Lafayette Parish. Taylor (1970) and Taylor and Michael (1971) described bullfrog habitats in eastern Texas (Nacogdoches County). Details on bullfrog habitats within the Atchafalaya River Basin of south central Louisiana may be found in Keiser (1974a, 1974b, 1976a, 1976b). The most inclusive of these reports (1976a) listed bullfrogs in the following habitats within the Basin: cottonwood-willow-sycamore forest, cypress-tupelo, rarely flooded bottomland forest, upland forests of Belle Isle at marsh-forest junction, levees, forb and grass complexes, sandbars within and adjacent to bayous, bays, and the Atchafalaya River, mud flats, treeless ridges and spoil banks, Atchafalaya and East Cote Blanche bays, tidal ditches, freshwater marshes, bayous, canals, shallow woodland pools and ditches, shallow non-woodland pools and ditches, land isolated ponds, freshwater lakes, and the Atchafalaya River, and within floating hyacinth mats. It should be noted that bullfrogs were not observed in waters of even moderate salinity during the course of Keiser's study. Keiser found individuals in crayfish holes and in the bottom mud as well as in numerous other habitats.

No published studies on bullfrog habitats within the Chenier Plain are known. Penn (1943) mentioned records for Sabine National Wildlife Refuge, but failed to note the habitat for the frogs. Brown (1950) recorded an individual specimen from south of Beaumont, Texas, but listed no habitat information. These frogs are fairly common in many freshwater ponds, streams, and marshes within the Chenier Plain, but detailed studies of niche parameters and responses to habitat fluctuations are warranted and essential for future management of Chenier Plain populations.

Extensive literature exists on the foods and feeding habits of bullfrogs. Among the more detailed reports are those of Needham 1905; Wright 1914, 1920; Frost 1935; Wright and Wright 1949; Ryan 1953; Gentry 1955; Korschgen and Moyle 1955; Smith 1956; Cohen and Howard 1958; Smith 1961; Korschgen and Baskett 1963; Brooks 1964; Reggio 1967; Stokes 1967; Schroeder and Baskett 1968; Mueller 1969; Taylor and Michael 1971; Stewart and Sandison 1972; Collins 1974; Mount 1975.

Mount (1975) commented: 'The bullfrog is a voracious feeder, capturing and swallowing almost anything of appropriate size that crosses its path. Invertebrates constitute the bulk of the diet, but birds, snakes, turtles, mice, and other frogs, including members of its own species, may also be included.' Insects and crustaceans are the major invertebrates consumed according to Smith (1961).

Published papers about food habits of Chenier Plain bullfrogs are not known, but future investigators would do well to examine the papers of Reggio (1967), Taylor and Michael (1971), and unpublished studies by D. D. Culley, Jr. of Louisiana State University.

Apparently no published studies exist on the reproductive requirements of bullfrog populations on the Chenier Plain.

The quality, depth, and duration of standing and moving waters must be of prime consideration in developing a bullfrog management program. The relationships of submergent and emergent vegetation, ground cover and shoreline cover, bottom quality, water temperature variation and the chronology of this variation, seasonal variability in presence and availability of dissolved gases, and water salinities to the various life history stages of bullfrogs must be studied in detail. The effects of periodic invasions of saltwater by hurricanes must be determined. Food availability must be at suitable levels and variety for early and late larvae and post-metamorphic stages. Chemical pollution of habitat waters must be avoided. Most pesticides, herbicides, defoliants, etc., should never be utilized near sites where bullfrogs are abundant.

Excessive predation, particularly hunting by humans, can be damaging. Keiser (1976a) noted that adult frogs in the Atchafalaya Basin are easy to capture in the spring when water hyacinths are not abundant, and that bullfrogging at such times may be responsible for the drastic reductions in local populations. He reported that most spawning occurred during the month of June and recommended that Louisiana's frogging season be closed from early March through June 15, in order to reestablish or increase bullfrog populations in areas where they are depleted. Other activities of humans are often detrimental, e.g., dredging, deforestation, and removal of brush along stream banks and lake borders.

Certain color phases of adult bullfrogs resemble those of adult pig frogs (*Rana grylio*) and these two species are often confused. Both are large, edible frogs and are common within their respective Chenier Plain habitats, though pronounced habitat differences should be evident when studies become available. Differences in the two species are discussed by Stejneger (1901), Wright and Wright (1949), Dundee (1974), and Keiser (1976a).

5.5 FINFISHES

5.5.1 SPOTTED GAR (*Lepisosteus oculatus*) and BOWFIN (*Amia calva*)

Spotted gar and bowfin are predatory freshwater species that have little sport or commercial value, despite their availability to sport and commercial gear. Individuals exceeding 1.8 kg (5 lb) in weight are common. Fishery management has been directed toward destroying these species because of their reputation for competing with sport fish for space and food and because of their predatory habits.

These two freshwater fishes are relatively common in the coastal wetlands and freshwater tributaries of much of the Gulf of Mexico. In southern Louisiana, the gar and bowfin are found largely in rivers, bayous, small lakes, canals, estuaries, and impoundments. They usually avoid fast-flowing waters. Because of their air-breathing capabilities, both species may survive in oxygen-depleted waters for relatively long periods of time, but in severely depleted waters high mortality may occur (Bryan et al. 1976).

Spotted gar are listed as common and bowfin as rare in low-salinity bayous and marshes of western Chenier Plain (Parker 1965). Of the two species, the spotted gar has a greater tendency to inhabit brackish waters (5‰) in the Chenier Plain (Kelly 1965, Parker 1965, Norden 1966, Herke 1971, Hoese 1976, Perry 1976).

In the more eastern areas of the Chenier Plain, near Lacassine and Sabine National Wildlife refuges, both species are abundant and comprise a significant part of the standing-crop biomass of fishes (Turner 1966). Trawling studies in Grand and White lakes and nearby coastal bays indicated that both species were rare at the time, while studies in adjacent brackish marshes showed that spotted gar are often very abundant (Gunter and Shell 1958, Norden 1966, Herke 1971, Morton 1973, Perry 1976). Fish populations studies in the brackish waters of Rockefeller Wildlife Refuge revealed a standing crop of 14.2 kg/ha (12.6 lb/a) for spotted gar and less than 1 kg/ha (0.89 lb/a) for bowfin (Perry 1976). In impounded waters of the Texas Chenier Plain, standing-crop estimates of both species were much higher; 180 kg/ha (161 lb/a) for spotted gar and 160 kg/ha (143 lb/a) for bowfin (Crandall et al. 1976).

Studies of the food habits of the fishes of the Chenier Plain and adjacent coastal areas indicate that spotted gar and bowfin are highly predacious. Food of the very young consists almost entirely of small crustaceans and larval insects. Young bowfin, measuring 3.5 to 5.3 cm (1.4 to 2.1 in) in total length, fed predominantly on cladocerans, amphipods and copepods (50% of total volume) and to a lesser extent on isopods, odonate naiads and adults, and diptera larvae at Lacassine National Wildlife Refuge (Stacey et al. 1970). Similar results were reported from outside Louisiana (Schneberger 1937, Pflieger 1975). No references on food habits of young spotted gar in the Chenier Plain are available, but Pflieger (1975) reported that young spotted gar in Missouri ate foods similar to those eaten by young bowfin. As they grew older, both species fed heavily on fishes and macrocrustaceans.

Although the major diet of adult bowfin from impounded waters of the Chenier Plain is fish, grass shrimp (*Palaemonetes* sp.) and crayfish (*Procambarus* sp.) are commonly eaten (Stacey et al. 1970). Bowfin from the Atchafalaya Basin fed heavily on crayfish throughout the year (primarily *Procambarus clarkii*) and to a lesser extent on fishes (Bryan et al. 1975). Adult spotted gar are also reported to feed mostly on fishes and macrocrustaceans. In nearby Atchafalaya Bay, spotted gar fed heavily on Gulf menhaden (Hoese 1976), whereas in Lake Ponchartrain, blue crab, sunfishes, and shad were consumed (Lambou 1952, Darnell 1958). In the Atchafalaya Basin, fishes made up the majority of the spotted gar's diet, but a significant amount (33% of food items) of crayfish was also eaten (Bryan et al. 1975).

Information is scarce about the spawning habits of spotted gar and bowfin in coastal waters, but in the Atchafalaya River Basin the major spawning season apparently is from March to May. Bowfin may spawn earlier in the year than most Basin fishes. Ripe males and females were observed as early as January when water temperatures were as low as 9° C.

Ripe female spotted gar have been observed in the Basin as early as March and as late as October. Suttkus (1963) reported that spotted gar spawned during April, May, and June in Lake Ponchartrain. Both species spawned primarily in the quiet, sluggish waters of interior bayous and swamps.

Bowfin are nest-builders, and the males guard the nest through the hatching period (Pflieger 1975). Spotted gar apparently exhibit no parental care. Eggs of both species are adhesive and adhere to any substratum (Suttkus 1963, Pflieger 1975). Young bowfin, measuring less than 10 cm (4 in) total length were observed in schools in the Lacassine National Wildlife Refuge in early April. Young bowfin take up a more or less solitary existence after they exceed 10 cm (4 in) in length. In Louisiana, young gar have been collected from the Atchafalaya River and lower Mississippi River drainages from April through June. Young gar appear to be solitary individuals and show little inclination to school. Neither species exhibits much daily or seasonal movement.

Salinity, turbidity, and current appear to be the most significant factors affecting distribution of bowfin and spotted gar. Although spotted gar occur frequently in large numbers in brackish waters there is no evidence that the species spawn there. Bowfin show a strong tendency to avoid salinities above 5‰ and neither it nor spotted gar frequent saltwater habitats.

Turbid river channels, large lakes, and coastal bays are apparently avoided by both species, but it is unclear whether current velocity, turbidity, or the lack of cover is responsible.

5.5.2 BLUE CATFISH (*Ictalurus furcatus*) and CHANNEL CATFISH (*I. punctatus*)

The blue and channel catfishes are valuable sport and commercial species that sometimes exceed 20 lbs (9.1 kg) in weight. Channel catfish are extensively cultured in ponds for U.S. markets.

Blue catfish and channel catfish are native primarily to the Mississippi River Basin and nearby coastal waters and inhabit a wide variety of habitats ranging from small ponds (when stocked) and clear flowing streams, to large reservoirs and rivers. In Louisiana, channel catfish tend to favor small to moderate-sized bayous, canals, lakes, and rivers, whereas blue catfish occur more frequently in large turbid riverine areas and coastal bayous, lakes, and bays (Lantz 1970, Davis et al. 1970, Juneau 1975, Hoese 1976, Tarver and Savoie 1976). Both species are most abundant in large bodies of water such as the Mississippi and Red rivers, and the Atchafalaya River Basin, and in interconnecting coastal lakes and bays.

In the Chenier Plain area, blue catfish are more abundant than channel catfish in brackish waters (5‰) and less abundant in fresh waters (Darnell 1958, Kelly 1965, Norden 1966, Fontenot and Rogillo 1970, Herke 1971, Adkins and Bowman 1976).

In studies of relative abundance of fishes in the Chenier Plain area, channel catfish were more abundant than blue catfish in only two studies (Lantz 1970, Crandall et al. 1976); blue catfish predominated in all others (Gunter and Shell 1958, Norden 1966, Morton 1973, Perry 1967, 1976). Perry (1967) found twice as many blue catfish as channel catfish in waters surrounding Rockefeller Wildlife Refuge. Standing crop estimates were 10.2 kg/ha (9.1 lb/a) for blue catfish and 2.5 kg/ha (2.2 lb/a) for channel catfish (salinities not given). The density of Texas Chenier Plain populations of both species is apparently considerably smaller than those in Louisiana (Reid 1956, Parker 1965, Crandall et al. 1976, Texas Parks and Wildlife Department, unpublished reports).

Both blue and channel catfishes are omnivorous feeders throughout most of their lives. Young fish feed on a diversity of items such as small crustaceans and insects, living plant material, and organic detritus. At Rockefeller Wildlife Refuge, Perry (1969) found amphipods, diptera, filamentous algae, vascular plants, and small fishes as major foods of young channel and blue catfishes measuring 9.5 to 20 cm (3.8 to 8 in) total length. Darnell (1958) concluded that, in nearby Lake Ponchartrain, blue catfish up to 10 cm (4 in) total length fed mostly on zooplankton (calanoid copepods, mysid shrimps, isopods and amphipods), while older juveniles measuring up to 24 cm (9.6 in) total length fed more heavily on small benthic organisms including surface and burrowing forms (amphipods, clams, snails, annelids, isopod and aquatic beetles). In the fresher waters of the Atchafalaya Basin, amphipods, midge larvae and copepods were the most common food items of young channel catfish measuring from 3 to 16 cm (1.2 to 6.4 in) total length (Levine 1977).

As blue and channel catfishes mature, larger and more motile prey items (fish and macrocrustaceans) are utilized, but the basic omnivorous habits of the two species are maintained. Adults measuring over 20 cm (8 in) feed mostly on macrocrustaceans, fishes, vascular plants, and filamentous algae in brackish waters of Rockefeller Wildlife Refuge (Perry 1969). Principal fishes and macrocrustaceans consumed were bay anchovy, sailfin molly, striped mullet, Gulf menhaden, penaeid shrimps, and blue crab. Studies conducted in Lake Pontchartrain also indicated a greater consumption of fishes and macrocrustaceans by large-sized catfish (Darnell 1958).

In the Atchafalaya Basin, adult blue catfish consumed crayfish, fishes, and vegetable matter (Bryan et al. 1975). Lambou (1961) reported blue crab as the principal food item of adult blue catfish in the Bonnet Carre Spillway near Lake Pontchartrain. Adult channel catfish measuring 15 to 30 cm (6 to 12 in) fed on benthic crustaceans, aquatic insects and clams in nearby Lac Des Allemands (Lantz 1970). The increased utilization of larger motile animals does not appear to seriously diminish the importance of other items in the diet of adults of either species. Over 50% of volume of the food items of Lake Pontchartrain catfishes consisted of isopods, amphipods, mollusks, and vegetation (Darnell 1958). Hoese (1976) in addition, reported that mollusks (*Rangia* sp., *Congeria* sp., and *Corbicula* sp.) were the most common food items recovered from 203 adult blue catfish taken from Atchafalaya and Vermilion bays.

Literature from outside Louisiana largely substantiates the omnivorous feeding habits of blue and channel catfishes (Miller 1966, Pflieger 1975). There is little evidence that either species is a selective feeder although they will gather in large numbers at times to feed on certain foods.

Little information is available on spawning or the early life history of blue or channel catfishes in the Chenier Plain or adjacent coastal waters. The exception is the Atchafalaya Basin, where Bryan et al. (1975) reported that spawning begins in early spring and reaches a peak in June and July. A late spring to early summer spawning period is also characteristic of channel catfish in nearby Lac Des Allemands (Lantz 1970). Similar spawning periods are reported for both species from more northern latitudes (Harlan and Speaker 1956, Cross 1967, Pflieger 1975).

Under natural conditions, spawning usually takes place in secluded, semi-darkened areas near vegetation, under roots, logs or other debris, or in holes or any bottom depression. Under managed situations both species will spawn in man-made shelters (milk cans, wooden boxes, etc.) or on the open bottom in muddy ponds (Miller 1966). Water temperatures at the time of spawning range from 15° C to 30° C (59° F to 86° F), with the higher temperatures generally being more desirable. Female channel catfish normally spawn only once a year, while males may spawn several times in a season (Clemens and Sneed 1957).

A well-defined nesting procedure is typically exhibited by both species (Harlan and Speaker 1956, Miller 1966, Cross 1967, Pflieger 1975). Before spawning, males select and clean out a favorable nest site. Females are then accepted and the externally fertilized eggs are deposited in the bottom of the nest in a large gelatinous mass. Males remain on the nest to protect the eggs from predators and to keep them aerated. Eggs hatch in 5 to 10 days, depending on water temperature, and males guard the fry for a week or so after hatching. Young remain near the nest until their yolk sacs are absorbed, after which they disperse in schools along shallow shorelines.

Survival of the young has been noted to be greater in turbid than in clear waters (Cross 1967, Lantz 1970, Pflieger 1975), but it is not certain whether turbid areas are preferred spawning sites. Large schools of young-of-the-year blue and channel catfishes occur along shorelines of the Atchafalaya Basin each fall. It is probable that these habitats serve as nurseries for both species (Bryan et al. 1975). Exact Basin spawning sites are unknown but are believed to be concentrated in rivers, channels, and adjoining lakes. Spawning of channel catfish has been reported to occur in cans or barrels placed in the open turbid waters of Lac Des Allemands (Schafer et al. 1966).

Although blue and channel catfishes thrive in a wide variety of riverine habitats and coastal bays, their distribution in Louisiana often is governed by changing oxygen, temperature, and salinity patterns (Perry 1967, Lantz 1970, Bryan et al. 1976).

In coastal waters of the Chenier Plain, salinity is the major controlling factor. Natural spawning of channel catfish has not been reported in salinities exceeding 2‰ (Perry 1973), and blue catfish do best in salinities less than 5‰ (Norden 1966, Morton 1973, Adkins and Bowman 1976, Hoese 1976, Tarver and Savoie 1976). Intrusion of salt water or blockage of interconnecting coastal waters could be detrimental to both species.

5.5.3 GIZZARD SHAD (*Dorosoma cepedianum*), THREADFIN SHAD (*Dorsoma pentense*), and STRIPED MULLET (*Mugil cephalus*)

Although these three species have little or no sport or commercial value, they are valuable forage for predatory fishes, birds, and other animals. Threadfin shad rarely exceed 20 cm (8 in) in length. Gizzard shad and striped mullet do not usually exceed 30.5 cm (12 in). In most of Louisiana these species are characteristically euryhaline. They are easily caught and often used for bait in crab and crayfish traps.

Gizzard and threadfin shad are widely distributed throughout much of the Mississippi River system and in coastal tributaries, lakes, and estuaries. Shad have strong schooling tendencies and migrate into a wide range of habitats for spawning or feeding.

In the Chenier Plain area, the two shad species are most abundant in freshwater but are also common in estuaries and bayous with salinities of less than 6‰. The striped mullet tends to favor more saline coastal waters, but may sometimes be abundant for relatively long periods of time in freshwater (Reid 1956, Herke 1966, Lantz 1970, Crandall et al. 1976, Perry 1976).

Available data suggest that mullet are more abundant than shad in Chenier Plain coastal waters. Standing crops in the Rockefeller Wildlife Refuge were 44.4 kg/ha (39.6 lb/a) for striped mullet, 21.4 kg/ha (19.1 lb/a) for gizzard shad, and 12.9 kg/ha (11.5 lb/a) for threadfin shad (Perry 1976). Similar results were obtained for the low-salinity marsh canals near Terrebone Bay, Louisiana, where striped mullet was the most abundant and gizzard shad the second most abundant species (Adkins and Bowman 1976). However, in the freshwater of the Atchafalaya River, standing crops of 130 kg/ha (116 lb/a) and 47 kg/ha (42 lb/a) were recorded for gizzard shad and striped mullet, respectively.

These three species are most active in the daytime when they do most of their migrating, feeding, and spawning; otherwise, their daily movements have no particular pattern. Gizzard shad form large schools during the spring spawning period in the Atchafalaya and lower Mississippi basins. Both shad species tend to migrate long distances and occupy diverse habitats. Striped mullet migrate seaward to spawn in the spring, but the young migrate shoreward to use coastal wetlands as nursery grounds.

Gizzard shad, threadfin shad, and the striped mullet strain tiny plant particles from the water, although zooplankton are sometimes consumed in large quantities by juvenile shad. Adults consume primarily algae, vascular plants, planktonic crustaceans, and organic detritus (Reid 1955, Darnell 1958, Miller 1960, Burns 1966, Pflieger 1975). Young shad feed more on cladocerans, protozoans, ostracods, and insect larvae and pupae.

Adult gizzard shad and striped mullet often feed on the top layer of bottom ooze, as indicated by the large amounts of organic detritus, algae, and mud and silt in their digestive tracts (Darnell 1958, Dalquest and Peters 1966). Threadfin shad are either pelagic or limnetic feeders (Baker and Schmitz 1971).

Gizzard and threadfin shad spawn primarily from mid-March through June in a variety of habitats from lentic waters of sloughs, ponds, lakes, and bayous to the more lotic waters of large rivers. During the spring in the Atchafalaya and lower Mississippi rivers, ripe gizzard shad migrate upstream in large schools to spawn. Both gizzard shad and threadfin shad typically spawn in large schools near the surface. Eggs are adhesive and demersal and either sink to the bottom or float in the current until they attach (Miller 1960, Burns 1966). Beginning in late March, the larvae occur in large schools in the Mississippi and Atchafalaya drainages and remain abundant through June. Developing juveniles are most abundant after July. Neither species is known to spawn in waters of greater than 5‰ salinity.

Striped mullet spawn offshore in the Gulf of Mexico, principally from October through February (Arnold and Thompson 1958, Hoese 1965). Complete larval development apparently occurs offshore, as only juveniles are taken in tidal passes and inshore (Perret et al. 1971, Sabins and Truesdale 1974). Young-of the-year begin to invade coastal waters as early as December and by mid-summer juveniles are found throughout coastal habitats. Like many other species spawned in Gulf waters, striped mullet apparently utilize inshore areas as nursery grounds, and make extensive use of coastal marshes.

Except for introductory plantings of threadfin shad (as forage for sport fish) in reservoirs as far north as Kentucky, there have been few, if any, reported historical changes in the abundance or distribution of the three species. This stability in numbers and distribution is due to the capability of these fishes to thrive in a wide diversity of habitats, especially in southern waters.

Since each of the three species tends to move about in loose aggregations or in large schools for feeding and migration, they require rather large water systems for their survival. In the Chenier Plain, such a water system would consist of a number of interconnected bayous, canals, estuaries, and tributary rivers. Since these fishes are important forage species, excessive closure or interruption of coastal waterway systems could reduce their populations and thus alter coastal foodchains.

Since gizzard shad and threadfin shad spawn in waters with a salinity of about 0.5‰, saltwater intrusions could affect their distribution and abundance. Threadfin shad are the most sensitive of the three species to low water temperatures. High mortality may occur when temperatures drop to 8° C or lower (Burns 1966, Pflieger 1975). Die-offs of all three species have been known to occur in the Atchafalya Basin because of oxygen deficiency (Bryan et al. 1976).

5.5.4 LARGEMOUTH BASS (*Micropterus salmoides*) and BLACK CRAPPIE (*Pomoxis nigromaculatus*)

Largemouth bass and black crappie are valuable freshwater sport fishes throughout much of the Mississippi River drainage and in some of the coastal waters of the Gulf of Mexico. Largemouth bass are extensively cultivated as a pond fish.

Largemouth bass and black crappie thrive best in lentic waters of natural lakes, bayous, open river floodplains, ponds, and large impoundments. In most areas they show a preference for habitats of low turbidity that support a moderate growth of aquatic vegetation (Emig 1966, Goodson 1966). In Louisiana, however, both species may be found in some turbid rivers, lakes, ponds, and bayous.

Freshwater areas of the Chenier Plain support sizeable populations of largemouth bass and black crappie. Both species are locally abundant in marsh ponds, bayous, and canals, where salinities average less than 0.5‰ (Carver 1965, Turnver 1966, Lantz 1970, Manuel 1971, Crandell et al. 1976). Largemouth bass are more salinity tolerant and survive better in shallow water (less than 1 meter) than black crappie (Morton 1973, Adkins and Bowman 1976, Tarver and Savoie 1976). The most favorable coastal habitats appear to be shallow, interconnected systems with gradually sloped shorelines and moderate growths of emergent and/or submergent vegetation.

Standing crops of 39.5 kg/ha and 36.1 kg/ha (35.3 lb/a and 32.2 lb/a) are estimated for black crappie and largemouth bass respectively in the lower Atchafalaya Basin (Sabins 1977). These values compare favorably with standing crops recorded for the two species in large impoundments in Texas (Turner 1966). Estimated standing crops of less than 1 kg/ha were recorded for both species in brackish waters of the Rockefeller Refuge (Adkins and Bowman 1976).

Both largemouth bass and black crappie are characteristically predatory feeders. Month-old fry of the two species feed on small pelagic zooplankters, primarily copepods and cladocerans (Emig 1966, Goodson 1966). Older juveniles take larger pelagic prey such as larval or adult diptera (chironomids), ephemeropterans, amphipods, and other decapods. By the time they reach 10 cm (4 in) in length, largemouth bass and black crappie begin to feed on a variety of prey fishes (Emig 1966, Goodson 1966, Levine 1977).

Juvenile largemouth bass (21 to 40 mm, or 0.8 to 1.6 in, in total length) in the Atchafalaya Basin fed upon corixids, copepods, dipterans, mysid shrimp, and cladocerans (Levine 1977). Information on food habits of juvenile black crappie in Louisiana is lacking.

Foods consumed by adult largemouth bass are less varied than those consumed by young bass. Most studies indicate that fishes and macrocrustaceans are the principal foods, but aquatic insects, reptiles, amphibians, and even small mammals are occasionally eaten (Emig 1966, Heidinger 1975). Macrocrustaceans (crayfish, blue crab, river and grass shrimp) are commonly found in stomachs of Louisiana largemouths (Darnell 1958, Lambou 1961, Bryan et al. 1975). Largemouth bass found in the Atchafalaya Basin exhibit seasonal feeding cycles; crayfish are primarily consumed during high water (December to May), whereas fishes constitute the bulk of the diet during low-water periods.

Adult black crappie feed on a variety of items, including insects, crustaceans, fishes and plants. In a South Carolina reservoir, insects were the most important food item consumed (Stevens 1959), while black crappie from the Atchafalaya Basin fed throughout the year on insects, plants, fishes and crayfish (Bryan et al. 1975). Studies about the habits of black crappie or largemouth bass in the Chenier Plain are lacking.

Largemouth bass and black crappie spawn in the spring when water temperatures approach 15° C (Goodson 1966, Heidinger 1975). In the Atchafalaya Basin, spawning occurs primarily in March through May at temperatures ranging from 19° C to 14°C (Bryan et al. 1975). Spawning is reported to occur over a variety of substrates from gravel and sand to roots and aquatic vegetation. Silt bottoms are apparently avoided (Emig 1966, Goodson 1966). Relatively hard, muddy bottom substrates of interior bayous, lakes, and swampy floodplains are probably the principal spawning grounds in the Atchafalaya Basin. Typically, spawning occurs in waters ranging in depth from 15 cm (6 in) to 1.5 m (5 ft) (Bryan et al. 1975, Heidinger 1975).

Both species spawn in nests prepared by the male. Nests of the largemouth bass are usually located in protected areas and are generally spaced a minimum of 2 m (6.6 ft) apart (Heidinger 1975).

Although largemouth bass and black crappie are relatively tolerant of a wide range of environmental variables (Emig 1966, Goodson 1966), these species in Louisiana coastal waters may be most adversely affected by saltwater instrusion and high turbidity. Coastal oil and gas development activities have been reported to cause fish kills (Manuel 1971).

5.5.5 ATLANTIC CROAKER (*Micropogon undulatus*) and SPOT (*Leiostomus xanthurus*)

Atlantic croaker and spot are estuarine-dependent species. Planktonic larvae migrate from spawning areas in the Gulf of Mexico to nursery grounds in coastal estuaries from November to April (Herke 1971, Parker 1971, Arnoldi et al. 1973, Sabins 1973, Tarbox 1974). Here they develop into juveniles. Later, maturing juveniles leave the nursery grounds and migrate to the lower reaches of the estuaries. Most return to the Gulf in the fall.

Spot and Atlantic croaker migrate each fall from the lower estuaries and Gulf shorewaters to near the edge of the continental shelf. After spawning, most adults return to the nearshore Gulf or lower estuaries.

Atlantic croaker and spot are common in the nearshore Gulf of Mexico and adjacent coastal bays, lakes, and estuaries (Moore et al. 1970, Parker 1971, Perret et al. 1971). Although adults of both species are sometimes found in the upper reaches of estuaries, most prefer the higher salinity of the nearshore Gulf or adjacent estuarine areas (Gunter 1945, White and Chittenden 1976). During the fall spawning season, the adult population concentrates closer to the edge of the continental shelf.

Young-of-the-year spot and Atlantic croaker are found in nursery areas from late winter to early summer. Postlarval and early juvenile croakers usually concentrate near sources of fresh or brackish waters that flow through marshes and deltas or over tidal flats before entering bays. Studies within marshes (Herke 1971, Conner and Truesdale 1972, Arnoldi et al. 1973) indicate that the deeper low-salinity areas are the primary nursery habitat for postlarval and early juvenile croakers. In contrast, postlarval and juvenile spot are usually found in brackish to saline marsh areas (Parker 1971, Sabins 1973). Adults of both species tend to concentrate in deeper, firm-bottomed inland open water areas (especially over and near reefs), while young fishes tend to occupy shallow, soft-bottomed areas (Reid 1955, White and Chittenden 1976).

Greatest concentrations of Atlantic croaker in inland open water areas along the Louisiana coast are in the Chenier Plain (Perret et al. 1971). In the nearshore Gulf, croakers contribute more than half of the average catch per effort (by weight) in the industrial bottomfish trawl fishery (Moore et al. 1970). Spot, on the average, account for only 11% of the demersal catch in the North Central Gulf of Mexico (Roithmayer 1965).

Although no analyses of croaker or spot food habits have been conducted in the Louisiana Chenier Plain, investigations in northern Gulf estuaries indicate that they are roughly similar throughout the area (Pearson 1929, Gunter 1945, Reid 1955, Reid et al. 1956, Darnell 1958, Parker 1971, Day et al. 1973). In Barataria Bay, croakers are more onmivorous, feeding on micro- and macrobenthic animals, small fishes, and organic detritus (Day et al. 1973). Darnell (1958) reported on the feeding habits of Atlantic croaker in Lake Pontchartrain. Very young fish (less than 25 mm or 1 in) subsist largely on zooplankton (epecially the copepod *Acartia tonsa*). Croakers (35 to 50 mm or 1 to 2 in) fed primarily on small benthic organisms. Larger juveniles and young adults (50 to 200 mm or 2 to 8 in) fed primarily on organic detritus. Adult croakers fed mainly on small fishes, shrimp, crabs, and mollusks.

Darnell (1958) reported that spot undergo two feeding stages in the course of individual development. Very young spot graze mainly on plankton, but they also eat microcrustaceans. Adults are chiefly bottom feeders. Major crustaceans consumed by spot include harpacticoid copepods, ostracods, isopods, and amphipods. As growth continues, bottom-burrowing organisms such as the brackish-water clam, *Rangia cuneata*, and organic detritus constitute a large portion of the diet.

Feeding activity patterns of croaker and spot differ (Darnell 1958). Young croakers (less than 75 mm or 3 in) feed at low intensity in the early morning, gradually increase to a peak in early afternoon, and taper off toward evening. Intermediate-sized fish (75 to 150 mm or 3 to 6 in) feed moderately throughout the day with a slight increase in feeding intensity toward evening. Adult croakers feed moderately throughout the day, but show a greater feeding intensity during the mid-morning and early evening hours. Spot feed mostly at twilight and during the hours of darkness.

Various sizes of Atlantic croaker prefer different temperatures and salinities. Parker (1971) collected croakers 'in abundance' at salinities from 0.2‰ to 35.1‰ and concluded that salinity per se had little effect on their distribution. His data, however, as well as those reviewed by Copeland and Bechtel (1971) and Conner and Truesdale (1972), indicate that young Atlantic croaker prefer slightly or mo'erately brackish waters. Croakers have been encountered at temperatures of 0.4° to 38° C (32° to 100° F). The young appear to be well adapted to 6° to 20° C (45° to 68° F), but older fish are noticeably absent at temperatures below 10° C or 50° F (Parker 1971, Gallaway and Strawn 1974).

Spot also exhibit a wide salinity and temperature tolerance. Adults appear to avoid temperatures below 10° C (Parker 1971, Perret et al. 1971). In contrast to Atlantic croakers, very young spot appear to prefer brackish to high-salinity areas as nurseries.

5.5.6 SPOTTED SEATROUT (*Cynoscion nebulosus*) and RED DRUM (*Sciaenous ocellata*)

Spotted seatrout and red drum are highly valued estuarine-dependent sport and food fishes that inhabit coastal waters of the Gulf, estuaries and marshes. Both have a strong tendency to school.

Spotted seatrout do not have strong migratory habitats. Since they tend to be resident in a given coastal area, catastrophic depletion of a local population could have serious long-term effects (Tabb 1966). Despite their non-migratory tendencies, spotted seatrout are frequently stimulated to move from one area to another because of particular ecological conditions. For example, this species tends to congregate along beaches for short periods when prolonged southeastern winds result in lower turbidities.

Most young red drum migrate seasonally from their spawning grounds near tidal passes to nearby inshore nursery grounds. Adults and older juveniles, called 'rat reds' by fishermen, migrate to low-salinity marsh lakes, bayous and canals during cold months. They move into inundated grassy areas with high tides, and retreat from them with outgoing tides. Large adults ('bull reds') migrate to the outer reaches of estuaries and shallow waters of the Gulf to spawn (Pearson 1929, Simmons and Breuer 1962).

Although spotted seatrout spend most of their life in estuaries (Tabb 1966), adults and larger juveniles commonly inhabit nearshore Gulf waters. Red drum are also sometimes widespread in the nearshore Gulf and adjacent estuaries.

The ecology of spotted seatrout is based largely on the studies of Tabb (1966) in the more saline and less turbid estuaries of western Florida and southern Texas. He noted that one of the principal deficiencies in knowledge about the species is the lack of data on regional differences in habitats. For example, most of the classical studies indicate a strong dependence upon shallow 'grass flats' as nursery habitat for postlarval and early juvenile spotted seatrout. The destruction of this nursery habitat has been blamed for local declines in populations (Tabb 1966). In the Chenier Plain, such grass flats are rare, yet spotted seatrout populations here are not as small as might be expected. A study of the distribution of young spotted seatrout in Barataria Bay indicates that the fish occupy a wide variety of shallow littoral areas and are not concentrated in grass flats. However, in a study of Caminada Pass (one of the tidal inlets of Barataria Bay), postlarval spotted seatrout were frequently encountered in masses of floating 'coffee grounds' detritus. Such material may offer protective cover for developing young (Sabins and Truesdale 1974). Also, an abrupt decline in abundance of young spotted seatrout in a Texas marsh seemed to be related to the disappearance of beds of widgeongrass (*Ruppia maritima*).

Red drum sometimes occur in brackish waters, but they prefer moderate to high salinity. Tagging studies in Texas (Simmons and Breuer 1962) suggest that some 'schools' of red drum are almost permanent residents in the Gulf proper, while others rarely leave the bays or estuaries. Young red drum tend to seek out sheltered coves and lagoons, where they occupy shallow waters along marsh edges (Sabins 1973, Tarbox 1974, Bass and Avault 1975). Older juveniles and some adults tend to prefer marsh lakes, bayous, and canals during cold months. Large adults seem to concentrate near shell reefs, wrecks, and oil platforms during warm months.

Little is known about the densities or relative abundance of spotted seatrout or red drum in the Chenier Plain or adjacent areas. Population estimates reported by Herke (1966), Perret et al. (1971) and Perry (1976) are too subject to sampling error to be reliable.

Spotted seatrout and red drum are typically recognized as 'top carnivores' (Darnell 1958, Day et al. 1973, Wagner 1973). Although no detailed analyses of the diet or feeding behavior of either species have been reported for the Chenier Plain, food studies in other areas suggest that they prey on a wide range of fish and crustaceans (Miles 1949, Simmons and Breuer 1962, Tabb 1966, Boothby and Avault 1971, Odum 1971). Many food 'preferences' attributed to spotted seatrout probably are only indications of changes in the availability of various prey among seasons or locations (Tabb 1966). Indeed, Lorio and Schafer (1966) found food preferences of spotted seatrout to be highly correlated with prey availability in a southeastern Louisiana marsh system.

Because spotted seatrout less than 40 mm (1.6 in) were found to subsist largely on copepods and other zooplankters (Moody 1950), they are perhaps more appropriately classed as 'primary carnivores' as defined by Day et al. (1973). The relative significance of palaemonid shrimp, silversides (*Menidia beryllina*), and sheepshead minnows (*Cyprinodon variegatus*) in diets of juvenile spotted seatrout suggests that they feed mainly along littoral zones.

Although red drum generally feed on the most available animals of ingestible size, three feeding phases have been recognized. Post-larvae and small juveniles (less than 15 mm or 0.6 in) seem to feed primarily on zooplankton; intermediate-sized juveniles (15 to 75 mm or 0.6 to 3 in) eat mainly microbenthic animals and small fishes; large juveniles and adults prey on crabs, shrimp, and fishes (Boothby and Avault 1971, Bass and Avault 1975). Red drum appear to feed mainly on crabs in inland open water habitats, and fishes and shrimps in Gulf waters (Darnell 1958, Simmons and Breuer 1962).

Spotted seatrout and red drum spawn at different times of the year, but in similar habitats. Spotted seatrout generally spawn in estuaries from April to September near tidal passes, although precise sites and habitat conditions are not known for southwestern Louisiana estuaries (Pearson 1929, Hoese 1965, Sabins 1973, Tarbox 1974). Some offshore spawning has been reported by Hildebrand and Cable (1934). Recently hatched larvae and early juveniles are typically found near marsh shorelines of lower estuaries from May through August. The rhombic markings of young spotted seatrout enable them to blend well with the mottled patterns created by bottom vegetation and debris (Tabb 1966). By fall and early winter, juveniles have migrated to the upper reaches of estuaries, where they often concentrate in bayous, canals, and along lake shorelines.

Red drum are believed to spawn in or near the mouths of tidal passes from late August through November (Gunter 1945, Simmons and Breuer 1962, Sabins 1973). The young tend to seek sheltered coves and bayous where they occupy the shallow waters in and along marsh edges (Tarbox 1974, Bass and Avault 1975). Like spotted seatrout, older juvenile red drum tend to concentrate in marsh lakes, bayous, and canals during cold months.

Spotted seatrout adults and large juveniles have been repeatedly observed to move to deeper and more saline areas when salinities drop below 5‰ and temperatures drop below 10° C (50° F) (Gunter 1945, Tabb 1966). Overall, the species is known to occur from freshwater to hypersaline conditions, but tends to prefer waters with salinities of 5‰ to 20‰ (Gunter 1945). Normal habitat temperatures range from 8° to 35° C (46° to 95° F).

Although broadly euryhaline, red drum tend to be most frequently encountered (especially older juveniles and adults) at salinities greater than 20‰ (Simmons and Breuer 1962). Temperatures of 3° to 33° C (37° to 90° F) are tolerated, but, like most other local sciaenids, the red drum is susceptible to sudden cold shocks (Gunter 1945, Simmons and Breuer 1962).

5.5.7 SOUTHERN FLOUNDER (*Paralichthys lethostigma*)

The southern flounder, common in Gulf coastal waters, is a valuable sport and food fish. This species is commonly found in habitats occupied by spotted seatrout and redfish.

Adult southern flounder apparently migrate from estuaries to the nearshore Gulf of Mexico each fall to spawn. Larvae, in turn, migrate from the shallow Gulf to marsh nurseries in estuaries. Occurrence of adults far inland into freshwater during some months (Conner and Truesdale 1972, Bryan et al. 1975) suggests that the species moves extensively.

Adults have occurred frequently over soft, muddy bottoms (Hoese and Moore 1977), but large numbers are also known to frequent sandy beach areas (Fox and White 1969, Sabins 1973). The young appear to be distributed from high-salinity waters near tidal passes to low-salinity waters of inland river deltas (Conner and Truesdale 1972, Sabins and Truesdale 1974).

In comparison with other estuarine areas along the Louisiana coast, only moderate commercial catches of southern flounders have been recorded in the Chenier Plain area (Perret et al. 1971). The catch was largest in January through April. Perry (1976) found southern flounder to rank fifth in standing crop estimates (19.5 kg/ha or 17.1 lb/a) of fishes in the marshes of Rockefeller Wildlife Refuge.

Although Day et al. (1973) refer to flounders as 'mid carnivores' and 'top carnivores,' the latter is more appropriate for all but the smallest size classes (Gunter 1945, Knapp 1950, Reid et al. 1956, Darnell 1958, Fox and White 1969). Adult flounders are highly predatious and are reported to consume 'large quantities' of fishes, crabs, and shrimps (Knapp 1950, Darnell 1958, Fox and White 1969). Food habits of young flounders have not been studied. Darnell (1958) suggested that they feed mainly on small benthic invertebrates.

The spawning habits of southern flounder are poorly known. Each fall, adults concentrate in the lower reaches of estuaries. This phenomenon is generally believed to be in preparation for Gulfward spawning migrations. Spawning apparently takes place in the nearshore Gulf of Mexico from late autumn through early spring, but mostly in November through February (Sabins 1973). Recruitment of young into inland open water areas occurs mainly from December through April (Sabins 1973, Tarbox 1974). Marshes of either high or low salinity may serve as nurseries.

Factors limiting the distribution or occurrence of southern flounder in northern Gulf waters have received little attention. In general, adults and large juveniles occur from freshwater to maximum Gulf salinities, and in inland areas, appear to be rather ubiquitous with respect to salinity (Perret et al. 1971). They have also been collected at temperatures from 5° to 35° C (41° to 95° F). Spawning, however, is apparently restricted to the colder months and high-salinity waters of the nearshore Gulf.

5.5.8 GULF MENHADEN (*Brevoortia patronus*)

The Gulf menhaden or pogy is migratory throughout much of its life cycle. Daily movements of adults occur typically in the form of large surface-feeding schools which become the focus of a large summer fishery (Chapoton 1970, 1972, 1973). Fishing season occurs from April to October.

The Gulf menhaden is a schooling species throughout its life. As adults they inhabit the open Gulf of Mexico. They concentrate nearshore (less than 10 fm) through spring and summer and move farther offshore during fall and winter (Roithmayer and Waller 1963, Fore 1970, Chapoton 1973). Young-of-the-year, on the other hand, are principally inhabitants of estuarine waters, where they remain from 6 to 12 months after hatching (Combs 1969). Interior marsh lakes and bayous are judged to be the primary nursery habitats of young Gulf menhaden (Conner and Truesdale 1972). These shallow areas are slightly brackish and turbid, and have soft, detritus-rich bottoms. In the Chenier Plain and adjacent areas, young menhaden sometimes inhabit the more inland portions of estuarine systems (Gunter and Shell 1958, Herke 1966, Baldauf et al. 1970, Herke 1971, Arnoldi 1974).

On the basis of limited data reported by the National Marine Fisheries Service menhaden juvenile-monitoring program, it appears that, in some years, at least, Chenier Plain estuaries may produce the highest catch rates of young menhaden in the western Gulf of Mexico. This may be due to the proximity of the Chenier Plain to the major spawning area, just off the Mississippi Delta, and to hydrographic conditions (i.e., the westward-flowing longshore currents). As many as 133,016 juvenile menhaden were caught in a 4-minute surface trawl (0.25-in bar mesh) in Calcasieu Lake marsh bayous in late May (Herke 1966, 1967). Mean catch per trawl sample at several stations was 49,400. Although weirs appeared to affect the distribution of some fish species in the study area, they did not seem to influence menhaden. In a study of fishes at Rockefeller Wildlife Refuge, Perry (1976) reported a standing crop of 64.2 kg/ha (57.2 lb/a).

Studies of food preferences or feeding behavior of Gulf menhaden have not been conducted in the Chenier Plain. In nearby Barataria Bay, however, Day et al. (1973) referred to menhaden simply as 'herbivores,' making no distinctions as to life history stages. Reintjes and Pacheco (1966) stated that food was probably the principal biological factor affecting the well-being of menhaden in estuaries. Larval Gulf menhaden are particulate-feeding carnivores, (chiefly on microcrustaceans) and juveniles are nonselective, filter-feeding omnivores, chiefly on planktonic algae and microcrustaceans (Reintjes and Pacheco 1966). Adults in the Gulf seem to feed on phytoplankton by filtration (Reintjes and June 1961). However, Darnell (1958) concluded that phytoplankton were not the primary food of larger menhaden (83 to 103 mm or 3 to 4 in) in the turbid waters of Lake Pontchartrain. He found that suspended bacteria and material other than living plants (e.g., silt, detritus, benthic microinvertebrates) were the most important dietary components. In addition, the blue-green alga *Anabaena* was an important supplement in the diet of juveniles.

Fore (1970) reported that the principal spawning area for menhaden in Louisiana is in 'offshore areas near the Mississippi River Delta.'

Gulf menhaden enter estuaries as larvae. Immigrations of larvae occur along the Louisiana and upper Texas coasts from November through April (Gunter 1956, Suttkus 1956, Arnold et al. 1960, Fore 1970, Herke 1971, Fore and Baxter 1972, Sabins 1973, Sabins and Truesdale 1974, Tarbox 1974). At the tidal inlets of the Chenier Plain and immediate adjacent areas, peaks of immigration have most frequently occurred in December to March (Herke 1971, Fore and Baxter 1972, Arnoldi 1974).

Larval and postlarval Gulf menhaden move rapidly to the interior portions of the estuaries. As they increase in size, they spread throughout the estuaries, becoming ubiquitous by the time they have attained juvenile size (about 30 mm or 1.2 in standard length) (Suttkus 1956). The young menhaden generally remain in the estuaries for about one year (Combs 1969). Adults move out of the bays and inhabit the nearshore Gulf and adjacent slightly deeper waters throughout the spring and summer. These shallow coastal areas (less than 10 fm) are the focus of the summer fishery, which consists largely of 1- to 2-year-old fish (Reintjes and June 1961, Chapoton 1970).

Gulf menhaden are euryhaline and inhabit fresh to saline waters (salinities as high as 60‰) (Gunter and Christmas 1960). Copeland and Bechtel (1971) suggested that the marked abundance of these species in extreme upper portions of estuaries is related to low salinities and abundant food sources. Temperature tolerance in juvenile Gulf menhaden is also quite broad, especially in low salinities (Copeland and Bechtel 1971). Nevertheless, shock caused by abrupt temperature drops during relatively severe cold weather sometimes induces mass mortalities of juvenile menhaden.

5.6 SHELLFISH

5.6.1 RANGIA CLAM (*Rangia cuneata*)

Rangia is a burrowing clam, but not a very active one. With the exception of short-range burrowing and locomotion by adults, the mass movement of individuals occurs during the free-swimming larval stage (a 7-day period from fertilization to setting). At that time the principal transportation is provided by water currents. Larval stages may occur in all seasons, but are most abundant during the warmer months of the year when water temperatures are above 12° C (57° F) (Hopkins et al. 1973).

Tarver and Dugas (1973) sampled areas of Lake Pontchartrain and Lake Maurepas (outside the study area), and found rangia on sand and silty clay bottoms. Tenore et al. (1968), Gooch (1971), and Cain (1972) found larger rangia inhabiting sandy bottom areas. The several explanations are that large-size particles trapped more food, sand substrata facilitated burrowing, and excretions did not accumulate. Hopkins et al. (1973) reported that along the Texas coast, rangia was often found in muddy substrates, but was also present in combinations of sand, silt, and clay.

Rangia is usually a dominant species in salinities up to 15‰. Tarver and Dugas (1973) found the highest concentration of all sizes of rangia adjacent to either a source of fresh or salt water. In those environments, the clam is subjected to salinity shock, which is an important requirement for reproduction.

Examples of the sensitivity of rangia to environmental change have been reported for the Chenier Plain by several authors. Hopkins et al. (1973) described one example. White Lake, in the southeastern portion of the Mermentau Basin, supported a large rangia population. Studies by Gunter and Shell (1958) showed many living rangia in this region in 1952. By 1971, Hoese (1972) and his helpers could find no live rangia, although Gooch (1971) had found a few clams surviving in 1969. Hoese (1972) attributed the disappearance of the White Lake rangia population to the control structure built in 1951 to prevent saltwater intrusion into the lake. It apparently took 19 years for all rangia to die after the construction of the control structure.

This change could have been avoided by allowing a controlled periodic influx of brackish water. Maintenance of the rangia populations would have required only a pulse of saline water every few years to a level of about 5‰ for less than a month in order to induce reproduction and spawning.

An abundance of shells in Calcasieu Lake indicates the former existence of a substantial population of rangia, but in 1971 and 1972, Hoese (1972) could find no live clams in the lake. Kellog (1905) substantiates that rangia were at one time abundant in upper Calcasieu Lake. Hoese (1972) attributed the apparent extermination of rangia in Calcasieu Lake to the higher salinities (15‰ to 26‰) caused by the saltwater intrusion through the Lake Charles Ship Channel.

Pollution may also limit the abundance and spatial distribution of rangia. Thorson (1957) reported that biological waste buildup prevented larval establishment.

Adult rangia feed on suspended detritus and phytoplankton by a filter-feeding process in which food particles are captured on the gills. Until the swimming larvae reach the setting stage, they feed on flagellated unicellular algae (Hopkins et al. 1973).

The reproductive cycle and stages of rangia are strongly linked to environmental parameters. The clams have mature gonads that produce gametes more than half the year, but they do not spawn continuously. An individual, though gravid with gametes, will seldom release them until shocked by a sudden change in temperature, salinity, or both. Changes, not just a favorable level, are necessary to induce spawning (either up from 0 or down from 15‰). Hopkins et al. (1973) report that a rise from near 0 to 5‰ was the best spawning stimulus, and that a temperature rise from 22° C (72° F) to 34° C (93° F) was also sufficient to induce the release of gametes for external fertilization.

Embryos and larvae survive only in salinities between 2‰ and 15‰. After reaching the setting stage (6 to 7 days after fertilization), the juvenile clams become more tolerant of salinity fluctuations. Rangia is incapable of reproducing or of maintaining permanent populations at salinities higher than about 15‰. The stabilization of salinity at any level will result in the dying out of the population in 15 to 20 years, when old clams reach the limit of their life span.

Optimum temperatures for larvae occur at 24° C (75° F), but fastest growth occurs at higher temperatures (32° C or 90° F). Temperatures of 30° to 35° C (86° to 95° F) are critical; damage occurs above 35° C (95° F) for rangia. Temperature affects respiration most drastically at the extremes of the salinity range (2‰ to 32‰). Lower temperatures usually have no lethal effects on adult rangia, although rates of respiration and growth are reduced.

Predators may also limit the abundance of rangia. Rangia is a major food of lesser scaup, blue crab, and bottom-feeding fishes (croaker, drum, etc.).

5.6.2 AMERICAN OYSTER (*Crassostrea virginica*)

The planktonic eggs and larvae of the American oyster are at the mercy of currents. However the larvae can swim vertically and take advantage of the horizontal movement of salt wedges that allow populations to be transported shoreward or inland. At the end of their larval stage, young oysters (now called spat) attach to a firm substrate where they remain and grow to adults.

Natural oyster reef areas are located where bottoms characterized by firm mud, rock, or shell. Typically, the bays bottoms of south Louisiana are firm around their periphery, increasing in softness toward the center (Van Sickle et al. 1976). Therefore, bay perimeters are usually the best habitat for oysters. Along the Gulf coast, especially in Louisiana, oyster reefs are often associated with raised features of the water bottom.

The formation of a natural oyster reef begins with the attachment of larvae to a piece of shell or to other hard objects. Other larvae will attach to those already set, forming a small cluster of juvenile oysters. There is a high rate of mortality among oysters. Dead shells provide additional surfaces for attachment. Successive sets begin the cycle again, and the reef grows horizontally and vertically (Galtsoff 1964). The annual accretion of oyster shells provide additional stability. Gunter (1976a) found shells at the base of some Galveston reefs to be more than 6,000 years old.

In attempts to reestablish natural oyster reefs or to provide additional material for spat attachment in the vicinity of producing reefs, cultch materials are often deposited. The most common cultch materials are oyster and clam (rangia) shells. Clam shell is more abundant and is preferred by many oystermen because it generally promotes the development of more larger unclustered oysters (Van Sickle 1977).

Salinity levels are crucial to oysters. The productivity of an oyster community is governed not only by average levels of salinity, but also by extreme seasonal fluctuations (Butler 1949). According to Galtsoff (1964), oysters can tolerate a salinity range from 5‰ to 40‰, but optimum salinity for Louisiana oysters is 15‰. In Louisiana and Texas waters, the optimum salinity range for natural oyster growth and survival lies between 5‰ and 20‰ (Hofstetter 1977).

Because free exchange of water is essential for growth and survival of oysters, stagnant water is detrimental to oyster reefs. The spat must set on firm substrate located where bottom currents are strong enough to bring in sufficient food and oxygen and to carry away metabolic waters (Galtsoff 1964).

The velocity of water currents helps determine the amount of sediment deposited on an oyster reef. The more productive oyster reefs are usually located in areas free from siltation. Reefs are often located with the long axis perpendicular to the direction of prevailing water currents. Such reefs are common along the Texas coast (Hedgepeth 1953).

Oyster larvae feed on phytoplankton and detrital particles. Spat are suspension feeders (i.e., they obtain food by pumping large quantities of water across their gills and filtering out suspended particulate matter, even oyster larvae). A single oyster can pump up to 34l/hr (9 gal/hr) of water across its gills (Galtsoff 1964). Although the American oyster is adapated to do well in moderately turbid water, a large increase in turbidity can cause a decline in feeding by impairing the feeding mechanism (Loosanoff and Tommers 1948).

Oysters in Louisiana spawn from spring to late fall. Enormous numbers of eggs and sperm are released into the water column, yet only a small proportion of the eggs are fertilized. About 2 weeks elapse from the time of fertilization until the larvae are fully developed.

Oyster production is a function of available habitats, hydrological processes, and natural and man-caused stresses within each basin. Water salinity is the most important parameter.

In addition to an optimum salinity level, oysters must have suitable substrate for attachment and sufficient water movement both for transporting the planktonic phase and for exchanging food and wastes during the attached phase.

Dredging may severely damage oyster reefs by destroying the reef or by causing increased turbidity in the vicinity of the reef. Sediments impair the oysters' feeding mechanism. Dredging may alter salinity regimes by creating passages for salt water to move closer to or farther from reef areas. In 1940-41, a navigation channel 30 feet (9 m) deep with a bottom width of 250 ft (76 m) was dredged through Calcasieu Lake and Pass to the Gulf of Mexico, resulting in significant salinity increases in the Calcasieu River and Calcasieu River-Mermentau River section of the Gulf

Intracoastal Waterway (U.S. Army Corps of Engineers 1950). It was speculated that the shift in oyster distribution and the drastic reduction in the amount of oysters taken were related to the dredging and channeling activities. The confinement of the Calcasieu River Ship Channel within a constant levee system in 1964 may have altered the current circulation of the lake (White and Perret 1973). Between 1966 and 1974, there were no reported commercial oyster harvests from Calcasieu Lake.

Natural and man-caused alterations in the Chenier Plain drainage basins have profoundly affected oyster distribution and production. Urban and industrial pollution (i.e., the menhaden processing plant in Calcasieu Lake) has contributed to oyster contamination and mortality. Oyster beds in Sabine Lake were closed to fishing due to high coliform bacteria count. Intensive fishing, especially by oyster dredging, has been associated with the depletion of many natural reefs in Texas and Louisiana (Owen 1955, Hofstetter 1977).

5.6.3 RED SWAMP CRAYFISH (*Procambarus clarkii*) and RIVER CRAYFISH (*Procambarus acutus*)

Crayfishes reside in rivers, streams, marshes, swamps, lagoons, roadside ditches, and pits excavated for highway fill. As the names indicate, the red swamp crayfish is found primarily in swamps and marshes, while the river crayfish resides mostly in rivers and streams (Gary 1974).

Both species prefer turbid water (Gary 1975), usually less than 38 cm (15 in) deep. Optimum habitats are permanent bodies of water exposed to full sunlight and usually subject to annual spring flooding (Penn 1956, Comeaux 1975). The habitats usually have mud bottoms with a variety of aquatic vegetation for cover (Penn 1956).

Crayfishes are generally nondiscriminant feeders, eating both living and dead plant and animal tissue. They prefer fresh meat and are not usually attracted to rancid bait. They are not active predators and are unable to catch most mobile animals. They eat worms, insect larvae (LaCaze 1970), a variety of plants (Gary 1974) and, under laboratory conditions, fishes, chicken liver, shrimp meal, and carrots (Amborski et al. 1975). Young crayfish, which are able to forage almost immediately after hatching, may be attracted to decaying plant material colonized by microorganisms (LaCaze 1970).

Mating is thought to occur primarily in open water. The male crayfish deposits the sperm into a receptacle on the female. The female retains the sperm until the eggs are laid several months later (LaCaze 1970). Although mating usually occurs in May and June, breeding may occur throughout the year, depending upon water conditions (Hill and Cancienne 1963, de la Bretonne and Avault 1976). After breeding, the female will "dig in" or burrow. Burrowing occurs while open water is still present and offers protection both from desiccation and from predation. The burrows may range from 61 to 91 cm (24 to 36 in) deep. When the water level is minimal, the female will plug the burrow with mud and remain inside for several months. A male may live in the burrow of a female near the entrance or in holes formed by tree roots (Gary 1974). Although it is believed that mating sometimes occurs within a burrow, most females carry sperm in receptacles to produce young (LaCaze 1970).

Spawning typically occurs in September and October inside a burrow or in an open pond, depending upon the water level. The eggs are laid and simultaneously fertilized. The fertilized eggs adhere to the female's swimming legs by a sticky substance. Red swamp crayfish eggs hatch in 14 to 21 days after laying (de la Bretonne, unpublished), whereas those of the white river crayfish require 3 to 8 additional days. There is no larval stage (LaCaze 1970). The young remain attached to the female for one to three weeks, depending on water characteristics (Comeaux 1972, de la Bretonne, unpublished).

For an abundant crayfish crop, inundation is needed during September and October to force young from the burrows or to allow for hatching in open water (LaCaze 1970, White 1970). Crayfish normally live from 12 to 18 months (Gary 1974).

Several parameters exercise a controlling influeence on crayfish. Although considered a freshwater species, both hatchlings and adults have shown salinity tolerances directly proportional to their size (Loyacano 1967, Avault et al. 1970).

Experiments which were conducted in a marsh over a 2-yr period established that red swamp crayfish prefer salinities from 3‰ to 8‰ (LaCaze 1970). Rapid changes or extremes in salinity, particularly during the egg-laying and hatching period, could result in decreased crayfish production (LaCaze 1970).

According to a pond study by Loyacano (1967), newly hatched young died in 5‰ salinity, intermediates were killed at 30‰, but adults tolerated 30‰ for about a week before significant mortality occurred. Growth may be retarded in areas where salinities are 20‰. Populations in brackish waters were more tolerant of high salinities than freshwater populations (Loyacano 1967).

Water hardness is also limiting. Crayfish require a minimum of 0.05% water hardness, but no more than 0.2%. The optimum hardness is 0.1% (Avault et al. 1970). Minerals in hard waters provide the necessary elements for shell hardening after molting.

Dissolved oxygen and pH also control distribution and productivity of crayfishes. LaCaze (1970) found large populations of marketable size crayfishes in waters ranging from a pH of 5.8 to 8.2. Compared to open ponds, which are used in crayfish culture, natural swamp ponds have relatively low productivity. This is attributed to low oxygen levels and to acidities that are either too high or too low (Avault et al. 1970, Gary 1975). Small amounts of forage plants and high or low temperatures may also contribute to a low level of swamp pond production. Young crayfish grow best at temperatures of 24° to 27° C (75° to 80° F).

Water levels may control crayfish distribution, productivity, and harvest. If the amount of rainfall is low from September through November, then the season of peak crayfish harvest the next spring will be later than normal (LaCaze 1970).

Crayfish are preyed upon by insects, fishes, amphibians, reptiles, birds, and mammals (LaCaze 1970, White 1970, Gary 1974, H. R. and J. J. Hebrard unpublished). They are also susceptible to a bacterial infection ("burned spot" disease). Bacteria invade abraded areas of the shell and feed upon chitin, a component of the shell. The early stages of the infection cause dark discolorations of the exoskeleton. Advance stages of bacterial infection weaken the crayfish (Amborski et al. 1975). The effect is most apparent in older crayfish that molt slowly. The rapid molt of young crayfish prevents the formation of deep lesions.

The bulk of the crayfish crop is collected east of the Chenier Plain study area in the Atchafalaya Basin. Sixty percent of the total commercial catch is from natural habitats and the remaining 40% is from pond aquaculture. The remaining crayfishing area of significance in the Texas coastal zone is the lower Trinity River, which includes parts of Liberty and Chambers counties (C. D. Studzenbaker, unpublished).

5.6.4 BROWN SHRIMP (*Penaeus aztecus*) and WHITE SHRIMP (*Penaeus setiferus*)

Adult brown and white shrimp spawn offshore in Gulf waters at different depths and peak times. Fertile eggs hatch into planktonic larvae, which then develop through a series of molts into postlarvae. The postlarvae (8 to 14 mm or 0.3 to 0.5 in) are a transitional stage and at this point normally enter the estuary (recruitment).

Postlarvae of the brown shrimp usually enter the estuary between February and May (Copeland and Truitt 1966, Ford and St. Amant 1971). Though recruitment is greatest on incoming tides (St. Amant et al. 1965, King 1971), it may not be a passive phenomenon. An overwintering of postlarval brown shrimp in the shallow Gulf has been postulated, with recruitment correlated to the warming of estuarine waters (Compton 1965, Temple 1968, and King 1971).

The initial seasonal distribution of postlarvae in estuaries is believed to be governed by circulation patterns and the intensity of wind-driven tides. During months of peak recruitment, strong north winds followed by strong south winds cause a flushing-filling action in the estuary which transports larval shrimp to the critical marsh-water interface. Here they adopt a benthic existence, continue to feed, and grow into subadults.

Brown shrimp emigrate from Louisiana's estuaries in two stages. The first consists of 60- to 70-mm (2.3- to 2.7-in) shrimp that move from fringing marshes to open bays. This movement normally begins in May. The open bays serve as a "staging area" for the second offshore emigration (90- to 110-mm or 3.5- to 4.3-in shrimp), which begins in late May and peaks in June or July (Gaidry and White 1973). The spring and summer peaks in emigration are strongly correlated with the tides of the full and new moon (Blackmon 1974). Once juvenile brown shrimp begin to emigrate from the open bays, they move steadily to the deep waters of the Gulf (37 to 92 m or 120 to 300 ft), where they mature and spawn.

White shrimp follow a similar movement pattern. The postlarvae enter the estuary with peak recruitment from June to September (Copeland and Truitt 1966). In September and October when the shrimp attain a length of 145 to 160 mm (5.66 to 6.24 in), they begin their emigration offshore (Gaidry and White 1973). Cold fronts and rapidly cooling waters force the youngest white shrimp to migrate offshore in October, November, and December. By January, most shrimp have left the estuaries. White shrimp remain in shallow nearshore Gulf waters (0 to 27.5 m or 0 to 90 ft), and may reenter the estuaries periodically in the spring and fall.

The portion of the shrimp's life cycle spent in estuaries represents a crucial phase. Environmental conditions (e.g., temperature, salinity, protection from predation, and adequate food supply) critically influence populations.

Saline, brackish, and intermediate marshes should be considered prime shrimp nursery grounds. The marsh-water interface is an extremely important habitat for juvenile shrimp (Chapman 1966, White and Boudreaux 1977). Mock (1966) noted that more than 90% of the shrimp caught in shallow estuarine areas of Galveston Bay, Texas, were near salt marsh habitats. Primary reasons may be an abundance of detritus and protection from predators (Trent 1967).

When an estuary is altered by the construction of bulkheads, dredge spoil disposal, etc., a reduction in the carrying capacity of the estuary can be expected (Mock 1966). In this regard, Williams (1958) observed a preference of young brown and white shrimps for soft mud or fibrous peat (natural substrate of nearshore environment), and an avoidance of bare clay or shell bars (types of environments associated with spoil disposal).

Offshore, brown shrimp are found at depths down to 108 m (360 ft), with adults being most abundant at 27 to 55 m (90 to 180 ft). White shrimp are found primarily at depths less than 90 m (300 ft).

Adults of both species prefer mud and silt bottoms and are found, to a lesser extent, on mud and shell, or mud and sand substrate (Christmas and Etzold 1977b).

Larval shrimp in the Gulf feed on plankton and suspended detrital material (Christmas and Etzold 1977b). During the estuarine phase of their life cycle, juvenile shrimp are opportunistic omnivores. They feed mainly at the marsh-water interface on a variety of organic matter, including algae mats. Jones (1973) found that 25- to 44-mm (1- to 1.7-in) shrimp randomly ingest nearshore surface sediments and detritus which is composed of decaying marsh plant vegetation and animal feces. The detritus and sediment contain an organically rich community of microorganisms that are digested by juvenile shrimp.

As the shrimp grow larger (45 to 64 mm or 1.8 to 2.5 in), predation on benthic animals such as amphipods and polychaetes becomes important, though the shrimp continue to ingest detritus. The partial shift in diet is associated with movement from the nearshore environment to the deeper waters of the estuary (Jones 1973).

Shrimp spawn in the Gulf of Mexico. Adult brown shrimp (over 135 mm or 5.3 in) spawn at depths of 46 to 110 m (150 to 360 ft), with a major peak from September to December, and a minor peak from March to May (Kutkuhn 1962, Renfro and Brusher 1963, Temple and Fisher 1968, Cook and Lindner 1970).

Adult white shrimp over 140 mm (5.5 in) spawn in shallower water (8 to 31 m or 27 to 102 ft) than brown shrimp. They exhibit a June peak in the April to August spawning period (Lindner and Anderson 1956, Renfro and Brusher 1963, Temple and Fisher 1968, Bryan and Cody 1975).

Factors that may threaten the shrimp resource include the alteration of freshwater inflow into estuarine water circulation patterns, temperature, and salinity regimes, as well as reductions in the supply of marsh plant detritus. Thus, marsh deterioration, land loss, bulkheading, channelization, dredge spoil disposal, leveeing, and modification of river discharge patterns are all concerns of the shrimp industry and the renewable resource manager.

The time and intensity of spring warming of the estuaries is important in the initial growth and survival of brown shrimp. Little or no growth of juvenile brown shrimp occurs below 20° C (68° F). When temperature exceeds this value, growth rates from 1 to 2 mm (0.04 to 0.08 in) per day are expected (St. Amant et al. 1965).

Summer growth of juvenile white shrimp does not appear to be temperature-limited, and proceeds at a rate comparable to juvenile browns. However, during the fall, rapidly decreasing temperatures associated with passing cold fronts reduce growth rates.

Perret et al. (1971) reported that densities of brown shrimp in estuaries are more related to temperature than salinity. The average density was normally low at temperatures less than 20° C (68° F). This supports the observation of the Louisiana Department of Wildlife and Fisheries (LDWF) that distribution of brown shrimp is largely limited to salinities of 15‰ or greater when temperatures are below 20° C (68° F). When water temperatures remain above 20° C (68° F), salinity does not appear to limit the distribution of brown shrimp.

The density distribution of white shrimp, however, is not correlated with temperature above 10° C (50° F) (Perret et al. 1971). This lack of pattern is consistent with the observation that catch of white shrimp is less predictable than brown shrimp, and that white shrimp have a greater tolerance than brown for salinities less than 10‰.

Gunter et al. (1964) found that salinity optima vary from 5 to 20‰ for young shrimp of commercial varieties found in estuaries along the Gulf coast.

A prime example of man's effect on shrimp production occurred in Sabine Lake. Winter discharges from the Toledo Bend Dam were retained in Sabine Lake until mid-May at which time the water was released. Instead of the natural occurrence of increasing salinities in estuaries during spring and summer, a nearly freshwater condition was created during late May and continued throughout the summer. This was devastating to the brown and white shrimp populations (White and Perret 1973).

5.6.5 BLUE CRAB (*Callinectes sapidus*)

In summer the adult female blue crab migrates inland to mate in brackish water (less than 25‰). The mating process usually lasts about two days (Leary 1967). After mating, the female moves back to higher salinity areas to spawn.

How far offshore the female spawns is unclear but it may be in shallow oceanic water or even in bays if the salinity is high enough. Burke and Associates, Baton Rouge (unpublished data), saw "berry" crabs taken by dip net along the beaches of Grand Isle in the summer, indicating that spawning takes place nearshore. Nichols and Keney (1963) found the greatest numbers of larval blue crabs 32 km (20 mi) from shore, which indicates that spawning and subsequent hatching may also occur offshore.

Adult male and female crabs exhibit different salinity preference. Adkins (1972) found large females (120 mm or 4.8 in width) in deep water (salinity greater than 17.2‰) on hard bottoms. Smaller crabs (60 to 80 mm or 2.3 to 3.1 in width), primarily female, were found on soft bottoms in shallow water. Juveniles and adult males prefer brackish water.

Generally, blue crabs feed on whatever is available. Gut analyses have shown some specific food items such as rangia mussel, snails, fishes, plants, insect larvae, amphipods, shrimp, barnacles, xanthid crabs such as fiddlers, other blue crabs, and even human flesh (Adkins 1972, Dugas unpublished manuscript).

Low salinity is an important requirement for the reproduction of blue crab. The female crab must leave its usual habitat with high salinity and move inland to areas of lower salinity (less than 25‰) to mate. The sperm deposited during mating will serve to fertilize eggs of the female for its lifetime (about 2 yr). The female mates only once, while the male may mate several times. The male seldom leaves areas of low salinity.

After mating, the female moves back to waters of higher salinity where, within 9 months, it spawns. The eggs are carried on the ventral appendages, giving the crab the appearance of having a sponge attached to the ventral side. This condition is referred to as the "berry state," or the crab is said to be "in berry" (Gaidry and Dennie 1971). Adkins (1972) reported that eggs normally hatch in shallow oceanic water exceeding 20‰ salinity, but that some females spawn in bays during periods of high salinity.

The effect of certain physical parameters on blue crabs varies with age and sex. Although crabs are found from fresh to saline waters, adult males are seldom found in salinities above 25‰. Adult females predominate in waters above that level. In Vermilion Bay (Vermilion Basin), males were dominant in catches from the upper reaches of the bay and females were dominant in catches from the lower reaches (Adkins 1972). In his study, the highest salinity Adkins measured was 32‰ and the lowest was 3.8‰.

Rounsefell (1964) reported that abundance of juvenile crabs appeared to be independent of individual environmental factors such as salinity and temperature. Henry (1967), however, reported that individual growth is accelerated in higher salinities, but temperature and salinity changes have the greatest effect on juveniles. Adkins (1972) found that juveniles are less tolerant to low salinities at high water temperatures and that growth is most affected by temperature. The optimum temperature range for juveniles was reported as 20° to 30° C (68° to 86° F) and the upper lethal temperature is 33° C or 91° F (Holland et al. 1971). The maximum water temperature measured in Vermilion Bay by Adkins (1972) was 31° C (88° F) and the minimum was 5° C (41° F). Optimal temperature ranges for adult blue crabs are not available.

Biological factors are possibly more significant as limiting factors than are physical parameters. Not only are blue crabs food for many predators, they are also affected by microbial and parasitic infections. The "naked" barnacle (*Loxothylacus texanus*) is the most common parasite of blue crabs. The parasite burrows through soft parts of the juvenile crab at joints, suppressing growth and causing atrophy of the gonads. Infected crabs do not reach commercial size and cannot reproduce (Barnes 1968). After a developmental period, the barnacles emerge and attach to the outer abdominal surfaces of the crab. Usually, crabs measuring 33 to 78 mm (1.3 to 3.0 in) in width (widest carpace diameter) are often infected with external naked barnacles. Infections are most common from July through October (Adkins 1972). The external infection is most often found in crabs in high-salinity areas (Ragan and Matherne 1974). The parasite also infects crabs in freshwater, but low salinities appear to inhibit emergence (Ragan and Matherne 1974).

Black cysts, caused by fluke larvae, have occurred in blue crabs in Louisiana and Texas (Moore 1969). These cysts do not affect the edibility of crab meat, but they do adversely influence its appearance.

Microbial infections ("burned spot" disease) also occur in the blue crab. The name describes the appearance of shell lesions. The suspected agents of this disease are bacteria and fungi that invade shell abrasions. Although this disease does not affect edibility, it may be fatal for the crabs. The infection can destroy the chitinous layer on the gill filaments and expose internal tissues to pathogenic organisms. The diseases may be cured by a single molt so that juveniles do not normally contract more than low-level infections. Older, more slowly molting crabs are affected most. The disease is most common from October to January and is more prevalent in males than in females; "berried" females are more susceptible than other females.

The "berry" period is also a crucial time for young crabs because some predators (e.g., the trigger fish) devour egg masses attached to females. Few of the eggs produced will survive to adulthood (Van Engel 1958).

Pesticides and herbicides, domestic and industrial waste products, alteration of currents, and destruction of marshlands also limit the abundance of crabs.

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Socioeconomic and environmental information on the subject area was collected, reviewed and synthesized to produce this volume. The present physical setting of the Chenier Plain is described, as well as the geological history of the region. The effects of agricultural and oil and gas industries on the natural (biological) resources in each of six drainage basins are discussed. Habitat types in the Chenier Plain are described, and the impact of human activities on them are evaluated. The conversion of habitats from one type to another over a twenty-year period is documented. Life history information is provided for many of the important fish and wildlife species in the ecosystem.

17. Document Analysis a. Descriptors
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b. Identifiers/Open-Ended Terms

c. COSATI Field/Group 0603, 0606

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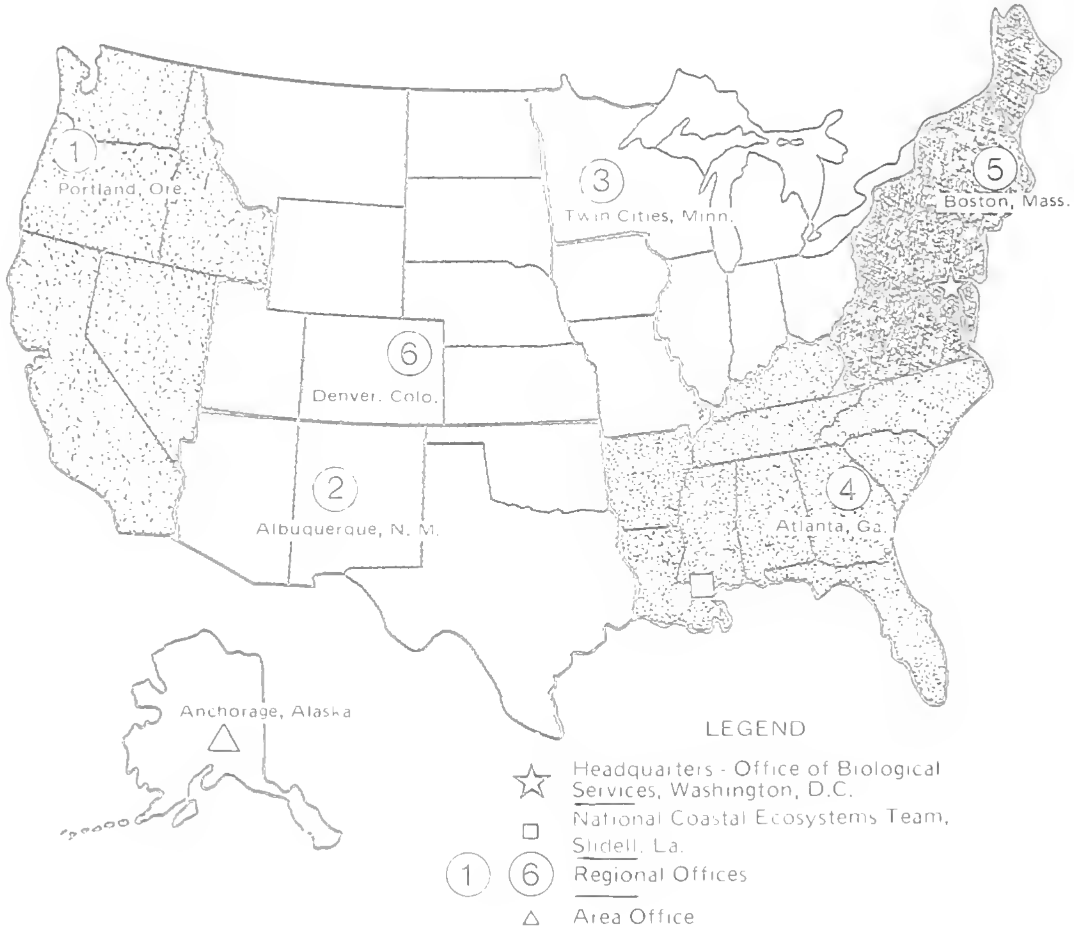

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