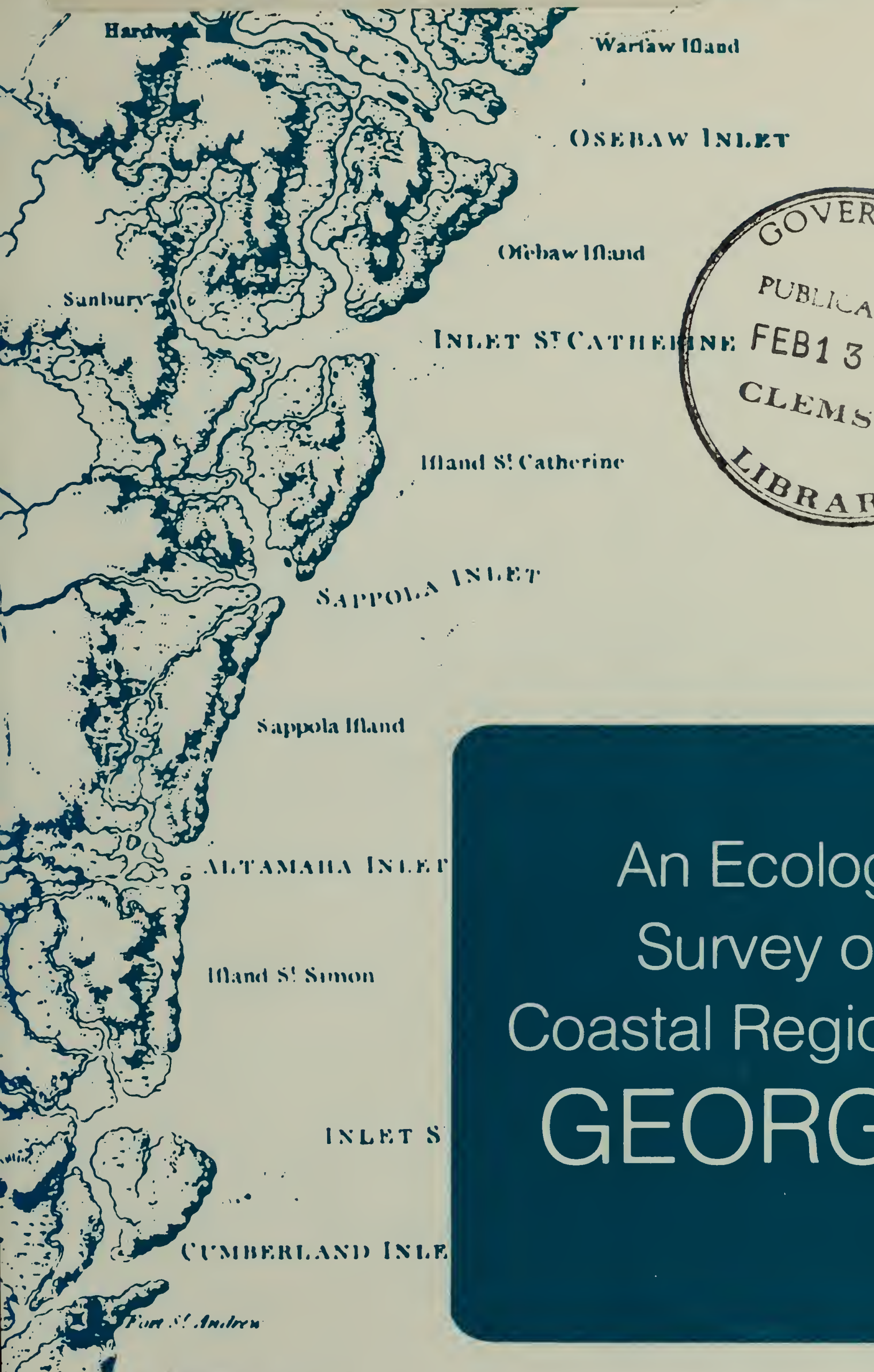

An Ecological Survey of the Coastal Region of GEORGIA

FEDERAL PUBLICATION

An Ecological Survey of the Coastal Region of GEORGIA

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September 1971

Summary

The Georgia mainland is bounded on the east by a functional system of barrier islands, marshes, and coastal waters. The system is influenced by the movement of materials into and through it, especially from the mainland rivers and from coastal areas to the north via the southward-flowing littoral currents. The region is further influenced by animals migrating into and through it from other areas.

The chain of barrier islands extends the length of the Georgia coast. The islands were formed during the last 10,000 years probably as a result of dune ridges; they formed at low stands of the sea and were inundated when sea levels rose again. Barrier beaches form on the islands from littoral sands. Wind-blown sand from the beaches is trapped by vegetation to form dune ridges which ultimately become stabilized by salt-tolerant vegetation. The dunes protect the island from sea winds, salt spray, and storm tides and allow the establishment of forest vegetation. The major habitats of the island interior are live oak forests, pine forests, fields, and sloughs.

The islands absorb much of the energy from tides and waves and allow sediments from the continental shelf and mainland rivers to be deposited in the sheltered lagoons behind the islands. The lagoons become filled with sediments to form marshes. Deposition on the marsh continues as the waters spill onto the marsh at high tide, but increases in marsh elevation due to deposition are just about offset by rising sea levels. Few plant species can withstand the stress imposed by high salinity and daily inundation by tidal waters, and marsh vegetation is monotonously uniform. The tidal marsh is predominantly smooth cordgrass, although there is a zonation of species related to gradients in salinity and elevation.

The marshes are very productive and export nutrients to the estuaries and waters of the continental shelf. Smooth cordgrass accounts for most primary production in the marsh. Mud algae and phytoplankton, though less important than cordgrass, also contribute substantially to primary production. A relatively small proportion of the total energy flow is through the grazer food chain. Most energy and nutrients pass from the marshes into the estuaries in the form of detritus particles which form the base of

an aquatic detritus food chain that supports economically important estuarine organisms. Nutrients exported by the marshes are trapped in the estuaries, which are more fertile than either the rivers that drain into them or the adjacent offshore waters.

All of the major elements of the island-marsh-estuary system are intimately interrelated. Sand beaches and dunes protect the islands from erosion and inundation by the sea. The islands protect the marshes from the force of the sea, and the marshes trap sediments discharged from mainland rivers, protecting the aesthetic and recreational qualities of the island beaches. The marshes contribute much of the primary production for aquatic food webs which support the fisheries resources of the open waters. The open waters remove waste materials from the marshes, circulate nutrients, and transport certain types of organisms.

Certain elements in this functional web are particularly sensitive to the disrupting influences of human activities. Seemingly insignificant actions affecting some sensitive areas ultimately may have far-reaching effects on other elements of the system. Man has exerted his influence on the region for centuries and, especially in recent years with increasing industrialization on the mainland and recreational development on the islands, often has placed severe stresses on the natural system.

The ecological characteristics of the coastal region make it peculiarly sensitive to pollution. The processes that concentrate nutrients in the estuaries to form a "nutrient trap" also concentrate pollutants such as heavy metals and chlorinated hydrocarbon pesticides. Many estuarine organisms harvested by man (especially oysters, clams, and other mollusks) concentrate pollutants (e.g., radionuclides, chlorinated hydrocarbons) in their tissues at levels potentially dangerous to the health of the consumer. Arthropods such as shrimp and crabs are sensitive to even small quantities of chlorinated hydrocarbons. The concentration of many of these pollutants already has reached disturbing levels. Concentrations of heavy metals are high in some organisms on the Georgia coast and some areas have been closed to harvesting because of this.

Because of low oxygen content, estuarine waters are also quite sensitive to oxygen-demanding pollutants such as domestic sewage. Sewage also contaminates clam and oyster beds causing them to be unusable as a food source.

For planning purposes, the coastal zone logically may be classified into four basic management units: the mainland, the islands, the marshes, and the coastal waters. These in turn may be classified into management subunits: the specific habitat types (e.g., beach-dune complex, live oak forest, low tidal marsh, etc.).

Future residential and industrial development should be restricted to the mainland. Pollution standards should be strictly enforced and a continuous monitoring program should be established. Industries that would place great demands on an already overtaxed ground water supply probably should not be encouraged to locate on the coast. Existing industries should be required to make greater use of surface water and develop and implement technology for recycling.

The insularity of the islands should be preserved; there should be no additional bridges or causeways to the islands. The islands should be maintained as nearly natural as possible. Vulnerable components of the island ecosystem that should receive special protection include dune vegetation, sea turtle rookeries, sloughs, wading bird rookeries, mature live oak forests, and endangered and unique wildlife (e.g., pocket gophers, bald eagles, alligators).

Marshes and estuaries generally should be preserved in a relatively natural state for public use and enjoyment. Marsh alteration for aquaculture and waterfowl, while desirable and acceptable forms of marsh management, should be regulated.

1 Introduction

The coastal region of Georgia, in contrast to such areas in most states, remains relatively undisturbed. Its extensive marshes, once regarded as unproductive wasteland, are now known to be highly productive ecological systems, extending their productivity to coastal waters (Odum 1961; Schelske and Odum 1961; Odum and de la Cruz 1967; Thomas 1966). Furthermore, they are now known to cover potentially valuable mineral deposits (Cheatum et al. 1968; Furlow 1969).

The offshore islands beyond the marsh remain in a relatively natural state because of their inaccessibility and the good stewardship of those who have owned them. Their recreational potential recently has become a matter of considerable public and political interest (e.g. Keeling et al. 1968; Fraser 1969; Francisco et al. 1970; Clement 1971).

The future development of the coastal region of Georgia is now of major public interest in Georgia, and various proposals for mining, aquaculture, recreational development, and preservation have stimulated much controversy in the legislature, in the local press and national magazines, and at public hearings.

Much of the information needed for making management decisions is lacking. The information that is available is scattered through a variety of scientific journals, agency reports, and unpublished files and is often inaccessible or unintelligible to managers and planners.

The objective of this study was to describe the overall structural and functional ecology of coastal Georgia, defined for purposes of this study as the region bounded by the mean high-tide mark on the mainland extending eastward to include the marsh-estuary system, the offshore islands, and the adjacent marine areas of the continental shelf (Fig. 1).[1]

[1] Fig. 1 is a map located at the back of the book.

The procedure involved extensive review, interpretation and synthesis of existing information, supplemented by aerial and ground surveys. Data on the islands, especially, were lacking and much of the field work was devoted to surveying the vertebrate fauna and vegetation of the islands. Aerial surveys were made in order to inventory wading bird and sea turtle rookeries, and additional information on vegetation and wildlife was acquired through ground surveys. In addition, there were extensive efforts at trapping and collecting mammals, amphibians, and reptiles. Inferences from outside the study area were drawn upon when necessary.

In order to characterize in some detail the ecology of such a large and diverse region, we have separated it into smaller, more homogeneous units. The units of discussion are the major habitat types: the islands, the marshes, and the open marine and estuarine waters. It must be emphasized that the habitats are interacting components of a larger system, which is itself not a closed system that is isolated or insulated from others. It is a dynamic system through which materials and organisms constantly move to and from other areas and is therefore not easily delimited by artificially drawn lines.

2
The Regional Setting

Geology

The mainland rivers that flow into the Atlantic Ocean along the Georgia coast drain three major physiographic provinces: the Blue Ridge Mountains, the Piedmont Plateau, and the Atlantic Coastal Plain (Fig. 2). The geology of these provinces greatly influences the amount and characteristics of surface water, groundwater, and sediments transported to the marshes, estuaries, and continental shelf.

Soils of the Blue Ridge and Piedmont provinces are derived from crystalline rocks dating to pre-Cambrian time. The two major river systems of the Atlantic drainage in Georgia have their origins in these provinces. The headwaters of the Savannah River are in the Blue Ridge province and the Altamaha River originates in the Piedmont.

The lower (southern and eastern) edge of the Piedmont is marked by the Fall Line, an old shoreline formed by the greatest advance of the sea late in the Mesozoic Era. The Coastal Plain is overlaid by many sedimentary strata tilted toward the sea. These deposits were formed during the many changes in sea level associated with glaciation during the Tertiary and Quaternary periods. The thickest deposits are in the coastal area (about 6000 ft at Savannah), tapering to a thin edge at the Fall Line, where the oldest (Cretaceous) sediments are exposed. Progressively more recent strata occur at the surface toward the coast, and relict coastal features, such as barrier islands and lagoons, are still evident in many places.

Limestones of Tertiary and Quaternary age underlying the Coastal Plain form one of the most productive aquifer systems in the country. The Tertiary limestone is several thousand feet thick, ranging in age from Paleocene to Pliocene. The hydrologic unit of this limestone, deposited in the period from mid-Eocene to mid-Miocene, is the principal artesian or Coastal Plain aquifer, which is recharged with water where it is exposed near the Fall Line (Fig. 3). It slopes gently to the coast and appears on the continental slope as freshwater springs in the ocean.

The region is generally one of low seismic activity. However, a major earthquake, having its epicenter at Charleston, S.C., occurred in 1886. This earthquake, registering 10 on the Richter scale, caused 150 human deaths and damaged buildings in the Savannah area.

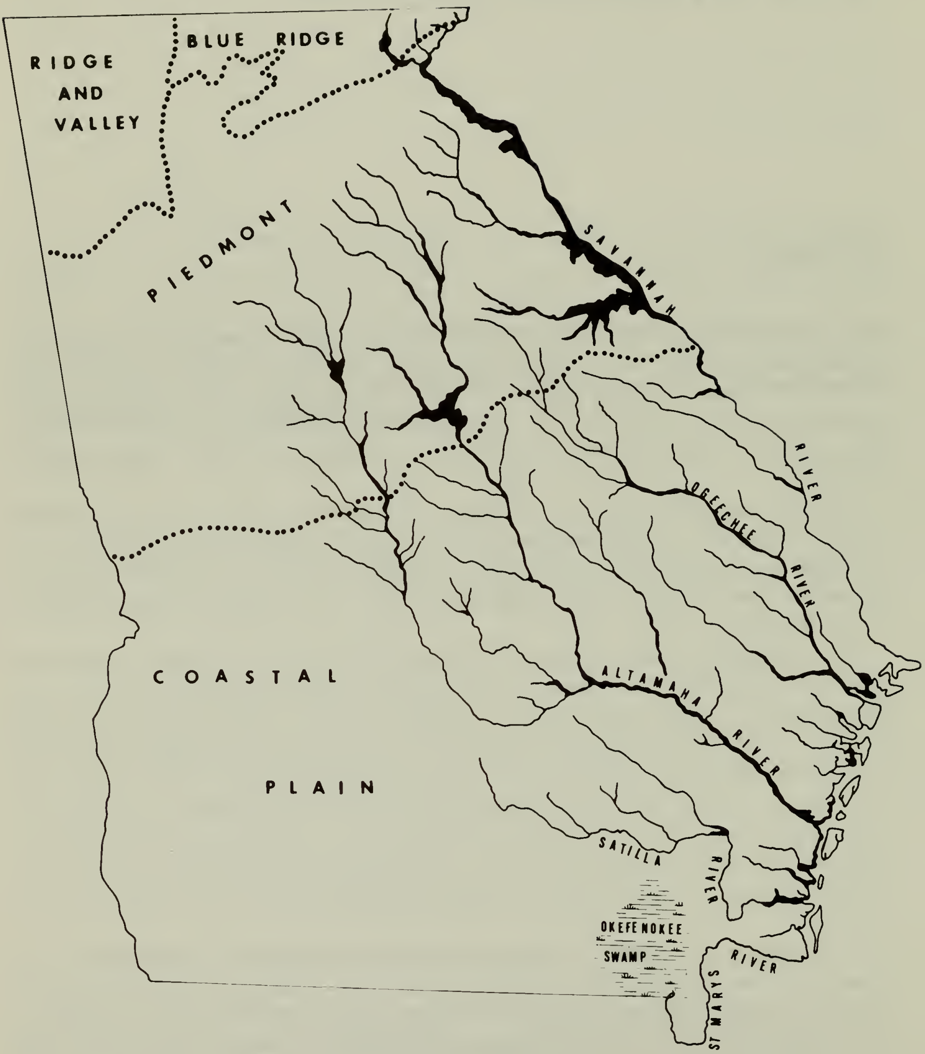

Fig. 2. Mainland river systems discharging into the estuaries of Georgia.

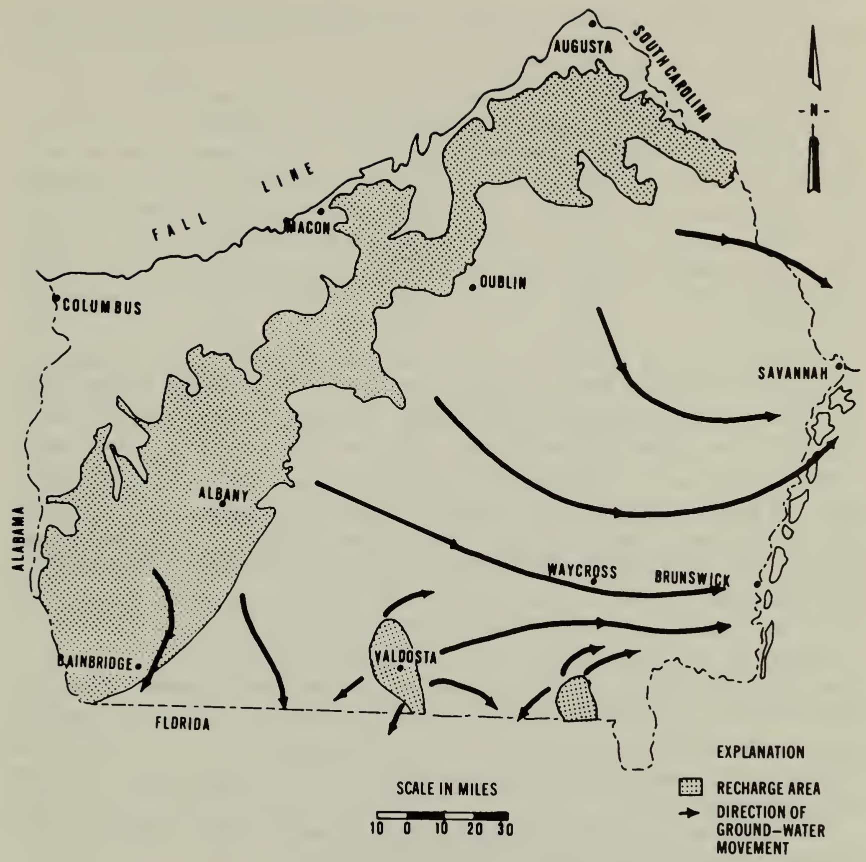

Fig. 3. Recharge area of the principal artesian aquifer and direction of groundwater movement. (Redrawn from Callahan 1959, 1964.)

Climate

The coastal region of Georgia has a relatively moderate climate. Average temperatures of the islands are slightly lower than on the mainland. Sea breezes offer relief from intense summer heat. Daily maximum temperatures in July and August (the warmest months) are usually in the 80s and low 90s. The islands are the only part of the state south of Atlanta that has mean daily maximum temperatures below 90°F in July and August (Carter 1967).

Winters are relatively mild and short. The average minimum temperature for December and January (the coldest months) is about 43°F. On the average, there are 305 freeze-free days at Brunswick and 267 at Savannah (Carter 1970b).

Average temperatures for four coastal stations are shown in Table 1.

The coastal islands have an average annual rainfall of about 53 inches. Average monthly precipitation is presented in Table 2. Rain is most abundant in the summer and early fall, with half of the annual precipitation occurring between June and September. The driest period is November through February (Carter 1967). Most precipitation in late fall and winter is of the frontal type, but most rain in the spring and summer comes as afternoon thundershowers (convectional precipitation). Heavy rainfall in September commonly is associated with hurricane conditions.

The first recorded hurricane to cause significant damage to the Georgia coast struck the Charleston, S.C., area on 15 September 1752 (Carter 1970a). Since that time, numerous hurricanes have passed along the Georgia coast, but surprisingly few have caused serious damage. Between 1886 and 1968, 669 tropical cyclones developed in the Atlantic, the Caribbean, and the Gulf of Mexico. Of these, 93 passed into Georgia, or passed so near that they had an appreciable effect on the state's weather. Only 56 of these reached hurricane magnitude, and just eight carried hurricane winds into the state. Therefore, the frequency of true hurricanes on the Georgia coast averages one per 10 years. Less intense storms may cause major damage more frequently (Carter 1970a).

Hurricanes off the east coast tend to follow the path of warm, lighter air above the Gulf Stream, which is flanked on both sides with heavier, cooler air. Brunswick, Ga., is farther (80 miles) from the Gulf Stream and the accompanying warm air than any other place on the southeastern coast. Consequently, the Georgia coastal area is less exposed to hurricanes than areas farther north or south (Gibson 1948).

All hurricanes that have affected Georgia between 1886 and 1968 have occurred between August and October (Carter 1970a).

History

By various estimates, man has inhabited the North American continent for 10,000-40,000 years. There is increasing evidence that human occupancy of what is now the coastal region of the southeastern United States extends at least 10,000 years into the past. This is difficult to prove because archaeological evidence in coastal areas is quickly destroyed by changing sea levels with constant erosion and deposition so that many early sites are probably located under the water on the continental shelf and visible traces of human occupation date back only about 4000 years. Sites on the barrier islands dating from A.D. 500 to 1300 reveal that the inhabitants cultivated corn, beans, pumpkins, and other crops before contact with Europeans. Shell heaps and middens attest to the importance of shellfish in the diet of the original inhabitants.

TABLE 1. *Normal temperatures for four locations on the coast of Georgia.*[a]

Month	Location and Temperature			
	Savannah	Blackbeard Is.	Brunswick	St. Simons Is.
January	51°F	53°F	55°F	52°F
February	53	54	57	55
March	59	58	62	60
April	66	67	68	67
May	73	74	76	74
June	79	80	81	80
July	81	82	82	81
August	81	82	82	81
September	76	78	79	78
October	67	69	71	69
November	58	59	62	60
December	51	52	55	53
Annual	66	67	69	67

[a]Data from Carter 1967, 1970b and U.S. Fish and Wildlife Service 1962.

TABLE 2. *Average rainfall at four locations on the coast of Georgia.*[a]

Month	Location and Rainfall (inches)			
	Savannah	Blackbeard Is.	Brunswick	St. Simons Is.
January	2.8	2.1	2.3	2.5
February	3.7	3.6	3.0	3.1
March	4.0	3.5	3.8	3.8
April	3.7	3.3	3.2	3.4
May	3.8	3.4	3.6	3.1
June	5.1	3.9	5.5	5.6
July	6.6	5.6	7.3	5.9
August	6.6	4.4	7.0	5.3
September	5.3	9.7	9.1	10.3
October	2.6	4.3	4.5	4.8
November	2.1	1.9	1.5	2.2
December	2.8	1.9	2.6	2.5
Annual	48.9	47.6	53.3	52.6

[a]Data from Carter 1959, 1967 and U.S. Fish and Wildlife Service 1962.

Archaeologists from the University of Georgia are conducting intensive excavations on St. Catherines Island. These studies, not yet published, should greatly increase our understanding of the aboriginal inhabitants of the islands. Results of previous archaeological studies in the area are summarized by Caldwell (1952), Williams (1967), and Fairbanks (1968).

European influence began in 1568 with the establishment of the first Spanish missions. Although periodically destroyed or otherwise interrupted, these missions tenaciously clung to survival for over one hundred years. During their tenure, the Spaniards enriched the native fare by the introduction of exotic plants (figs, oranges, other fruits) and domesticated animals (hogs, goats).

In 1685 the English and their native allies invaded from the north and destroyed the missions and the island natives. For about 50 years the islands remained uninhabited and, except for occasional visits by pirates and Indians, undisturbed.

In 1732 George I granted the region to General James Oglethorpe as a buffer against the Spanish in Florida. Oglethorpe landed in Savannah in 1733, and his efforts toward colonization extended south to St. Simons where he built Fort Frederica and ended the Spanish threat in North America.

By 1776 Savannah, Richmond Hill, Midway, Sunbury, Darien, Brunswick, and St. Marys were thriving agricultural communities. Naval stores (tar, pitch, turpentine) and live oak timbers were the earliest major economic resources of the islands, which soon came under intensive agriculture. On the mainland as well as the islands the colonists experimented with a variety of subtropical plants including olives, dates, oranges, figs, rice, indigo, hemp, pomegranates, coffee, tea, and silk. The climate proved unsuitable for oranges, although they persisted as a minor crop for many years. Silk was a major crop for a few years and was produced on a minor scale as late as 1790. By 1750 rice and indigo were well established as profitable crops. The Revolutionary War brought about a decline in the market for indigo, which was largely supplanted by rice except on the islands (Bonner 1964).

Rice was grown in diked fields at the mouths of mainland rivers. Production reached its peak between 1850 and 1860. Chatham County was the leading producer, followed by Camden, McIntosh, Glynn, Liberty, and Bryan counties (Long 1958). In 1859 planters were harvesting an average of 50 bushels per acre, with about 23,000 acres in cultivation. Total state production was 52,507,652 lb (Long 1958).

Long-staple cotton, imported from the Bahamas about 1785, was first grown on St. Simons and was soon cultivated on the other islands and the adjacent mainland along the Georgia and South Carolina coasts. This variety known as sea island cotton, far superior to upland cotton, sold for two to five times the price of the latter.

The plantation era on the Georgia coast was marked by a sophisticated level of land management. Despite malaria and yellow fever, which drove the white planters and their families inland during the growing season, the planters cleared thousands of acres of forest and cypress swamp to grow rice and other crops. Plantation owners were well educated and included some of the most advanced agriculturists in the nation, employing practices generally attributed to a much later age. These included irrigation, drainage, liming, fertilization, crop rotation, fallowing, composting, mulching, and biological insect control (using flocks of turkeys to control leaf worm caterpillars in cotton). Of particular interest was the application of marsh mud, crushed oyster shell, cordgrass, and stable manure to the fields. The application of marsh mud to the fields was considered essential to successful crop production. These agronomic practices and the social life on the sea island plantations are discussed in detail by Johnson (1930).

The war for southern independence and the ensuing abolition of slavery marked the beginning of the end for the plantations and for prosperity and a way of life. Survivors of the war returned to their devastated lands and attempted to restore the plantation system with paid labor, but the freed slaves and imported Irish and Chinese laborers proved to be undependable sources of labor and the plantations were soon abandoned.

Thus, within a few years, the coastal area changed from one of the most prosperous regions in the nation to one of the poorest.

Most of the islands were more or less deserted until the 1890s when wealthy industrialists purchased them and restored some of the remaining plantations. Except for Blackbeard, which was in public ownership, and Tybee, Sea Island, and St. Simons, which became residential areas, the islands remained private, relatively natural, well-managed retreats.

The fascinating history of the sea islands has been a favorite topic of writers. For further information on the subject see Johnson (1930), Lovell (1932), Vanstory (1956), and Fancher (1971).

Economics

The settlement and development of the Georgia coast was dependent upon agriculture. Lack of a satisfactory substitute for plantation agriculture, after its destruction, resulted in a long period of economic depression still evident in many parts of the region. This has been responsible for the relatively slow rate of population growth (Table 3). The cities of Savannah and Brunswick have accounted for most population growth and the population of the coastal counties has become urbanized at an increasing rate. Sudden bursts of growth in population have occurred locally in the rural counties as a result of the establishment of new industries or, in the case of Liberty County, a military installation.

Vital statistics and socioeconomic data for the coastal counties during the period 1950-70 are summarized by Clement (1971) and Pinson and Weldon (1964) for Bryan, Camden, Glynn, Liberty, and McIntosh counties; by Sanders (1968) for Chatham County; and by Keeling et al. (1968) for Camden and Glynn counties. Carley (1968) presented economic data concerning the commercial fisheries industry.

Commercial fishing and forestry have been the most important economic activities of this century. The fisheries and forest resources support an increasing

TABLE 3. *Population trends for the coastal counties of Georgia*: 1790-1970.[a]

Year	County and Population					
	Chatham	Bryan	Liberty	McIntosh	Glynn	Camden
1790	10,769	-	5,355	-	413	305
1832	14,127	-	7,233	4,998	4,567	4,578
1860	31,043	4,015	8,390	5,546	3,889	5,420
1890	57,740	5,520	12,887	6,470	13,420	6,178
1930	105,431	5,952	8,153	5,763	19,400	6,338
1940	117,970	6,288	8,595	5,292	21,920	5,910
1950	151,481	5,965	8,444	6,008	29,046	7,322
1960	188,299	6,226	14,487	6,364	41,954	9,975
1970	182,912	6,116	17,156	6,938	48,474	10,815

[a]U.S. Census data from reports of the Bureau of Census, U.S. Department of Commerce.

number of industries engaged in processing, manufacturing, and marketing seafoods and wood products. The pulp and paper industry has expanded, however, at the expense of the fishing industry, which has suffered greatly from pollution caused by the paper mills.

The Coastal Plain of Georgia and the Carolinas generally is regarded as an economically depressed region and efforts are being made at the local, state, and national levels to improve economic conditions in the area. But, ironically, economic growth often produces undesirable impacts on the local environment and culture; the low level of economic growth has kept the level of environmental degradation relatively low. Consequently, the people of this region still have options open to them as to future development that are not available to those in other areas.

3
The Islands

Georgia meets the Atlantic Ocean along the beaches of the offshore islands, popularly known as the sea islands or the Golden Isles. Scientists call them barrier islands because they form a barrier between the sea and the land. Barrier islands occur along the Atlantic and Gulf coasts from New Jersey to Texas. A chain of southern sea islands having similar natural and cultural histories occurs from North Island, S.C., to Anastasia Island, Fla. The Georgia islands are several miles offshore and are separated from the mainland by extensive marshland, tidewater streams, and sounds.

Other islands, in addition to the barrier islands, are scattered throughout the estuarine systems. These islands are of various origins. Some of the hammock (forested) islands are remnants of old barrier islands formed in the past during periods of higher sea level (Hoyt et al. 1964). Others may have been separated from larger islands by erosion (Teal and Teal 1964). Some of the small islands are thought by many to have been formed from ballast dumped by ships (Emery et al. 1968). Most of the marsh islands are alluvial deposits dissected and shaped by estuarine drainage systems.

This chapter deals primarily with the barrier islands: their formation, floral and faunal composition, and functional ecology. The barrier island system of Georgia consists of eight island complexes including 13 barrier islands (Fig. 1). Table 4 shows the length of the beach and the area, excluding salt marsh, of each of the barrier islands.

Elevations on the barrier islands typically range from sea level to about 25 ft, although individual dunes may be higher. (Some on Cumberland are over 50 ft high according to maps of the U.S. Geological Survey.) Topography of the islands is typically characterized by broad, nearly level areas interspersed with low, gently sloping ridges. Islands and portions of islands that are of more recent origin may be characterized by steep, parallel dune ridges (especially Wassaw, Blackbeard, and Little Cumberland). The entire coastal region of Georgia is mapped by the U.S. Geological Survey at three different scales: 1:24,000 (7.5′ quadrangles), 1:62,500 (15′ quadrangles), and 1:250,000 (1° lat. by 2° long.).

Upland soils are mostly porous sands derived from recently deposited marine sediments that are resistant to weathering (Regosols). These soils have a distinct A horizon (surface layer) with significant accumulations of organic matter that

TABLE 4. *Areas of Georgia islands and lengths of their beaches.*[a]

Island	Approximate acreage[b]	Approximate miles of beach
Tybee	1,500	3.4
Little Tybee	1,600	3.0
Wassaw	2,500	6.0
Ossabaw	11,800	9.5
St. Catherines	7,200	11.0
Blackbeard	3,900	7.5
Sapelo	10,900	5.6
Little St. Simons	2,300	6.5
Sea	1,200	4.7
St. Simons	12,300	3.8
Jekyll	4,400	8.0
Little Cumberland	1,600	2.4
Cumberland	15,100	16.9

[a]From U.S. Geological Survey maps.

[b]Includes forested area, pastures, beaches and dunes, and freshwater marsh and ponds. Does not include salt marsh.

accounts for most of the exchange capacity (Byrd et al. 1961). They are subject to moderate to severe leaching, and many are excessively drained. Principal soil series include Blanton, Galestown, Klej, Lakeland, and Palm Beach (Byrd et al. 1961). Lower, poorly drained sites are characterized by intrazonal soils of the following series: Leon, Ona, Plummer, Rutlege, and St. Johns (Byrd et al. 1961 and unpublished soil survey information). Most of these soil series are characteristically very acid, but locally on the islands they may be neutral to slightly alkaline due to the presence of oyster shells in the profile.

Of the 13 barrier islands, only Blackbeard has not been in private ownership in this century. Acquired by the Navy Department in 1800 for its live oak forests, it is now a national wildlife refuge. All or parts of several other islands have passed into public ownership in recent years. Jekyll Island was purchased by the State of Georgia in 1947 for intensive public recreation. A portion of Sapelo Island was purchased by the Georgia Game and Fish Commission in 1969, and Wassaw was acquired by the Bureau of Sport Fisheries and Wildlife in 1969. A major portion of Cumberland Island has been acquired for a national seashore pending enactment of authorizing legislation.

Of the islands in private ownership, Tybee, St. Simons, and Sea islands are in multiple ownership and have been intensively developed as residential and recreational areas. Part of Sapelo owned by the Sapelo Island Research Foundation is the site of the University of Georgia Marine Institute, where much of the research on which this report is based was conducted. The remaining privately owned islands are used for vacation retreats, wildlife refuges, commercial livestock production, and research and education in cooperation with educational institutions in the state.

Despite their wild appearance, the Georgia islands are not undisturbed. Most of them have been under intensive agriculture at one time. Timber has been harvested from all except Wassaw, although a few small virgin stands remain on some of the islands. Vegetation on several of the islands has been modified by large numbers of hoofed animals. Many native animals have been extirpated and exotic species have been introduced.

Barrier island formation [1]

Although barrier islands border the Atlantic coast and many other coasts that are tectonically stable, the way in which these islands form is not known. They formed many thousands of years ago; direct observation of their origin and development is not possible, but several theories have developed. A widely accepted theory proposed by a Frenchman over a century ago was that waves coming from the open ocean into shallow water become steeper, and when they break they lose energy and dump some of the sand they have been carrying, forming a bar which grows until it reaches high water level (Beaumont 1845). Eventually there is a time, this theory proposes, when dunes develop on top of this bar to form an island (Fig. 4).

Recent geological studies indicated that there were several things wrong with this theory. One was that during the early stages of bar formation there must have been an open marine beach in the area behind the bar. However, the shells, fauna, and sediment that should be in this location, if this theory were correct, were never found during drilling on Sapelo Island (Hoyt et al. 1964) and elsewhere (Bernard et al. 1959; Fish 1959; Shepard 1960; Shepard and Moore 1960; Rusnak 1960; Straaten 1965). It was finally concluded that the barrier islands probably did not form in this way.

The formation of the glaciers that covered North America and Europe during the Pleistocene ice ages affected the ocean by withdrawing a large quantity of water. At the maximum extent of ice formation, sea level was probably as much as 330 ft lower than it is now and the seashore of Georgia was 70-80 miles eastward of its present location. The ice started to melt about 18,000 years ago, returning water to the ocean, and the level of the sea rose to its present position.

[1] This section is contributed by the late John H. Hoyt, and is modified from a previous publication (Hoyt 1968c).

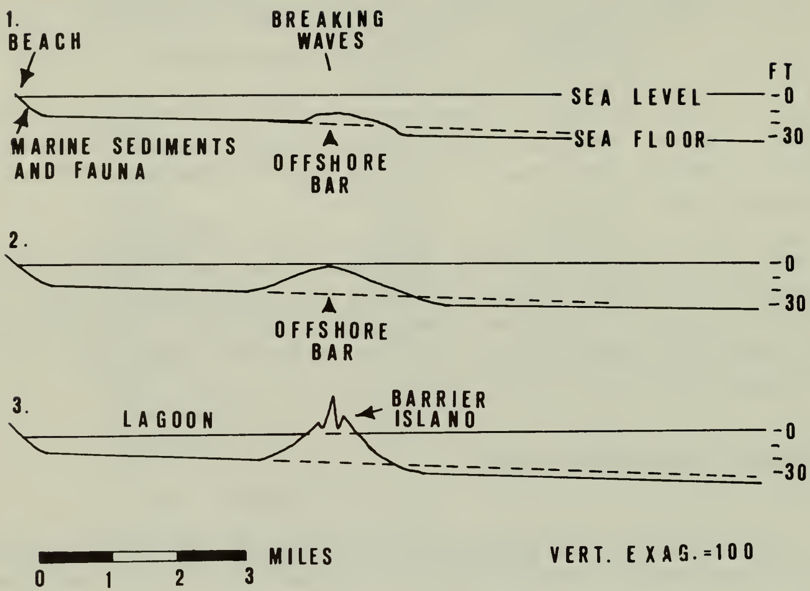

Fig. 4. Idealized cross-sections showing barrier island formation from an offshore bar. *1*. Waves agitate sea floor and deposit sediment to form bar in area of energy loss. *2*. Sediment accumulates to near sea level. *3*. Bar is converted to island with lagoon on landward side. (From Hoyt 1968c.)

It was concluded that dune formation, which occurs nearly everywhere along the sand beaches, followed by flooding of the area by sea water, is a more reasonable explanation of the formation of barrier islands (Hoyt 1967, 1968a,b). Initially a series of dune ridges forms along the shoreline. If the dunes are stable and large enough, they are not destroyed during a submergence of about 20 ft. The area landward of the dunes is flooded and becomes a lagoon, which eventually fills with sediment and forms a salt marsh (Fig. 5).

The coastal islands are of two ages. Sea Island, for instance, is quite young geologically. It was probably formed within the last 4000-5000 years. St. Simons Island, just to the west, is older, having formed during the Silver Bluff submergence of the Pleistocene. Sea Island and the other Holocene islands have very poorly developed soil profiles because there has not been time for stratification to occur. St. Simons Island, however, has a mature soil profile with an extensive accumulation of humic matter at a depth of 3-8 feet. The age of the islands can be shown on a graph (Fig. 6) which indicates the relation of time to the altitude of the sea (Hoyt et al. 1968). Five samples of shells from sediments of the Silver Bluff submergence, analyzed by the carbon 14 method, were estimated to be

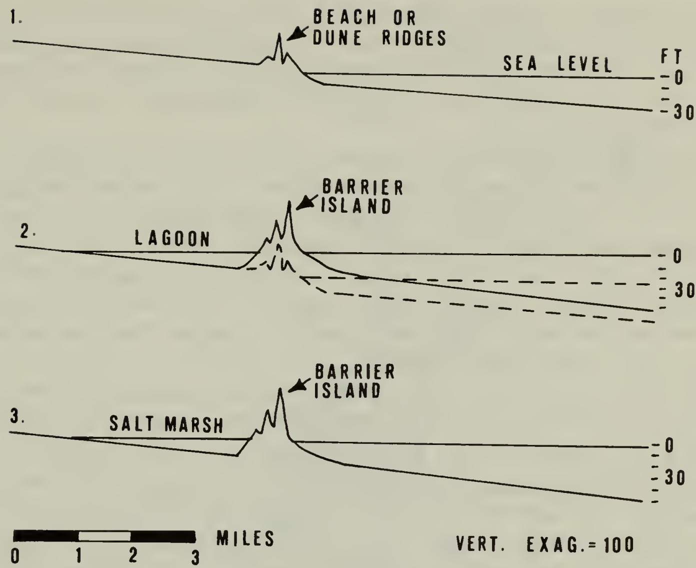

Fig. 5. Formation of barrier islands by submergence. *1*. Beach or dune ridges form adjacent to shoreline. *2*. Rising sea level results in inundation of areas landward of ridge to form barrier island and lagoon. (From Hoyt 1968c.)

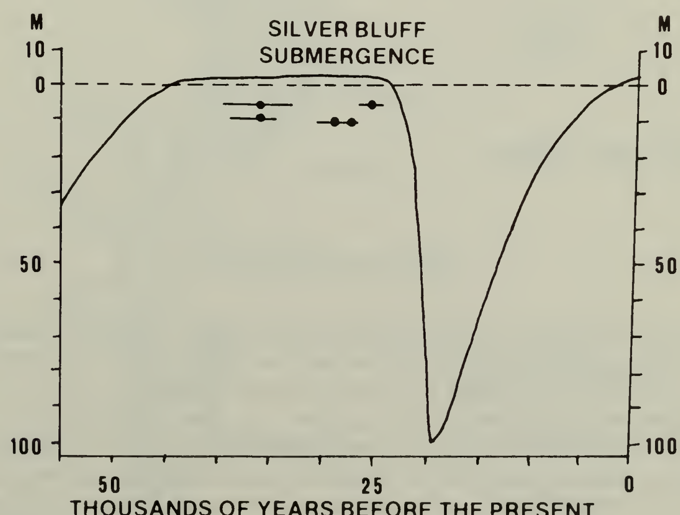

Fig. 6. Diagram showing altitude of sea level during past 55,000 years. Control points are from carbon 14 dates of shells from Sapelo Island. Length of horizontal line represents age uncertainty. Sea level altitudes from 18,000 years to present compiled from several published sources. (From Hoyt 1968c.)

36,000-25,000 years old. These ages give a rough idea of the time the main parts of Sapelo and St. Simons islands formed. The seaward parts of these islands have formed within the last 4000-5000 years (Holocene). Figure 7 indicates which islands and parts of islands are Silver Bluff (Pleistocene) in age and which are modern (Holocene).

The geologic development of the lower Georgia coast is the result of barrier island formation during stages of the Pleistocene when sea level was higher than it is now. The oldest series of islands formed when sea level was as much as 100 feet higher than it is now (Wicomico shoreline). At that time a great barrier island, now called Trail Ridge, formed in front of the area now known as the Okefenokee Swamp (Fig. 8), which was then a very large salt marsh. The Wicomico barriers can be traced across coastal Georgia. They are discontinuous now but were formerly more extensive.

Subsequent to the development of the Wicomico barrier, there was another period of ice formation and melting, and another sequence of barrier islands developed at a slightly lower altitude (about 75 ft above present sea level) known as the Penholoway shoreline (Fig. 9). Five subsequent fluctuations of sea level resulted in five additional systems of barrier islands now above sea level and traceable across coastal Georgia: Talbot, 40-45 ft; Pamlico, 25 ft; Princess Anne, 15 ft; Silver Bluff, 5 ft; and Holocene (Hoyt and Hails 1967) (Figs. 10,11).

Beaches and dunes

Physical features

The seaward side of Georgia's barrier islands is made up of fine quartz sands (Greaves 1966) which form the beaches and dune ridges. The beach is the gently sloping shore which is washed by waves and tides. It extends from the normal high tide line to 30 ft below the low tide line. The beach and dune area is commonly characterized by the following zones (Fig. 12): (1) Shoreface—the narrow zone seaward from the low tide shore line permanently covered by water over which the beach sands and gravels move with wave action. (2) Foreshore—the lower shore zone between ordinary low and high water levels. (3) Backshore—the upper shore zone beyond the reach of ordinary waves and tides extending to the base of the dunes. (4) Dunes—ridges of windblown (eolian) sand.

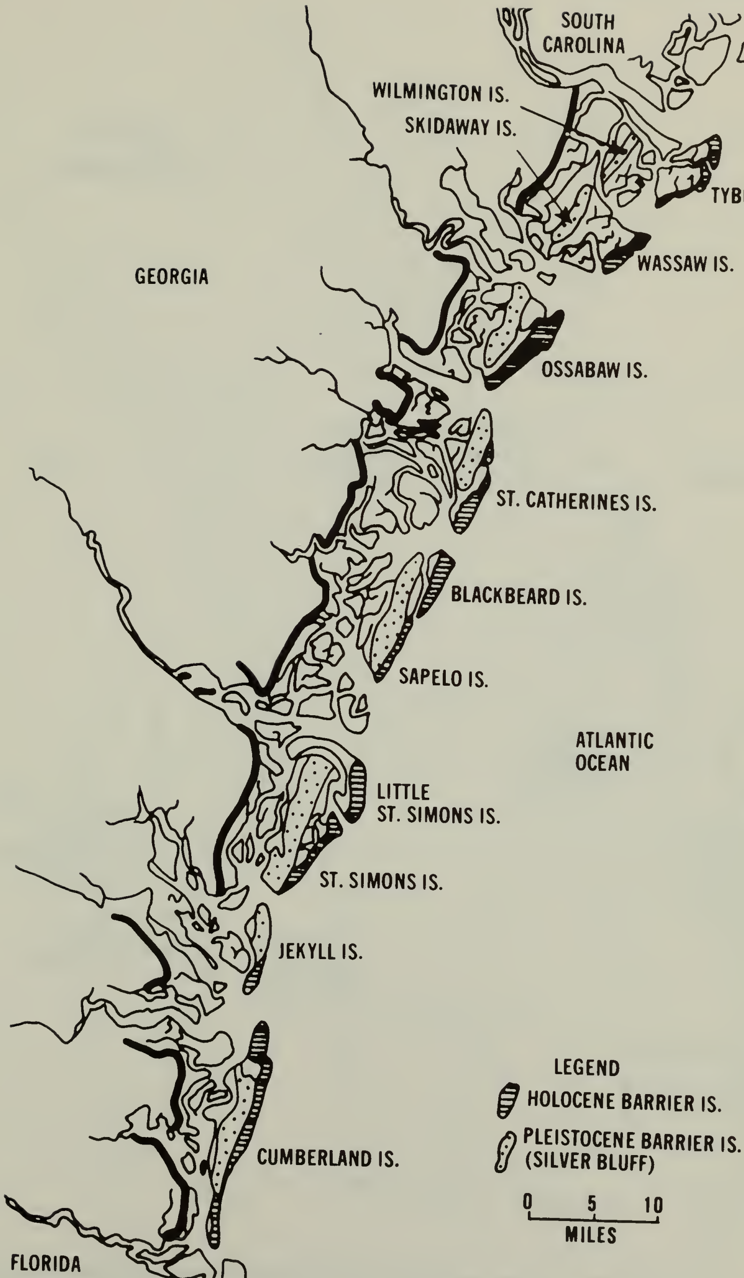

Fig. 7. Geologic ages of the barrier islands of Georgia. (From Hoyt 1968c.)

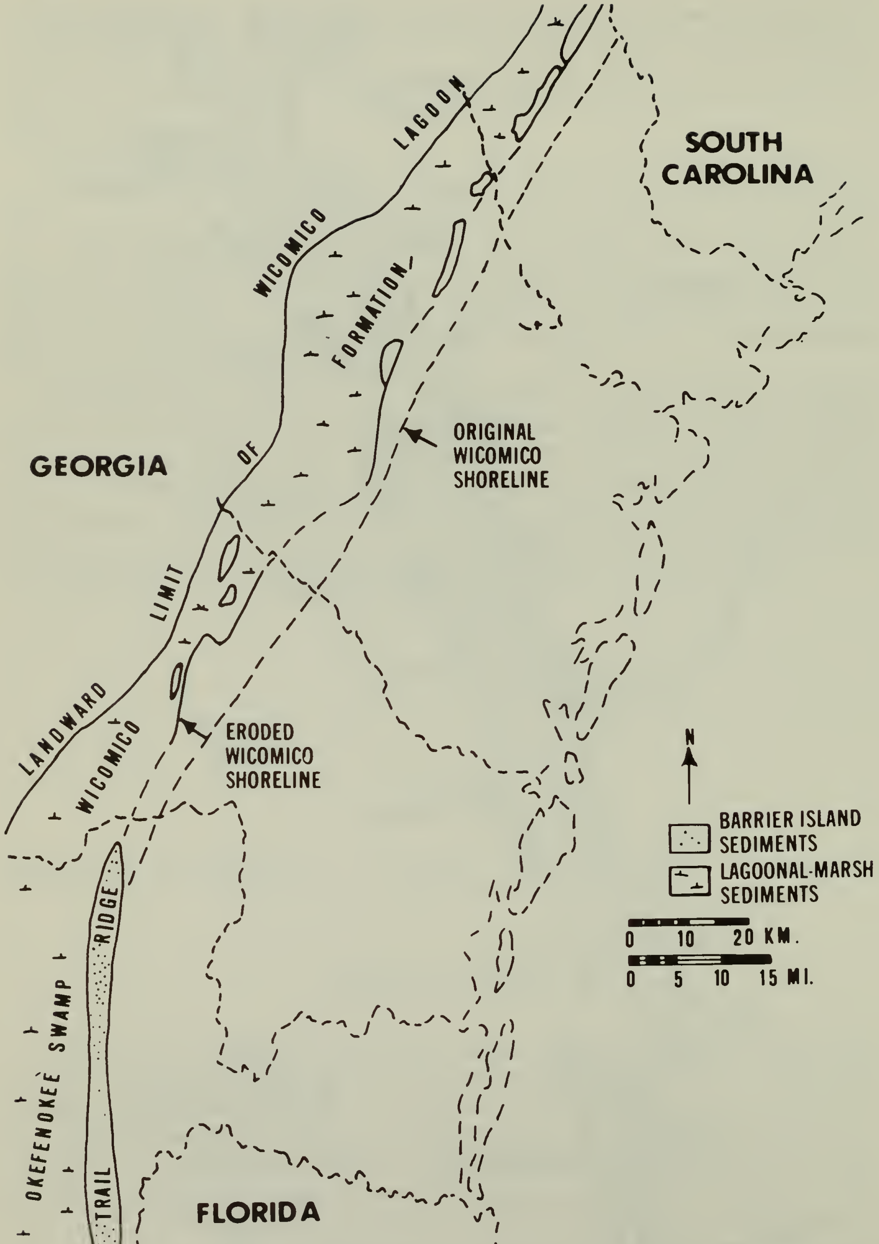

Fig. 8. Locations of former barrier islands and salt marshes along eroded Wicomico shoreline (sea level altitude, 95-100 ft). Inferred location of preerosion shoreline also indicated. (From Hoyt 1968c.)

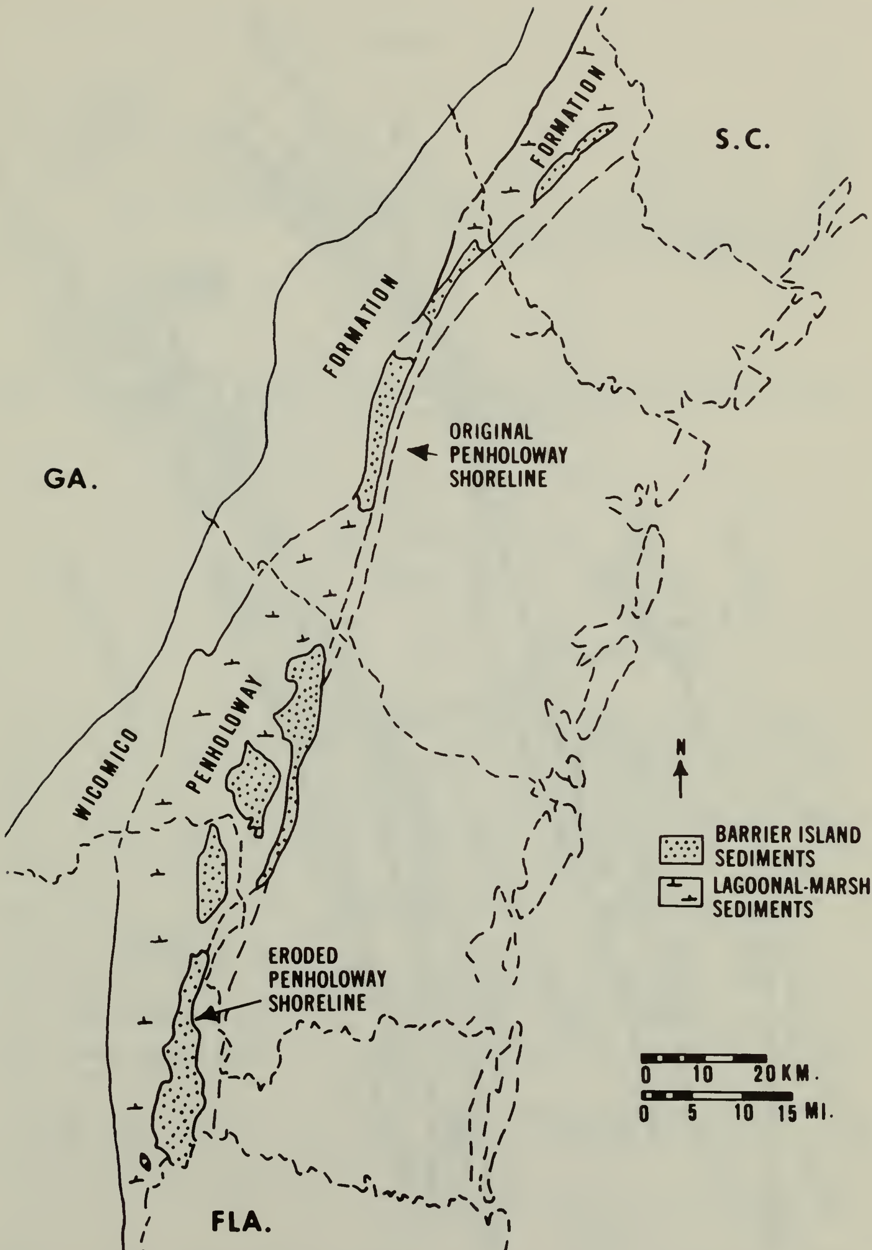

Fig. 9. Locations of former barrier islands and salt marshes along eroded Penholoway shoreline (sea level altitude, 70-75 ft). Inferred location of preerosion shoreline also indicated. (From Hoyt 1968c.)

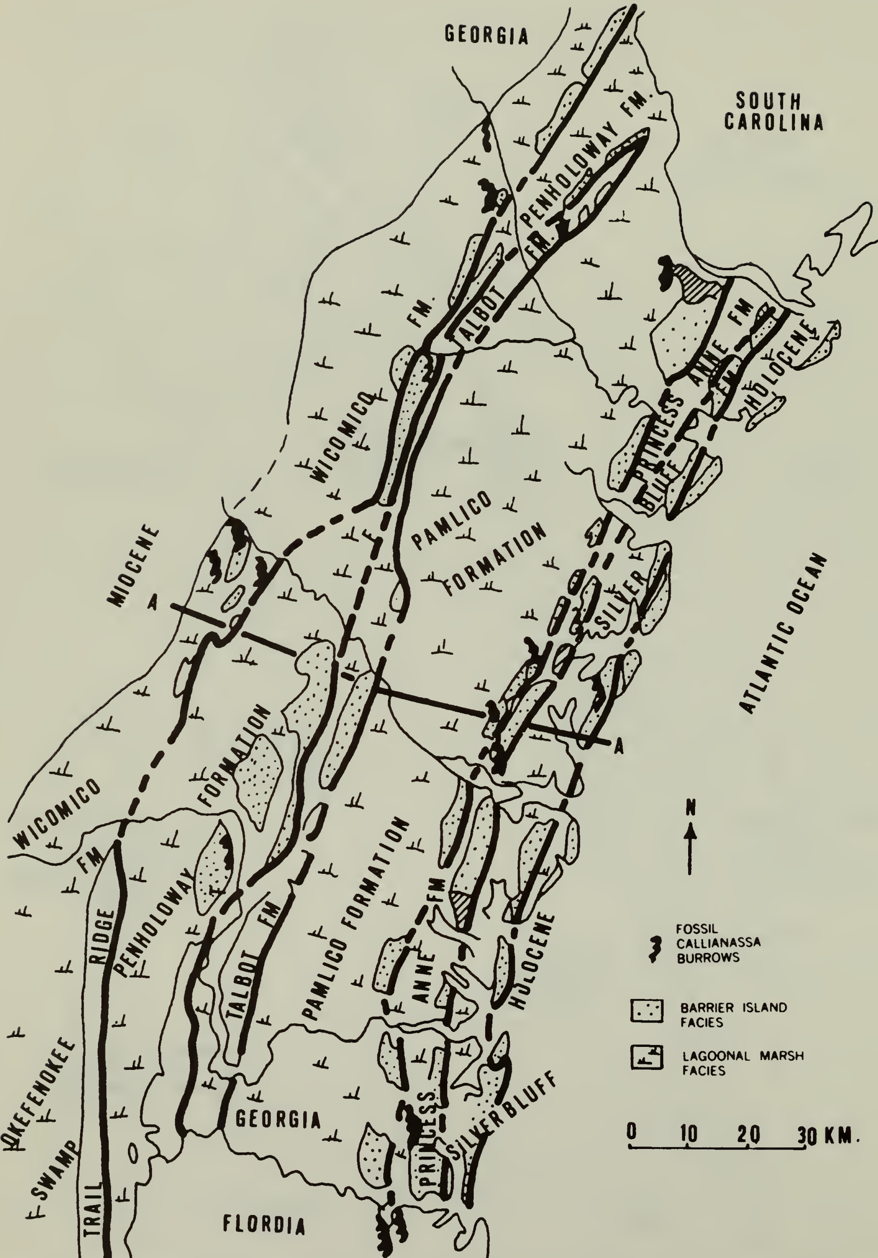

Fig. 10. Locations of barrier island and lagoonal-salt marsh sediments for six sequences of Pleistocene coastal deposits and for the Holocene deposits. (From Hoyt 1968c.)

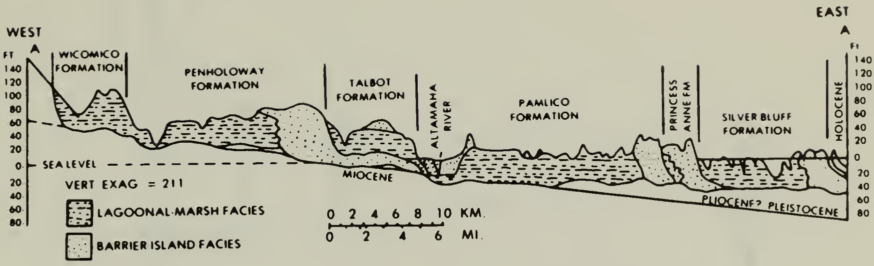

Fig. 11. Cross-section of Pleistocene and Holocene sediments of coastal Georgia. Location of cross-section shown on Fig. 10. (From Hoyt 1968c.)

The beaches and dunes are constantly being resculptured by the action of waves, currents, and wind, which interact to keep the beaches and dunes in a dynamic state. Baldwin and Lofton described six beach types used as nesting sites by loggerhead sea turtles on Cape Island, S.C. (Caldwell 1959). These types, described below and in Fig. 13, are also geologically descriptive of those occurring in coastal Georgia. Many, if not all, of the types may occur on each barrier island. The dynamic state of the beaches and dunes often produces a gradation from one type to another.

A. Truncate dunes: Sharply eroded dunes backing a beach 5-10 ft wide on an average high tide. Unusually high tides erode the base of these dunes.

B. Ledge section: A stretch of beach having a 0.5-3 ft ledge breaking the middle of its natural slope. This type is formed by the action of wind and tide (undertow) and is variable.

C. Wide sloping beach: Twenty-five to 40 ft wide from average high tide line to base of dunes. The outer dune forms a continuous ridge paralleling the ocean front and is broken in only a few places.

D. Narrow flat beach: Ten to 20 ft wide and backed by small separated dunes.

E. Wide flat beach: Similar to the narrow flat beach, 30-50 ft wide and backed by small isolated dunes.

F. Barren areas: Stretching 100-400 ft back from the crest of the beach, with only traces of vegetation or low dunes to break their flatness.

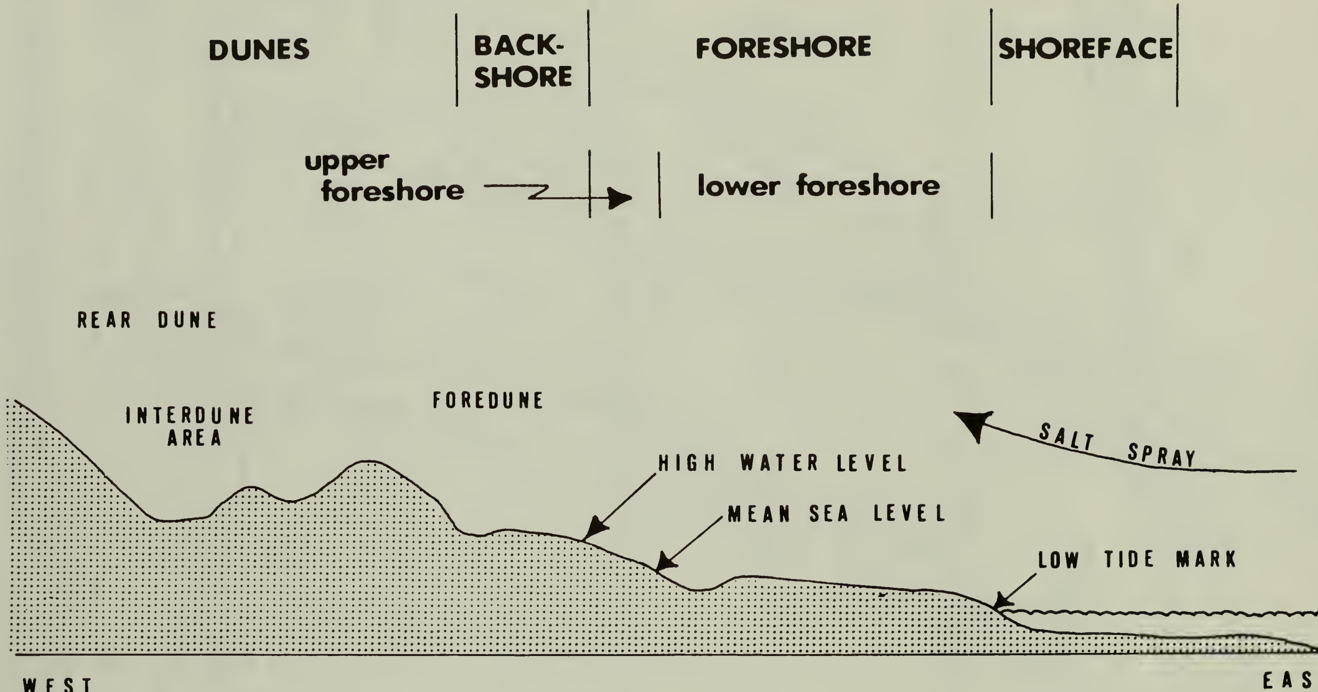

Fig. 12. Typical profile of beach and dunes showing zonation.

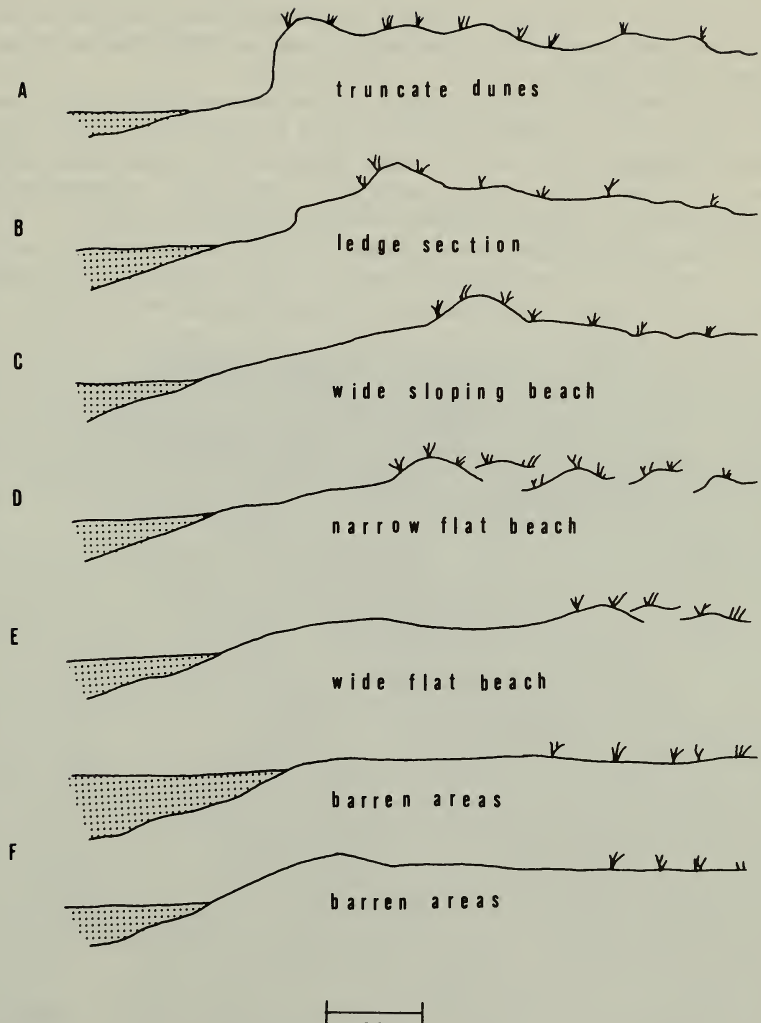

Fig. 13. Diagrammatic cross-sections of generalized beach types occurring on the barrier islands. See text for explanation. (Adapted from Caldwell 1959.)

EFFECTS OF WAVES AND CURRENTS ON BEACH MORPHOLOGY AND STRUCTURE

Waves are formed when water particles are set into orbital motion by wind action. The height (amplitude) and energy of waves depend on the velocity and duration of wind and the extent of open water across which the wind can blow (fetch). The maximum fetch for the Georgia coast is 4000 miles to the east-northeast (Greaves 1966).

The Georgia beaches occur in a region of moderate wave energy—the lowest recorded along the southeastern Atlantic coast (Tanner 1960). The average height of breaking waves on the Georgia coast is 9-12 inches (Helle 1958). Because of a gently sloping terrace, water deepens gradually along the Georgia coast and much wave energy is dissipated before reaching the beaches.

As the waves enter shallow water, the drag of the bottom distorts the orbital motion of water molecules, shortens the wave length and the wave becomes steeper and forms a crest. The cresting wave breaks when the water depth is one to two times the amplitude of the wave. The more gradual the slope of the beach and continental slope, the farther offshore the waves will break.

The turbulence in the breaker zone and the swash of waves on the beach constantly rearrange sand particles and reshape the shoreline. Materials stirred up by waves are deposited as offshore bars just inland from the zone of greatest breakers. Sand grains are repeatedly carried onto the beach by the swash and carried back out with the backwash.

Lateral bars and troughs (ridges and runnels) commonly develop on the lower foreshore. Troughs on Sapelo Island are 20-40 ft wide and retain water at low tide (Greaves 1966). They apparently are formed by breaking waves. Troughs are separated by bars 0.5-3 ft high and 50-100 ft wide which are formed, at least in part, of materials from the troughs (Greaves 1966). The seaward slope of bars is usually less than 2°, whereas the landward slope is considerably steeper (up to 30°) (Hoyt 1962; Hoyt and Hails 1967).

The foreshore is commonly marked by water ripples of various types. Backwash ripples on the upper foreshore have rounded crests and narrow troughs. Oscillation ripples have sharp, symmetrical crests with broader troughs and occur in troughs (runnels) on the foreshore (Hoyt et al. 1966). Current ripples are produced by current flowing steadily out of troughs at low tide (Hoyt et al. 1966). They have a long, gentle slope on the upper side and a shorter, steeper slope on the lee side. Rhomboid ripples occur along crests of bars and are formed by water flowing landward over the bar (Hoyt and Henry 1963).

Several features are produced by the entrapment of air in the sands of the upper foreshore. Bubbled sand results in a very soft beach surface (Hoyt and Henry 1964), and sand domes about 4 inches in diameter are produced when trapped air forces up a thin layer of surface sand (Hoyt et al. 1966).

On beaches in other areas there are major seasonal changes in beach profiles. During the summer, when wave energies are lowest, many sand grains are not moved out with the backwash and there is a net movement of sand landward. This results in the gradual buildup of sand on the backshore. A horizontal bed of sand (a berm) extends from the foot of the dunes to a pronounced beach ridge at the high-tide mark. The berm area serves as a source of sand for replenishment and growth of the dunes. In the fall and winter wave energy is greater, the berm erodes, and there is a net movement of sand from the beach to the breaker zone where it is deposited as an offshore bar.

But on most Georgia beaches the berm is poorly formed because seasonal changes in wave energy are relatively slight. The backshore typically slopes gradually, and there is no pronounced beach ridge. There is no consistent difference in slope between winter and summer beaches (Pilkey and Richter 1964), although there is a constant exchange of sand between the dunes, the beach, and the offshore bar.

There is also a longshore movement of sand caused by littoral currents. A pattern of north-to-south sediment transport is well documented (e.g., Hoyt et al. 1964; Greaves 1966; Frey and Howard 1969; and others). Islands are eroding (Fig. 14) on the north and aggrading on the south. For example, the erosional

Fig. 14. Aerial photograph of acute beach erosion on the northern end of Wassaw Island, May 1970.

process is evidenced in Fig. 15 by the sharply truncated dune ridges on the north end of Blackbeard Island. The sediment from the erosion is transported southward and deposited at the south end of Sapelo Island where beaches are prograding and dunes are increasing in size. Thus, the islands are shifting southward. Hoyt and Henry (1967) estimate a southward advance of Sapelo Island of about 0.75 mile during the present (Holocene) high stand of the sea. The rate of movement varies and may be much greater on some islands.

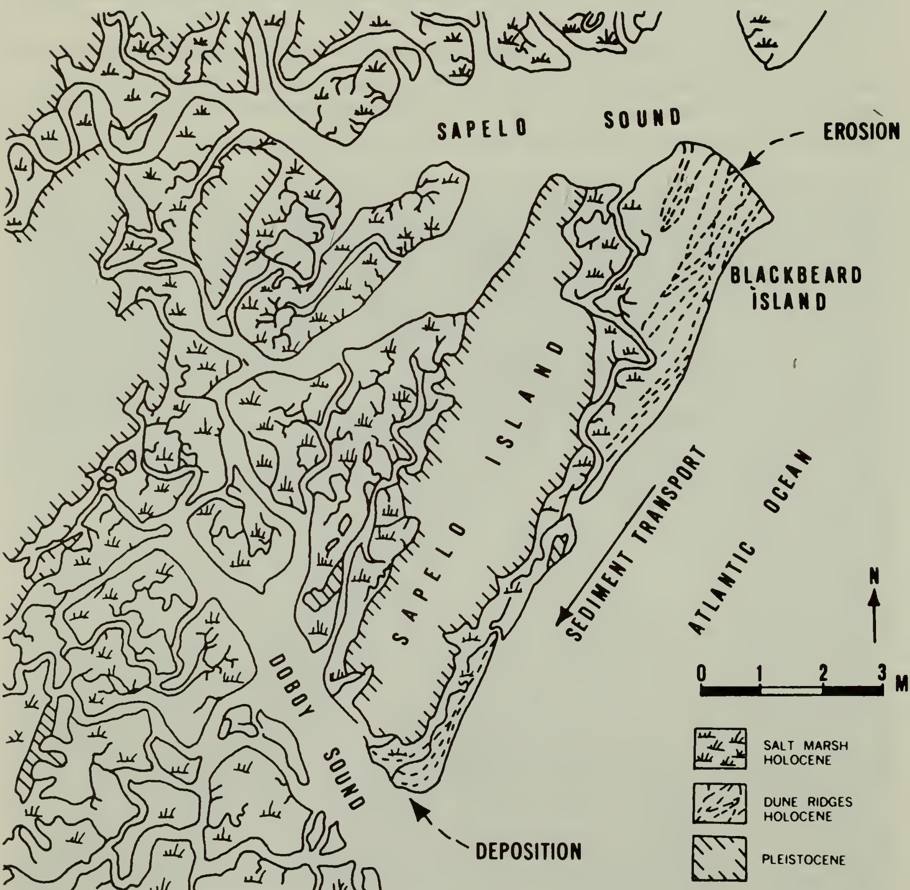

Fig. 15. Patterns of sediment deposition, erosion, and transport, Sapelo Island and vicinity. (From Hoyt 1968c.)

DUNE FORMATION

Dunes form as a result of windblown sand piling up behind minor obstacles. Once started, the dune itself becomes an obstacle to windblown sand, and the lodgment of more sand causes the dune to grow. Dunes and dune ridges along the Georgia coast normally grow to 10 or 12 ft in height (occasionally much higher) and acquire a distinct morphology characterized by gentle windward and steeper leeward slopes. Surface ripples parallel the dune ridge at right angles to the wind.

Vegetation plays an important part in the formation and stabilization of dunes. Salt-resistant beach plants trap windblown sand, forming little mounds of sand or dunelets which grow as the plants respond with increased growth and trap more sand. These foredune plants must have the ability to withstand salt spray, roots that will endure exposure, and stems that will withstand burial by shifting sands. They must be perennials able to keep above the sand, spread laterally, and withstand drought (Cowles 1899).

Sea oats (*Uniola paniculata*) is the most important dune-former on the Georgia coast (Fig. 16). Sometimes sea beach panic grass (*Panicum amarum*) also may form substantial dunes. Other species produce only low, temporary dunes because they lack a sufficient lateral root system, have excessive water requirements, or lack the ability to keep above the sand (Kurz 1942). Wagner (1964) conducted detailed studies on the ecology of sea oats and their role in the formation of dunes. The following discussion is based upon his work.

Spikelets fall from the plant late in the fall and early in the winter and are rapidly disseminated by the wind. Spikelets falling on sites of sand accretion are rapidly buried. (Most of those falling on stable sites are eaten by birds and mammals.) Seedlings are produced in the spring and become established during the first growing season. During the second season, extensive tillering occurs. For several years thereafter plants put on vigorous growth, followed by flowering. Colonization is by windblown seed dispersal followed by tillering to enlarge the colony. Sea oats trap windblown sand and respond to the sand deposition with vigorous growth of rhizomes and vertical shoots. This stimulates further growth and the process continues until dunes form in a series of parallel ridges. Sea oats are replaced by other vegetation when the dunes become partially stabilized.

Dunes cease vertical accretion when they have reached such a height that wind no longer can transport sand to the top. New dunes then form to the windward (seaward) side. Thus, the largest dunes are farthest inland, sheltering the forest behind.

Even partially vegetated dunes are subject to blowouts and shifting. Erosion of dunes is accelerated by grazing, human activity, or other disturbance. When the sand on the windward slope is not anchored, it is continually carried over the top by the wind and deposited on the lee side, resulting in migrating or "marching" dunes. Dunes may protect the forest during its formation only to bury it later (Oosting 1954) (Fig. 17). Oosting and Billings (1942) reported that grazing transformed several of the banks in North Carolina into almost barren seas of

Fig. 16. Sea oats (*Uniola paniculata*), an important plant in dune stabilization. (Photograph by Merry M. Tyler.)

shifting sand. Similar damage from grazing has been reported from South Carolina and Texas (Johnson 1900: Cottam 1970) and is evident on several islands along the Georgia coast (Fig. 18). Storms may breach the dunes, especially where erosion has occurred, creating blowouts and unstable terraces and damaging trees and shrubs (Oosting 1954; Wagner 1964).

Fig. 17. Large dune encroaching upon interior forest on Cumberland Island. Height of the dune is approximately 45 ft, June 1971.

Fig. 18. *Top*. Natural dune system on Blackbeard Island, June 1971. Dunes are well-stabilized by sea oats and other vegetation. *Bottom*. Severely overgrazed beachfront on Cumberland Island, June 1971. Overgrazing has resulted in the loss of dune vegetation with the subsequent loss of the dune system resulting in a wide, flat beachfront. Extremely high tides (storm induced) may inundate the entire beachfront and erode the older, well-established dune systems protecting the island interior.

COMPOSITION OF BEACH AND DUNE SAND

Constant washing and grinding wears down sand grains and sorts them as to size, resulting in a lamination of beach particles.

A regional sorting of materials might be expected as a result of the southward movement of sediments. Studies indicate, however, that the composition of beach sands is primarily related to source materials and regional wave energy (Giles and Pilkey 1965; Giles 1966). Sands of Georgia beaches and dunes are of finer median grain size than those farther north and south, apparently because higher wave energies transport coarser sands (Giles and Pilkey 1965; Giles 1966).

Samples of sands from Georgia beaches contained virtually no calcium carbonate, whereas this was an important component of beach sands to the north and south (Giles and Pilkey 1965; Giles 1966). This too is apparently a result of the inability of waves of low energy to transport, fragment, and abrade shells (Giles and Pilkey 1965; Giles 1966). Dunes along Georgia beaches contain relatively few shell fragments.

Heavy minerals in sands of Georgia beaches have been analyzed by Neiheisel (1962, 1965, 1966), Giles and Pilkey (1965), and Giles (1966). The most prevalent heavy minerals on beaches at Jekyll Island are ilmenite, zircon, and epidote (Neiheisel 1962). Other components of the heavy mineral fraction of beach sands are as follows: tourmaline, sillimanite, kyanite, staurolite, hornblende, garnet, rutile, leucoxene, and monazite (Neiheisel 1962). Neiheisel (1962) showed that heavy minerals in sands on Jekyll Island are evidenced as (1) thin, narrow, black surface seams concentrated in the upper littoral zone; (2) thin horizontal beds of black sand extending shoreward beneath dunes; (3) cross-bedded lamination in dunes; and (4) disseminated particles in beach and dune sediments. The distribution of heavy minerals as a result of selective sorting by waves is determined largely by mineral shape and density. Heavier minerals occur in greater concentration lower on the beach (Neiheisel 1962). On Jekyll Island the heavy mineral fraction comprised 50-90% of enriched concentrate on the upper beach, 5-30% of the laminations and thin bands in the foredunes, and only 4-5% disseminated in average dunes (Neiheisel 1962).

SOURCES OF BEACH AND DUNE SAND

The principal sources of heavy minerals and sands on the Georgia coast are (1) the Altamaha and Savannah watersheds which originate in the Piedmont and mountain areas of the state; (2) the smaller Coastal Plain watersheds that are of more recent origin; and (3) suspended material from the continental shelf.

Heavy minerals of the beaches and dunes more closely resemble assemblages from the Piedmont rivers than they do assemblages from Coastal Plain rivers (Giles 1966). This suggests that Coastal Plain rivers are not important contributors to present beach sediments (Giles 1966).

There is also an apparent relationship between the composition of beach sands and the mineralogy of the adjacent continental shelf, and continental shelf material is another important sediment source (Giles and Pilkey 1965; Giles 1966; Levy 1968).

The salt spray community of plants

Few species of vascular plants can survive the extremely harsh physical environment of the beaches and dunes. In order to inhabit this area, plants must possess characteristics enabling them to withstand the combined effects of salt spray, constant wind, full light intensity, high evaporation, and high temperatures. They must be capable of becoming established in and keeping above the shifting sands. Distance from the surf and location relative to dunes or protective vegetation on the seaward side will determine the exposure of a site to these limiting factors. Thus there is a gradient or, more commonly as a result of the modifying effect of the dunes, a zonation of vegetation from mean high tide toward the interior of the island.

Most ecologists attribute this zonation to the effects of salt spray or to the combined effects of salt spray and wind (Wells and Shunk 1937; Wells 1942; Doutt 1941; Boyce 1954). Studies by Boyce (1951,1954) revealed that salt spray forms as a result of droplets of sea water being forcefully ejected from the crests of waves and the bursting of bubbles during effervescence of foam. These droplets are concentrated by evaporation and transported inland by winds as a salt spray to be deposited on sands and vegetation. Droplets deposited on the surface of the sands remain there until rain leaches the salts out of the porous sand. Consequently, there is no significant salinity in dune soils and little chloride is absorbed through the roots of plants. There is apparently no correlation between soil salinities and plant distribution on the dunes (Oosting and Billings 1942; Boyce 1954). Boyce concludes that the limiting effect of salt spray results from direct deposition on the foliage and that the plants best adapted to the salt spray are those with characteristics that minimize deposition and absorption of salts.

Zones of beach vegetation have been classified in various ways (Wells 1942; Boyce 1954; Oosting and Billings 1942; Oosting 1954). Although this progression of vegetation types is commonly referred to as successional, the concept of succession is probably not applicable to the beach-dune environment because of the overwhelming effects of harsh physical factors. Apparent successional relationships between zones are not primarily a result of reaction of plants on habitat (Oosting 1954).

No studies of beach and dune vegetation have been reported from Georgia, and the discussion of vegetation that follows is based upon the authors' observations in Georgia, published reports from North Carolina (Wells and Shunk 1937; Oosting and Billings 1942; Wells 1942; Doutt 1941; Oosting 1945; Boyce 1951,1954; Oosting 1954; Wagner 1964) and Florida (Kurz 1942), and unpublished lists of plants from several Georgia islands.

Plants occurring on the beach include sea rocket (*Cakile* spp.); beach hogwort (*Croton punctatus*); beach sandspur (*Cenchrus tribuloides*); salt meadow cordgrass (*Spartina patens*); salt wort (*Salsola kali*); sea-purslane (*Sesuvium* spp.);

beach-spurge (*Euphorbia polygonifolia*); and seashore-elder (*Iva imbricata*). Principal plants of the foredunes are sea oats, sea beach panic grass, railroad vine (*Ipomoea stolonifera*), beach pennywort (*Hydrocotyle bonariensis*), Spanish-bayonet (*Yucca* spp.), and some of the plants of the beach (e.g., seashore elder, beach spurge, and sea rocket). Annuals such as camphorweed (*Heterotheca subaxillaris*) may temporarily colonize dunes until killed out by salt spray.

The foreslope and the crest of the foredunes are subject to the greatest intensity of salt spray. Little salt is deposited on the lee slope of the foredunes or in the interdune area. In these areas principal species include, in addition to some of the species previously mentioned, little bluestem (*Andropogon scoparius*), prickly pear (*Opuntia* spp.), seaside goldenrod (*Solidago sempervirens*), beach primrose (*Oenothera humifusa*), juniper (*Juniperus virginiana*), yaupon (*Ilex vomitoria*), wax myrtle (*Myrica cerifera*), and live oak (*Quercus virginiana*).

Bluestem occupies the drier sites. Low, flat areas behind breaks in the foredunes that are periodically inundated by unusually high tides may be occupied by stands of salt meadow cordgrass (Oosting and Billings 1942; Oosting 1945).

Salt spray, after passing over the interdune area, next contacts the windward slope of the rear dunes and is deposited on the vegetation that occurs there. Consequently, sea oats and other salt-tolerant plants of the windward slope of the foredunes are also dominant there. Behind the crest of the rear dunes, sites are more protected and vegetation is more diverse. Shrubs and trees may dominate this area. Trees and shrubs most commonly occurring in this zone are live oak, red bay (*Persea borbonia*), wax myrtle, juniper, yaupon, cabbage palm (*Sabal palmetto*), saw palmetto (*Serenoa repens*), and groundselbush (*Baccharis halimifolia*).

Shrubs and trees are commonly pruned by the wind and salt spray, producing a sloping, sheared effect (Fig. 19). Studies by Boyce (1954) have shed light on the mechanism by which the salt spray produces this effect. Salt enters the leaves through abrasions caused by the lashing of wind action. High chloride ion concentration produces necrosis and death of exposed leaves and branches. Chloride ions are transported to the leaf apices and twigs and accumulate there. They are not translocated to the leeward side of the tree in injurious quantities, so only the windward sides of the plants are killed, producing an asymmetrical form. Pruning stimulates vigorous sprouting which results in the rapid formation of a dense canopy that reduces the efficiency of deposition on the plant and on the individual stems. Most dune plants have a uniformly closed crown which is less efficient in accumulating salt deposition. Projecting limbs subject to greater salt accumulation are killed. Mechanical action of winds that prune and bend leaves and branches and high transpiration rates augment the effects of salt spray.

Wells and Shunk (1937, 1938) listed characteristics of the live oak that are advantageous in a salt spray environment, and Wells (1939) designated the live oak forest as a "salt spray climax," but this concept has been strongly challenged (Oosting 1954; Laessle and Monk 1961).

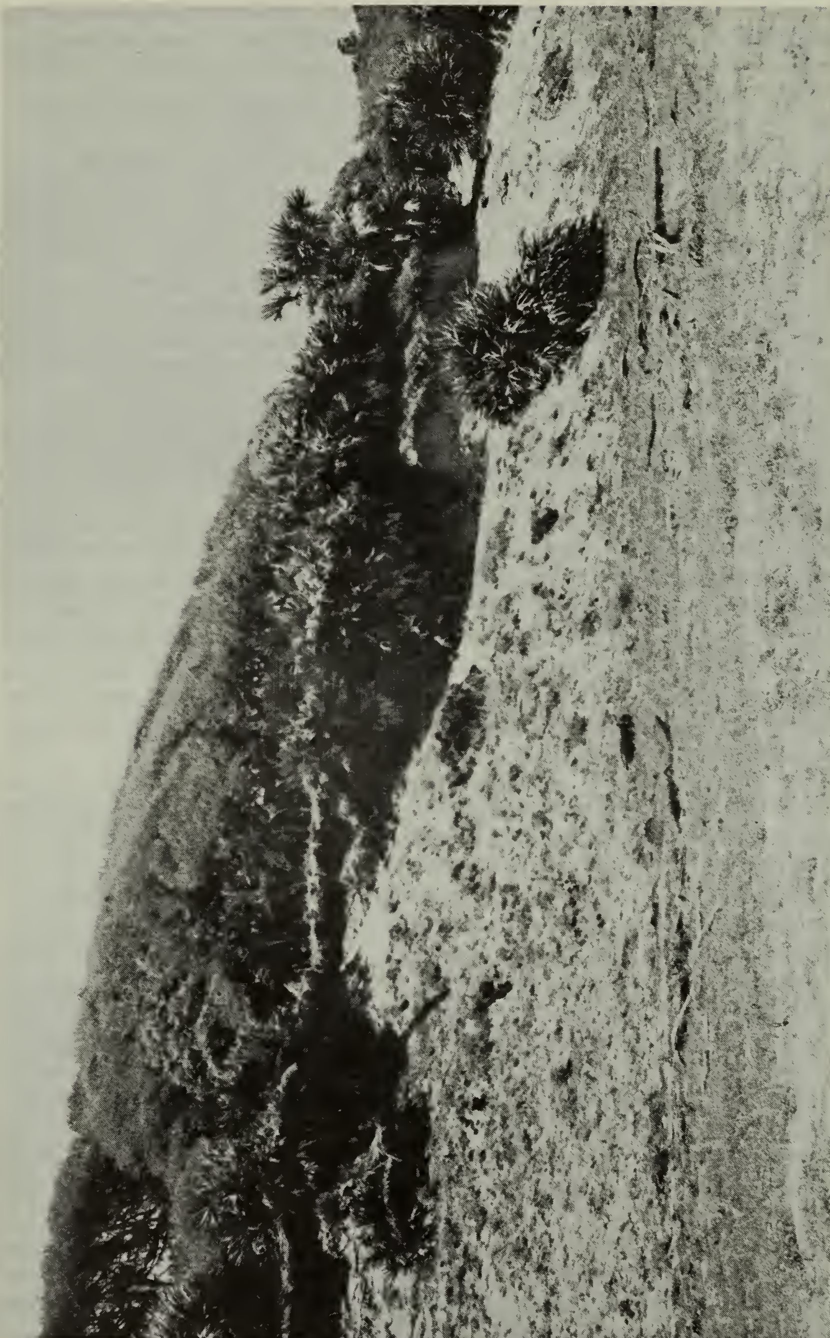

Fig. 19. Live oaks pruned by wind and salt spray on St. Catherines Island. (Photograph by H. N. Neuhauser.)

Animals and food webs

THE TIDAL BEACH

The monograph of Pearse at al. (1942) described the ecology of tidal beaches in North Carolina and listed the inhabitants of beach zones. Studies of the beach fauna in Georgia are limited to a survey of isopods (Frankenberg and Menzies 1966), a study of amphipods and associated fauna (Croker 1967), and studies of species that leave tracks and trails in the geologic record (Frey and Howard 1969). Table 5 is a compilation of the species listed in these three works. It is by no means complete or comprehensive, but it may serve as a preliminary listing of the major infauna.

Sand beaches are harsh environments requiring highly specialized adaptations. They are areas between land and sea that are alternately flooded and drained. While flooded, the substratum may be drastically rearranged, and inhabitants are preyed upon by predators from the sea. When drained, at low tide, the beach is exposed to the desiccating effects of sun and wind, and inhabitants are preyed upon by predators from the land.

Permanent inhabitants burrow into the sands at low tide, thus avoiding desiccation and exposure to predation. Many other species use the beach as a feeding ground, either occupying it when it is covered with water (e.g., fish, crabs) or foraging there as the tide recedes (e.g., shorebirds).

The distribution of burrowing forms is greatly influenced by the size of sand grains which determines pore volume and thus moisture and oxygen content. There is a zonal segregation where tides ebb and flow. The coarsest particles are found where wave energy is greatest. Finer sediments occur above and below the tidal zone. Consequently, there is a zonation of burrowing fauna (Pearse et al. 1942). Because of low wave energies, the median size of sand grains on Georgia beaches is smaller than on beaches to the north and south (Giles and Pilkey 1965).

Burrowing forms usually lack pigment, have reduced sense organs, and have highly specialized adaptations that allow burrowing and feeding (Pearse et al. 1942). Burrow structures (*lebensspuren*) are abundant, especially in the lower foreshore. The more distinctive ones are produced by ghost shrimp (*Callianassa* sp.), mole crabs (*Lepidopa* sp.), sandworms (Class Polychaeta), razor clams (*Tagelus* sp.), acorn worms (Phylum Hemichordata), and sea cucumbers (*Synapta* sp.) (Frey and Howard 1969). The deep burrows of ghost shrimp are especially evident and have been useful in ascertaining Pleistocene sea levels on the Georgia coast (Weimer and Hoyt 1964).

More active inhabitants include various gastropods, sand dollars (*Mellita* sp.), and brittle stars (Class Ophiuroidea) (Frey and Howard 1969).

In the spring and early summer, horseshoe crabs (*Limulus polyphemus*) appear on the beaches in large numbers to breed and lay their eggs. The female scoops out a shallow depression in the moist sand slightly below or at the high-tide line

TABLE 5. *Some infauna of barrier beaches in Georgia.*[a]

Organism	Tidal zone[b]
Phylum Cnidaria (Coelenterata)	SF
Sagartia lacteus	
Phylum Nemertinea	
Cerabratulus lacteus	SF-LF
Micrura sp.	
Phylum Sipunculoidea	
(unidentified)	mid-FS
Phylum Mollusca	
Class Pelycepoda	
Dinocardium robustum	SF
Donax variabilis	LF-UF
Mactra fragilis	LF-UF
Tagelus divisus	SF
Tagelus pleveius	SF
Tellina agilis	SF
Class Gastropoda	
Busycon carica	SF-LF
Busycon perversum	SF-LF
Oliva sayana	SF-LF
Polinices duplicatus	SF-LF
Sinum perspectivum	SF-LF
Terebra dislocata	SF-LF
Phylum Annelida	
Class Oligochaeta	
(unidentified)	mid-FS
Class Polychaeta	
Diopatra cuprea	SF-LF
Heteromastus sp.	SF
Laonereis culveri	UF
Nephthys picta	SF-LF
Onuphus microcephala	SF-LF
Owenia fusiformis	SF
Paraonis sp.	SF
Pectinaria gouldii	SF
Scololepsis sp.	FS
Scoloplos sp.	UF
Spiochaetopterus oculatus	SF
Streblospio benidicti	SF

[a]Compiled from Frankenberg and Menzies (1966), Croker (1967), and Frey and Howard (1969).

TABLE 5. *Some infauna of barrier beaches in Georgia.*[a] *(continued)*

Organism	Tidal zone
Phylum Arthropoda	
Class Crustacea	
Order Cumacea	
Bodotriid	SF
Order Isopoda	
Ancinus depressus	
Chiridotea caeca	
Cyathura polita	
Exosphaeroma diminutum	
Sphaeroma quadridentatum	
Order Amphipoda	
Acanthohaustorius sp.	LF
Corophium sp.	SF
Haustorius sp.	UF
Lepidactylus dytiscus	mid-FS
Monoculodes sp.	FS
Neohaustorius schmitzi	FS
Parahaustorius longimerus	LF
Protohaustorius deichmannae	SF
Pseudohaustorius caroliniensis	SF
Talorchestia sp.	UF
Order Decapoda	
Callianassa major	SF-UF
Callianassa atlantica	SF-LF
Emerita talpoida	SF
Lepidopa websteri	LF
Ocypode quadrata	UF-BS
Ogyrides alphaerostris	SF
Pagurus longicarpus	SF
Pinnixa chaetopterana	SF
Phylum Echinodermata	
brittle stars	SF
Mellita quinquiesperforata	SF-LF
Synapta inhaerens	SF
Phylum Hemichordata	
Saccoglossus kowalevskii	SF
Balanoglossus biminiensis	SF

[b]BS = backshore; FS = foreshore;
LF = lower foreshore; SF = shoreface;
UF = upper foreshore.

in which she deposits 200-300 eggs, which are immediately fertilized by the male. The female then quickly covers the nest and the pair returns to the surf (Lochhead 1950). Late in the summer tiny crabs may be seen on the beach sand at low tide. The breeding and reproductive stage of the life cycle is the only time horseshoe crabs come ashore. Both young and adults normally feed in the bottom habitat of shallow waters. Some of the largest individuals of the species have been reported from the Georgia coast (Shuster 1955).

There is considerable nutrient exchange between the beach and the sea. Much organic matter of marine origin, especially macroscopic algae, is washed up on the beach. Brown algae (Phaeophyta) of the genus *Sargassum* may virtually cover the beach after high winds (Caldwell 1968). Additional organic matter is contributed by cordgrass (*Spartina*) stems and bird droppings. This organic matter is acted upon by bacteria, which are abundant in the beach sands (Pearse et al. 1942). The products of bacterial decomposition are dissolved and returned to the sea. The bacteria themselves form one of the bases of the food chain, being fed upon by copepods, nematodes, flatworms, protozoa, and amphipods (Pearse et al. 1942). Another important base of the food chain involving beach animals is one-celled algae.

Beach invertebrates are predators, plankton-feeders, or detritus-feeders. Many plankton- and detritus-feeders have bristle-like structures (setae) on the legs (*Callianassa*), the antennae (*Emerita*), or mouth parts (*Lepidopa*) for collecting small particles of organic matter (Pearse et al. 1942). Burrowing clams (e.g., *Donax*) siphon water through the mantle cavity and catch organisms on threads of slime (Pearse et al. 1942). Other animals (e.g., *Balanoglossus*) ingest large quantities of sand, digesting the organic matter, and passing the remainder through the alimentary canal (Pearse et al. 1942).

Carnivores are typically more mobile and include marine animals that follow the rising tide (silversides[2], killifish, flounders, lizard fish, crabs, creeping starfish) and terrestrial predators that feed on the exposed beach at low tide (Pearse et al. 1942).

Among those birds which feed on mollusks, crustaceans, and other invertebrates at low tide are the American oyster-catcher, semipalmated plover, pipping plover, Wilson's plover, black-bellied plover, ruddy turnstone, willet, American knot, least sandpiper, semipalmated sandpiper, western sandpiper, and sanderling. Several species feed below and in the intertidal zone on small fish. These include common terns, least terns, royal terns, and black skimmers. Herring gulls, ring-billed gulls, black vultures, and fish crows are common scavengers of the beach and dune areas. Formerly, the bald eagle was a commonly observed scavenger along the beach.

[2]Scientific names of vertebrates can be found in Appendices 1-5.

UPPER BEACH AND DUNES

The area of the beach above the high-tide mark is inhabited or frequented primarily by organisms with terrestrial affinities, but some marine types inhabit or use the area.

Various arthropod predators and scavengers of terrestrial origin forage along the drift line. These include tiger beetles (*Cicindelidae*), rove beetles (*Staphylinidae*), earwigs (*Dermaptera*), springtails (*Collembola*), and spiders (Pearse et al. 1942).

Most conspicuous among the invertebrates of this zone is the ghost crab or sand crab (*Ocypode quadrata*). Although of marine origin, the adult ghost crab lives in burrows along the upper beach and well back into the dunes. Primarily nocturnal, the ghost crab forages as a scavenger and predator.

The upper beach also serves as a nesting area for certain species. Loggerhead turtles, with ancient evolutionary ties to the terrestrial environment, instinctively return to the beach to lay eggs. This important species will be discussed in a separate section to follow.

Several species of birds nest on the upper beaches. These include royal tern, least tern, American oyster-catcher, Wilson's plover, and willet. Also black skimmers and gull-billed terns have been reported to nest on Little Egg Island, a "sandbar island" in the mouth of the Altamaha River.

Except for the loggerhead turtle and the ghost crab, animals using the dunes are terrestrial. Food habits data of animals from dune areas are lacking, but it is evident that many species forage in the dunes.

One of the few permanent mammal residents of the dune area is the eastern mole, one of the most common mammals on some islands. Its extensive runways are very common in the dunes, and occasionally they extend to below the high-tide line. Moles are generally insectivorous, although a certain amount of plant material occasionally may be consumed (Golley 1962).

Sea oats, in addition to their important role in dune formation and stabilization, also form an integral part of the food web involving important animals characteristic of the habitat. Tippins and Beshear (1968) reported scale insects (*Duplasionaspis*) infesting sea oats, and *Circulaspis* and *Odonaspis* seriously affecting other dune grasses (*Spartina* and *Panicum*). Wagner (1964) reported 15 species of beetles and three species of sucking bugs associated with sea oats panicles during flowering. *Collops nigriceps* and *Isomira* sp. were especially common. He examined the stomach contents of seven individuals of each of these species and found that all contained pollen grains of sea oats.

Wagner (1964) also examined the stomachs of 11 house mice. Eight contained seeds of sea oats; 10 contained bluestem seed; and two contained arthropod fragments. There were no *Peromyscus* on Bogue Bank, N.C., where Wagner conducted his studies, but he cited Nelson (1918) as reporting that the old field mouse feeds extensively on sea oats in Florida.

Both the old field mouse and the cotton mouse occur on some, but not all of the Georgia islands. On Cumberland Island cotton mice commonly forage in the dunes. Their tracks may be seen during the early morning hours leading from one clump of vegetation to the next. On the mainland the cotton mouse is usually found in relatively moist habitats, and the old field mouse is more common in drier habitat (Golley 1962). Few data exist on the food habits of either species on the islands.

The marsh rabbit is a common animal frequenting the dune area. Droppings are frequently observed in the sheltered area behind the dunes. Exact food habits of marsh rabbits are not known, but cut stems on Sapelo and Blackbeard islands indicated that they were feeding on sea oats.

Songbirds, especially song sparrows and other fringillids, and red-winged blackbirds are the major consumers of the seed of sea oats. Sea beach panic grass, which produces a panicle of large seed, is no doubt a very important source of food for seed-eating birds and mammals, although data are lacking. Beach hogwort and beach primrose probably also contribute to the diet of these birds.

Trees and shrubs that grow in the lee of the rear dunes produce large quantities of fruit and seed that are heavily utilized by a variety of animals including such larger, important species as wild turkeys, raccoons, deer, and hogs. Notable among these plants are live oak, wax myrtle, saw palmetto, yaupon, and dahoon (*Ilex cassine*).

Hogs visit the dunes to forage on beach pennywort. Cattle graze sea oats and other grasses and forbs on the dunes and move onto the open beaches at night to avoid mosquitoes. The activities of cattle and hogs are very detrimental to dune stability, as previously pointed out.

THE LOGGERHEAD SEA TURTLE

The Atlantic loggerhead sea turtle is a conspicuous element of the beach fauna in summer when mature females emerge from the sea to lay their eggs on the beaches.

The nesting range of the loggerhead is restricted primarily to the temperate zone (Caldwell et al. 1955) on barrier island and mainland beaches from Texas to Cape Lookout, N.C. (Caldwell et al. 1959). The loggerhead concentrates its nesting activities in specific areas and on specific beaches along a coastline. These nesting areas are commonly termed "rookeries." Two of the six largest rookeries of the Atlantic states are located on the Georgia coast: one on Blackbeard and the other on Little Cumberland and Cumberland islands.

Caldwell (1962) reported that loggerheads nested on St. Simons Island prior to the severe erosion of the seaward side of the island during the late 1950s, after which nesting declined considerably. It is not known if the turtles moved to the beaches of nearby Jekyll and Little Cumberland islands.

Prior to 1959, the beaches of Jekyll Island were used extensively by nesting loggerheads. However, following the development of Jekyll Island into a public recreation area in 1959, most loggerheads apparently moved to the beaches of nearby Little Cumberland and Cumberland islands (Caldwell 1962).

Little Cumberland and Cumberland islands support a large and important rookery today. The female population of Little Cumberland Island is currently estimated at 600-800, approximately one-third of which nests each year (J. I. Richardson, pers comm.). The total number of females using the Cumberland-Little Cumberland rookery is probably just under 1000 individuals.

Records indicate that Sapelo Island has not been used extensively for nesting in several years (Caldwell et al. 1959). Aerial surveys in 1970 indicated little use of the Sapelo beach.

Blackbeard Island has been the site of considerable nesting of loggerheads for many years. During 1969, 221 nests were recorded (W. L. Towns, pers. comm.).

The beaches on Little St. Simons, St. Catherines, Ossabaw, Wassaw, Wolf, and Tybee islands are used to a lesser degree. Our aerial survey of these beaches in May 1970 indicated that, except for the rookery beaches, the beaches of Little St. Simons and Ossabaw islands were used by the turtles more than the others.

Baldwin and Lofton reported that the "wide sloping beach" (Fig. 13C) was the most preferred nesting beach on Cape Island, S.C. (Caldwell 1959). They reported that turtles could easily crawl from the surf to the base of the dunes to nest. Caldwell (1959) noted that the nesting turtles along the Georgia coast preferred a "beach backed by high dunes or vegetation." The currently used beaches of Little Cumberland Island, Cumberland Island (portions), and Blackbeard Island are mainly of the "wide sloping beach" type.

The truncate dunes beach type (Fig. 13A) occurs on the rookery beaches of Georgia as well as on most other beaches. Normal high tides frequently inundate many nests located on this beach type, and therefore exert selection pressures decreasing the frequency of turtle nesting on the truncate dunes beach type.

The truncate dunes beach often grades into the "ledge section" beach (Fig. 13B). This type of beach often presents a physical deterrent to female turtles attempting to nest. The female loggerheads often turn back to the sea if they encounter this ledge (Caldwell 1959).

A wide sloping beach backed by high dunes practically insures the female loggerhead a safe return to the sea after nesting, as the unbroken dunes act as a deterrent to any inland travel. Many female turtles often become quite disoriented in their attempts to return to the sea after nesting on other types of beaches. Those females that nest on a beach backed by broken dunes (Fig. 13D,E) often crawl behind the dunes after nesting and frequently become hopelessly lost and die in the heat of the following day (Caldwell 1959). A similar fate often awaits those females that attempt to nest beyond the crest on the barren beaches (Fig. 13F). These females are often beyond sight of the sea after nesting and may wander for hundreds of feet in search of the surf. Many are not successful. A nesting site located at the base of the unbroken dunes on a wide sloping beach also assists the hatchling loggerheads in the necessary orientation to the surf (Daniel and Smith 1947; Caldwell 1959).

Natural processes acting on beach and dune formations produce constant change of many nesting beaches. Those beaches used by nesting turtles over a long period of time are usually characterized by stable dunes. An example of changes in dune types influencing nesting is given by Baldwin and Lofton (Caldwell 1959). They reported that a section of the Cape Island beach backed by little-used truncate dunes in 1939 was changed into the much preferred wide sloping beach in 1940. Since then a large number of turtles have been using them.

Nest destruction is high throughout the loggerhead's range. Natural predators destroy large numbers of nests and, in many areas, depredation by man is a serious limiting factor on reproduction. Man also has introduced hogs into some nesting areas, and they often are serious nest predators. Finally, natural and artificially induced beach erosion destroys many nests.

Sand crabs and raccoons are the principal natural nest predators in Georgia and in many other areas. Both have an uncanny ability to locate sea turtle nests. Usually, sand crabs are the first to arrive at a nest. They normally dig small holes down into the nest cavity and bring several eggs to the surface. The eggs are then eaten at the nest or transported to the nearby burrow of the crab. Baldwin and Lofton (Caldwell 1959) found that sand crabs entered 40.8% of the nests on Cape Island, S.C., but did not destroy all of those nests.

Raccoons are the most common natural vertebrate predators of turtle nests (Carr 1967) (Fig. 20). They are common even on the most isolated of the barrier beaches. On Cape Island, S.C., Baldwin and Lofton (Caldwell 1959) found that raccoons patrolled the beaches during the nesting season singly or in family groups and that relatively few individuals were responsible for nest depredation. These individuals covered the same area throughout the summer.

On many of Georgia's barrier islands, both European wild hogs and domestic (now feral) hogs have been introduced. On some beaches these animals are serious nest predators of sea turtles (Carr 1967). McAtee (1934) wrote that "the work of natural enemies is insignificant compared to the depredation of hogs where they are present." J. I. Richardson (pers. comm.) states that, because of nest depredation by feral hogs and raccoons, natural reproduction of sea turtles on Little Cumberland Island has been almost nil. However, the conservation-minded owners of Little Cumberland maintain an artificial hatchery which increases hatching success to approximately 60-80% (6000-10,000 young turtles per year).

Cumberland Island has a large feral hog population. Cumberland also has a large nesting population of turtles and approximately 16 miles of nesting beach, yet it probably produces fewer turtles per unit of beach than any other island.

Ossabaw and St. Catherines islands also have numerous feral hogs that no doubt seriously reduce natural nest production. Forty-five hogs were counted on the beaches of Ossabaw during a morning flight in May 1970. Several groups of hogs were concentrated at the apex of turtle crawls made the previous night. Their behavior and signs of excavation indicated that they were feeding in a turtle nest.

Erosion by storms and strong shoreward winds during high tides frequently washes out turtle nests. However, these natural factors probably do not seriously affect the long-term population dynamics of sea turtles. Baldwin and Lofton found that most washing occurred on the low beach below the truncate dunes, a site least preferred for nesting on Cape Island, S.C. (Caldwell 1959).

Human destruction of nests is very common on those nesting beaches with

Fig. 20. *Top*. Loggerhead sea turtle nest destroyed by raccoons on Blackbeard Island, 23 June 1971. *Bottom*. Wire shield placed over sea turtle nest to retard raccoon depredation, Blackbeard Island.

easy access and, to a lesser degree, on those beaches with limited access. Dietary motivation ("turtle egging"), malicious recreation ("turtle egg fights," LeBuff 1969), and general curiosity are responsible for the destruction of many nests. Fortunately, the Georgia rookeries receive excellent protection from human depredation due to the conscientious efforts of some of the private landowners and the efforts of personnel of the Georgia Game and Fish Commission and of the U.S. Fish and Wildlife Service on Blackbeard Island and other nesting beaches. However, nests located on many of the barrier island beaches cannot be adequately protected from human depredation because of the limited manpower available for patrolling the extensive area involved.

The development of several of Georgia's beaches for recreational purposes has seriously reduced the amount of nesting beaches along the coast. While some beaches may not be altered physically, the construction of highways and buildings nearby deters female loggerheads from nesting (Caldwell 1962; Carr 1967), and also emerging hatchlings often become disoriented by the artificial illumination of highways and buildings and move toward these sources of light instead of the sea (Caldwell 1962; Caldwell and Caldwell 1962). Carr (1967) reported that thousands of young loggerheads are crushed on some of the coastal highways adjacent to nesting beaches, and many others succumb the following day to desiccation and predation.

Savannah Beach has been totally destroyed as a nesting beach by development; a sea wall now replaces the dunes. Both natural and man-induced erosion has destroyed the nesting beach on St. Simons Island. Very few turtles nest on St. Simons today. The development of Jekyll Island, site of a former rookery, apparently influenced the movement of the rookery to nearby Little Cumberland Island. The development of Jekyll included both the destruction of the beaches and dunes and the construction of beachside motels and other buildings. The destruction of the beaches created a physical impediment to nesting, and the illumination of the motels deterred many females from nesting on beaches that were still physically acceptable.

The island interior

Forest associations and successional relationships

Despite much study of the forests of the southeastern Coastal Plain, only the pine forests are well understood. Little is known about the maritime forests. Except for the compilation of species lists (which have not been published), there have been no studies of the forest vegetation of the Georgia islands. Bourdeau and Oosting (1959) described the structure of the maritime forest in North Carolina, but the geology of the North Carolina islands differs somewhat from the Georgia islands, and some of the subtropical plants that are very important on the Georgia islands are not present in North Carolina. Coker (1905) briefly described the forests on the Isle of Palms near Charleston, S.C. Laessle and Monk (1961) reported on some live oak forests of northeastern

Florida. Otherwise, there have been no relevant studies of areas ecologically comparable to the Georgia islands. Consequently, much of the discussion of the forest vegetation of the Georgia islands is based on our observations and interpretations. The major forest types on the Georgia islands are live oak, pine, mixed hardwood, cypress-gum, and bay. Other less discrete associations may be recognized.

The maritime live oak forest is characterized by a distinct dominance of live oak (Fig. 21). Sandy soils of old dune ridges on the seaward side of the islands support small, slow-growing live oaks of poor form. Cabbage palms frequently intrude into the canopy, and an understory of saw palmetto, vacciniums, and other species of low woody vegetation may be present. Where exposed to winds from the sea, the closed canopy usually forms a continuous sloping surface which affords protection of the interior of the forest from the winds and salt spray.

Fig. 21. Live oak forest, Cumberland Island, June 1971. Note absence of Spanish moss. Many old stands have more dense canopy and woody understory.

Size of the oaks increases toward the interior of the island, and the oaks develop large trunks and huge, spreading crowns. The diversity of species is also much greater in the interior of the island. Some important woody components of the community are listed in Table 6.

Conspicuous features of the maritime live oak forest are an abundance of sclerophyllous (leathery-leaved) broad-leaf evergreens, lianas, and epiphytes, and relatively few herbaceous plants.

Spanish moss (*Tillandsia usneoides*) drapes the larger trees, especially the live oaks, obtaining nutrients from dust particles and from particles in the water that

TABLE 6. *Some important woody plants of live oak forests on the barrier islands of Georgia.*

Common name	Scientific name
Trees and shrubs	
Loblolly pine	*Pinus taeda*
Juniper	*Juniperus virginiana*
Switchcane	*Arundinaria tecta*
Saw palmetto	*Serenoa repens*
Cabbage palm	*Sabal palmetto*
Wax myrtle	*Myrica cerifera*
Live oak	*Quercus virginiana*
Water oak	*Quercus nigra*
Laurel oak	*Quercus laurifolia*
Sweet bay	*Magnolia virginiana*
Southern magnolia	*Magnolia grandiflora*
Red bay	*Persea borbonia*
Hercules'-club	*Zanthoxylum clava-herculis*
American holly	*Ilex opaca*
Dahoon	*Ilex cassine*
Yaupon	*Ilex vomitoria*
Red buckeye	*Aesculus pavia*
Devil's walking stick	*Aralia spinosa*
Sparkleberry	*Vaccinium arboreum*
Devilwood	*Osmanthus americana*
Beauty-berry	*Callicarpa americana*
Woody vines	
Smilax	*Smilax* spp.
Poison ivy	*Rhus radicans*
Virginia creeper	*Parthenocissus quinquefolia*
Grape	*Vitis* spp.
Pepper-vine	*Ampelopsis arborea*
Rattanvine	*Berchemia scandens*
Yellow jessamine	*Gelsemium sempervirens*
Coral honeysuckle	*Lonicera sempervirens*

drains onto it from the limbs above. Ecologically and aesthetically, Spanish moss is probably the second most important plant in the live oak forest, the most important being the live oak itself. Draping the spreading crown of the live oak, Spanish moss significantly reduces the amount of light that penetrates the canopy and is to a large extent responsible for the dark, humid atmosphere beneath the canopy and, consequently, the composition of the understory vegetation. The moss provides nesting habitat for at least three species of songbirds: parula and yellow-throated warblers and painted buntings (Teal and Teal 1964). It provides nest-building material for many other birds. At least two species of bats (*Lasiurus seminolus* and *L. intermedius*) commonly use Spanish moss for roosting sites (Barbour and Davis 1969). The moss provides habitat for many kinds of insects important in the food chain. Rainwater (1941) reported 164 species of arthropods associated with Spanish moss.

Beginning about 1967, serious mortality of Spanish moss was noted in Florida (Edward Allen, Report of Smithsonian Center for Short-lived Phenomena, 27 December 1967) and along the Georgia coast. In the summer of 1970 most of the moss along the coast south of Liberty County was apparently dead (Fig. 22). The mortality did not extend far inland in Georgia but extended southward to Jacksonville, Fla., and across Florida to Tampa. The cause of this mortality is not definitely known, and we have been unable to establish whether similar mortality has occurred in the past. A common pathogenic fungus (*Fusarium solani*) has been implicated (Roberts et al. 1971). Pollution has been suspected as a contributory factor, but this has not been demonstrated. Although new growth is evident and the Spanish moss appears to be recovering, this situation needs to be seriously studied.

Other epiphytes—lichens, mosses, and ferns—grow in abundance in the organic matter that accumulates in the deep fissures of the bark on the nearly horizontal branches of the oaks. Most conspicuous among these is the resurrection fern (*Polypodium polypodioides*). The number of species of epiphytic bryophytes increases with increasing age of the forest (Mackaness 1942).

Little is known about successional processes of the island forests. Wells (1939) contended that the live oak becomes dominant only near the coast where salt spray reduces competition from other species. He noted that the maritime live oak forest is a long-lived, relatively stable community even on mature soils capable of supporting "ordinary broad-leaved climax species of the region." Consequently, he designated the maritime live oak forest a "salt-spray climax." Oosting (1954) questioned this concept on the grounds that the sequence of vegetative types that develops on a site is determined not by the reaction of the community on the site, but by physical factors such as wind and salt spray and the topographic position of the site. Laessle and Monk (1961) concluded that inland climax species can exist under the influence of salt spray in Florida, and that the live oak forest is not a salt-spray climax in Florida.

Because of its tolerance to salt spray, xeric conditions, and infertile soils, live oak is commonly the first forest community to become established on coastal sand dunes. Thus established with this competitive advantage, the live oak forest apparently persists indefinitely and appears to be a near-climax community.

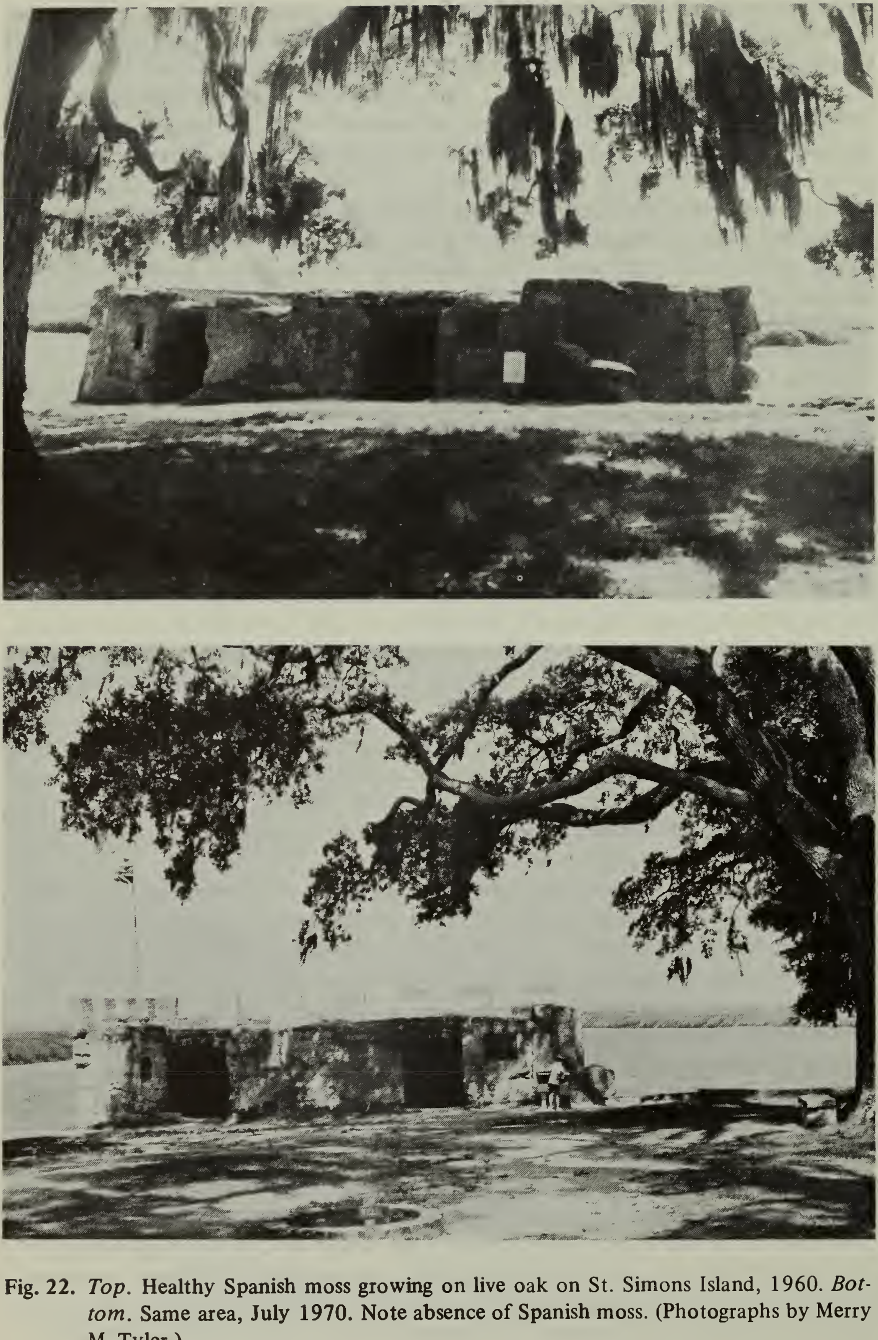

Fig. 22. *Top*. Healthy Spanish moss growing on live oak on St. Simons Island, 1960. *Bottom*. Same area, July 1970. Note absence of Spanish moss. (Photographs by Merry M. Tyler.)

Even as the island grows seaward by the formation of new dunes and the site becomes relatively protected from the influence of salt spray, the live oak forest withstands all competition and is extremely resistant to change.

Infrequent fires of low intensity may contribute to the maintenance of live oak dominance (Laessle and Monk 1961). Live oaks are very susceptible to fire (Fowells 1965), and their occurrence on the mainland is restricted to areas protected from frequent, intense fires (Heyward 1939; Laessle and Monk 1961). But on the islands the initial establishment of live oaks occurs without being preceded by a "fire-type" (pine) community. Islands in general are relatively more isolated from wild fires (Harper 1911), and the likelihood of a stand burning is related to the size of the island. Furthermore, the sand dunes, where the live oak forests develop, are often somewhat isolated from fires that do occur on the island and usually do not have enough ground cover to support fires. As the trees mature under such conditions, they become less susceptible to destruction by fire, and the live oak forest itself acquires characteristics that protect it from fire. The high humidity, relatively sparse ground cover and fire resistant litter beneath the mature live oak stand do not allow fires of such intensity as to bring about a decline in live oak dominance.

Thus, the maritime live oak forest is a long-lived, near-climax community that becomes established as a result of an interaction of physical factors that reduce competition from other species and protect the community from fire. Once established, this forest type is quite stable and resistant to change because of the long lifespan of the tree, its ability to sprout prolifically and its adaptation to site characteristics. Also, occasional fires may deter invasion by climax species (Laessle and Monk 1961).

The pine forest typically occurs on well-drained sites protected from sea winds where original live oak forests have been cleared for agricultural or other purposes and secondary succession has proceeded along lines more typical of mainland forests (from herbaceous pioneers to pine forests). The pine type with its more open canopy allows development of herbaceous ground cover and the formation of a mat of needles which together provide fuel for frequent fires. The effects of periodic burning are favorable to the maintenance of a predominantly pine stand (e.g., Garren 1943; Chapman 1950).

Even where fire is excluded on the islands, it is questionable if secondary succession, in the absence of salt spray and other uncommon circumstances relating to soils and moisture, leads to a climax dominated by live oak. More likely, succession is toward an association of mixed hardwoods with a number of codominants (the southern mixed hardwood forest of Quarterman and Keever 1962) (Fig. 23).

The pine forests on the islands are dominated by loblolly pine or, less commonly, slash pine (*Pinus elliottii*) or longleaf pine (*P. palustris*). Pond pine (*P. serotina*) occurs on wet, acid sites but usually does not attain dominance. Pine forests that are frequently burned are generally open, with a ground cover of grasses and herbaceous plants and a rather scattered understory of saw palmetto, wax myrtle, beauty-berry, various species of *Ilex* and *Vaccinium* and other small trees and shrubs tolerant of fire. The open aspect of the pine woods is further

Fig. 23. Mature hickory stand on Cumberland Island. Small stands of hickory occur on several of the barrier islands. Their origin and former distribution on the islands are not known, but they probably are the climax of secondary succession on certain sites (whereas the live oak forest may be the product of primary succession). Other associations of mixed hardwoods also occur on the islands.

developed on some islands by large numbers of grazing animals (Fig. 24). In the absence of fire and grazing, a dense, tangled understory of woody vegetation develops that generally is less productive habitat for most species of wildlife. Some deliberate (prescribed) burning is done on the islands to accomplish certain management objectives such as reducing undesirable competition in stands of merchantable timber, improving wildlife habitat and livestock range, reducing fire hazard (fuel), and improving access, visibility, and aesthetic appeal.

Very wet sites support communities of wax myrtle, buttonbush (*Cephalanthus occidentalis*), willow (*Salix* sp.), gum (*Nyssa* sp.), red maple (*Acer rubrum*), ash (*Fraxinus* sp.), and occasionally cypress (*Taxodium ascendens*). Succession is toward a bay community dominated by such species as loblolly bay (*Gordonia lasianthus*), sweet bay, and red bay.

Ponds and sloughs

Low areas between dune ridges on the islands commonly form sloughs containing fresh or slightly brackish water. These ponds and sloughs play a major role in maintaining some of the more interesting wildlife of the islands, notably alligators and wading birds.

Fig. 24. Open pine forest and pastures grazed by cattle on St. Catherines Island.

The sloughs vary considerably in size and depth. Some dry up completely in summer; others contain water throughout the year. The water is usually acid and stained so that light penetrates only 2 or 3 ft below the surface. Consequently, if the sloughs are deep, there may be relatively little growth of submersed aquatics and an abundance of emergent plants, rooted plants with floating leaves, and unrooted floating plants. (See Table 7 for common species.)

Sloughs are not static communities (Fig. 25). Succession and eutrophication lead to cat-tail marsh and ultimately to forested swamp. Fire, the intrusion of salt water on hurricane tides, and fluctuating water levels may alter vegetative composition and temporarily set the community back to an earlier successional stage. During prolonged dry periods sloughs may be invaded by cypress and gum.

In the fall, sloughs are important resting and feeding areas for migrating and wintering waterfowl which feed upon various parts of water-shield, pondweed, bushy pondweed, bulrushes, the introduced banana water-lily, and other aquatic plants. Acorns and other kinds of mast from adjacent trees also provide much food for waterfowl. (See Table 12 for significance of specific aquatic plants as waterfowl foods.)

In the spring, large numbers of herons, egrets, and other wading birds form nesting colonies in the sloughs. (See Appendix 4 for locations and descriptions of rookeries on the Georgia coast.) Large numbers of nestlings fall into the water providing food for alligators and cottonmouths, and dense populations of these

TABLE 7. *Some common plants of sloughs and ponds on Georgia islands.*

Common name	Scientific name
Submerged	
Bushy-pondweed	*Najas* spp.
Fanwort	*Cabomba caroliniana*
Coontail	*Ceratophyllum demersum*
Parrot's-feather	*Myriophyllum brasiliense*
Floating-leaved, rooted	
Pondweed	*Potamogeton* spp.
Water-shield	*Brasenia schreberi*
Banana water-lily	*Nymphaea mexicana*
White water-lily	*Nymphaea odorata*
Yellow cow-lily	*Nuphar luteum*
Floating, not rooted	
Mosquito fern	*Azolla caroliniana*
Duckweed	*Lemna* spp.
Duckweed	*Spirodela* spp.
Water-meal	*Wolffia* spp.
Wolffiella	*Wolffiella floridana*
Bladderwort	*Utricularia* spp.
Emergent	
Cat-tail	*Typha* spp.
Bulrush	*Scirpus* spp.
Rush	*Juncus* spp.
Sawgrass	*Cladium* spp.
Pickerelweed	*Pontederia cordata*
Arrow arum	*Peltandra virginica*
Alligator-weed	*Alternanthera philoxeroides*
Arrowhead	*Sagittaria latifolia*

reptiles may build up in sloughs having large colonies of nesting birds (Wharton 1969; Teal and Teal 1964).

Alligators and most of the amphibians and freshwater turtles are dependent upon the sloughs for survival. The smaller sloughs that are periodically dry are especially important breeding habitat for amphibians because of the absence of predatory fish. The importance of the island sloughs in the preservation of the endangered American alligator is discussed in another section.

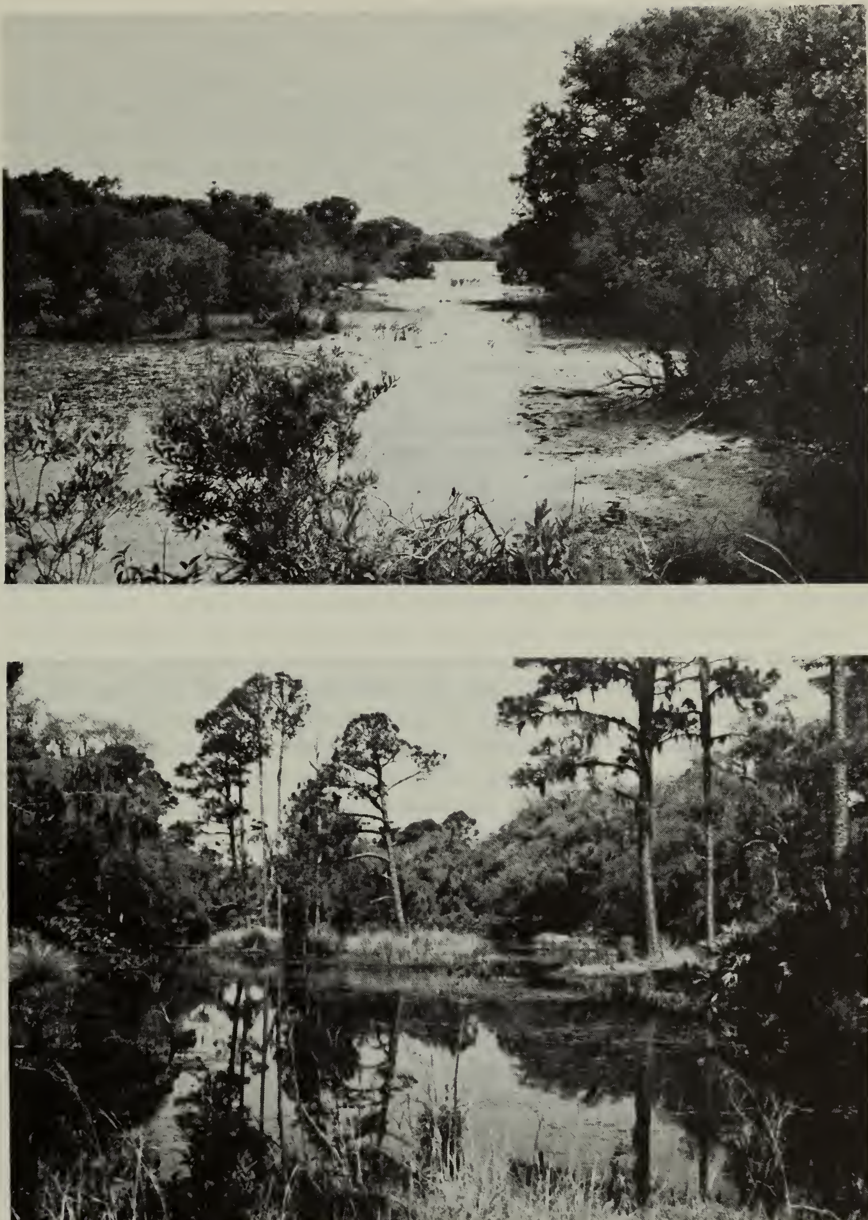

Fig. 25. *Top*. Slough of recent origin behind dunes on Cumberland Island, June 1971. *Bottom*. Slough in interior of St. Catherines Island, May 1971. (Photographs by H. N. Neuhauser.)

Food webs and nutrient cycling

Forest vegetation utilizes solar energy to convert carbon dioxide and water to simple sugars. These and certain minerals from the soil are metabolized in plants to produce various fats, proteins, and carbohydrates which enter the food web when the green plants are consumed by other organisms. These organisms are fed upon by secondary consumers, and the energy and nutrients are thus passed through the ecosystem. Fallen leaves and branches are acted on by fungi and microorganisms. Nutrients in solution enter the root systems of plants and are thus continually recycled. Energy, however, is not recycled because some energy is converted to heat and radiated into the atmosphere at each transfer. Thus the number of transfers is limited.

Much of the solar energy reaching the mature live oak community is intercepted in the canopy by live oaks and other large trees, lianas, and Spanish moss and other epiphytes. Of that which does penetrate the canopy, most is intercepted by an understory of small trees, shrubs, and woody vines; little reaches the forest floor. Consequently, in a mature live oak forest, photosynthesis of trees and shrubs accounts for most energy conversion. This energy and minerals from the soil enter the food web by way of decomposers (especially fungi), invertebrate consumers of wood, foliage and other plant parts, a few grazers and browsers, and many fruit-eating birds and mammals.

The live oak community includes an abundance of woody species that produce fruit and mast, which is important in the diet of the omnivorous birds and mammals inhabiting this habitat. Live oak acorns are probably the most important single food for many species of wildlife including deer, raccoons, feral hogs, wild turkeys, and other birds. Other important fruit- and seed-producing trees and shrubs providing food for these animals include laurel oak, saw palmetto, smilax, American holly, yaupon, dahoon, wax myrtle, vacciniums, red bay, sweet bay, southern magnolia, beautyberry, rattanvine, Virginia creeper, and muscadines and other wild grapes.

In the pine type relatively little light is intercepted by the canopy and, especially where fire is a frequent factor, there is an abundance of ground story vegetation (especially grasses). In this habitat primary consumers are more likely to be grazers (especially insects), browsers, and small seed-eaters.

Larger, more mobile animals commonly use both the live oak and the pine forests and especially the ecotone where the two types meet.

Insectivorous birds are very abundant in both habitat types. Other secondary and tertiary consumers include various insects, reptiles, and mammals. There are relatively few mammalian carnivores on the islands, most of those formerly present having been exterminated (e.g., foxes, wolves, bobcats, pumas, bears). The terminal carnivore niches are filled mainly by predatory birds, the diamondback rattlesnake, and relatively inefficient mammalian predators such as raccoons and opossums.

Because of the complexity of food webs in forests and sloughs and the lack of local food habits data, no attempt will be made to trace specific nutrient pathways.

Fauna

NATIVE VERTEBRATES

Although this study produced much information on the distribution of vertebrates on the coastal islands, lack of adequate data on species interactions inhibits a detailed functional and conceptual discussion. However, an attempt has been made to integrate the available information on distribution, abundance, preferred habitat, and limiting factors. (See Appendices 2-5 for annotated lists of species, scientific names, and discussions of wading bird rookeries.)

Because of the limited size of the islands, population size is restricted and immigration is limited by open water barriers, restricting opportunities for genetic exchange. Such conditions favor the evolution of forms that are phenotypically distinguishable from their mainland ancestors. Island populations are frequently recognized as distinct taxonomic entities, and currently there are four recognized forms that are restricted primarily to one or more of Georgia's barrier islands: the Cumberland Island pocket gopher (*Geomys cumberlandius*), the Anastasia Island cotton mouse (*Peromyscus gossypinus anastasae*), the St. Simons Island raccoon (*Procyon lotor litoreus*), and the Blackbeard Island deer (*Odocoileus virginianus nigribarbis*). However, lack of specimens and historical data relating to the island fauna inhibits study of the relationships of populations.

1. Mammals: The mammal fauna of the Georgia islands has been poorly known, mainly because there has been little systematic collecting on the islands. Access to many of the islands has been restricted, and investigators sometimes have been denied permission to collect mammals on some of the privately owned islands (e.g., Bangs 1898; Elliot 1901).

Subsistence hunting, deliberate persecution, and disease probably caused extirpation of some species of mammals from the islands. Habitat changes effected by agriculture and timber management probably have not caused the loss from the islands of any mammal populations. However, it is evident that habitat changes associated with certain types of development may seriously reduce or eliminate some populations before their taxonomic position, range, distribution, and ecology can be determined. Therefore, during the course of this study, a concerted effort was made to develop a check list of existing mammals of the islands. The results are presented in Appendix 5 and are summarized in Table 8. The following discussion deals with select species and groups (see also sections on beach fauna, marsh fauna, and marine mammals).

The opossum is conspicuous on the islands where it occurs. The past and present distribution of the opossum suggest how man may have affected the distribution of island animals. White (1849) reported that the opossum was abundant on Cumberland Island, but subsequent visitors made no mention of its presence there. A plausible explanation for the opossum's absence was given by Lucy Ferguson (*in* Lee et al. 1963), a lifetime resident of the island, who stated that after the War Between the States the freed slaves killed for food all of the

TABLE 8. *Mammals of the coastal islands of Georgia.*[a]

Species	Oysterbed	Cockspur	Tybee	Little Tybee	Wassaw	Ossabaw	St. Catherines	Blackbeard	Sapelo	Wolf	Little St. Simons	St. Simons	Sea	Jekyll	Little Cumberland	Cumberland
Opossum		O	O						S		O	S	O	S	L*	L*
Short-tailed shrew						S			S							S
Least shrew								S	S							S
Eastern mole						S	S	S	S			S		S	O	S
Southeastern myotis									S							
Eastern pipistrelle															O	S
Big brown bat									S							S
Red bat									O							
Seminole bat									S							S
Yellow bat																S
Cottontail rabbit												O				
Marsh rabbit	S	S	O		O	S	S	S	S	S	O	S	S	S	S	S
Gray squirrel		O	L		S	L	S		S		O	O		S		S
Fox squirrel						S						O				S
Southern flying squirrel												O				
Cumberland Is. pocket gopher																S
Marsh rice rat		S	S		S	S		S	S			O		S	O	S
Eastern harvest mouse																S
Oldfield mouse																L
Cotton mouse						S		S	S					S	S	S
Hispid cotton rat		S	S			S		S	S			S		S	O	S
Eastern wood rat												L				
Black rat	S	S	S			L	S		S					S		S
Norway rat	L					S	S	L								
House mouse	S		S													
Nutria								L*								
Goose-beaked whale					S							L			S	
Pygmy sperm whale								L	S				L	L	S	S
Dwarf sperm whale						S										
Atlantic bottle-nosed dolphin					L	S		S	S	S					S	S
False killer whale			L													
Pilot whale					S	S					S	L		S	S	
Gray fox																L*

TABLE 8. *Mammals of the coastal islands of Georgia.*[a] (*continued*)

Species	Oysterbed	Cockspur	Tybee	Little Tybee	Wassaw	Ossabaw	St. Catherines	Blackbeard	Sapelo	Wolf	Little St. Simons	St. Simons	Sea	Jekyll	Little Cumberland	Cumberland
Black bear												L*				L*
Raccoon	L	O	O	O	S	S	S	S	S	S	O	S	O	S	S	S
Mink	L					S	L	L	S	L	O	O		S	O	S
River otter	L		L	L	L	L	L	S	L	L	L	L	L	L	S	L
Bobcat		O*				S*			L*							L*
Manatee																L
European wild boar					L*	O*					O*	O*		L*	O*	O*
European fallow deer											L	O	O	O		
Red deer or European elk											L*					
White-tailed deer			L	L	S	S	L	S	S	L	L	L	L	L	L	S

[a]Symbols—S=specimen; L=literature; O=observed; *=extirpated; Scientific names and documentation in Appendix 5.

opossums on Cumberland and Little Cumberland islands. The present distribution of the opossum is confined to Sapelo, Little St. Simons, and islands to which man has constructed bridges and thus provided a route for invasion and reinvasion, i.e., Cockspur, Tybee, St. Simons, Sea, and Jekyll.

Rodents are represented on the islands by gray and fox (introduced) squirrels, pocket gophers, and native and naturalized rats and mice.

Gray squirrels are absent on Blackbeard and Little Cumberland islands and recently have been introduced on Tybee, Wassaw, Ossabaw, and Sapelo islands (Tomkins 1965a). It is not known if those on Cumberland and St. Catherines are native. Hardwood forests are preferred habitat and high populations of squirrels often occur near residential areas.

The Cumberland Island pocket gopher described by Bangs (1898) is an insular mammal species occurring only on Cumberland Island. It is now endangered and should be added to the list of *Rare and Endangered Fish and Wildlife of the United States* (U.S. Fish and Wildlife Service 1968).

When Bangs first collected the species, he said, "... the hills straggled off through the pine woods for miles." E. B. Chamberlain of the Charleston Museum visited the island in 1932 and 1933, and his notes (Charleston Museum) indicated "several nice colonies on the island. Largest on golf links at Stafford Place." During a recent collecting expedition (March 1970), Baker and Dopson found that only one old field exhibited signs of gopher activity. A month later, this field was plowed for agriculture.

The drastic reduction in the pocket gopher population on Cumberland probably has been due to agriculture, excessive grazing, and, to some extent, excessive specimen collection. There are at least 53 specimens of this species in museums, three of which were pregnant with a total of six embryos. Additional collecting should not be permitted.

The habitat of this species is similar to that of mainland forms in that relatively loose friable soil is preferred. Specimens from Cumberland have been taken from old fields and pine woods. Harper (1912) stated that Cumberland was the only island with longleaf pine and turkey oak and that the presence of the pocket gopher might somehow be related to this. However, these trees do occur on some of the other islands, and the most recent (March 1970) pocket gopher sign observed during this study was 4-5 miles from the nearest longleaf pine stand.

Rats and mice are found on the islands, but the species involved and their distributions are poorly known. The cotton rat is found on most of the islands, living preferentially in old fields and fence rows but also in the dunes and salt marshes. Cotton rat remains is one of the most common items occurring in pellets regurgitated by barn owls on the islands. A large collection of owl pellets from Sapelo yielded 152 cotton rat skulls and 26 skulls of three other mammal species.

The cotton mouse is abundant on only two islands, Cumberland and Little Cumberland, although it is present on several others. The Anastasia Island cotton mouse, described from specimens from Anastasia Island, Fla., occurs on Little Cumberland and Cumberland islands. The population on Anastasia Island has been drastically reduced or extirpated (Pournelle and Barrington 1953), so the populations on Little Cumberland and Cumberland islands should be protected to insure survival of this insular subspecies. This subspecies should be considered for inclusion in the list of rare and endangered wildlife, previously mentioned (U.S. Fish and Wildlife Service 1968).

The reason for the scarcity of native mice on most of the islands is a matter of some conjecture. Pournelle and Barrington (1953) suggested, among other reasons, possible competition between the cotton mouse and cotton rat. They reported that an inverse relationship appeared to exist between populations of cotton rats and cotton mice. Data obtained from trapping and owl pellets suggest that this relationship holds on Tybee, Sapelo, Jekyll, Little Cumberland, and Cumberland islands.

The distribution of the house mouse (unintentionally introduced) is peculiar in that, while normally almost ubiquitous, it is restricted on the coast to two islands near Savannah. On Little Cumberland and Cumberland islands, the habitat normally occupied by house mice is occupied by cotton mice. On other islands, such as Sapelo, no sizeable numbers of any kind of mouse have invaded what appears to be favorable habitat.

Carnivores on the islands formerly included several species now extirpated. Today, only the raccoon, mink, and otter represent this group. Mink and otter are discussed in the section on marshes. Raccoons are very common. They inhabit every island and occur in every habitat type. Populations are often high, and several wildlife refuges conduct control measures primarily during the sea turtle nesting season. However, control is only temporary because of rapid recruitment from surrounding areas. Raccoons are hunted by some island inhabitants, but raccoon hunting has declined in recent years. Rabies occurs with a relatively high frequency in raccoon populations on the mainland, but it has not been reported from raccoons on the coastal islands.

The white-tailed deer is the only native hoofed animal on the islands. The introduced fallow deer is discussed later. White-tailed deer now occur on most of the barrier islands although many existing populations are not derived entirely from native stock. Unfortunately, deer that have been used to stock and restock the islands often were not obtained from nearby islands having native white-tails. For instance, deer from Pennsylvania were introduced on Wassaw Island (Francisco et al. 1970). The past introductions of deer having diverse genetic backgrounds confuses the exact taxonomic status of the herds occurring on some of the islands. The subspecies *Odocoileus virginianus nigribarbis* occurs on Blackbeard and Sapelo islands and apparently, at least on Blackbeard, has not been genetically contaminated by introduction of animals from other geographic areas. The range of *O. v. virginianus* which includes the Georgia coast is poorly known; Hall and Kelson (1959), however, include Cumberland Island in the range of this subspecies.

The island deer occupy almost all of the terrestrial habitat types. They are most conspicuous in the live oak-pine forest but are frequently seen in the dune areas. Deer are also sometimes observed on the island edge of the salt marsh.

The white-tailed deer that occurs on the islands generally is smaller in size than the deer that occurs on the adjacent mainland. Deer from Blackbeard Island average 60 lb (L. Wineland *in* Lund et al. 1962). Mature bucks weigh about 110 lb. The small size of island deer may be a genetic adaptation or a response to habitat deficiencies or both. Annual archery deer hunts are held on Blackbeard Island. Deer hunting is conducted on some other islands by island owners; generally the harvest is low.

2. Birds: The diverse habitat of the barrier islands supports a large number of bird species. Appendix 3 includes a list of species, seasonal abundance, and habitat preferences. The extensive live oak forests draped with festoons of Spanish moss provide nesting and feeding habitat for large numbers of songbirds and woodpeckers. Pastures and fields are used by wild turkeys, cattle egrets, meadowlarks, and other ground-feeding birds. Sloughs and ponds are favorite feeding areas for anhinga, ibis, herons, egrets, and waterfowl. Large wading bird rookeries are also located near many of the sloughs and ponds on some of the islands.

The live oak and pine forests are used extensively as feeding areas by many resident species. Resident birds that occupy this habitat type include Carolina chickadee, brown-headed nuthatch, Carolina wren, brown thrasher, pine warbler, cardinal, and rufous-sided towhee (Teal 1959). Numbers of birds in the live oak-pine forests are greatly augmented each year with migrant species. Some migrants such as the yellow-bellied sapsucker, ruby-crowned kinglet, eastern phoebe, and white-throated sparrow become winter residents. Other migrants that feed in oak-pine forests include solitary vireo, black-and-white warbler, prothonotary warbler, and American redstart (Teal 1959).

The habitat diversity provided by the live oak forests will become in future years increasingly important for many bird species as mainland live oak forests are reduced in extent by modern pine forestry practices and industrial, residential, and recreational development. Preservation of the live oak forests on the islands should be continued as in the past.

The distribution of the endangered red-cockaded woodpecker (U.S. Fish and Wilflife Service 1968) on the barrier islands is unknown. Burleigh (1958) stated that this bird has been reported breeding on Blackbeard Island, but it is not known to breed there now. Teal (1959) reported the species on Sapelo Island but stated that it was rare. Its distribution apparently is determined by the presence of mature pine trees infected with red-heart disease (*Fomes pini*). Red-cockaded woodpecker nests are restricted to such trees. Tracts of pinelands containing known nesting sites of red-cockaded woodpeckers are being preserved on the mainland.

The blue jay is a common mainland bird that has a sporadic distribution among the islands. Its presence on the mainland and on some islands has been described or reported by several observers (Austin 1965; Davenport 1966; Tomkins 1965a). Tomkins (1965a) reported that the blue jay was present on Tybee, St. Simons, and Jekyll islands. Sprunt (1936) reported it on Cumberland Island. Jays were not reported by Tomkins on some of the barrier islands such as Sapelo, Blackbeard, Wassaw, and Little Cumberland. Since Tomkins' paper, the blue jay has been reported on Sapelo (1966) and is now a common permanent resident there. Blue jays were not seen during recent trips to Ossabaw Island (June 1970) and Blackbeard Island (June 1971). Apparently the distribution of the blue jay is influenced by human habitation. The jay is very common on Jekyll and St. Simons islands where high-density development has occurred.

Robert et al. (1956) reported the absence of the tufted titmouse from Sapelo and other islands. The Carolina chickadee, a frequent associate of the tufted titmouse on the mainland, is rather common on Sapelo Island.

Several of the islands have small wild turkey populations. The wild turkey probably was extirpated from most of the islands and later reintroduced. The present populations are relatively tame and do not exhibit typical behavioral characteristics of wild turkeys. Blackbeard Island probably has the purest strain of wild turkey, but the population currently is very low. Turkeys could be reintroduced on those islands having few or no turkeys, but every attempt should be made to obtain live-trapped wild stock for restocking. The Georgia Game and Fish Commission has begun a wild turkey management program on the R. J. Reynolds Wildlife Refuge on Sapelo Island. Eventually the Commission hopes to remove a number of turkeys annually for restocking elsewhere in Georgia.

Five wading bird rookeries occur on the barrier islands. Two are located on Ossabaw Island, one on Blackbeard Island, and two on Cumberland Island. Species that nest in these rookeries include snowy, cattle, and common egrets; and black-crowned night, great blue, Louisiana, and green herons. Wading bird rookeries are mapped and described in Appendix 4.

The maintenance of rookery sites is essential in the conservation of wading birds. Rookeries are usually used year after year when not encroached upon by development, pond drainage, or excessive disturbances. Rookeries on the islands are perhaps the ones best protected from human disturbance. However, some rookeries are lost by habitat changes such as have occurred at the rookery on the north end of Sapelo. This rookery site was formed when a finger of salt marsh was diked and then flooded by an artesian well. The rookery was abandoned after aquatic vegetation became too dense.

The ponds and sloughs on the islands are intensively used by waterfowl during the fall and winter. Blackbeard Island National Wildlife Refuge has management units consisting of permanent ponds. Ducks wintering on Blackbeard include, in order of abundance, ring-necks, scaups, mallards, gadwalls, baldpates, canvasbacks, pintails, green-winged teals, and shovelers. Duck populations have ranged from 10,000 during 1955-56 to 61,660 in 1960-61 (U.S. Fish and Wildlife Service 1962). Most of these species of ducks use the ponds and sloughs on other islands. The proximity of the Blackbeard refuge positively influences the waterfowl populations on the other islands. (Waterfowl are discussed in more detail in the chapter on marshes.)

Many other water birds are attracted to the aquatic habitat on the islands. Most common among these are the coot and both common and purple gallinules. Wood ducks also breed and raise broods in the sloughs and ponds. Nesting boxes have been erected on Blackbeard Island in an attempt to increase local populations of wood ducks.

The endangered southern bald eagle (U.S. Fish and Wildlife Service 1968) occurs uncommonly on the Georgia coast. The size of the present resident population is not known. One pair nested and reared two young on St. Catherines Island during 1970. This is the only known reproduction occurring in coastal Georgia during 1970. Formerly the bald eagle nested on most of the barrier islands and elsewhere along the coast. The old-growth, dead timber that occurs on the islands provides preferred nesting habitat for bald eagles and ospreys. The lack of human disturbance also contributes to successful nesting. Great horned owls often nest in abandoned osprey and eagle nests.

3. Amphibians and reptiles: The herpetology of Georgia's barrier islands is poorly known. Until recently, many of the islands were inaccessible to herpetologists, and there has been very little collecting on the islands. Only one report has dealt exclusively with the herpetofauna of the islands: Martof (1963) listed the reptiles and amphibians collected on Sapelo Island during a 10-year period. The U.S. Fish and Wildlife Service has inventoried the larger vertebrates of the national wildlife refuges on the Georgia coast. Their reports list and discuss such

forms as alligators and sea turtles (Blackbeard Island) but do not include the small reptiles and amphibians of the area. Neill (1948) discussed the island glass lizards collected on Wolf Island, a marsh island south of Doboy Sound.

Because there has been very little systematic collecting on the islands, a description and discussion of the herpetofauna of the islands still must be incomplete. An attempt has been made to collect specimen records, literature references, and reliable sight records relating to the amphibians and reptiles of the barrier islands. The resulting information is presented in Appendix 2. Undoubtedly, additions will be made to the list of species as the islands become more accessible to collectors.

A wide variety of habitats exist on the islands, but because of the restricted area of the islands some habitat types are necessarily limited (e.g., extensive swamps do not exist). Therefore, the occurrence of some reptiles and amphibians is restricted.

The herpetofauna of the barrier islands includes 2 salamanders, 11 frogs, 6 turtles (exclusive of one estuarine and three marine species), 1 crocodilian, 9 lizards, and 12 snakes. None of the species is endemic to the islands, although future taxonomic investigation may reveal subspecific differences among several species. Martof (1963) stated that all of the herpetofauna of Sapelo Island has been acquired from the adjacent mainland. This apparently is true for the populations occurring on the other barrier islands.

The extensive salt marshes and sounds which separate the islands from the mainland and from each other apparently present a rigorous barrier to most amphibians and many reptiles for colonization of the islands. The tidal amplitude (about 7 ft) is the greatest anywhere along the coast of the southeastern United States and estuarine salinites are high along the Georgia coast, ranging from 20 to 30 parts per thousand (ppt) (Williams 1964). The natural occurrence of most of the reptiles and amphibians on the islands is related to their (1) tolerance to brackish and salt water, (2) habitat preferences, and (3) locomotor abilities. Obviously some forms are better adapted than others to movement across the marshes and estuaries. Reptiles are protected by a tough skin and shell (turtles) or skin and scales (snakes and lizards), enabling them to better withstand the rigors of crossing the barriers to the islands. To some degree, this is reflected by the larger number of reptiles than amphibians that occur on the Georgia islands.

All of the frogs and toads occurring on the Georgia islands (except the spadefoot toad) also have been reported in or near brackish or salt water elsewhere (Neill 1958). For example, narrow-mouthed toads have been reported from brackish ponds, and Neill (1958) reported their occurrence on a salt flat at Merritt Island, Fla. Hardy (1953) observed that this amphibian appeared to have a "vigorous proclivity for haline habitats" in the Chesapeake Bay marshes. W. E. Brode (Neill 1958) found narrow-mouthed toads breeding near Bay St. Louis, Miss., in water too salty to drink. Similar tolerance to salt water has been reported for the southern leopard frog (Carr 1940; Pearse 1911) and the southern toad (Allen 1932; Neill 1958), so it is not surprising that the above species commonly occur on the Georgia barrier islands. Similar examples of adaptation to haline habitats exist for many turtles and snakes.

Certain habitat preferences have undoubtedly contributed to successful island colonization by some reptiles and amphibians. Engels (1949) reported he collected the southeastern five-lined skink on Harkers Island and Shackleford Banks, N.C., "beneath loose bark on standing trees." He suggested that this habitat preference may have favored the accidental transportation of the species to the islands. This skink occurs on Sapelo Island along with the five-lined and broad-headed skink.

The cottonmouth and the diamondback rattlesnake occur in considerable numbers on most of the islands. Carr (1936), Allen and Neill (1950), and Wharton (1969) have reported that cottonmouths occur on coastal islands in Florida. Neill (1958) reported that the diamondback rattlesnake is more common in the salt marsh than in any other habitat in two Gulf coastal counties in Florida. He also stated that it is a good swimmer and has been sighted in the ocean several miles from land.

The cottonmouth is semiaquatic but is often found considerable distances from water. Its preferred habitat includes the sloughs and ponds. It commonly feeds on aquatic vertebrates.

The diamondback rattlesnake occupies most types of terrestrial habitat on the islands. It may be found from the drift line along the beaches to the salt marsh. It is least common in the live oak forest. It is commonly thought that this snake is less abundant on islands having feral hog populations. Hogs are generally thought to eat snakes but data are lacking to support this supposition. If hogs do influence rattlesnake numbers, they may do so indirectly by altering the habitat of various prey species such as cotton rats.

Black racers, king snakes, and banded water snakes are perhaps the most common snakes on Sapelo Island. Black racers also are common on St. Catherines, Little Cumberland, and Cumberland islands.

The island glass lizard occurs on coastal islands in South Carolina, Georgia (Sapelo, Wolf), and Florida but is not an insular species. It also is found in the "scrub" patches in the interior of peninsular Florida (Neill 1958) and is known to occur in the vicinity of the Okefenokee swamp in Georgia (Wright and Funkhouser 1915).

Martof (1963) reported the green anole as the most common lizard on Sapelo Island. The large broad-headed skink and the diminutive ground skink are also common there, although the latter is seldom seen without searching under leaf litter.

The endangered American alligator (U.S. Fish and Wildlife Service 1968) occurs on all of the undeveloped barrier islands of Georgia and in portions of the marshlands. The Bureau of Sport Fisheries and Wildlife estimates the 1969 alligator population on their coastal refuges as follows: Savannah, 150+; Wassaw, few; Harris Neck, 10; and Blackbeard, 750-1000 (W. L. Towns, pers. comm.). Population estimates are not available for other barrier islands. The number of alligators on each island is constantly changing because alligators frequently move between the marshes and islands. Although the alligator is rigidly protected by state law in Georgia, some poaching undoubtedly occurs, mainly on those alligators inhabiting the marshes. Alligators on the islands are afforded additional protection by the island owners.

The alligators in the coastal area of Georgia contribute significantly to the total numbers of this species. The barrier islands are, in a way, individual refuges for the alligators, and they play an important role in the conservation of this interesting reptile.

The amphibians (13 species) have not been as successful as the reptiles (28 species, exclusive of estuarine and marine forms) in island colonization. The frogs and toads have been more successful than the salamanders. Only two salamanders, both aquatic, have been reported or collected on the islands. The amphiuma or congo eel, a large aquatic salamander, is probably common in the freshwater sloughs and ditches on many of the islands. However, it is difficult to collect and little is known of its distribution; several have been collected on Sapelo Island. Similar aquatic salamanders, such as the siren, have not been reported from the barrier islands. The central newt, also aquatic, is fairly common on Sapelo Island. This salamander has an immature terrestrial stage called an eft which is commonly found under logs. The eft is especially susceptible to predation by feral hogs on some islands. This may influence the distribution or abundance of this species.

The pig frog was reported by Martof (1963) to be the most common frog or toad on Sapelo. However, pig frogs are conspicuous, and it is difficult to compare their population density with less conspicuous forms such as the tree frogs.

INTRODUCED VERTEBRATES

1. *Exotic birds and mammals*: Several exotic birds and mammals have been intentionally introduced onto the barrier islands. Only a few have become established as perpetuating populations. The relatively large number of species that have been introduced on the Golden Isles is related to the affluence of the island owners. Many owners were attempting to supplement the native wildlife populations with game species that might increase hunting diversity.

Norris (1956) reported that five species of gallinaceous birds were introduced onto Jekyll and Sapelo islands between 1890 and 1924. These included the guinea fowl (*Numida goleta*), tinamou (*Tinamus robustus*), Central American currasow (*Crax rubra*), ocellated turkey (*Agriocharis ocellata*), and chachalaca (*Ortalis vetula*). Since all of these birds are primarily forest-dwelling species, it was hoped that they would thrive in the oak-pine forests of the islands. However, only the chachalaca became established—on Sapelo Island where a small population has maintained itself since 1923. The chachalaca is known to inhabit the dense stands of live oaks on Sapelo (Jenkins 1949), but little else is known of its ecology and relationships to other species on the island.

Several species of big-game animals have been introduced on the islands. These include European wild boar (Cumberland, Little Cumberland, Jekyll, St. Simons, Little St. Simons, Ossabaw, Wassaw); fallow deer (Jekyll, Little St. Simons, Sea, St. Simons); and red deer (Little St. Simons). Only the fallow deer remains. A large population (400-500 animals) exists on Little St. Simons Island,

and a small number occurs on Jekyll Island; individuals occasionally move from Little St. Simons to Sea and St. Simons islands. Although the ecological impact of these animals on the island flora has not been studied, casual observation indicates they contribute to the severe overbrowsing of the vegetation on Little St. Simons, including the dune vegetation and some marsh vegetation.

Hanson and Karstad (1959) said that the European wild boar was introduced into feral herds of swine to increase their sporting value. However, the European wild boar has been extirpated from those islands where it was introduced, or it has been genetically integrated into the large feral hog populations that occur on many of the islands. The ecological impact of feral hog populations will be discussed in the following section.

The nutria, introduced on Blackbeard Island by the U.S. Fish and Wildlife Service in 1949 (Jenkins 1953) as a possible biological control agent for several species of aquatic plants, failed to control or eliminate the problem plants and was exterminated by the early 1960s. A few nutria are reported to occur in the coastal marsh near Brunswick (Wilson 1968).

The fox squirrel probably was introduced on Ossabaw Island in the 1920s or 1930s. Although the exact origin of the squirrels is not known, they are thought to have been obtained from Michigan (Charles Marshall in corresp. 13 October 1970). The ratio of fox squirrels to gray squirrels is approximately 20:1 on Ossabaw (Charles Marshall in corresp. 13 October 1970).

2. *Domestic and feral animals*: Several species of domestic animals have been introduced on the islands. These include common household pets such as dogs and cats and farm animals such as horses, donkeys, cows, hogs, goats, and chickens. (See Table 9 for distribution.) Some of these animals have become established as feral populations. Many of the early owners of the islands derived a considerable portion of their income from the sale of cattle and hogs raised on their islands. However, recent owners have had other sources of income and the need for good animal husbandry has declined. To an extent, this has created ecological problems for many of the islands.

Large, free-ranging herbivores such as horses and cattle and the omnivorous pig have seriously reduced the extent and quality of several island habitat types. The most serious damage has occurred on the dunes. Dune-stabilizing plants have been eliminated or seriously reduced on some islands. The importance of these plants in dune stabilization, hence island stabilization, has been discussed in a previous section.

The mere presence of livestock does not necessarily constitute a threat to the habitat. Only when the numbers of these animals become too great does serious damage occur. In some instances cattle may actually constitute a desirable ecological element. For instance, in the absence of fire, cattle create and maintain openings within the island interior compatible with wild turkey management. Stoddard (1963) cited the attractiveness of grazed areas to turkeys during the brood-rearing season. Recent studies in Alabama (Hillestad and Speake 1970) revealed the apparent compatibility of cattle and wild turkeys. The cattle maintained brood-rearing habitat (pastures) that provided poults with forage and an abundant supply of easily obtainable insects—a preferred food of turkey poults.

TABLE 9. *Present distribution of domestic and feral mammals on the barrier islands.*

Species	Island
Hog	Cumberland, Little Cumberland, Jekyll, St. Simons, Sapelo, St. Catherines, Ossabaw, Wassaw
Horse	Cumberland, St. Simons, Sea, Little St. Simons, Sapelo, Ossabaw
Donkey	Cumberland, Ossabaw
Cattle	Cumberland, St. Simons, Little St. Simons, Sapelo, St. Catherines, Ossabaw
Goat	Ossabaw

Prescribed numbers of cattle could enhance turkey production in some habitat types.

Although there is a certain amount of overlap of food habits between free-ranging cattle and deer, it is not significant enough to force the exclusion of one species. Moderate numbers of both animals may be compatibly maintained on the islands.

Cattle also may be used to maintain open, park-like conditions under the live oak forest where these conditions cannot be obtained satisfactorily with fire. Such conditions facilitate travel and observation and generally enhance the recreational value of this habitat type.

Several of the islands have large populations of free-ranging hogs. On many of the islands they are in a semi-wild or feral state. Most writers are in agreement that free-ranging hogs seriously compete for food with many desirable wildlife species, including deer and turkeys. Many people who are familiar with the hog populations on the islands contend that they interfere with reproduction of ground-nesting birds such as quail and turkey. Hogs also may be influencing small vertebrate populations on some islands. The serious problem of hog depredation on sea turtle nests is discussed in another section.

C. W. Wharton (pers. comm.) found that hogs on Cumberland were feeding in the dune areas on pennywort, a plant which assists in dune stabilization.

Undoubtedly, numbers of free-ranging hogs on several of the islands should be reduced until their ecological relationship to island fauna and flora can be better evaluated.

Bantam chickens recently have been introduced on Ossabaw Island. These domestic birds are free-ranging and are subjects of a study of the ecology of domestication (I. L. Brisbin, pers. comm.). A pure wild strain of red jungle fowl (*Gallus gallus*) is to be released on Ossabaw in a continuation of these studies. Since chickens and jungle fowl are potential vectors of blackhead (*Histomonas meleagridis*), a deadly disease of wild turkeys, precautions have been taken to insure against accidentally introducing it into the turkey population on Ossabaw.

INVERTEBRATES–NOXIOUS ARTHROPODS

The diversity of the invertebrates of the island interior is too complex and inadequately studied to permit a comprehensive discussion here. Therefore, only those forms creating human discomfort and annoyance are included in the following discussion. Mosquitoes, sandflies, deerflies, chiggers, and ticks appear in vast numbers periodically and cause considerable human discomfort as well as serving as potential vectors of a number of diseases affecting man and domestic animals. Recreational activities on the island must sometimes be asynchronous with the appearance of these forms.

Portions of the salt marshes are the breeding sites of two mosquitoes, *Aedes sollicitans* and *Aedes taeniorhynchus*, which often are a severe annoyance to people inhabiting the islands (salt marsh mosquitoes are discussed in Chapter 4). Domestic mosquitoes, including *Aedes aegypti* and *Culex pipiens quinquefasciatus*, are common around dwellings on the islands. The *Culex* mosquito breeds in ground pools and in polluted waters. *Aedes aegypti* is a container-breeder and often can be controlled by eliminating breeding sites such as trash dumps containing cans and bottles (King et al. 1960).

Perhaps the most annoying insects to man on the islands are the deerflies of the family Tabanidae and principally of the genus *Chrysops*. These diurnal insects are most common in wooded areas on the islands and often emerge in such numbers that deer and cattle move into the dune areas where the insects are less abundant and where the wind retards the flight of the flies.

Several species of ticks occur on the islands. The more common species include *Ixodes affinis, I. scapularis, Dermacenter variabilis, Amblyomma americanum*, and *Haemaphysalis* sp. White-tailed deer commonly are heavily infested with *Amblyomma americanum. Ixodes scapularis* has been found on both warm-blooded and cold-blooded hosts. All of these species occasionally are an annoyance to people on the islands.

4 The Marshes

Lying behind the barrier islands is a 4- to 6-mile band of marshland comprising about 393,000 acres (Spinner 1969). Nearly 286,000 acres of this is covered by a single species of marsh grass, known as saltmarsh or smooth cordgrass. (See Table 12 for scientific names of marsh plants not given in the text.) The remaining 107,000 acres consist of several other types of salt, brackish, and freshwater marshes.

Formation and sediment characteristics

Tidal marshes are formed in conjunction with barrier island development. When sea levels rise, dune and beach ridges become partially submerged. Water filling the trough between these structures and the mainland or other barrier islands is subject to relatively less energy perturbation than open waters, and clay and silt sediments suspended in the water are deposited, leaving a mud-type substrate. In time, salt-tolerant marsh plants such as cordgrass stabilize the area.

Deposition continually occurs on the tidal marsh, but at a very slow rate. The added weight of the sediment contributes to submergence and the accumulation of additional sediments (Hoyt 1968d). As flood tides rise above creek banks and inundate the marsh floor with a shallow layer of water, the energy maintaining the sediments in a suspended state is reduced, and the sediments drop out of suspension. As the tides recede, some sediments are resuspended, but this amount averages less than that of flood tides. The receding tide waters form an extensive drainage system of tidal creeks and rivers (Fig. 26). Some tidal channels erode deeply enough to expose Pleistocene sands and frequently penetrate barrier island deposits (Hoyt et al. 1966).

Four sources contribute to the suspended material that is deposited in the marsh: (1) continental shelf, (2) mainland rivers, (3) the marsh itself, and (4) organic deposits (Levy 1968). Continental rivers are the principal source of this material which is distributed and sorted by longshore currents, waves, and tidal currents (Neiheisel and Weaver 1967).

Fig. 26. Aerial photograph showing typical salt marsh drainage pattern.

Superficial deposits are up to 6 ft deep. Cross-bedding related to channeling is common (Henry and Hoyt 1968). Total depths of recent marshes range from 30 to 50 ft (Hoyt et al. 1964).

Grain size of sediments in the marsh range from clay to fine sand. Large amounts of sand from reworked sandy sediments are locally common. Teal and Kanwisher (1961) have analyzed the salt marsh substratum for percentage of sand, silt, clay, organic matter, and roots. Their results show that higher marsh sites have more sand and less organic matter than lower marsh sites. When saturated on high tides, the upper layers of marsh mud contain 50-70% (wet weight) water (Teal and Kanwisher 1961).

Two distinct layers of salt marsh sediments are revealed in cross-section. The aerated and leached sediments of the upper few centimeters are brown. The sediments below are black and rich in reduced organic end products including hydrogen sulfide, methane, and ferrous compounds.

Although marsh soils are normally neutral or slightly alkaline, some of them have the potential to become extremely acid under certain conditions. When marsh soils containing large amounts of organic matter are regularly flooded and anaerobic conditions exist, the sulfates in sea water are reduced and precipitated as sulfides. These conditions occur most commonly at the mouths of larger rivers, in brackish water marshes thickly vegetated with species such as big cordgrass and reed cane. So long as anaerobic conditions prevail, soil pH remains high. But when the soils are exposed to prolonged aeration (as in drained areas, dikes, or spoil areas), the sulfides are oxidized, and one of the products is sulfuric acid. The soil becomes extremely acid (pH may drop to as low as 2.0) and no plant growth can occur. Such soils are then called "cat clays." The acidity is so severe that it is not feasible to correct the condition by liming and the area may remain barren for many years (Edelman and Staveren 1958; Fleming and Alexander 1961).

Vegetation

The U.S. Fish and Wildlife Service has classified the wetlands of the United States into 20 types (Shaw and Fredine 1956). Six of these are coastal marshes occurring in Georgia. These are characterized in Table 10. The extent of these types of marsh on the Georgia coast is as follows (Spinner 1969):

Types 12 and 13	31,700 acres
Types 15 and 16	650 acres
Type 17	74,850 acres
Type 18	285,650 acres

More specific marsh types may be recognized according to plant associations. Many factors contribute to the determination of plant composition of coastal marshes. These include water levels and fluctuations, salinity, type of substratum, acidity, available nutrients, and fire, among others. Salinity and inundation are most important, and gradients or zonations of vegetation related to these factors are commonly evident. Intolerance for salinity and inundation prevent most species from occupying tidal salt marshes (Table 11), and species diversity is greatest in shallow, freshwater marshes. The harsh combination of critical limiting factors in the marsh produces conditions allowing a few tolerant species such a competitive advantage that they develop pure stands. On the Georgia coast, the most extensive of these monospecific marshes are smooth cordgrass, needlerush, and giant cutgrass.

TABLE 10. *Coastal wetland types occurring on the Georgia coast.*[a]

Type	Water levels	Characteristic species
12 Coastal shallow fresh marshes	6 inches or less	reedcane, big cordgrass, cat-tail, arrowhead, smartweed
13 Coastal deep fresh marshes	6 inches to 3 ft	cat-tail, wild rice, pickerelweed, giant cutgrass, pondweeds
15 Coastal salt flats	Always wet, but rarely inundated	glasswort, saltgrass
16 Coastal salt meadow	Always wet, but rarely inundated	saltmeadow cordgrass, saltgrass
17 Irregular flooded salt marsh	Flooded irregularly	needlerush
18 Regularly flooded	6 inches or more at high tide	smooth cordgrass

[a]From Shaw and Fredine 1956.

TABLE 11. *Relative salt tolerance of some plants important in the coastal marshes of Georgia.*[a]

Species	Per cent salt
Sawgrass	0.00-0.20
Cat-tail	0.00-1.68
Giant cutgrass	0.00-0.89
Reedcane	0.00-2.04
Southern bulrush	0.00-1.13
Olney's three-square bulrush	0.55-1.68
Salt marsh bulrush	0.64-3.91
Needlerush	0.12-4.43
Big cordgrass	0.55-2.04
Salt meadow cordgrass	0.12-3.91
Smooth cordgrass	0.55-4.97
Saltgrass	0.45-4.97

[a]Data from Penfound and Hathaway 1938.

Freshwater and brackish marshes

Freshwater marshes occur primarily near the mouths of larger mainland streams and are most extensive at the mouth of the Altamaha River. They may extend for some distance up the rivers before being replaced by cypress-gum or hardwood swamps. Much of the area now covered by freshwater marsh was cypress swamp before it was cleared and diked for rice culture. Shallow freshwater marshes contain a variety of species including cattails, several bulrushes, smartweeds, aneilema, arrowhead, arrow arum, and others. The deeper freshwater marshes are more extensive, occupying about 25,000 acres along the Georgia coast. In many areas this marsh type is comprised almost exclusively of giant cutgrass. Stands of sawgrass occur intermittently. Around the deeper margins of the marsh, stands of cattail are common and wild rice occurs in sporadic stands. In the deeper creeks and potholes, submersed and floating-leaved plants are dominant.

As salinities increase to brackish conditions (about 0.5-2%), giant cutgrass is replaced primarily by big cordgrass and, to a lesser extent, by salt marsh bulrush.

Salt marsh

Most indigenous plants cannot survive salinities approaching sea strength; they are replaced in the salt marsh by a few species with high salinity tolerances. Included in this group are smooth cordgrass, needle rush, saltgrass, glasswort, salt meadow cordgrass, and sea oxeye (*Borrichia frutescens*).

The salt marshes of the southeastern states have been the subject of much study. Studies of plant associations in the salt marshes of North Carolina have been reported by Wells (1928), Reed (1947), Bourdeau and Adams (1956), and Adams (1963). Kurz and Wagner (1951) reported on salt marsh vegetation in Florida and at Charleston, S.C. General treatments of salt marshes include those of Townsend (1925), Ragotzkie et al. (1959), Chapman (1960), and Teal and Teal (1969).

Of the local marsh plants only smooth cordgrass is adapted to both the salinities and the tidal fluctuations of the low tidal marsh. Teal and Teal (1969) describe the adaptive mechanisms in smooth cordgrass that enable it to exist in the marsh. Root membranes prevent the entry of much salt into the plant, and the cells selectively absorb sodium chloride to maintain osmotic pressure and prevent plasmolysis. Special glands on the leaves excrete excess salt.

Ducts in the stems carry oxygen to the roots of the plant where it is used in the oxidation of iron sulfides to soluble iron compounds that are used by the plant. The high iron requirement of smooth cordgrass is one of the factors that restrict it to the salt marsh (Adams 1963).

Smooth cordgrass and most other salt marsh plants grow best in fresh water, at least under laboratory conditions (Taylor 1939). But they do not commonly occur in freshwater marshes, partly because they are unable to compete with more vigorous species. Their tolerance to salt stress enables them to persist in the salt marsh free of competition. Thus, zonation in the salt marsh is primarily related to elevation as it determines frequency, depth and duration of inundation, and soil salinity.

The zones of the salt marshes of the southeastern United States have been classified in various ways (Wells 1928; Penfound 1952; Adams 1963; Teal 1958; Stalter and Batson 1969, and others). Following is a description of the usual gradient in vegetation in Georgia salt marshes, proceeding generally from the tidal creek landward (Fig. 27). Unless otherwise indicated, *Spartina* used hereafter refers to smooth cordgrass.

A portion of the creek banks exposed at every low tide is devoid of vegetation. These banks are composed of sand, mud, or oyster shells. Slumping occurs along some banks and results in relatively large deposits being exposed directly to tidal currents. The upper slopes of the banks are vegetated with smooth cordgrass. The cordgrass grows tallest here (3-10 ft), and Teal (1958) designated this zone the "tall *Spartina* edge marsh." The cordgrass grows to about 3 ft on top of the levees. Teal (1958) called this zone the "medium *Spartina* levee marsh."

Behind the levees the marsh is thickly vegetated with smooth cordgrass and is covered by every tide for several hours each day. Sand content is 0-10% (Teal 1958). Teal (1958) called this area the "short *Spartina* low marsh." Stalter and Batson (1969) designated this zone together with the creek banks and levees as the "low low marsh."

With increasing elevation toward the edge of the marsh, inundation is to a lesser depth and is for a shorter period of time. Sand content is from 10 to 70% (Teal 1958), and salinity of the soil beneath the cordgrass progressively increases (Penfound and Hathaway 1938; Bourdeau and Adams 1956; Stalter and Batson 1969). A dwarf form of smooth cordgrass occurs in this zone that is probably a genetic variant, environmental conditions reinforcing the differences between the two forms (Broughton and Webb 1963; Stalter and Batson 1969). Teal (1958) termed this zone the "short *Spartina* high marsh," and Stalter and Batson (1969) called it the "high low marsh."

At elevations where the marsh is flooded for only about one hour each day, the dwarf *Spartina* gives way to other species: notably glasswort, saltgrass, sea oxeye, and sea lavender (*Linomium carolinianum*). Sand content is 85-95% in this zone (Teal 1958). This zone is called the "*Salicornia-Distichlis* marsh" (Teal 1958) or the "low high marsh" (Stalter and Batson 1969).

Sandy, unvegetated areas are locally common in the higher portions of the marsh. These areas are commonly called salt barrens or salt pans. Subject to infrequent flooding and rapid evaporation, the barrens are too saline to support vegetation. Glasswort occurs around the margins and grades into saltgrass.

Salt meadow cordgrass (which, farther north on the Atlantic coast, forms extensive meadows that are harvested for hay, straw, and upholstery stuffing) occurs on the Georgia coast only at the rim of the marsh in a zone that is flooded only a few times each week. Salinity decreases abruptly in this zone

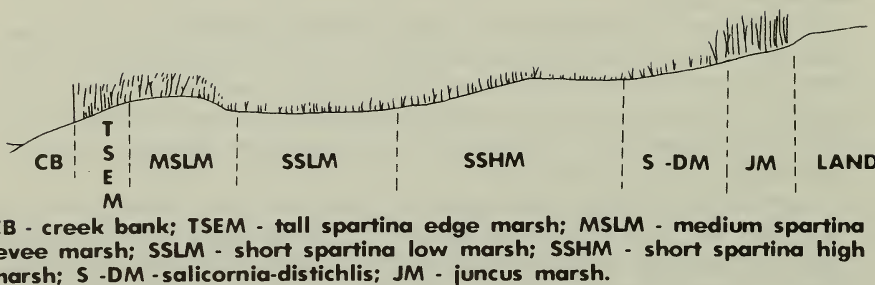

Fig. 27. Typical profile of a salt marsh showing the marsh types described by Teal 1958. (Adapted and redrawn from Teal 1958.)

(Bourdeau and Adams 1956). Salt meadow cordgrass occurs only where relatively low salinities prevail. Other plants that characterize this zone are high tide bush (*Iva frutescens*), groundsel tree (*Baccharis halimifolia*), and salt myrtle (*Baccharis glomeruliflora*).

Needlerush marsh occurs at slightly higher elevations that are infrequently flooded, especially where salinity is lower. It occurs as a narrow zone around the salt marsh on the islands, and forms extensive pure stands in many areas adjacent to the mainland.

Marsh fauna

Animals that complete their life cycles in the salt marsh have morphological, physiological, and behavioral adaptations for coping with extremes of salinity, inundation, and exposure in the marsh, and the activity cycles of most species are keyed to the tides.

Following is a discussion of some of the animal forms occurring in the salt marsh: their distribution, abundance, and ecological relationships. This information was obtained from published material and from our own field observations. The discussion is extended to include rails and waterfowl in the freshwater marshes; otherwise, it is restricted to animals of the salt marsh.

Vertebrates

1. Mammals. The harshness of the salt marsh restricts the numbers of resident mammals to a few species. Raccoons are one of the most abundant mammals, and marsh rabbits are common along the edges of the marsh adjacent to high ground. Mink are more common than otter, but both of these carnivores are seen infrequently. The rice rat is common along the levees of tidal creeks.

Mammals that have adapted to living or feeding in the marsh are highly mobile. Racoons feed in the marsh at low tide and are inactive at high tide regardless of whether it is night or day. They retreat to the higher ground on the mainland or islands at high tide or construct a bed of cordgrass above the high-tide level. In freshwater marshes nearby, their activity is mostly nocturnal (Ivey 1948). Mink and otter are well adapted to feeding in the aquatic environment of the marsh, but they often retire to higher ground for nesting and denning purposes. Kale (1965) stated that mink may spend much of their life in the marsh. He observed that they constructed beds of dead cordgrass on the high ground of the marshes or used hollow tree trunks washed into the marsh. The rice rat is well adapted to spend a 24-hour day in the salt marsh. The rat constructs its own nest in the tall *Spartina* or occupies an abandoned nest of the long-billed marsh wren (Sharp 1967).

Food for marsh mammals is abundant but is of limited diversity. Raccoons are known to feed heavily upon fiddler and squareback crabs (*Uca* spp. and *Sesarma* spp.), two of the most abundant animals in the marshes. They also prey on the eggs of diamondback terrapins (Coker 1906), clapper rails (Oney 1954), and marsh wrens (Kale 1965). They are not considered a limiting factor on wren populations (Kale 1965). The food habits of marsh mink are not known for the coastal region of Georgia. Teal and Teal (1969) state that clams and crabs are the principal foods of marsh mink in autumn, and Wilson (1954) reported that fish occurred in 61% of the digestive tracts of mink from marshes of northeastern North Carolina. Oney (1954) listed the mink as a predator on clapper rail eggs. Otters feed mostly on fish. Wilson (1964) found fish in over 90% of otter digestive tracts and fecal samples from northeastern North Carolina.

The rice rat is preferentially carnivorous. Studies on Sapelo Island (Sharp 1962, 1967) reveal that during the summer the rats feed primarily on fiddler and squareback crabs and the larvae of the rice borer, with other insects occurring as incidental food items. In the fall, crabs are the major food items, but small amounts of seed and fibrous portions of smooth cordgrass also are used. Kale (1965) attributed considerable egg loss and nestling mortality of the long-billed marsh wren to predation by rice rats. Sharp (1967), however, found no remains of wrens in 22 rats examined, and he suggested that the wren is only an incidental food item during the summer.

Marsh rabbits are characteristic of high marsh and normally do not occur in tidal salt marsh (Tomkins 1955; Teal 1962). Marsh rabbits are strictly herbivorous, but their exact food habits are unknown.

Harvest of marsh furbearers such as raccoon, mink, and otter generally is low in the coastal area because of the low market value of pelts, especially from this area. There are an estimated 300 fur trappers (Spinner 1969). Raccoons are taken for food by a small number of hunters; there is no closed season. The only management for mink and otter is the regulation of harvest by an established trapping season.

2. Birds. Kale (1965) stated that three species of birds were intimately associated with the salt marsh community in coastal Georgia. These are the long-billed marsh wren, the clapper rail or marsh hen, and the seaside sparrow. Kale (1965) studied the ecology and bioenergetics of the marsh wren, and Oney (1954) studied the biology, distribution, and limiting factors of the clapper rail in Georgia. The seaside sparrow has not been intensively studied in Georgia.

The following discussion of the long-billed marsh wren is based primarily on Kale's (1965) study in the vicinity of Sapelo Island. During the breeding season, the marsh wren establishes territories averaging 100 m^2 in the tall *Spartina* edge marsh. Singing males establish breeding territories, and nesting and brood rearing take place within the territory. The peak of the breeding season is May to July. Predation is the primary cause of mortality of eggs and young. Major predators are rice rats, raccoons, and mink. However, mortality factors are minor limiting factors on marsh wren populations; Kale concluded that the highly developed territorial and colonial behavior of the marsh wren was the principal factor limiting population size. A discussion of food habits and bioenergetics of the wren is included in the section on food webs and energy flow.

The clapper rail is a common game bird in coastal salt marshes. Clapper rails begin nesting in the medium *Spartina* marsh early in April. Oney (1954) found that some nests were inundated by as much as 19 inches of water during high tides and hatched successfully. Teal and Teal (1969) also reported that the eggs of the marsh hen can withstand tidal inundation. The major nest predators probably are raccoons, mink, and crows. The major food is the squareback crab, which occurs in the soft mud areas of the tidal streambanks. Other foods include fiddler crabs and periwinkle snails (*Littorina irrorata*). During the winter months when the crabs become inactive, clapper rails shift to other foods. Richard Heard (pers. comm.) observed that rails feed on snails (*Melampus* sp.) during cold weather.

The clapper rail is hunted by a small number of hunters–5000 in 1968 (Spinner 1969)–during the high tides of September-November. Prior to 1948 the rail harvest approached 86,000 birds (Oney 1954). However, the use of outboard motors in rail hunting was prohibited by Federal law beginning in 1948 and rail hunting declined sharply. Oney (1954) recommended that outboard motors be allowed in rail hunting.

The king rail, a close relative of the clapper rail, occurs in the freshwater and brackish marshes. Meanley (1969) reported that king rails nested in giant cutgrass and softstem bulrush along tidal canals on the Savannah National Wildlife Refuge. The fiddler crab (*Uca minax*) of the latter habitat is a preferred food of the rail. King rails feed on freshwater insects, fish, crustaceans, and amphibians that are abundant in mats of alligator-weed in the canals and ditches (Meanley 1969).

The willet, although common on beaches, is more common in the salt marsh.

It feeds on fiddler and squareback crabs and periwinkle snails in the short *Spartina* low marsh (Tomkins 1965b).

The seaside sparrow has not been studied in coastal Georgia. Kale (1965) observed that in his study area the seaside sparrow fed primarily on the ground. Howell (1932) listed small crabs, pelecypods, gastropods, dragonflies, grasshoppers, spiders, and beetles as foods.

Wading birds use the marsh as a feeding and nesting area. Five species frequent the marsh in large numbers throughout the year. Other species occur seasonally in the marsh, especially during the summer. Several large rookeries are located on some of the marsh islands (Fig. 34, Appendix 4).

Great blue herons, little blue herons, common egrets, snowy egrets, and Louisiana herons are common residents of the salt marshes. During high tides, they feed in shallowly flooded marsh grass. Snowy and common egrets are most frequently encountered in the marsh at low tide. Cattle egrets have been observed feeding on fiddler crabs near tidal creeks; they feed more commonly near agricultural areas inland.

During the summer of 1970, a large wading bird rookery was discovered on a marsh island in the Altamaha River (Fig. 34). This rookery contained, in addition to large numbers of white ibis, 75-100 nesting pairs of glossy ibis. Hebard (1950) reported glossy ibis nesting in Georgia, but Burleigh (1958) did not acknowledge his record, and Sciple (1963) considered it too "tenuous" to accept. The observation of glossy ibis nesting in Georgia in 1970 fills the hiatus in the breeding distribution for this species as noted by Teal (1959).

Georgia is within the Atlantic flyway of migratory waterfowl, and the coastal region is on the southern portion of the flyway. The major species of ducks occurring in this flyway include mallard, black, pintail, gadwall, baldpate, shoveler, green-winged teal, scaup, ring-necked, and canvasback. All of these species occur in varying numbers along the Georgia coast. The number of waterfowl wintering on the Georgia coast has been affected by refuges farther north where many waterfowl spend the winter instead of migrating farther south to their natural wintering areas. For example, very few Canada geese now winter on the Georgia coast, and populations of wintering mallards are significantly reduced by northern refuges.

Most waterfowl management on the Georgia coast is on lands owned by state and Federal wildlife agencies. Despite the fact that several areas in private ownership offer excellent opportunities for attracting waterfowl, little private management is practiced as compared with South Carolina, for example. There are a few marsh areas near the Satilla River that are under the management of private hunting clubs, but the management programs of these clubs are minimal.

Freshwater marshes have greater variety of aquatic plants (Table 12) and are most heavily used by waterfowl. Except on Blackbeard Island, most coastal waterfowl management is in old rice field impoundments and newly diked marsh in brackish water areas. Water control devices are strategically placed in the dikes, and water levels are manipulated to favor plants used by waterfowl. These include in brackish impoundments submersed plants such as widgeon-grass, musk-grass, and pondweed, and emergent plants such as dwarf spikerush and salt

TABLE 12. *Some naturally occurring plants of significance in waterfowl management.*

Species		Growth habit[a]	Habitat[b]
Generally desirable			
Muskgrass	*Chara* spp.	Sb	Fr, B
Soft-stem bulrush	*Scirpus validus*	E	Fr
American 3-square bulrush	*Scirpus americanus*	E	Fr
Olney's 3-square bulrush	*Scirpus olneyi*	E	Fr, B
Salt marsh bulrush	*Scirpus robustus*	E	B
Dwarf spikerush	*Eleocharis parvula*	E	B
Giant foxtail grass	*Setaria magna*	E	Fr
Wild rice	*Zizania aquatica*	E	Fr
Wild millet	*Echinochloa crusgalli*	E	Fr
Pondweed	*Potamogeton* spp.	Sb, Fl	Fr, B
Bushy-pondweed	*Najas* spp.	Sb, Fl	Fr, B
Wild celery	*Vallisneria americana*	Sb	Fr, B
Widgeon-grass	*Ruppia maritima*	Sb	Sa
Aneilema	*Aneilema keisak*	E	Fr
Water-shield	*Brasenia schreberi*	Fl	Fr
Banana water-lily	*Nymphaea mexicana*	Fl	Fr
Smartweed	*Polygonum* spp.	E	Fr
Generally undesirable			
Needlerush	*Juncus roemerianus*	E	B, Sa
Sawgrass	*Cladium* spp.	E	Fr, B
Giant cutgrass	*Zizaniopsis miliacea*	E	Fr, B
Smooth cordgrass	*Spartina alterniflora*	E	B, Sa
Salt meadow cordgrass	*Spartina patens*	E	Sa
Big cordgrass	*Spartina cynosuroides*	E	B
Reedcane	*Phragmites communis*	E	Fr
Saltgrass	*Distichlis spicata*	E	B, Sa
Pickerelweed	*Pontederia cordata*	E	Fr
Golden club	*Orontium aquaticum*	E	Fr
Arrow arum	*Peltandra virginica*	E	Fr
Glasswort	*Salicornia* spp.	E	Sa
Alligator-weed	*Alternanthera philoxeroides*	E	Fr
Yellow cow-lily	*Nuphar luteum*	Fl	Fr
White water-lily	*Nymphaea odorata*	Fl	Fr
Lotus	*Nelumbo* spp.	Fl, E	Fr
Fanwort	*Cabomba caroliniana*	Sb, Fl	Fr
Cat-tail	*Typha* spp.	E	Fr
Arrowhead	*Sagittaria latifolia*	E	Fr
Waterweed	*Elodea canadensis*	Sb	Fr
Bladderwort	*Utricularia* spp.	Sb, Fl	Fr
Parrot's-feather	*Myriophyllum* spp.	Sb	Fr
Coontail	*Ceratophyllum* spp.	Sb	Fr

[a]Sb = submersed, E = emergent, Fl = floating leaved.

[b]Fr = freshwater, B = brackish, Sa = saline.

marsh bulrush, and in freshwater impoundments smartweeds, aneilema, and panic grasses.

The salt marshes (not including potholes and tidal streams) have limited appeal as feeding areas for most species of waterfowl. Lynch (1968) stated that the "true worth of the southern tidal marsh lies not so much in its direct appeal to waterfowl, but rather in its subtle contributions to waterfowl food chains of adjacent environments." Foods available to waterfowl in salt marshes are mainly animal forms. In tidal creeks and potholes widgeon-grass, a submersed aquatic, is the most important duck food. Most dabbling and diving ducks utilize this plant. The black duck, the most common duck using the salt marsh, feeds primarily on snails. Many species of waterfowl use areas within the salt marsh as resting and loafing areas (Teal and Teal 1969).

The open waters of the tidal creeks are especially attractive to diving ducks and other birds preferring animal foods. Pied-billed grebes, red-breasted and hooded mergansers, and large numbers of scaup commonly feed in the tidal creeks.

At low tide the exposed mud flats of the tidal creeks and marshes are preferred feeding areas for many species of shorebirds such as willets and greater yellowlegs.

Species and preferred habitats of birds occurring on the coast of Georgia are tabulated in Appendix 3.

3. Reptiles. The diamondback terrapin is the only reptile inhabiting the salt marsh throughout the year; it is very common there. Formerly the diamondback was a "gourmet's delight" and commanded high prices in northern markets; about 1900, marketable females commonly sold for $30-36 per dozen (Coker 1906). Only the females reach a marketable size of about 6 inches; males seldom exceed 4.5 inches in length. Experimental rearing studies were conducted by state and Federal agencies (Coker 1906; Hildebrand 1929, 1932; Barney 1922), and although artificial production was successful, it did not prove to be commercially profitable. Small numbers of terrapins are currently taken from Georgia marshes for personal use, and a few turtles are still sold commercially.

The terrapin feeds mainly on periwinkles in the short *Spartina* marsh during periods of high tides. Martof (1963) reported that the peak in egg-laying in the marshes near Sapelo Island occurred late in May and early in June. Female terrapins dig nests and lay their eggs slightly above the high tide line. Raccoons are their main predators.

Alligators sometimes are observed in the tidal creeks and sounds when they move to and from freshwater and brackish marshes. A few alligators feed in the salt marsh.

Invertebrates

Approximately 50 species of insects occur in the salt marshes (Teal and Teal 1969). Some of these complete their life cycle in the marsh, others only breed or spend a portion of their life cycle there. The salt marsh grasshopper (*Orchelimum fidieinium*) is restricted to the salt marsh and is one of the few marsh insects that have been studied intensively. Smalley (1960) found this species to be the primary grazer of smooth cordgrass in Georgia. It is more fully discussed in the section on food webs and energy flow. The plant hopper, *Prokelisia marginata*, very common in the marshes, sucks the juices of smooth cordgrass (Teal and Teal 1969).

An ant, *Crematogaster clara*, feeds on the surface of the cordgrass but lives within the stem of the plant. During high tides, a specially adapted individual blocks the entrance to the nest with its head and thus prevents the colony from being flooded (Teal and Teal 1964).

Two species of salt marsh mosquitoes occur on the coast, *Aedes taeniorhynchus* and *A. sollicitans. Aedes taeniorhynchus* is the more common species , but *A. Sollicitans* is more aggressive in attacking humans (Bidlingmayer and Schoof 1957). Both species breed above the intertidal zone and lay their eggs in potholes and depressions that are covered only by excessive amounts of rainfall or above-normal high tides (King et al. 1960). Oviposition occurs on moist soil or grassy areas within the zone (King et al. 1960). Saltgrass is a good indicator of these zones. However, it is not essential to the breeding of either species as both commonly breed in the cracks that occur in silt dredged from coastal rivers (H. F. Schoof, pers. comm.). The eggs can withstand droughts of 4-6 months, and eggs may hatch within hours following flooding. The detritus-feeding larvae live in the tidal pools before transforming into adults.

The salt marsh mosquito is a vector of the dog heartworm (*Dirofilaria immitis*). Although certain arboviruses have been isolated from these mosquitoes, diseases of public health significance, such as encephalitis, have not been traced to *A. taeniorhynchus* or *A. sollicitans* (H. F. Schoof, pers. comm.).

Three blood-sucking midges, *Culicoides furens, C. hollensis*, and *C. melleus*, occur in the coastal area of Georgia. These noxious insects breed in the marsh and are very abundant during the summer.

Deer flies (*Chrysops* spp.) are extremely common in the coastal region. During the peak emergence in mid-May (Snoddy 1970), they are a severe annoyance to inhabitants of the area. Breeding takes place in habitat similar to the breeding sites of salt marsh mosquitoes. However, the larvae of deerflies are semiaquatic; they are seldom found in areas which are covered with tides.

Several species of crabs are common in the marsh. The brown squareback crab (*Sesarma cinereum*) occurs on the landward side of the marsh, and the purple squareback crab (*S. reticulatum*) and mud crab (*Eurytium limosum*) occupy the soft mud area on the levees of tidal creeks in the dense cordgrass (Oney 1954; Teal 1958).

Teal (1958) studied the factors responsible for the distribution of the three species of fiddler crabs in the Georgia marsh. He determined that *Uca pugnax* and *U. minax* select sites with a muddy substratum suitable for digging burrows that do not collapse when flooded by tides. *Uca minax*, the largest species, prefers marsh habitat in brackish water and has the highest tolerance to fresh water. *Uca pugilator*, commonly called the sand fiddler, selects sandy marsh areas for its burrows. Teal noted that this crab is excluded from some sandy marsh habitat by competition from the other two crabs. *Uca pugilator* plugs its burrow before tidal inundation and, although the burrow is in sandy marsh, the air trapped within the burrow prevents collapse (Teal and Teal 1969). All of the fiddlers feed on organic detritus, and food is not a limiting factor in their distribution (Teal 1958). All of the fiddler crabs reach the adult stage in one year.

Two species of snails, the periwinkle and *Melampus lineatus*, are common in the salt marshes. The shell of the periwinkle is sealed by a horny, protective shield (operculum) attached to the foot, an adaptive protection against desiccation. *Melampus* is susceptible to desiccation because it has no operculum and therefore must remain near damp sites. It moves up and down the cordgrass stalks with the tides, and feeds on detritus deposits on the plant. Experiments with *Melampus* indicate that it has a biological clock timed to tidal movements and begins to climb the *Spartina* stalks before the tidal water arrives (Teal and Teal 1969).

Primary production

Primary productivity is the rate at which energy is fixed or carbon is stored by the photosynthetic and chemosynthetic activities of producer (autotrophic) organisms. The fixed energy becomes available for consumption by consumer (heterotrophic) organisms within the system. Therefore, any analysis of total productivity is really an analysis of the rate of plant growth (Schelske and Odum 1961).

Research at the University of Georgia's Marine Institute reveals that the marsh-estuaries of Georgia are highly productive ecosystems. Schelske and Odum (1961) list five factors that are responsible for this high productivity. These are: (1) three types of primary production units; (2) tidal ebb and flow; (3) abundant supplies of nutrients; (4) rapid regeneration and conservation of nutrients; and (5) year-round production with successive crops.

Primary production units are smooth cordgrass (Smalley 1959), benthic algae (Pomeroy 1959), and phytoplankton (Ragotzkie 1959). Each producer unit occupies a different "production niche." *Spartina* thrives in the intertidal zone and produces two-thirds to three-fourths of the total primary production. Net *Spartina* production is about 6580 kcal/m^2/year (Teal 1962). Maximum production occurs during the summer months. Mud algae contributes one-third to one-fourth of the total primary productivity (Schelske and Odum 1961). Pomeroy (1959) determined gross productivity to be approximately 1800 kcal/m^2/year and net production to be 1620 kcal/m^2/year. Thus the mud algae are the most efficient producer systems in that only 180 kcal/m^2/year is lost to respiration. Production rates were approximately the same throughout the year. During the summer, production was high when marshes were flooded and light intensity was reduced. However, in winter, when insolation was less, maximum productivity occurred when the marsh was exposed. Phytoplankton production is greater than previously thought (Schelske and Odum 1961), but exact production figures are not available. Schelske (1962) has determined that nutrients are not a limiting factor on phytoplankton production. However, high turbidity in estuarine waters limits light penetration and phytoplankton production below a depth of about 6 ft. Phytoplankton production increases when the marsh is flooded because the surface area is four to five times greater at high tide than at low tide (Ragotzkie and Bryson 1955).

Tidal action is perhaps the most important factor influencing primary production. Twice daily, tides of approximately 7 ft carry essential nutrients into the marshes, export detritus and nutrients back into estuaries, and provide a large surface area for phytoplankton production. Tidal flushing maintains a desirable vertical distribution of nutrients and detritus.

Nutrients are abundant and probably are not a limiting factor in estuarine production (Schelske and Odum 1961). The nutrients of the fertile estuarine waters are contributed by the marshes and not directly by inflowing rivers (Schelske and Odum 1961; Thomas 1966).

A significant factor relating to primary production is the rapid turnover of nutrients within the system. Such is the case in Georgia estuaries where nutrients are not "tied up" but move rapidly through the system (Pomeroy 1960). Fewer nutrients are needed for production if they are continually available to organisms (Schelske and Odum 1961).

Nutrients are conserved in the system by recycling; they are repeatedly reused with little loss to the system. The horse mussel, for example, is an important biological agent in the recycling of phosphorus (Kuenzler 1961), an essential element in estuarine production.

The three primary producers sustain production on a year-round basis (Schelske and Odum 1961). Spartina produces two crops per year, mud algae produce at a fairly constant rate, and phytoplankton contribute to production throughout the year (Schelske and Odum 1961).

The combined effect of these factors produces one of the most naturally fertile areas of the world. The net production of the marshes and estuaries amounts to approximately 2000 gm/m^2/year or 10 tons (dry weight) per acre of organic material (Odum 1961).

Energy flow and food webs

The most comprehensive studies of energy flow in the salt marsh have been conducted at the University of Georgia's Marine Institute. These studies have revealed that energy stored by the primary producers follows two pathways through the ecosystem (Fig. 28): the grazer food chain and the detritus food chain (Odum 1961, 1963). The grazer food chain has four primary consumers: *Orchelimum fidieinium* (Smalley 1960), *Prokelisia marginata, Trigonotylus* sp., and *Ischnodemus badius* (Marples 1966). Smalley (1960) found that during a

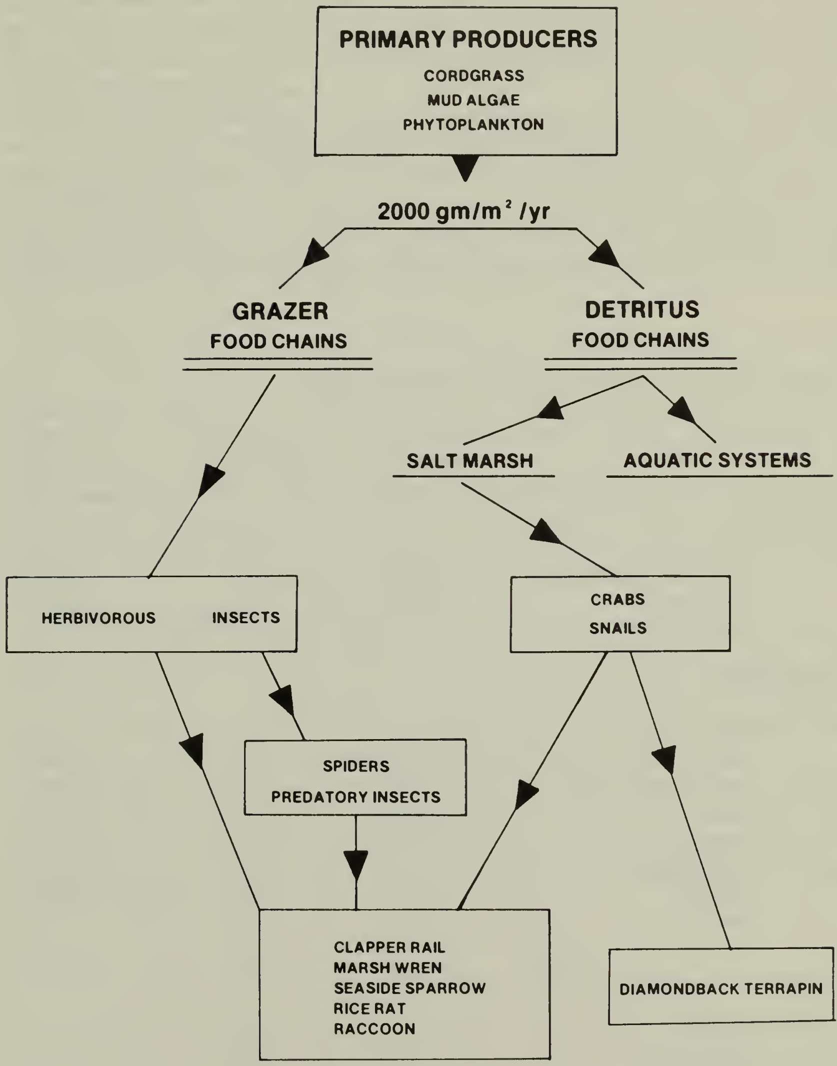

Fig. 28. Very generalized diagram of production and utilization of organic matter in the salt marsh. Approximately 5% of the primary production is utilized by the grazer food chain and 95% by the detritus food chain. Approximately 55% of the primary production is accounted for by the salt marsh ecosystem, leaving 45% available for export into the aquatic system.

period of about 100 days, salt marsh grasshoppers consumed approximately 2% of the total *Spartina* crop. The utilization efficiency of salt marsh grasshoppers (0.57%) was low because *Spartina* grows throughout the year at varying rates and because the grasshopper has a short life span (4 months) and ingests only leaves (Smalley 1960). Total energy flow for the grasshoppers and planthoppers is summarized in table 13. Odum (1961) reported only 5% of the total *Spartina* production is utilized by the herbivores *Orchelimum* and *Prokelisia*; therefore, most of the marsh production is available to detritus-algae consumers.

The base of the detritus food chain is dead *Spartina* which is attacked by microorganisms. Odum and de la Cruz (1967) stated that "organic detritus is the chief link between primary and secondary productivity" (autotrophic and heterotrophic levels). It has been suggested by several workers that bacteria may be an

TABLE 13. *Summary of energy flow in the salt marsh.*[a]

Organism	Gross production	Respiration	Net production
I. Producers			
smooth cordgrass	34,580[b]	28,000	6,580
mud algae	1,800	180	1,620
phytoplankton	——————	no comparable data	——————
II. Consumers			
A. Primary			
salt marsh grasshopper	29.4	18.6	10.8
plant hopper	275.0	205.0	70.0
crab	206.0	171.0	35.0
annelid	35.0	26.0	9.0
nematode	85.0	64.0	21.0
mussel	56.0	39.0	17.0
snail	80.0	72.0	8.0
Total	766.4	595.6	170.8
B. Secondary			
mud crab	27.2	21.9	5.3
clapper rail	1.7	1.6	0.1
raccoon	1.7	1.6	0.1
Total	30.6	25.1	5.5

[a]Modified from Teal (1962).
[b]Values in kcal/m^2/yr.).

important link in the food chain, making some of the hard-to-digest materials available as well as serving as food themselves. They colonize the detritus particle and, upon ingestion, may be stripped off and utilized as food (Burkholder and Bornside 1957; Teal 1958, 1962; Pomeroy et al. 1969). Burkholder and Bornside (1957) estimated that the standing crop of bacteria in the marsh is 10^7 bacteria per gm wet mud.

Teal (1962) considered the important detritus-algae feeders to be fiddler crabs, oligochaetes, periwinkle snails, and nematodes among the deposit feeders, and *Modiolus demissus* and *Mamayunkia aestuarina* among the suspension feeders. Marples (1966) reported that the periwinkle snail and fiddler and squareback crabs were the most important detritus feeders. Several investigators have determined rates of energy flow for some of these forms. Teal (1962) presented some of his own data and summarized the data of others relating to these detritus feeders. This information is summarized in Table 13.

Predaceous insects (secondary consumers) feed on the herbivorous insects and in turn are fed upon by marsh wrens and rice rats (tertiary consumers). The marsh wren was shown by Kale (1965) to be also a secondary consumer on the grazer food chain since it also fed on herbivorous insects. Predators of the detritus feeders include mud crabs, raccoons, clapper rails (Teal 1962), and the diamondback terrapin. Additional predators which have been observed to prey upon fiddler crabs (detritus feeders) are red drum, willet, white ibis, herring gull, gull-billed tern, boat-tailed grackle, whimbrel, snowy egret, cattle egret, and little blue heron. Table 13 summarizes the energy flow data presented by Teal (1962) for the mud crab, raccoon, and clapper rail.

The utilization of organic matter in the salt marsh (Fig. 28) accounts for approximately 55% of the total primary productivity. Therefore, roughly 45% (4.5 tons per acre) of the production is available for utilization by and support of an abundance of estuarine animals (Teal 1962), including numerous finfish and shrimp which sustain an important industry.

In summary, 6.1% of incident light energy is utilized by the salt marsh in gross production and 1.4% of light energy becomes net production (2000 $gm/m^2/yr$). Fifty-five percent of the net production is consumed by the marsh inhabitants and 45% is available for export into the estuarine system (Odum 1961; Teal 1962).

5
The Open Marine and Estuarine Waters

The marshes, being protected by the barrier islands from frontal assault by the ocean, interact with the ocean indirectly, through systems of tidal streams and estuaries (Fig. 26). Estuaries are semi-enclosed bodies of water having free connections with the open sea and having sea water measurably diluted with fresh water derived from land drainage (Pritchard 1967a). The estuaries of Georgia connect with the sea through the sounds that separate the barrier islands. These are north to south from the Savannah River Entrance to the St. Marys River Entrance: Wassaw Sound, Ossabaw Sound, St. Catherines Sound, Sapelo Sound, Doboy Sound, Altamaha Sound, St. Simons Sound, and St. Andrews Sound. Salt water is diluted by fresh water from the Savannah, Ogeechee, Altamaha, Satilla, and St. Marys rivers. The coastal or inshore waters extend from the mouths of the sounds and from the barrier beaches to a depth of about 60 ft. The offshore waters of the continental shelf lie beyond.

The continental shelf along the Georgia coast is 70-80 miles wide with a gentle slope of about 2 ft per mile (Henry and Hoyt 1968). It is covered by sediments deposited during low stands of the sea. The topography of the continental shelf off the Georgia coast is shown in Fig. 29. The poorly defined valley in the shelf east of Sapelo Island is thought to be a filled valley once occupied by the Altamaha River (Pilkey and Giles 1965). An abrupt increase in slope of descent occurs at 50-80 m (Pilkey and Giles 1965). This break marks the edge of the continental shelf and the beginning of the upper continental slope. Seaward of the continental shelf is the Blake Plateau, an intermediate plateau between the continental shelf and the ocean basin. The Blake Plateau averages 700-1000 m depth (Pilkey and Terlecky 1966).

The coastal (inshore) waters are somewhat diluted with fresh water; they are turbid and most productive. Beyond the continental slope, ocean waters are clear and relatively unproductive. The waters of the continental shelf are of intermediate fertility.

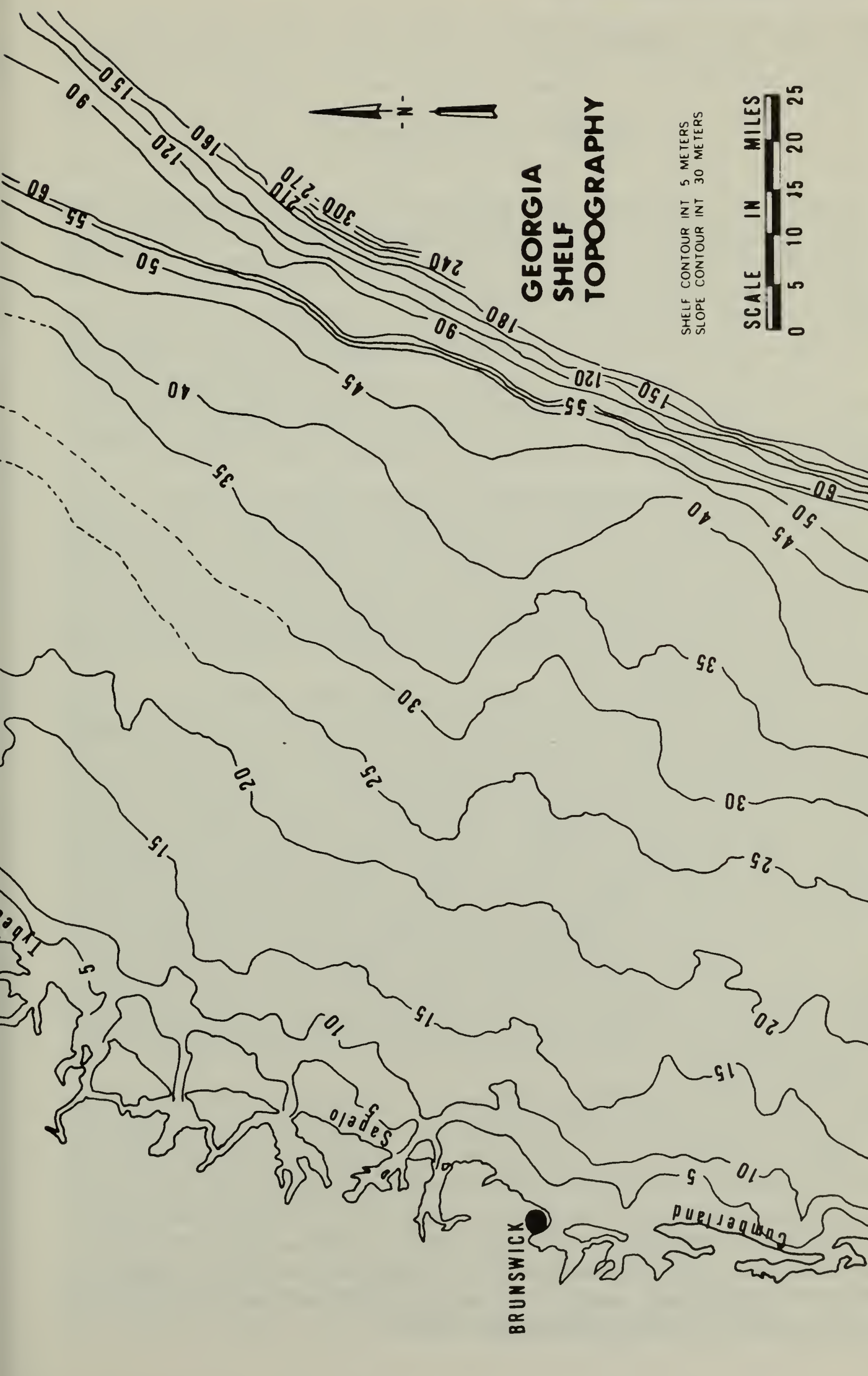

Fig. 29. Bottom topography of the continental shelf off Georgia. Contour interval changes at continental shelf. (Adapted and redrawn from Pilkey and Giles 1965.)

Physical characteristics

Patterns of circulation

The waters of the Georgia coast are subject to many interacting forces that produce complicated patterns of circulation that to a large extent determine the distribution of sediments, nutrients, oxygen, temperature, salinity, food, and planktonic forms of larval and adult organisms.

Ocean currents are produced by wind, gravity, and differences in density of water strata. Surface currents commonly are caused by the stress that winds exert on the water surface; tidal currents are caused by the interacting forces of gravity of the earth, the moon, and the sun; and density currents are related to differences in density that result from variations in temperature and salinity within a body of water.

The Gulf Stream, a northerly flowing current of warm, saline water beyond the continental slope, is a density current. It results from warm, tropical waters spreading northward over the more dense polar waters which sink and flow toward the equator. The currents are deflected from direct poleward flow by wind friction, earth rotation, and land masses. Eddies form inshore from the Gulf Stream and may be responsible, in part, for the southward transport of sediment along the Georgia coast.

The movement of the waters inshore from the Gulf Stream has not been studied systematically and must be assumed from a limited number of observations. Bumpus and Lauzier (1965) summarized data from drift bottles on seasonal direction of surface currents of the continental shelf from Newfoundland to Florida. The data from Georgia, admittedly inadequate, indicate currents flowing as follows: winter—southerly; spring—northerly; summer—southerly and northerly; and fall—southerly. Bellinger (1968) reports that flow is southward during the summer, fall, and winter, extending out 20-30 miles during the summer and about 45 miles during the other seasons. Rates of surface flow vary from 2 to 10 miles per day; bottom currents flow at about 1/10 the rate of surface currents. Superimposed on the southward circulation is either an inshore surface current and an offshore bottom current or vice-versa. Bellinger (1968) reports that there are no data on the current flows between the Gulf Stream and the longshore current.

The surface currents are mostly dependent on the direction of the wind. The wind is predominantly from the northeast and northwest in the winter (December—February), from the south in spring and summer (March—August), and from the northeast in the fall (September—November) (Carter 1959; U. S. Naval Oceanographic Office 1963; Kuroda and Marland 1969). These prevailing winds coincide with the direction of the surface currents, and seasonal differences in wind velocities are partly responsible for the longshore movement of sediments southward. The northerly winds of the winter and fall are much stronger than those of the summer and spring (Neiheisel 1965).

As previously stated, the Georgia coastline is reported to have the lowest energy levels along the southeastern coast (Tanner 1960). Neiheisel (1965) confirmed this by analysis of wave refraction diagrams. The shoreline is aligned at about N23°E; the continental shelf is broad; the surf is mainly from the southeast, and when waves approach shore from this direction they are refracted, resulting in an approach parallel to the shore. During this process, energy is dissipated over a broad area. Waves approaching from the northeast, the direction from which the strongest winds and the highest seas approach, are refracted more and energy reduction is greater. Neiheisel (1965) concludes that the low energies along the Georgia coast are due to the wide continental shelf and the gentle offshore slope which cause incoming waves to be refracted more, and to the fact that the greatest refraction of waves occurs when wind is from the direction of strongest force.

Density differences caused by seasonal changes in salinity and temperature also produce water movements. Depth profiles made during cruises of the R/V *Gill*, the results of which have been reported by Anderson and Gehringer (1957, 1958, 1959) and Anderson et al. (1956), provide the basis for the following discussion. Inshore waters have temperatures of 29°C and salinities of 35 ppt in August and are less dense than those at the shelf break which have similar temperatures, but higher salinities. By November, inshore waters are cool, while the offshore waters remain warm because of the influence of the Gulf Stream. High salinities prevail throughout, reflecting the low fresh water input from June through September (U.S. Geological Survey 1960). Inshore waters are now more dense than offshore waters. In February waters are colder both inshore and offshore; inshore waters are less saline because of greater fresh-water runoff; and the difference in the densities of the water masses is less. As temperatures begin to rise in the spring, inshore waters warm faster and the temperature gradient gradually disappears, but the salinity gradient is steeper than at any other time of the year because of heavy freshwater discharge. The lessening temperature gradient and steepening salinity gradient compensate to produce water of similar densities inshore and offshore. These shifts in densities probably result in slow, seasonal water movements. They could be responsible for setting up the inshore-offshore components mentioned by Bellinger (1968).

Tidal currents are the horizontal movements of water which, unlike the currents caused by wind and density differences, are periodic. The tidal component is most pronounced in narrows such as entrances to bays and constricted parts of rivers. Tidal currents for the Georgia estuaries were given by Haight (1938).

The Georgia coast is subject twice daily to tides approximately the same height. The height of the tide increases from about 5.5 ft at Nassau Sound, Fla., to about 7 ft near Savannah. The tidal movement of saline waters into the estuaries and the drainage of rivers into them cause the complicated hydrologic patterns characteristic of estuaries.

Pritchard (1967b) described four hypothetical circulation patterns for estuaries, two of which may be applicable to Georgia estuaries. *The moderately stratified estuary* is one in which tidal action serves as the dominant force mixing fresh and salt waters. The Savannah River exhibits this type of circulation. In an estuary with no tide or friction, undiluted sea water would extend upstream along the bottom to a point where the river surface was approximately at sea level. The less dense fresh water would flow seaward on top of the salt water. When there is tidal action, as in the moderately stratified estuary, turbulence carries fresh water downward and salt water upward. The salt content of both layers increases toward the sea, but at any given point the bottom layer is more saline than the top. *Vertically homogeneous estuaries* occur where tidal mixing is vigorous and freshwater input is low. In this case vertical salinity stratification breaks down.

The circulation patterns and physical characteristics of only a few Georgia estuaries have been studied. The Savannah River, a moderately stratified estuary, has been studied by the U.S. Corps of Engineers. It has a drainage area of approximately 9850 mile^2 and an average discharge of 11,290 cubic ft per second (cfs) (U.S. Geological Survey 1960). It is tidal for approximately 50 miles upstream. A physical model of the river has been designed in order to study shoaling (U.S. Army Corps of Engineers 1949). Figure 30 shows the tidal currents at ebb and flood tides as predicted by the model.

The Altamaha River has the greatest discharge along the Georgia coast. It has a drainage area of approximately 13,600 mile^2 and an average discharge of 12,600 cfs (U.S. Geological Survey 1959). Several miles from the ocean it divides into a number of distributaries (Darien, Butler, Champney, and South Altamaha) which empty into Altamaha Sound and to a lesser extent into Doboy and St. Simons sounds. The hydrography of this river has been studied to only a limited extent. Neiheisel (1965), in a study of the causes of shoaling in Brunswick Harbor, presents information on the mixing and flow of water in Brunswick Harbor as influenced by the Altamaha River. Discharge into Brunswick Harbor, a well-mixed estuary, by the Turtle River is negligible. However, during maximum peaks of discharge, fresher water from the Altamaha enters the harbor through the Mackay and Frederica rivers. The water discharged through the Altamaha Sound into the ocean is moved along the shore and enters Brunswick Harbor through the sound entrance. Salinity measurements in the Mackay and Frederica rivers show that they are partially mixed estuaries with some density stratification during a period of low discharge. During higher discharge it is assumed that the interface would become sharper and move toward the harbor. Salinities were approximately 5 ppt in the Mackay River near Altamaha Sound and approximately 20 ppt near St. Simons Sound (Neiheisel 1965).

The hydrography of Doboy Sound, recently studied by Levy (1969), is also affected by the Altamaha River. During ebb tide, fresh water from the Altamaha flows seaward through the Darien-Rockdedundy complex into Doboy Sound through the Black, South, and North rivers. During mid-ebb this water flows out the mouth of Doboy Sound along the south shore, while water from the sounds leaves by the north shore. Because of the limited fresh water flow, Doboy Sound is a mixed estuary (at least during the summer months) with no recognizable salt wedge and little vertical stratification. A salt wedge is present just seaward of the inlet, where less saline, highly turbid waters of the longshore drift overlie more saline oceanic waters. This moves shoreward on flood tide.

Ragotzkie and Bryson (1955) studied the Duplin River, a tidal river located near Sapelo Island and opening into Doboy Sound. It has no significant fresh water source, and it is an elongated tidal bay about 5.9 miles long with a tidal excursion of about 3 miles. At mean low water the river has a relatively small horizontal area; however, at 6 feet above mean low water the water flows over the banks and onto the salt marsh. The area of marsh flooded increases rapidly as the level of water rises. From one-third to two-thirds of the volume of water entering the Duplin River on a rising tide leaves the river to flood the marsh. The volume of water involved is greatly increased with relatively small increases in tidal height. The waterways are subject to high turbulence as this large volume of water enters and leaves. Mixing is rapid and no stratification long can be maintained under these conditions.

Sediments

Coastal sediments have been the subject of considerable study since 1960. Much of this work was done by the University of Georgia Marine Institute. Papers dealing with sediments of the continental shelf (shelf sediments) and of the shallow waters near shore (paralic sediments) are reviewed by Henry and Hoyt (1968).

Previous sections of this report have described origins, composition, depositional patterns, and migrations of sediments of offshore bars, beaches, dunes, and marshes. The following summary is restricted to some ecologically important aspects of shelf and inshore sediments not previously discussed.

Nearshore, a narrow band of fine sands is considered to be of Recent origin (Pilkey and Frankenberg 1964). Minerals of mainland (terrigenous) origin (mainly quartz) are the dominant constituents (Henry and Hoyt 1968).

A relatively sharp boundary between Pleistocene and Recent sediments occurs quite consistently at about 6 fathoms, generally about 12 miles offshore (Pilkey and Frankenberg 1964). Cenozoic deposits on the continental shelf range from 2000 to 2500 ft deep (Henry and Hoyt 1968). Quaternary sediments consisting of coarse-grained particles are less than 100 ft thick and are mostly of Pleistocene origin (Henry and Hoyt 1968).

Carbonate contents of shelf sediments are discussed by Gorsline (1963), Pilkey (1964), and Pilkey et al. (1969). Carbonates average less than 25% over most of the shelf and consist mostly of mollusks. Carbonate content increases seaward to about 50% on the shelf edge and nearly 100% on the upper slope where foraminifera are the major components (Pilkey 1964). This increase toward the shelf edge probably results from the diminishing contribution of terrigenous materials.

The presence of oolites off the Georgia coast is indicative of pre-existing shoreline conditions and low sedimentation rates, and the abrasive history of the carbonate fraction indicates that former shorelines in this area, like those of the present, were subject to relatively low wave energies (Pilkey et al. 1969).


HILTON HEAD ISLAND
Savannah Beach
Cabbage Is.
N

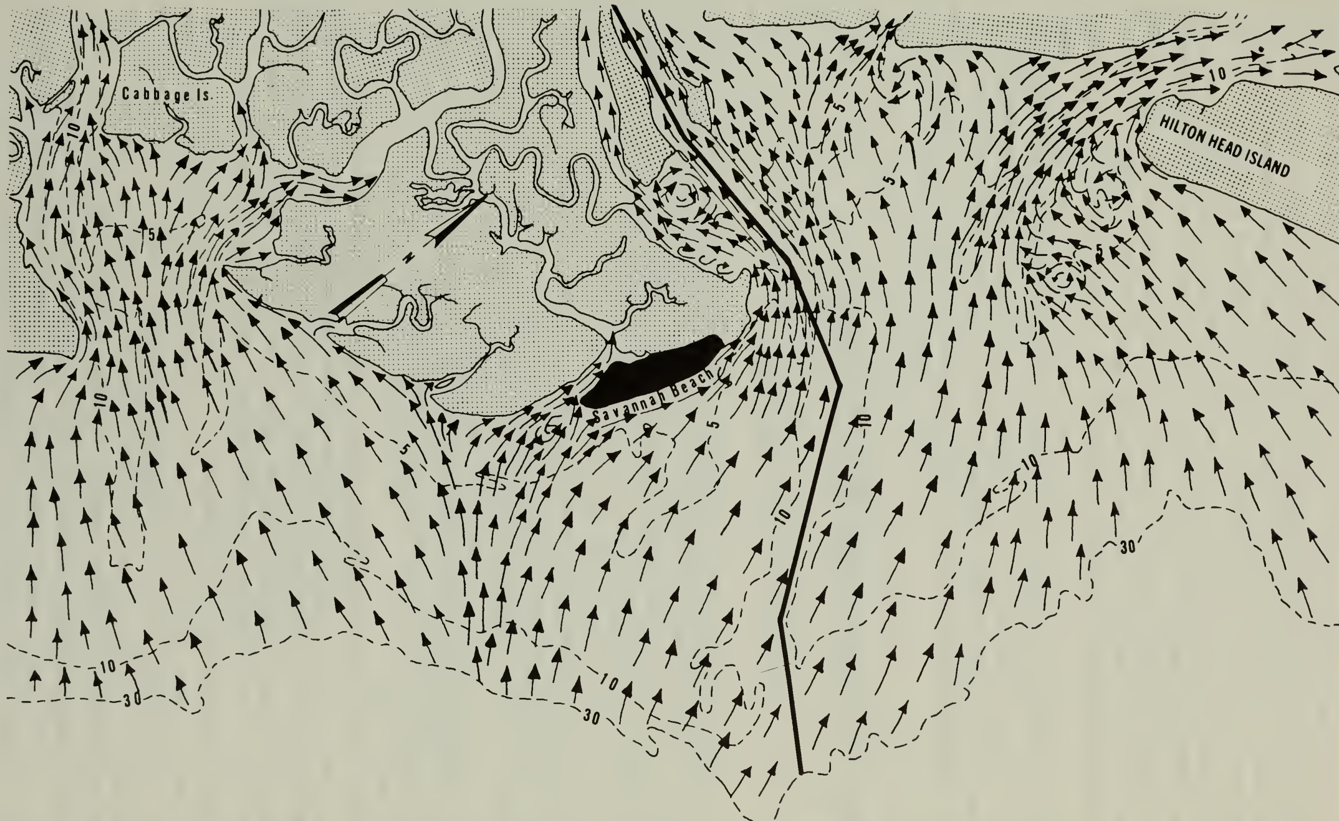

Fig. 30. Direction of tidal currents at ebb and flood tides in the Savannah area as predicted by a physical model. (Redrawn from U.S. Corps of Engineers 1949.

Phosphorite averages about 1.1% of shelf sediments (Henry and Hoyt 1968). Present-day rivers apparently lack phosphorite in their sediment loads, yet all shelf samples and most estuarine sands contain these grains in varying amounts (Pilkey and Terlecky 1966). Pevear and Pilkey (1966) and Pilkey and Terlecky (1966) concluded that much of the sands and nearshore fine sediments originate from landward transport from outer portions of the shelf and not from mainland rivers. Shelf phosphorite has evidently been derived from either Pleistocene rivers or from ancient phosphatic sediment outcrops on the shelf.

The heavy mineral fraction of shelf sediments averages less than 0.5% (Henry and Hoyt 1968). The heavy mineral suite includes staurolite, kyanite, garnet, zircon, epidote, pyroxenes, amphiboles, rutile, and tourmaline (Pilkey 1963). Heavy mineral distributions are frequently useful aids in the determination of sediment origins, but heavy minerals in shelf sediments off the Georgia coast show minimal variation because of their common origin in Piedmont rivers (Pilkey 1963).

Fauna of estuaries and inshore waters

Vertebrates

1. Fishes: The waters off the coast of Georgia support a variety of fishes related to the diversity of habitat. Some estuarine species enter fresh water to spawn and a few freshwater species enter the brackish estuaries. Some species are restricted to the estuaries and inshore waters and some are restricted to the waters of the continental shelf. But many species migrate between these habitats at various stages in their life cycles, and the estuaries are vitally important as nursery grounds and spawning grounds for many commercially important species harvested on the continental shelf. Stroud (1971) listed the species that are dependent upon the estuaries during some stage in their lives and reported that they comprised 63% of the Atlantic catch. He calculated that, for the Atlantic coast generally, each acre of estuarine habitat produces a yield of 535 lb on the continental shelf.

The continental shelf off Georgia generally is composed of shifting sediments and does not provide good fish habitat. However, a coral reef, or live bottom, recently has been discovered 16 miles due east of Cabretta Inlet on Sapelo Island. Such reefs provide a stable surface for the attachment of organisms important in the food chain. Artificial reefs also are being established by the Georgia Game and Fish Commission.

There has been relatively little work on the ecology of fishes of the Atlantic coast of the southeastern United States. Tagatz and Dudley (1961) studied the seasonality of fishes in four coastal habitats near Beaufort, N.C., and Tagatz (1968) and McLane (1955) surveyed the fishes of the St. Johns River, Fla.

Some pertinent work has been done off the Georgia coast. Anderson (1968) surveyed the fishes caught by shrimp trawling from South Carolina to northeastern Florida from 1931 to 1935. Miller and Jorgenson (1969) studied the seasonal abundance and length frequencies of fishes collected in two habitats and presented a list of fishes collected at a freshwater station in the Altamaha River. They made thorough surveys by seining at a beach habitat on St. Simons Island and two high marsh stations, one near Jekyll Island and one near Meridian, Ga. Dahlberg and Heard (1969) surveyed the common inshore elasmobranchs of the Georgia coast. Dahlberg and Odum (1970) sampled fish populations in St. Catherines and Sapelo sounds by trawling at 3-week intervals for 13 months. Struhsaker (1969) presented a list of fishes taken during 5 years of exploratory trawling on the continental shelf off Georgia and other southeastern states.

A list of fishes that may be encountered in Georgia's coastal waters is included (Appendix 1).

2. Reptiles: The loggerhead turtle, previously discussed, is the only marine reptile that is common on the Georgia coast. Green and Ridley's turtles have been reported from coastal Georgia (Appendix 2).

3. Marine mammals: Information on marine mammals of Georgia coastal waters is restricted mainly to stranding records and associated data. Only six species of whales, all toothed (Odontoceti), are recorded as having stranded on the island beaches, although sight observations and strandings from adjacent states indicate that about 23 species are probably components of Georgia's offshore fauna.

Atlantic bottle-nosed dolphins are probably the most common whales in the waters immediately adjacent to the coast. They are observed, frequently in pairs, swimming off the beaches and tidal rivers. Stranding dates are confined to the last half of the year, although the dolphin is commonly sighted throughout the year.

The pilot whale, also common, occasionally strands in large numbers on the island beaches. Between 15 and 25 stranded on St. Simons Island in 1962, and 53 stranded on Little St. Simons in 1968 (Caldwell et al. 1971). There is, as yet, no satisfactory explanation for these mass strandings.

Occasionally other whales such as the rare goosebeaked whale (with less than 20 known specimens from the western North Atlantic—Moore 1963) strand on the coast or are observed in the offshore waters.

The manatee occasionally is sighted or collected on the coast (Tomkins 1956, 1958), but its status as a permanent resident is doubtful.

Man inadvertently has introduced the California sea lion into the coastal waters of the southeastern United States, and sight observations (Caldwell et al. 1971) confirm the presence of the species off Sapelo Island.

Specific records of marine mammals in Georgia are given in Appendix 5.

Invertebrates

Most studies of estuarine invertebrates have dealt with those forms relating in a basic way to the estuarine food chain (plankton) and with species having commercial significance (shrimp, crabs, oysters).

Jacobs (1968) reported that *Acartia tonsa, Pseudodioptomus caronaius*, and

Paracalanus parvus were the most common zooplankton (copepods) encountered in the Duplin River and Doboy Sound. Other copepods included *Centropages hamatus*, common in the spring, rare in summer, and *Labidocera aestiva*, common in the summer and absent during the spring. High concentrations of zooplankton often occur in the estuaries. Jacobs (1968) recorded 20,000 *Acartia tonsa* per cubic meter of water near Sapelo Island. Studies relating to the taxonomy, distribution, and abundance of estuarine invertebrates include the following: Frankenberg (1966), *Nassarius trixittatus*; Frankenberg and Menzies (1966), a new isopod; Marcus and Marcus (1967), opistobranchs; Maturo (1966) bryozoa; Menzies and Frankenberg (1966), isopods; Bullis and Thompson (1965), crustaceans and mollusks; and Frankenberg (1968), amphioxus.

The invertebrate fauna of Sapelo and St. Catherines sounds and adjacent tidal rivers recently has been sampled by Heard and Heard (1970). Fouling organisms, or those inhabiting solid substrates such as rocks and pilings, were studied by taking monthly samples from the bottom and sides of a floating dock at Colonel's Island (Liberty County). Forty-seven species or forms representing the following phyla were obtained: Porifera, Cnidaria, Ectoprocta, Mollusca, Annelida, Arthropoda, and Chordata. Table 14 is a listing of those species that were considered common or abundant by the investigators in at least one monthly sample. Benthic epifauna and infauna were sampled within the sounds using a 20-ft otter trawl and a bucket dredge. One hundred and eighty-five genera or forms were reported. Of these, 79 were considered common in at least one sample. These species are listed in Table 15. Classification or higher taxa have been changed in Tables 14 and 15 to agree with those of Meglitsch (1967). The restricted sample area and the selection by the collecting devices for certain invertebrates contributed some bias to the lists.

Most invertebrates of commercial importance (e.g., crabs, oysters, and shrimp) have been extensively studied. Following is a brief discussion of blue crabs, oysters, and brown and white shrimp.

Studies by Durant (1970) indicate that in Georgia, oysters (*Crassostrea virginica*) begin to spawn when the temperature is about 73°F. Spawning was observed to begin in May and to continue until October, with peak periods in July, August, and September (Durant 1970). Larval stages last for 2-3 weeks (Wallace 1966), after which the young attach to some substrate. Galtsoff (1964) states that only soft mud and shifting sand are totally unsuitable. However, oysters may convert a mud bottom to a more suitable habitat if a few settle on a hard object and themselves become objects of attachment. Galtsoff describes the soft mud bottom of the South Atlantic as being only marginally suitable for oysters. He further states that oysters need a free exchange of water, salinities of 5-30%, and temperatures from 34°F to 86°F. Conditions are ideal for feeding when the water, free of pollution and containing a low concentration of small diatoms and dinoflagellates, moves over the bottom in a nonturbulent flow.

The negative factors influencing oyster production are described by Wallace (1966) as "pollution, predators, and people." He reports that oyster production is inversely proportional to human population growth in New England and the

TABLE 14. *Epifauna collected from docks at Colonels Island (North Newport River, St. Catherines Sound).*[a]

Phylum Cnidaria
Unidentified anemone
Unidentified hydroid
Phylum Ectoprocta
Anguinella palmata
Alcyonidium sp.
Amathia distans
Conopium tenuissimum
Phylum Annelida
Class Polychaeta
Nereis (Neanthes) succinea
Polydora sp.
Phylum Arthropoda
Class Pycnogonida
Tanystylum orbiculare
Class Crustacea
Subclass Copepoda
Doropygus laticonis
Order Thoracica
Balanus eberneus
Order Amphipoda
Amphithoe valida
Corophium simile
Gammarus mucronatus
Lumbos websteri
Mellita appendiculata
Paracaprella tenuis
Parapleustes n. sp.
Order Decapoda
Paleomonetas vulgaris
Paleomonetas pugio
Eurypanopeus depressus
Panopeus herbstii
Phylum Chordata
Subphylum Urochordata
Molgula manhattensis

[a]Heard and Heard 1970.

TABLE 15. *Invertebrate fauna of Sapelo and St. Catherines sounds.*[a]

Phylum Porifera
- *Halichondria* sp.
- *Microciona prolifera*

Phylum Cnidaria
- *Leptogorgia virgulata*
- *Renilla reniformis*

Phylum Nemertina
- Bicolored form

Phylum Phoronida
- Unidentified species

Phylum Ectoprocta
- *Aeverrillia setigera*
- *Alcyonidium verrilli*
- *Amathia distans*
- *Anguinella palmata*
- *Bowerbankia gracilis*
- *Bugula neritina*
- *Membranipora arborescens*
- *Membranipora tenuis*
- *Schizoporella unicornis*

Phylum Mollusca

Class Gastropoda
- *Anachis avara*
- *Busycon canaliculatum*
- *Busycon carica*
- *Cerithiopsis emersoni* (*C. subulata*)
- *Crepidula plana*
- *Doridella burchi*
- *Eupleura caudata*
- *Mitrella lunata*
- *Nassarius vibex*
- *Polinices duplicatus*
- *Pryogocythana* (*Mangelia*) *plicosa*
- *Terebra dislocata*
- *Turbonilla* (*Pyrgiscus*) *interrupta*

Class Pelecypoda
- *Abra aequalis*
- *Amygdalum papyria*
- *Barnea truncata*
- *Ensis directus*
- *Lyonsia hyalina*
- *Mulinia lateralis*

Class Pelecypoda–(continued)
- *Musculus lateralis*
- *Mya arenaria*
- *Solan viridus*
- *Spisula solidissima*
- *Tagelus divisus*
- *Tellina agilis*

Class Cephalopoda
- *Lolliguncula brevis*

Phylum Annelida

Class Polychaeta
- *Arabella iricolor*
- *Clymenella torquata*
- *Diopatra cuprea*
- *Glycera americana*
- *Harmothoe-Lepidonotus* spp.
- *Heteromastis* sp.
- *Hydroides dianthus*
- *Lumbrineris tenuis*
- *Marphysa sanguinea*
- *Nereis* (*Neanthes*) *succinea*
- *Notomastis* sp. (spp?)
- *Parapironospio pinnata*
- *Pectinaria* sp. (*gouldii*?)
- *Sabella microphthalma*
- *Sabellaria vulgaris*
- *Sabellaria* sp. (*floridensis*)
- *Sabellides* sp. (*oculatus*?)
- *Scoloplos-Orbinia* spp.
- *Spiochaetopterus oculatus*
- *Sthenelais boa*

Phylum Arthropoda

Class Pycnogonida
- *Anoplodactylus* sp.

Class Decapoda
- *Acetes americanus carolinae*
- *Alpheus normanni*
- *Eurceramus praelongus*
- *Latreutes parvulus*
- *Lysmata wurdemanni*
- *Pagurus longicarpus*
- *Pagurus pollicaris*
- *Palaemonetas pugio*

TABLE 15. *Invertebrate fauna of Sapelo and St. Catherines sounds.*[a] *(continued)*

Class Decapoda–(continued)
Palaemonetas vulgaris
Penaeus aztecus
Penaeus setiferus
Periclimenes longicaudatus
Trachypenaeus constrictus
Upogobia affinis
Phylum Echinodermata
Class Asteroidea
Asterias forbesi
Luidia clathrata
Class Ophiuroidea
Hemipholis elongata
Ophiothrix angulata
Phylum Chordata
Subphylum Urochordata
Molgula manhattensis

[a]Heard and Heard 1970.

mid-Atlantic states. Only in the southeastern and Gulf states does oyster production even approach that of 20 years ago. Wallace (1966) concludes that pollution is the primary cause of the decline of the oyster industry. Sewage is detrimental because it covers the bottom with sludge that smothers oysters and reduces oxygen (Galtsoff 1964). When *Escherichia coli*, bacteria associated with fecal matter and used as an index for pollution, reach certain numbers, the oyster grounds are closed for health reasons. Figures 35A-H (Appendix 6) show areas closed to oyster gathering by the Georgia Department of Public Health as of 1970. Industrial wastes also affect oysters. Galtsoff (1964) reports that red liquor and black liquor, both wastes from pulp mills, reduce the length of time the oyster shell remains open, thereby reducing the time available for feeding. Butler (1966) found that shell deposition is decreased in the presence of chlorinated hydrocarbon insecticides (e.g., DDT) at concentrations as low as 10 parts per billion (ppb). Oysters are especially susceptible to pollution because of their stationary mode of existence and their ability to concentrate pollutants in their tissues. Predators include flatworms, mollusks, echinoderms, crustaceans, fish, birds, and mammals (Galtsoff 1964).

The predominant species of marine shrimp occurring in Georgia waters are the white shrimp (*Penaeus setiferus*) and the brown shrimp (*P. aztecus*), both of which are important commercially. The life cycles of white and brown shrimp are basically similar. The bottom-dwelling (benthic) adults release their eggs freely into the waters offshore. Within a short time, the eggs hatch into planktonic larvae. After passing through several intermediate stages, the young shrimp (postlarvae) move into the estuary and adopt a benthic existence (Anderson 1955). After very rapid growth, they assume the adult form. Marking studies indicate that after migrating offshore the shrimp do not move into deep water but make seasonal migrations parallel to the shoreline (Anderson 1955). White shrimp penetrate the estuary to a greater degree, arrive later, and stay for a longer period of time than the brown.

Salinity optima for young penaeid shrimp are in the range of 5-20%, although shrimp can tolerate salinities from 1 to 600% (Kutkuhn 1966). A complex interaction of factors including circulation, temperature, salinity, and fertility of waters and type of vegetation and substratum determines distribution, survival, and growth of young shrimp (Kutkuhn 1966). Optimum conditions are approached in the nursery grounds of the marsh-estuary complex.

Nichols and Keney (1963) report that the identity and distribution of crabs of the genus *Callinectes* on the southeastern coast of the United States is uncertain. Rathbun (1930) reported two species, *C. sapidus* and *C. ornatus*, occurring between New Jersey and Indian River Inlet, Fla. Lunz (1958) found that only 30% of the crabs caught by trawlers in South Carolina were *C. sapidus*. The two species are not recognized as such by fishermen and are combined as blue crabs in catch data reported for coastal Georgia.

Van Engel (1958) reports that in the Chesapeake Bay area *Callinectes sapidus* begins mating early in May and continues into October. Females probably mate only once, at the time of the last molt. Sperm live in the female receptacles for at least a year and may be used as often as the female spawns (two or more times). The females migrate to saltier waters after mating, some passing out of the bay and into the ocean. Spawning is delayed at least 2 months after mating. When laid, the eggs are attached to the abdomen of the female where they remain about 2 weeks until hatching. Van Engel (1958) reports that there are two larval stages, four or five zoeal stages, and the megalops. These stages are passed through in about 1 month, after which the first crab stage is reached. Costlow and Bookout (1959) observed seven zoeal stages in laboratory-reared animals. Nichols and Keney (1963), based on the occurrence of early stage larvae, believe that spawning occurs throughout the year. Peak numbers of first-stage larvae were found in Georgia waters during July, August, and September, and large numbers of first and second stage zoeae were found near the beaches with progression to advanced stage zoeae 20-40 miles offshore. Van Engel (1958) reported that early in August many crabs reach the "first crab" stage and begin migrating into waters of lower salinity. Male crabs remain in less saline waters year round.

Thus blue crabs are a part of both the benthic and planktonic communities, and they use both inshore and offshore waters.

Fishery resources of estuaries and inshore waters

The estuarine and inshore waters of Georgia support a moderate-sized commercial fishery. The commercial harvest of fish and shellfish for the period 1960-65 averaged 21.4 million pounds valued at approximately $3.4 million (Carley 1968). The catch accounted for about 15% by weight and 17.6% by value of the harvest of the South Atlantic states. The commercial harvest of fish and shellfish has fluctuated considerably over a period of years, but total monetary value of the catch has been relatively stable because of increasing prices.

The shrimp fishery is the most important commercial fishery in Georgia, accounting for 83% of the harvest value (Carley 1968). Blue crabs account for one-half to three-fifths of the pounds of the annual harvest but account for less than 10% of the harvest value (Carley 1968). Oysters average about 1% of the total catch. Shad are the most important fish in the catch and, with other fish species, make up approximately 5% of the total catch (Carley 1968).

Shrimp are harvested on the Georgia coast by trawling during the 6-month season from 1 June - 31 December. The area open to harvest extends from the mouth of the sounds to 3 miles offshore. Shrimping outside the 3-mile limit is legal throughout the year. White shrimp dominate the catch until late in July when they are replaced by the brown shrimp. The browns then dominate the catch until they are again replaced by white shrimp late in August. The catch of white shrimp increases until it peaks in October. The total catch normally consists of two-thirds white shrimp and one-third brown shrimp (Carley and Frisbie 1968a).

Trawling is legal in Georgia during the daytime only. This regulation is a significant factor influencing the composition of the total catch. The white shrimp feeds during the day and burrows into the mud at night. Conversely, the brown shrimp is nocturnal, burrowing into the mud during the day.

The pink shrimp (*Penaeus duorarum*), also commercially important in some areas, occurs infrequently in the catch in Georgia. This shrimp has habitat requirements (relatively clear, shallow waters with a firm bottom) that are met in relatively few areas in Georgia waters.

Linton (1970) conducted a survey of the distribution and abundance of oyster beds in 1966 and 1967 and found about 10,180 acres of oyster beds, almost all of them intertidal and landward of the barrier islands. Oyster beds are better developed in the northern portion of the state where they occur in a band 7-8 miles wide (Figs. 35A-H, Appendix 6). All oysters in Georgia are taken from privately held areas through leasing arrangements (Carley and Frisbie 1968b). The most important factors limiting production are pollution, unsuitable substrate, and predation (Carley and Frisbie 1978b). Between one-third and one-half of the estuarine area suitable for oyster growth is polluted (Figs. 35A-H), and the oyster beds are closed to harvest for public health reasons (Carley and

Frisbie 1968b). Little effort has been made to manage oyster beds on a long-term basis. Assuming effective pollution control were possible, oyster production could be significantly increased. Oyster shells and other material suitable for spat-setting could be deposited in many areas, and raft or line culture would be feasible in many areas (Shaw 1968).

A relatively small hard clam fishery existed in coastal Georgia until about 1932. A recent study of Godwin (1967) revealed in the Altamaha Sound a population of brackish water clams (*Rangia cuneata*) that could support a commercial fishery, but the area is closed for shellfish harvest because of pollution. The hard clam or quahog (*Mercenaria mercenaria*) does not occur in harvestable numbers in Georgia (Godwin 1967).

Blue crabs are taken in greater numbers than any other commercial species but, due to a low unit price, they represent a small portion of the monetary value of the catch (Carley 1968). Crabs are harvested with pots and traps and are taken in otter trawls incidental to shrimp trawling.

Finfish have averaged about 5% of the total quantity and value of all fish and shellfish in Georgia. Harvest by species is shown in Table 16. The greatest proportion of the catch of finfish in 1967, 36% of the poundage and 45% of the total economic value, was American shad (Lyles 1969). Shad are anadromous fish, spawning in fresh water and moving into the ocean to mature. The adults move up the rivers from January until April. Many shrimp and crab fishermen supplement their income by fishing for shad during this time. Young shad begin to move down the rivers in July and are found in the Atlantic by October (Godwin and Adams 1969).

Whiting made up 20% of the finfish poundage and 15% of the dollar value in 1967 (Lyles 1969). They usually are caught while trawling for shrimp. Carley (1968) reports that there has been a downward trend in the abundance and catch of whiting. There are three species of whiting inhabiting the coast of Georgia (*Menticirrhus americanus, M. saxatilis*, and *M. littoralis*), but they are not distinguished in commercial records. *Menticirrhus littoralis* prefers shallows and surf, so it is not often caught in trawls. Both *M. americanus* and *M. saxatilis* spawn in spring and early summer. The young of the former occur in both offshore and inside waters, whereas those of the latter species live in the surf. The adults of both species are found in both inside and outside waters (Hildebrand and Cable 1934).

Red snapper accounted for 6% of the poundage and 17% of the cash value of the 1967 catch, and grouper accounted for 12% and 10%, respectively. These are by far the largest catches reported for these two species since 1957 (Power 1959; Power and Lyles 1964; Lyles 1965, 1966, 1968, 1969). Both species are caught with hand lines off the live bottom and shelf edge habitats. Red snapper are also caught in trawls (Lyles 1965, 1969; Struhsaker 1969).

The total value of the commercial fishery is probably underestimated. Carley (1968) reported that in many cases fish caught while shrimping were given to the crew of the vessel and were not reported. Menhaden form the base of the largest fishery in the United States by volume. The larvae and juveniles spend their first summer in the estuaries where they grow rapidly and serve as an important food item for many carnivorous species. They move into deeper waters in the fall where they are caught in large purse seines (June 1961). Approximately 2000 purse-seine sets were made in Georgia in 1959, each averaging 20-25 tons of fish (June 1961): a total of 40,000 tons. Because there are no menhaden processing plants in Georgia, these fish were landed outside the state, probably at Fernandina Beach, Fla., and are not listed in the Georgia landings.

Sport fishing is also an important element in the coastal economy. Expenditures by an estimated 281,400 salt water sport fishermen on the Georgia coast totaled $22,523,280 in 1968 (Cheatum et al. 1968). Table 17 lists the sport fish most commonly caught on the Georgia coast. Harvest figures are not available for salt water fish taken by sport fishermen in Georgia.

TABLE 16. *Fish with total landings in Georgia of more than 1000 lb per year.*[a]

Species	Pounds	
	1966	1967
Croaker	5,100	6,000
Flounder	33,500	22,000
Whiting	145,400	186,700
Sea bass	2,700	1,700
Black drum		2,400
Red drum		5,600
Grouper		92,300
Red snapper		54,900
Weakfish	1,300	
Spotted sea trout	1,200	6,900
Spanish mackerel	1,300	2,000
Spot	5,200	10,500
Bait and animal food	127,600	203,400
Hickory shad	2,000	1,300
American shad	385,900	334,100
Mullet	2,000	

[a]Lyles 1968, 1969.

TABLE 17. *Common salt water sport fishes of Georgia*

Inshore species	Offshore species
Spotted sea trout	king mackerel
Red drum (channel bass)	dolphin
Spanish mackerel	little tuna
Tarpon	great barracuda
Bluefish	Atlantic bonita
Cobia	pompano
Sheepshead	crevalle jack
Striped bass	greater amberjack
American shad	red grouper
Southern kingfish	red snapper
Triple tail	black sea bass
Southern flounder	sailfish
Weakfish	
Atlantic croaker	
Spot	

Productivity and energy flow

Nutrients

The waters comprising the coastal region are actually a solution of many inorganic and organic compounds and other materials in suspension. The movements and concentrations of these substances are important aspects of the ecology of the area. Elements such as carbon, nitrogen, and phosphorous are necessary for primary production and often prove to be limiting factors. Of these, phosphorus and zinc have been studied in the Georgia coastal waters.

Phosphorus is often limiting in oceanic waters (Raymont 1963). Pomeroy et al. (1965) found phosphorus concentrations of 1 micromole per liter (μM/L) in Doboy Sound. At this high concentration phosphorus was not considered to be a factor limiting primary production. Estuarine water of the Altamaha River contains phosphorus in concentrations ranging from 0.05 to 4.0 μM/L, whereas the river water has a phosphate concentration of 0.1 μM/L. Pomeroy et al. (1969) concluded that the estuary acts as a "sink" since it accumulates sediments that contain organic matter as well as many minerals. Experiments have been conducted in which ^{32}P was released in the headwaters of the Duplin River (Pomeroy et al. 1969). From this work it was determined that the sediments play an important role in the phosphorus cycle. Phosphorus from the surface sediments, which are in equilibrium with the water, moves into a number of deposit feeders and from them, via excretion, back into the water. Subsurface sediments, not in equilibrium with the water, are the source of phosphorus for smooth cordgrass. Bacteria within the sediments are probably accumulating phosphorus, which is released by the bacterial feeders (Johannes 1965). Thus, there is a separation between pathways within the salt marsh. Phosphorus in subsurface sediments is incorporated into the cordgrass which serves as the principal source for insects and spiders. Most of the cordgrass, however, dies and enters the detritus food chain. Thomas (1966) showed that the estuarine waters, rich in phosphorus, are flushed out into the offshore waters and serve as a nutrient source for phytoplankton.

Zinc is a trace element required by some organisms and often is concentrated by them. Tracer studies with ^{65}Zn indicate that the cycle of zinc, like that of phosphorus, is dominated by the sediments which act as a mixed-bed ion exchanger (Pomeroy et al. 1969). Organisms, except fiddler crabs and oysters, take up zinc and phosphorus at much the same rates. Oysters demonstrate a preferential retention of zinc, and fiddler crabs show high initial values of zinc activity, falling off rapidly and becoming erratic, suggesting movements in and out of the area. Bioelimination of zinc seems to be slow. Concentrations of zinc are, like phosphorus, high in the Duplin River as compared to sea water, and the same processes that concentrate phosphorus may concentrate zinc (Pomeroy et al. 1969).

Vitamin B_{12} is a nutrient essential for growth of many organisms such as bacteria, algae, and protozoa. It is synthesized mainly by bacteria and fungi (Burkholder and Burkholder 1956) and is found in large quantities in marine invertebrates and fish. Starr (1956) and Burkholder and Burkholder (1956) studied the distribution of this vitamin in suspended solids and marsh muds from the Georgia coast. Burkholder and Burkholder (1956) found that the dark-water rivers contained high concentrations of B_{12} per unit of suspended particles. Both studies showed a progressive increase in B_{12} from offshore stations to the head of a tidal creek. However, Starr (1956) reports that ocean waters contain detritus richer in B_{12} than the more turbid sound waters. The highest concentration of B_{12} is contained in the detritus at the headwaters of the tidal rivers. Starr (1956) also established that detritus entering the marsh at high tide was not as rich in B_{12} as that leaving on the ebb tide. Sediment samples taken from areas devoid of marsh were much lower in B_{12} than those taken from marsh areas; however, both were lower in B_{12} than water leaving the marsh. Starr (1956) concluded that the muds did not add appreciable quantities of vitamin-rich detritus to the waters. Burkholder and Burkholder, however, report that muds treated with sulfite yield values 3.8 times higher than untreated samples, and Starr did not mention this technique which could have changed his conclusion. More work is needed to clarify this problem as well as the role of B_{12} in productivity of the sea.

Most of the turbidity of coastal waters is caused by suspended sediments, but a significant portion (18%) is caused by organic material (Odum and de la Cruz 1967). A standing crop of 2-20 micrograms ash-free, dry organic matter per liter is reported for the Georgia estuaries, a value much greater than reported for open sea water or other sounds and bays (Odum and de la Cruz 1967). These measurements were taken at the mouth of a small tidal creek draining a salt marsh. Samples taken at mid-ebb tide always produced more organic detritus than did samples taken at mid-flood tide. This suggested that organic material is being exported from the marsh. Teal (1962) also calculated a net flow of organic material from the marsh to the estuary and beyond.

The waters of the coastal region appear to be rich in organic materials, the two inorganic nutrients phosphorus and zinc, and vitamin B_{12}. All of these are found in higher concentrations in the salt marsh-estuary system than in the open ocean.

Food webs

Food webs of the estuary are not nearly as well understood as those of the salt marsh. Many of the conclusions concerning the food webs of the Georgia estuaries must be inferred from work done in other regions. The estuarine environment is more complex than the marsh system, and many estuarine species migrate seasonally. Estuarine inhabitants can be categorized as plankton, benthic infauna, epifauna or fouling organisms, and nekton. Some are deposit feeders, some suspension feeders, and some are carnivores.

Specific food habits studies have been conducted on commercially important invertebrates such as crabs, shrimp, and oysters. Shrimp are deposit feeders; Darnell (1958) reports that detritus and fine organic material composed 58% of the food of shrimp examined, and mollusks 12%. He suggested that both young and mature white shrimp are omnivorous, feeding largely on detritus. Oysters are suspension feeders. Galtsoff (1964) studied ciliary currents produced by oysters and concluded that the food-sorting mechanism is designed for continuous feeding in low concentrations and that food selection, except on the basis of size, is open to question. The blue crab is both a scavenger and a predator; foods include mollusks, detritus, crabs (*Callinectes*, *Rithropanopeus*, and unidentified species), vegetation, and fish remains (Darnell 1958).

Data from published studies of the stomach contents of fish (Table 18) are summarized in Table 19 to show generalized feeding habits of estuarine fishes. Food items are divided into the following general types: detritus, algae, zooplankton, microbenthic invertebrates, macrobenthic invertebrates, shrimp, and fish. The majority of fish consume more than one type of food and are not confined to one trophic level. Ninety-two percent of the fish fed to some extent on benthic invertebrates. These percentages are based only on those common

TABLE 18. *Some food habits studies of common estuarine fishes.*

Species	Reference
Sphyrna tiburo (bonnethead)	Gunter 1945
Lepisosteus osseus (longnose gar)	Goodyear 1967
Megalops atlantica (tarpon)	Rickards 1968
Bevoortia sp. (menhaden)	June 1961
Anchoa mitchilli (anchovy)	Darnell 1958
Galeichthys felis (sea catfish)	Darnell 1958
Opsanus tau (oyster toadfish)	Schwartz and Ducher 1963
Pomatomus saltatrix (bluefish)	Grant 1962
Orthopristis chrysopterus (pigfish)	Hildebrand and Cable 1934
Archosargus probatocephalus (sheepshead)	Gunter 1945
Lagodon rhomboides (pinfish)	Darnell 1958
Bairdiella chrysura (silver perch)	Darnell 1958
Cynoscion nebulosus (spotted sea trout)	Darnell 1958
Cynoscion regalis (weakfish)	Hildebrand and Cable 1934
Leiostomus xanthurus (spot)	Darnell 1958
Menticirrhus americanus (southern kingfish)	Gunter 1945
Menticirrhus littoralis (Gulf kingfish)	Gunter 1945
Menticirrhus saxatilis (northern kingfish)	Welsh and Breder 1923
Micropogon undulatus (Atlantic croaker)	Darnell 1958
Pogonias cromis (black drum)	Welsh and Breder 1923
Sciaenops ocellata (red drum)	Darnell 1958
Stellifer lanceolatus (star drum)	Welsh and Breder 1923
Mugil cephalus (striped mullet)	Darnell 1958
Paralichthys lethostigma (southern flounder)	Darnell 1958
Chilomycterus schoepfi (striped burrfish)	Gunter 1945

species which have been studied, and the data were collected with varying degrees of precision from widely scattered areas. Some of the studies took the age of the fish into account; others did not. However, in every case where stomach analyses were done for individual size classes, a change of food habits was correlated with a change in size. For example, croaker less than 25 mm in length eat principally zooplankton; those 25-50 mm feed mostly on microbenthic invertebrates. Detritus, shrimp, and macrobenthic invertebrates are the main food items of fish 50-200 mm. Large croaker (greater than 200 mm) eat macrobenthic invertebrates, shrimp, and fish (Darnell 1958).

TABLE 19. *Feeding habits of estuarine fishes.*[a]

Type feeder	Per cent of species studied
Planktonic feeders only	4
Benthic feeders only	32
Fish feeders exclusively	8
Detritus feeders only	0
Plankton feeders	44
Benthic feeders	92
Fish feeders	52
Detritus feeders	16
Strict herbivores	0
Strict carnivores	34
Shrimp feeders	52
Limited to one type food	28
Eat more than one type food	72
Eat more than two types of food	52
Eat more than three types of food	32
Eat more than four types of food	12

[a]Summarized from data reported from studies listed in Table 18.

6
Ecological Implications of Human Use of the Coastal Area

Almost any type of human use of land and resources causes ecological disturbance. Man has exerted his influence on the Georgia coast for centuries, and the impact of man on this system is evident in the preceding discussion. Many of man's actions on the Georgia coast have produced undesirable consequences that could have been minimized by proper planning to avoid placing stress on the especially sensitive elements of the system. Frankenberg and Richardson (*in* Clement 1971) discussed many of the ecological restraints on recreational use of the Georgia coast. These restraints are equally applicable to other types of development and use.

This section deals with some of man's general uses of the coastal zone and its resources, their environmental impact, and the limitations imposed by nature on such uses.

Mainland influences

Although this report deals with the islands, the marshes, and the coastal waters, it should be reemphasized that the ecology of these habitats is greatly influenced by ecological changes on the mainland. Two human influences that are of special significance in planning future development are depletion of the artesian water supply and environmental pollution.

Ground water

Although the Coastal Plain or principal artesian aquifer is a very productive water source, heavy industrial withdrawal from it in the coastal area has caused a serious decline in artesian pressure, with resulting salt water encroachment into the aquifer at Savannah and at Brunswick (Warren 1944; Wait 1962; Counts and Donsky 1963; and others).

The water-bearing stratum is confined between impervious strata. The water is under pressure causing it to rise to varying heights in wells tapping the aquifer, depending upon the artesian pressure. An imaginary surface coinciding with these heights at all points within an area is called the piezometric surface. A significant decline in the elevation of the piezometric surface in the coastal area is well documented (Warren 1944, Stewart and Croft 1960; Wait 1962; Counts and Donsky 1963; Callahan 1964; McCollum and Counts 1964; Carver 1968) and is mapped in Fig. 31. If withdrawal is very great in a locality, the elevation of the piezometric surface is severely depressed locally, creating a "depression cone."

Three cones of depression are evident along the Georgia coast, centering about Savannah, Brunswick, and the St. Marys-Fernandina Beach area (Fig. 31).[1] The foci of these depressions are the pumping sites (wells) of major industries (Savannah, Union Camp Corp.; Brunswick, Hercules Powder Co. and Brunswick Pulp and Paper Co.; St. Marys, St. Marys Kraft Corp.). Local residents report declining artesian pressure in the Riceboro area since the Interstate Paper Co. mill began operating in that area in 1968. Originally, the piezometric surface at Savannah was 40 ft above sea level, but by 1960 it had receded to 120 ft below sea level.

Reduction of artesian pressure of aquifers in coastal areas creates a hazard of salt water encroachment into the aquifer. Salt water may encroach directly from the sea if pressure falls so low as to allow intrusion where the aquifer surfaces as a freshwater spring on the continental shelf, or it may encroach from ancient salt water strata below the freshwater aquifer. Both types of salt water encroachment are occurring near Savannah (McCollum and Counts 1964), and the latter type of encroachment is occurring at Brunswick (Wait 1962).

Geologists point out that a decline in elevation of the piezometric surface is accompanied by an increase in recharge rates and reduced loss from wild-flowing artesian wells (Callahan 1964). They calculate that at 1962 rates of withdrawal, Savannah's water supply will not be endangered (by salt water intrusion) for about 90 years (McCollum and Counts 1964). However, the rate of pumping has approximately doubled since 1962.

Despite the assurances of geologists that the decline in artesian pressure does not constitute an immediate and pressing problem, the fact remains that even present levels of withdrawal are affecting the entire aquifer (Carver 1968), and as additional areas on the coast are developed, the problem will become more acute. Unless greater utilization can be made of surface waters (and this assumes pollution control), limited groundwater supplies will place a significant restraint on future industrial development along the coast.

[1]Fig. 31 is located at the back of the book.

Pollution

The Georgia coast is not without pollution problems. Large industries have been attracted to the coastal region of Georgia by an abundance of groundwater and surface water, seaport facilities, climate, an available labor force, and a receptive attitude of the people. These industries, especially the pulp and paper and chemical industries, have contributed significantly to the economy of the region. Simultaneously, they have contributed most significantly to major pollution problems. Large volumes of pollutants are discharged into the air and water especially at Savannah, Brunswick, and St. Marys.

Pollution to a large extent is incompatible with many uses of the coastal zone, including commercial and sport fishing, mariculture, tourism, recreation, and wildlife management. It is aesthetically objectionable and many pollutants present a hazard to human health.

The coastal region is, in many ways, peculiarly sensitive to pollution. The sensitivity of estuaries to pollutants is well known and will be discussed in some detail. There is increasing evidence that terrestrial systems of the lower Coastal Plain also may be unusually susceptible to pollution. For example, disturbingly high concentrations of radio-isotopes (Cesium-137) from fallout have been detected in organisms, including game animals, from the Georgia coast (Jenkins and Fendley 1968 and unpublished). The causes of the high uptake of radionuclides in the coastal area are not known but may be related, at least in part, to dietary mineral deficiencies associated with the infertile soils of the region (Jenkins and Fendley 1968).

Waste disposal commonly is regarded as one of the most important uses of moving water. The addition of materials into the aquatic environment in quantities exceeding its capacity to dispose of them results in pollution. The estuaries of Georgia receive pollutants from industries and municipalities along the coast, and from river systems carrying agricultural pesticides and sewage and industrial wastes from towns and cities along the river.

Aquatic pollution is a serious problem in the estuarine system. Estuaries are not "open-ended" systems through which pollutants move via river currents and into the oceanic system. Pollutants released into the estuarine environment often remain there, retained by the same mechanisms that trap nutrients. Tidal oscillations prevent their dissipation into offshore waters and, to a large extent, they simply move back and forth within the estuary (Fig. 32).

The littoral current may move some pollutants southward alongshore (Neiheisel and Weaver 1967) and, therefore, estuarine pollution must be considered on a regional basis rather than on the basis of political boundaries. Pollutants dumped into estuaries as far north as Pamlico Sound, N.C., may be carried southward with the littoral current and eventually into Georgia estuaries.

Pollutants may be introduced into aquatic systems intentionally (waste disposal), accidentally (spillage, malfunction of treatment facilities) or in subtle ways that often go unnoticed or unidentified for many years (runoff from

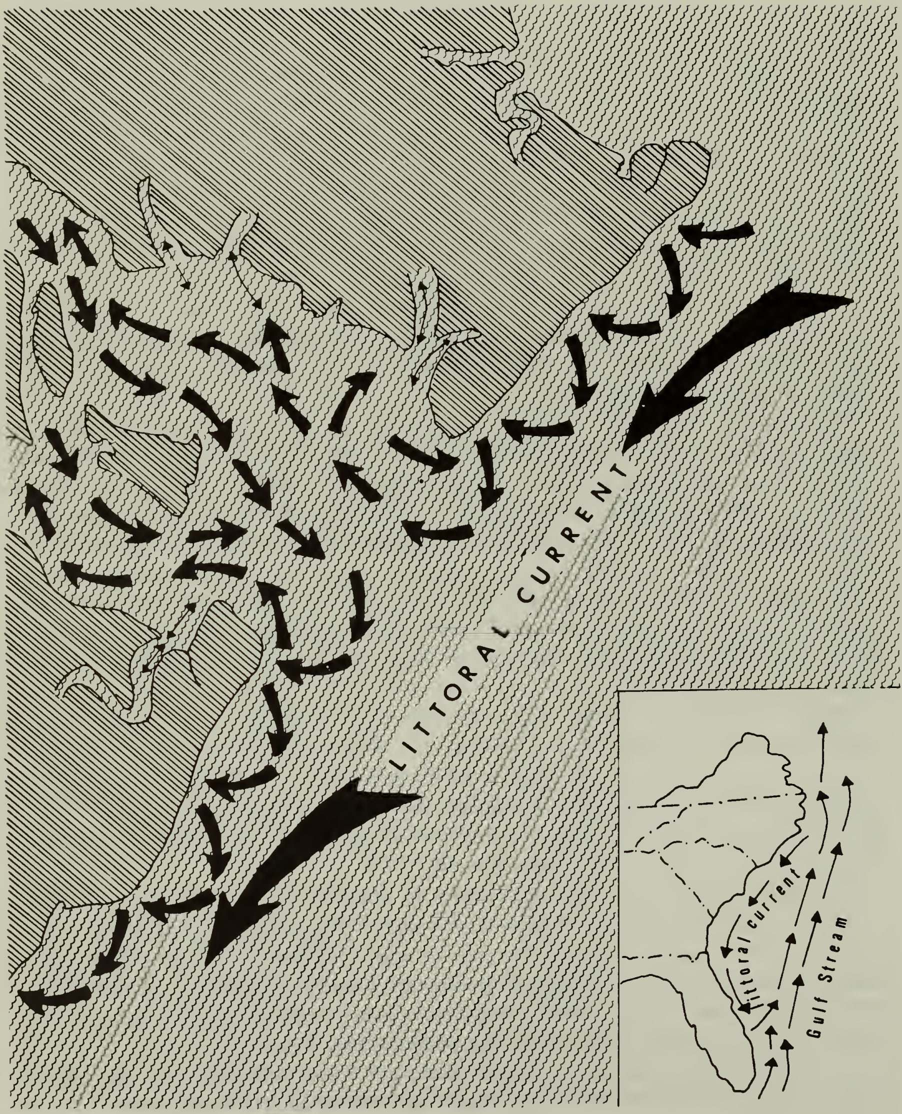

Fig. 32. Map showing oscillatory tidal currents (small arrows) in Ossabaw Sound and inshore waters and the littoral current (large arrows). Sediments and detritus as well as pollutants move back and forth within the estuary while being carried southward by the littoral current. Inset map shows the littoral current in relation to the Gulf Stream.

agricultural lands, radioactive fallout). Different kinds of pollutants create different kinds of problems. For example, sewage effluent consists largely of organic substances which are degradable by natural processes. The oxidation of these substances in waters results in increased biological oxygen demand (BOD), temperatures, fertility, and turbidity. These changes in water quality bring about major alterations in the biotic composition of the waters. Industrial wastes, which are much more variable, commonly include acids, dyes, oils, heavy metals, inert materials, wood fibers, and hot water. These substances may create many of the same problems as domestic sewage. In addition, many of them are not biodegradable and thus may persist for long periods of time. They may be stored in the tissues of organisms and thus increase in concentration at each trophic level (biomagnification). Some present problems of acute toxicity; others cause more subtle forms of physiological damage.

Domestic and industrial pollution in the lower reaches of some mainland rivers may be affecting the spawning runs of anadromous fish by forming barriers, preventing fish from ascending the rivers to spawn.

Most tidal creeks adjacent to areas of human habitation receive sewage effluent. Most of this effluent receives little or no treatment before its release. The extent of pollution by sewage may be seen in Figs. 35A-H (Appendix 6), which show areas closed to oyster gathering by the Georgia Department of Public Health. Pollution severely depresses the commercial harvest of this economically important shellfish even though the oysters themselves may not be harmed. Because many of the state's oyster beds are closed, few attempts have been made to determine the residue levels of chlorinated hydrocarbons, radionuclides, and heavy metals in oysters. However, oysters are known to concentrate very high levels of some of these substances, and oysters from many beds on the Georgia coast may be unfit for human consumption even if sewage pollution could be halted.

Among the more significant industrial pollutants discharged into the estuaries are heavy metals (mercury, cadmium, zinc, lead, et al.). The extent of heavy metal pollution in Georgia rivers and estuaries is not known at present, but studies are being initiated to determine types, distribution, and biological effects of heavy metals. In the summer of 1970 the Savannah River below Augusta was closed to fishing because of methyl mercury pollution attributed to Olin Mathieson Co. at Augusta. Blue crabs in the Savannah estuaries, 180 miles below the pollution source, were declared unsafe for human consumption. Blue crabs in Brunswick Harbor were also declared unsafe for eating because of mercury pollution, in this case attributed to Allied Chemical Co. These industries have reduced the volume of mercury discharged, but the residue will remain in the rivers and estuaries for an unknown period of time.

Some industrial pollution is very acid and is known to increase the acidity of nearby waters to toxic levels. Large volumes of industrial pollutants having a high BOD are released daily into the coastal ecosystem. As previously stated, these pollutants pose a serious threat to the productivity and stability of the estuarine community.

Pesticides most commonly enter the estuaries in runoff from agricultural and forest lands (Butler 1968). Many chlorinated hydrocarbon pesticides are magnified in the food chain. Detritus-feeding, bottom-dwelling organisms concentrate these pesticides, and they are further concentrated at each higher trophic level on the food chain. Pesticides may appear very quickly in some marine organisms following their use in the environment. Oysters accumulated 8 ppm DDT 24 hours after beaches in Florida were sprayed to control stable flies (Butler 1968). In addition to their implication to human health, pesticide residues adversely affect many animal populations. Crustaceans such as shrimp are very sensitive to chlorinated hydrocarbon pesticides, and high mortalities may result from their exposure to these compounds.

Mirex is a chlorinated hydrocarbon compound currently being distributed by airplane over vast areas in an attempt to eradicate imported fire ants (*Solenopsis saevissima*). Although estuarine areas are not to be treated, Mirex enters the estuarine community via runoff from mainland areas. Mirex is toxic to some marine organisms. It has been found to be lethal to juvenile blue crabs at the standard application rate of 1.25 lb treated bait per acre (Mahood et al. 1970).

Chemical control of salt marsh mosquitoes has caused pesticide pollution of some estuaries of the Atlantic states. Formerly, the most commonly used control agent was DDT. This compound has been used as an adulticide for mosquitoes in coastal Georgia, but Malathion is now being used (H. F. Schoof pers. comm.). Paris green (copper acetoarsenite) vermiculite pellets or No. 2 fuel oil with a surfactant are used as larvicides in the marshes (H. F. Schoof, pers. comm.). None of the chlorinated hydrocarbon compounds such as DDT have been used as larvicides in the marshes.

Pesticides have been detected in some economically important marine fish (e.g., tuna) at levels unsafe for human consumption. Species such as tuna seldom enter the estuaries to feed and therefore must be acquiring pesticide residues from prey species, such as menhaden, which migrate through the estuaries during their life cycle but move offshore at certain times (Butler 1968). Butler (1968) gave an example of the biological magnification of pesticides: water 1.0 ppb; plankton 70 ppb; fish 15 ppm; porpoise 800 ppm.

Pesticide residues are not necessarily confined to the aquatic environment. The decline of the bald eagle, osprey, and brown pelican is now thought to be a result of reproductive failure related to pesticide residues.

The accumulation and concentration of pesticide residues by nontarget organisms, the flux of these residues through the ecosystem, and their potential threat to man should be carefully studied. However, enough data now exists to convincingly demonstrate the biological hazards of dumping chlorinated hydrocarbon and other persistent pesticides into the estuarine environments.

Thermal pollution is not now a significant factor in the Georgia estuaries. Thermal pollution in other areas commonly has resulted from the operation of nuclear-powered electric-generating plants. Georgia Power Co. currently is constructing such a plant about 70 miles above Altamaha Sound on the Altamaha River. This plant is not expected to appreciably alter temperatures of the river because most of the cooling water will be recycled and reused. Water demands upon the Altamaha River will be approximately 25,000 gallons per minute, of which 12,000 will be returned to the river as cooling tower effluent. The temperature of the effluent will vary from 78° to 90°F (T. E. Byerley, pers. comm.).

The marshes and estuaries

Schelske and Odum (1961) point out that because marshes and estuaries interact so intimately they should be considered as one ecological unit. The marsh-estuary system is very sensitive to human-induced modifications such as pollution, draining, dredging, and filling. Of the many existing and potential uses of marshes and estuaries, some require such physical alterations and some require that the system be maintained in a relatively natural condition. Following is a discussion of some of these uses: their potentials, limitations, and environmental impacts.

Use and values of the natural marsh-estuary system

The marshes and estuaries are valuable natural environments that have many uses which are compatible so long as the physical habitat is not drastically altered. These include commercial harvest of fish, shellfish, and wildlife; research and education; and many forms of outdoor recreation. Compatible types of recreation include fishing, hunting, nature study, boating, sight-seeing, and swimming.

The marsh-estuary system performs ecological functions that contribute to maintaining the stability of the biosphere. Especially important are the roles of the system in regulation of atmospheric composition and in regeneration and exportation of nutrients to marine and terrestrial food chains.

Dredging, filling, diking, and ditching

Although dredging, filling, diking, and ditching are not uses of the marsh, they are forms of management employed for various reasons such as land development, mosquito control, exploitation of mineral resources, development and maintenance of navigational waterways, and highway construction. Approximately 2700 acres (0.7%) of Georgia's coastal marshes and 800 acres (0.6%) of its shoal water habitat were destroyed, primarily by navigation projects, between 1954 and 1968 (Spinner 1969). The construction of an interstate highway (I-95) will destroy, directly or indirectly, many acres of coastal marsh, including 243 acres of prime wildlife habitat on the Altamaha State Waterfowl Management Area.

Dredging associated with the maintenance of harbors and inland waterways, mineral exploitation, and highway construction, in addition to destroying a portion of the marsh, may also have long-lasting effects on the remaining marsh and on the estuaries. These effects result from alteration of patterns of circulation and sedimentation, from increased turbidity, and from BOD.

Dredging increases the silt load and turbidity of the waters, thereby reducing photosynthesis of phytoplankton and decreasing primary production. Sessile and bottom-dwelling marine organisms such as oysters and clams may be buried by silt following dredging. Disturbed bottom sediments increase the oxygen demand of estuarine waters which have a naturally low oxygen content. Frankenberg and Westerfield (1968) reported that sediments from Wassaw Sound had a potential to remove the oxygen from a volume of water 535 times the same volume of sediment. Oxygen depletion of the estuarine waters could bring about anaerobic conditions which would seriously affect shellfish and finfish.

Marsh areas filled with spoil from dredging operations (referred to as spoil areas) most often are permanently destroyed. Spoil dredged from inland waterways and deposited alongside the waterway destroys the marsh grass and lowers the productivity of the marsh system. Extensive spoil areas at Savannah and Brunswick have been formed from dredging channels and harbor basins. These areas often are used as industrial sites. Soils dredged and deposited on the marsh may become very acid and remain devoid of vegetation for many years. Spoil deposits often create breeding habitat for salt marsh mosquitoes and present additional control problems.

Spoil areas, however, often do provide preferred nesting, feeding, and loafing areas for migratory birds. Oyster Bed Island (Tybee National Wildlife Refuge), a 100-acre marsh island in the Savannah River that has been used for spoil deposition for many years, is heavily used by gulls, terns, shore birds, and many wading birds. Colonies of least terns, royal terns, and black skimmers commonly nest on the island in the years immediately following spoil deposition (U.S. Fish and Wildlife Service undated).

Improperly planned marshland causeways that obstruct tidal flow may cause the loss of extensive areas of marsh habitat. Uninhibited tidal flow is essential to the maintenance of the smooth cordgrass community. In addition to maintaining the cordgrass, tides remove sediments and transport nutrients and detritus to the estuaries. The obstruction of fluvial channels in freshwater and brackish water areas is also destructive of marsh in that it causes rapid sedimentation above the obstruction.

In the case of diking for aquaculture, waterfowl management, and mosquito control, water control structures normally are used to allow regulated tidal flow into the impoundments. When normal daily tidal fluctuations are reduced or restricted, the vegetative composition within the impoundments may be altered. Stabilizing water levels in marsh areas may reduce mosquito production because the eggs require alternate periods of flooding and drying to hatch. Predaceous aquatic animals destroy many of the larvae that do hatch from eggs deposited near the edges of these impoundments (Teal and Teal 1969). Although marsh habitat is altered when areas are impounded, diversity is created, affording habitat for some forms of wildlife such as waterfowl and wading birds.

Ditching marshes is a common practice for mosquito control. Ditching (1) allows a rapid runoff following heavy rain or storm tides; (2) permits free circulation of tidal water into landlocked areas; and (3) allows larva-eating predators (top minnows, killifish, and predaceous invertebrates) to enter pools of water where mosquito larvae accumulate during low water (King et al. 1960). Ditching for mosquito control usually is done in the saltgrass zone. Ditching in this zone does not destroy primary producers of estuarine food chains, but some disruption of the estuarine system (e.g., siltation, increased turbidity, and increased BOD) occurs.

Some man-induced physical modifications of coastal wetlands have enhanced aesthetic qualities and contributed to recreational diversity. Without question, the development of the intracoastal waterway system has improved salt water sport fishing opportunities. The waterway provides a protected route of travel for small craft and increases the amount of area accessible for fishing. As discussed previously, spoil areas provide desirable habitat for many migratory birds. For some bird species spoil areas may contribute to a basic habitat requirement. Diked impoundments, which are excellent loafing and feeding areas for waterfowl, often provide hunting recreation that would not exist otherwise.

A precise evaluation of the detrimental and beneficial effects of physical modification of marshland depends upon the specific circumstances and in some cases must await the results of current and future research.

Agriculture

Because of the high productivity of marsh soils and the example set by the Dutch, there have been many attempts to dike and drain marshes in order to convert them into agricultural lands. The drainage of marshes, especially salt marshes, for agricultural purposes generally is not feasible. The physical and chemical properties of the soils are poorly suited to agriculture. Control of soil moisture, salinity, and acidity is very difficult, and the potential of specific sites in the marsh to form cat clays cannot be confidently predicted.

Although some freshwater marshes (formerly river swamps) are potentially productive (Long 1958), management costs are high, and these lands are probably best reserved for wildlife, their present use.

Grazing

Marshes are profitably used as livestock range in many coastal areas. The coastal marshes are more productive rangeland than adjacent high ground, and freshwater marshes are more productive than salt marshes (Byrd et al. 1961). Native marsh grasses that are preferred forage generally are high in nutritive value, and cattle and hogs on marsh range often show impressive weight gains.

Freshwater marshes provide best grazing in the spring and summer (Byrd et al. 1961). Principal forage for cattle is the young, tender growth of giant cutgrass and reedcane. Hogs forage upon a variety of species of plants and animals, but especially upon roots and tubers of plants such as arrow arum, golden club, arrowhead, and yellow cowlily.

Salt marshes are best grazed in winter (October through April) because plant growth is more tender and nutritious and because mosquitoes and other insects are less troublesome then (Byrd et al. 1961). Principal forages are salt meadow cordgrass, saltgrass, and smooth cordgrass (Byrd et al. 1961).

Grazing in the salt marsh is restricted to areas that are not too soft to support livestock (i.e., short *Spartina* high marsh, the saltgrass zone, the salt meadow cordgrass zone, and the needlerush marsh). Lack of available fresh water is a problem in many areas.

The ecological effects of grazing and trampling in the marsh have not been adequately studied. Chabreck (1968) found that intensive use of marshes by livestock resulted (as on other types of range) in changes in plant composition and reduction in plant density. The tolerance of most marsh plants to intensive grazing is not known. Severe overstocking of marshes may bring about physical changes in the marsh substrate (e.g., bogginess, erosion).

Fish and shellfish culture

The culture of oysters, shrimp, crabs, and fish in diked impoundments (aquaculture or mariculture) is a potentially important use of marshes (Lunz 1968; Linton 1968). Much experimental work is currently underway, and there is considerable interest in mariculture on the Georgia coast. Marifarms, Inc. has sought permission to develop a 1200-acre shrimp farm on Barbour Island near St. Catherines Island. Mariculture currently is being practiced on a pilot basis by Thiokol Chemical Corp. on the Satilla River near Harriet's Bluff, by Marineland Farms south of Brunswick, and by S. L. Lewis on Raccoon Keys between Wassaw and Ossabaw islands. Much of this pilot work is being done in high-ground impoundments, with salt water being pumped in.

Ecological objections to mariculture have been raised because of the diking involved; the blocking of tidal exchange and consequent reduction in nutrient export; the loss of marsh as nursery grounds for marine organisms; the use of rotenone for predator control in impoundments; and the potential for disease problems. More information is needed before some of these objections can be properly evaluated. Most objections would not apply to impoundments above mean high tide. If mariculture becomes economically feasible, it may become necessary to place limitations on the amount of tidal marsh that may be diked for this purpose.

Mining

Although minerals are abundant in the marshes and estuaries, only phosphates have significant economic potential at this time. Prettyman and Cave (1923) investigated the petroleum and natural gas potential in Georgia and found the coastal region an unpromising area. Now there is some dredging for sand, gravel, and shell.

Phosphate deposits of major economic potential lie in upper Miocene strata under Wilmington, Little Tybee, Cabbage, and Wassaw islands. Limited data indicate mineable concentrations extend at least 10 miles offshore, probably farther. The deposits become too thin to be mineable between Wilmington Island and Savannah and are too deeply buried south of Ossabaw Sound to be economically recovered (Cheatum et al. 1968; Furlow 1969). It is estimated that, using present technology, at least 800 million tons of 100% bone phosphate of lime can be recovered at a profit (Furlow 1969).

The phosphorite (mineable phosphate) is covered with an overburden approximately 70 ft thick at Savannah Beach, increasing to about 150 ft under Ossabaw Island. Mining with present technology would involve stripping the overburden from the phosphorite and would produce major ecological disturbances, the overall significance of which is difficult to assess.

The Kerr-McGee Corp. applied in 1968 for a mineral lease of state-owned lands in Chatham County. This action created much controversy and, at the request of the Governor, the Chancellor of the University System of Georgia appointed an Advisory Committee on Mineral Leasing to study the impact of the proposed mining. The results of this study were reported by Cheatum et al. (1968). Undesirable ecological impacts that were identified included the destruction of large areas of marsh-estuarine habitat, increased BOD resulting from the disturbance of sediments, hydrologic changes and changes in patterns of sediment deposition, and increased mosquito problems. Accidental rupture of the impermeable layer capping the aquifer (the aquiclude) and consequent intrusion of salt water into the Coastal Plain aquifer is also a possibility. Many of these effects would extend well beyond the limits of the mined area. The economic impact of mining would depend upon a number of unpredictable, indirect factors including the effects on existing and potential industries such as fisheries, mariculture, recreation, and tourism.

Mining as a potential use of the marshes and estuaries must be considered as a single use that is incompatible with most other uses of coastal resources. It consists of relatively short-term utilization of valuable nonrenewable resources, generally resulting in long-term reduction in productivity of valuable renewable resources.

The islands

The coastal islands of Georgia and adjacent states have been used most commonly for recreation, resorts, research, and education, and for the production of agricultural crops, livestock, forest products, and wildlife. The major limitation on use has been the lack of vehicular access to the islands. Insects, tropical storms, soil conditions, and other factors have imposed less severe restrictions on use.

Soils of the interior habitats of the islands generally do not impose severe limitations on use. Although generally low in fertility and commonly either excessively drained (droughty) or poorly drained (swampy), they are moderately productive if intensively managed and may be used for agriculture or livestock production. Most island soils support good tree growth, and the average site index (height of the average dominant tree at 50 years of age) for slash pine is about 80 (Byrd et al. 1961).

The physical properties of the soils are rated as *fair* for engineering uses such as grading, road-building, pond construction, and septic tank drainage fields. The engineering properties of specific soil types are tabulated by Byrd et al. (1961).

To a large extent most of the previously listed uses of the islands are compatible. Although islands in private ownership normally will be managed according to the desires of the owners, the public has an interest in the welfare of the islands as a rare and endangered ecological type. Future use of the islands no doubt will be based upon either their value for intensive residential and recreational development or their ecological and aesthetic values as relatively natural areas.

Like the marshes, the islands are probably best kept as nearly natural as possible. Because they are small, they cannot support much development without losing their primitive nature.

It seems illogical to eliminate rare and essentially irreplaceable resources of high value in order to expand activities that can be accommodated in many other areas.

The islands offer essentially unique opportunities to observe, study, and enjoy ecological processes at work. There are few other situations where processes of geologic change are so evident, where there is such great floral and faunal diversity, and where wildlife in such abundance can be so readily observed. The values of the islands in the conservation of certain species, as natural laboratories for research on population genetics, behavior and population dynamics, and for recreational and educational nature study should be a focus for any public-use program. Swimming, fishing, hiking, picnicking, bird-watching, nature photography, and shell collecting are recreational activities compatible with the preservation of these values.

Above all, the islands should remain islands. Bridges or causeways make them accessible to invasion by mainland animals which could displace unusual or unique island populations. Bridges or causeways would also open the islands to the destructive impact of automobiles and the undesirable developments that accompany them. Furthermore, isolation is an important quality contributing to the charm of the islands.

Construction and development should be kept to a minimum on publicly owned islands, not only because buildings occupy space, but also because of the alterations associated with providing utilities and sewage and garbage disposal. Intensive structural development is best restricted to the mainland.

On publicly owned islands, natural vegetation should be preserved insofar as possible. Representative examples of all habitat types should be maintained. Live oak forests especially should be protected. Overmature, diseased, and dead trees should be allowed to remain standing to provide nesting cavities, dens, and insect food for songbirds, woodpeckers, raccoons, squirrels, and certain other wildlife species. Judicial application of vegetation control practices such as fire may be prescribed for naturalistic landscaping and to prevent undesirably dense growth of vegetation in some types, especially pine forests and sloughs. Management procedures for some island habitat types are not well known and experimental work may be necessary.

Special protection is needed for certain wildlife species such as pocket gophers and alligators. Wading bird rookeries should be protected from disturbance. Exotic species should not be introduced. Certain habitat management practices may be desirable, but very intensive artificial management should be avoided.

The beach and dune area, one of the most attractive areas for recreation, includes some ecologically sensitive elements that need special consideration. Beaches and dunes interact physically and biologically and comprise a logical management unit.

Beaches are capable of supporting high-density human recreational activities without deterioration. The number of people beaches can support is limited only by the physical dimensions of the beach and by the sociologcial restrictions the people impose upon themselves. The dynamic forces of the sea are constantly reworking the beach face, and after each high tide the impact of man is erased from the shoreface and foreshore. This pristine appearance is one of the primary reasons beaches are attractive recreation areas.

One of the main factors limiting recreation on the beaches is industrial and municipal pollution. Pollution effluent from the city of Savannah occasionally discourages swimming in the waters off Savannah Beach. Unsightly residual material such as construction debris and beverage containers are often deposited by high tides on the beaches. This material lowers the recreational quality of the beach and may reduce its use by recreationists.

In contrast to the beaches, the dunes can withstand only light recreational use. The fragile nature of dunes and the importance of dune stability to the overall ecology of the oceanfront long has been recognized by scientists but is still too often ignored by planners and engineers. Unfortunately, some of Georgia's most attractive beaches and dunes have been drastically modified by unsound development. Most of the dune complex has been destroyed by development at Savannah Beach and St. Simons and Jekyll islands (Fig. 33). Dunes

Fig. 33. Aerial photograph of Savannah Beach, Tybee Island, May 1970, showing high-density recreational use. Note that beachside developments have resulted in total loss of the dunes. A sea wall has been constructed to retard encroachment of the sea on beachside developments.

were reduced in size or removed completely during the construction of buildings, roads, and parking areas. Stabilizing dune vegetation also has been removed or reduced by unrestricted recreational use. These alterations have accelerated erosion of the protective dunes and beaches and have necessitated the construction of erosion control structures. Groins have been constructed perpendicular to the beach (and the littoral current) to impede sand movement, and sea walls have been erected to protect seaside structures from encroachment of the sea (Fig. 33).

Structures designed to control beach erosion are expensive and only temporarily effective. Sea walls have a longer functional life than groins, but they are still temporary measures for retarding sea encroachment. These structures are unnatural and unsightly, and they reduce the aesthetic appeal of the area to many people. In acute situations of beach erosion, sand may be pumped from offshore areas and deposited on the beach (beach nourishment). Beach nourishment, though geologically and aesthetically desirable, is a very expensive management option.

As previously noted, the loss of dune vegetation caused by overgrazing contributes to destabilization and erosion of the dune complex. Free-ranging livestock have seriously reduced or removed dune plants on Ossabaw, Little St. Simons, and Cumberland islands. Large numbers of fallow deer also have contributed to the loss of dune vegetation on Little St. Simons.

Many animal species are affected by the deterioration of beach and dune habitats. Depending upon their "successional" stages, the beaches and dunes provide nesting and feeding areas for sea turtles, gulls, terns, pelicans, and many species of shorebirds. Perhaps the animal species most affected by changes in beach forms is the loggerhead sea turtle. As discussed in Chapter 3, the loggerhead requries specific beach types for nesting purposes. Beach erosion reduces the amount of preferred nesting habitat and may cause turtles to shift their nesting to other beaches if they are available. Other human influences, such as artificial illumination of the beaches and nocturnal disturbance, affect loggerhead nesting. Female loggerheads are easily discouraged from nesting by lights on the beach, lights from automobiles on nearby highways, and the illumination of beachside motels and other facilities. Artificial illumination of nesting beaches also increases the mortality of hatching turtles by disorienting them during their trip to the sea after hatching.

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Appendix I

ANNOTATED LIST OF FISHES OF THE GEORGIA COAST

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INTRODUCTION

The following list includes those species of fish that are known from or likely to occur in estuarine and marine waters along the Georgia coast seaward to a depth of 10 fathoms. This encompasses waters of the estuary, beach, and "coastal habitat." In the text the term coastal habitat refers to that region from the ocean beaches to a depth of 10 fathoms as in Struhsaker (1969). Species listed are based primarily on my own records from Georgia inshore waters, from South Carolina by Bearden (1961a, 1965), and from the coastal habitat by Struhsaker (1969). For the benefit of sport fishermen, the common offshore sport fishes are also included. This list is extracted from my manuscript, *A Field Guide to Georgia Coastal Fishes.* This manuscript and the paper by Struhsaker (1969) report a large number of additional species that are restricted to deeper waters of the Continental Shelf; most of these species occur primarily on reefs.

Seasonal records in the text are based on inshore collections, i.e., beach and estuarine waters.

The classification of the American Fisheries Society (Bailey 1970) is followed.

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Class AGNATHA–Jawless Fishes
Order PETROMYZONTIFORMES

PETROMYZONTIDAE–Lampreys
Petromyzon marinus Linnaeus–sea lamprey
Anadromous. Rare in Georgia.

Class CHONDRICHTHYES–Cartilaginous Fishes
Order SQUALIFORMES–Sharks

The common sharks that occur inshore on the Georgia coast are not restricted to well-defined habitats. They may be collected in shallow beach waters as well as deeper waters of the sounds and offshore. Most of the sharks considered below prefer warmer waters and leave inshore waters of Georgia in the winter. One exception is the spiny dogfish, a northern species that migrates southward to Georgia in the winter.

ODONTASPIDIDAE–Sand Tigers
Odontaspis taurus (Rafinesque)–sand shark
Known from South Carolina but not Georgia.

LAMNIDAE–Mackerel Sharks
Carcharodon carcharius (Linnaeus)–white shark
Reported from South Carolina but not Georgia. Mainly pelagic but sometimes found inshore.
Cetorhinus maximus (Gunnerus)–basking shark
Rarely found inshore.

ALOPIIDAE (LAMNIDAE)–Thresher Sharks
Alopias vulpinus (Bonnaterre)–thresher shark
Reported from South Carolina but not Georgia. Pelagic but sometimes found inshore.

ORECTOLOBIDAE–Carpet Sharks
Ginglymostoma cirratum (Bonnaterre)–nurse shark
Specimens have been caught on the Georgia coast in the warmer months.

CARCHARHINIDAE–Requiem Sharks
Aprionodon isodon (Valenciennes)–finetooth shark
Common in warmer months.
Carcharhinus acronotus (Poey)–blacknose shark
Inshore in warmer months.
Carcharhinus leucus (Valenciennes)–bull shark
Reported from South Carolina but not from Georgia.
Carcharhinus limbatus (Valenciennes)–small blacktip shark
Common in warmer months.
Carcharhinus milberti (Valenciennes)–sandbar shark
Common in warmer months.
Galeocerdo cuvieri (Peron and Lesueur)–tiger shark
Caught in warmer months.
Mustelis canis (Mitchill)–smooth dogfish
Rare in South Carolina and not known from Georgia.

Negaprion brevirostris (Poey)–lemon shark
Common in warmer months.

Rhizoprionodon terraenovae (Richardson)–Atlantic sharpnose shark
Not known from Georgia but quite common in South Carolina in warmer months.

SPHYRNIDAE–Hammerhead Sharks

Sphyrna lewini (Griffith and Smith)–scalloped hammerhead shark
Common in warmer months.

Sphyrna tiburo (Linnaeus)–bonnet shark
Occurs inshore March through November.

Sphyrna zygaena (Linnaeus)–smooth hammerhead shark
Young are often collected on the South Carolina coast in spring and summer and they probably occur on the Georgia coast.

SQUALIDAE–Dogfish Sharks

Squalus acanthias Linnaeus–spiny dogfish
Occurs on Georgia coast in colder months.

Order RAJIFORMES–Skates and Rays

PRISTIDAE–Sawfishes

Pristis pectinata Lathan–smalltooth sawfish
Rare off South Carolina and not known from Georgia.

RHINOBATIDAE–Guitarfish

Rhinobatos lentiginosus (Garman)–Atlantic guitarfish
Uncommon; occurs May through September.

RAJIDAE–Skates

Raja eglanteria Bosc–clearnose skate
Common September through May.

DASYATIDAE–Stingrays

Stingrays are collected by hook, seine, and trawls in shallow beach waters and deeper estuarine waters.

Dasyatis americana Hildebrand and Schroeder–southern stingray
Common in warmer months.

Dasyatis centroura (Mitchill)–roughtail stingray
Rarely occurs inshore off South Carolina and not known from Georgia.

Dasyatis sabina (Lesueur)–stingaree
Abundant in warmer months and present throughout the year.

Dasyatis sayi (Lesueur)–bluntnose stingray
Common in coastal waters, April through November.

Gymnura micrura (Bloch and Schneider)–smooth butterfly ray
Common in trawl catches in warmer months and present throughout the year.

MYLIOBATIDAE–Eagle Rays

Aetobatus narinari (Euphrasen)–spotted eagle ray
Reported from South Carolina but not known from the Georgia coast.

Myliobatis freminvillei Lesueur–eagle ray
Uncommon.
Rhinoptera bonasus (Mitchill)–cownose ray
Uncommon.

MOBULIDAE–Mantas
The range of the devil ray, *Mobula hypostoma,* includes the Georgia coast, but it has not been reported from Georgia or South Carolina.
Manta birostris (Walbaum)–Atlantic manta
Large specimens are occasionally seen jumping in Georgia coastal waters and one reported to weigh 2500 pounds was caught in a shrimp trawl.

Class **OSTEICHTHYES**–Bony Fishes

Order ACIPENSERIFORMES

ACIPENSERIDAE–Sturgeons
Acipenser brevirostrum Lesueur–shortnose sturgeon
Primarily found in tidal waters but enters ocean. Commonly caught in gill nets in the Altamaha River.
Acipenser oxyrhynchus Mitchill–Atlantic sturgeon
Anadromous. Commonly caught in gill nets in the Altamaha River by shad fishermen.

Order SEMIONOTIFORMES

LEPISOSTEIDAE–Gars
Lepisosteus osseus (Linnaeus)–longnose gar
Primarily a freshwater species but often encountered in salt water on the Georgia coast.
Lepisosteus platyrhincus DeKay–Florida gar
A freshwater species not likely to be found in salt water.

Order ELOPIFORMES

ELOPIDAE–Tarpons
Elops saurus Linnaeus–Ladyfish, tenpounder
Small individuals are often collected in tidal pools and canals and occasionally along the beach, high marsh, and upper reaches, from May to November.
Megalops atlantica Valenciennes–tarpon
Large tarpon are commonly caught in warmer months on Georgia beaches and in the lower Altamaha River. Juveniles occur in tidal pools and creeks in low- to high-salinities from July to November.

ALBULIDAE–Bonefishes
Albula vulpes (Linnaeus)–bonefish
Rare.

Order ANGUILLIFORMES

ANGUILLIDAE–Freshwater Eels

Anguilla rostrata (Lesueur)–American eel

Catadromous. Common spring through fall in oligohaline and freshwater creeks, tidal creeks, low- and high-salinity tidal pools, and rare in high marsh.

CONGRIDAE–Conger Eels

Ariosoma impressa (Poey)–bandtooth conger

Largely offshore.

Conger oceanicus (Mitchill)–conger eel

Largely offshore.

OPHICHTHIDAE–Snake Eels and Worm Eels

In addition to the species listed, three other ophichthids occur offshore on the Georgia coast; these are *Letharchus velifer, Verma kendalli* and *Mystriophis intertinctus.*

Myrophis punctatus Lütken–speckled worm eel

Beach, high marsh, and ologohaline creek. Rarely seen on Georgia coast.

Ophichthus gomesi (Castelnau)–shrimp eel

Occasionally caught in moderate to deep estuarine waters.

Ophichthus ocellatus (Lesueur)–spotted snake eel

Occasionally taken in coastal habitat.

Order CLUPEIFORMES

CLUPEIDAE–Herrings, Shads

In addition to the species listed, the Atlantic round herring *(Etrumeus teres)* occurs off Georgia, but it is not known from inshore waters.

Alosa aestivalis (Mitchill)–blueback herring

Anadromous.

Alosa mediocris (Mitchill)–hickory shad

Anadromous.

Alosa sapidissima (Wilson)–American shad

Anadromous. An important commercial and sport fish in Georgia rivers during the January-March spawning migration.

Brevoortia smithi Hildebrand-yellowfin menhaden

Common along beaches; also found in the high marsh, tidal canals, and tidal pools, from May to November.

Brevoortia tyrannus (Latrobe)–Atlantic menhaden

Schools are abundant in lower and middle reaches and near beaches of Georgia estuaries in warmer months. Some occur in the sounds throughout the winter. Also found in the high marsh, tidal canals, and high-salinity tidal pools. Rare in the oligohaline creeks and low-salinity tidal pools. Most migrate south or offshore in winter.

Dorosoma cepedianum (Lesueur)–gizzard shad

Common in the lower reaches, high marsh, and probably in oligohaline creeks. Rare along the beach.

Dorosoma petenense (Günther)–threadfin shad

Collected at beaches at Savannah, Sapelo Island, and Brunswick. Also collected in the high marsh and tidal canals.

Harengula pensacolae Goode and Bean–scaled sardine
Occasionally collected at beaches and in the lower reaches and rare in the high marsh, June to October. More abundant south and offshore.

Opisthonema oglinum (Lesueur)–Atlantic thread herring
Known from the beaches, lower reaches, and high marsh, July to December. More abundant to the south.

Sardinella anchovia Valenciennes–Spanish sardine
Reported from a Georgia beach by Miller and Jorgenson (1969).

ENGRAULIDAE–Anchovies

Anchoa cubana (Poey)–Cuban anchovy
Collected at St. Simons Beach by Miller and Jorgenson (1969).

Anchoa hepsetus (Linnaeus)–striped anchovy
Common at Georgia beaches, lower and middle reaches, and high marsh, May to November.

Anchoa lyolepis (Evermann and Marsh)–dusky anchovy
Collected at St. Simons Beach by Miller and Jorgenson (1969).

Anchoa mitchilli (Valenciennes)–bay anchovy
Found at beaches, lower, middle, and upper reaches, in the high marsh, and in high-salinity tidal pools, common throughout the year.

Order MYCTOPHIFORMES

SYNODONTIDAE–Lizardfishes

Synodus foetens (Linnaeus)–inshore lizardfish
A bottom species occasionally collected at the beach, lower reaches, and middle reaches, April to November. More common in coastal and offshore habitats.

Order SILURIFORMES

ICTALURIDAE–Freshwater Catfishes

Ictalurus catus (Linnaeus)–white catfish
Freshwater creeks and rivers; occasionally enters brackish estuarine waters.

ARIIDAE–Sea Catfishes

Bagre marinus (Mitchill)–gafftopsail catfish
Common along beaches and in sounds, June through October.

Arius felis (Linnaeus)–sea catfish
Adults are common on beaches and deeper estuarine waters and juveniles are common in the deeper waters. Present in estuaries from March to November. Migrates to ocean in autumn and winter.

Order BATRACHOIDIFORMES

BATRACHOIDIDAE–Toadfishes
The leopard toadfish (*Opsanus pardus*) and Atlantic midshipman (*Porichthys porosissimus*) are found only offshore, often in association with reefs.

Opsanus tau (Linnaeus)–oyster toadfish
Common in lower and middle reaches usually around debris. Sometimes found in oyster reefs and along the beach.

Order GOBIESOCIFORMES

GOBIESOCIDAE–Clingfishes
Gobiesox strumosus Cope–skilletfish
Lower and middle reaches of estuary, in association with oyster reefs in shallows and shell in deeper waters.

Order LOPHIIFORMES

ANTENNARIIDAE–Frogfishes
The ocellated frogfish (*Antennarius ocellatus*) was reported offshore by Struhsaker (1969), and the two species listed below, reported from St. Simons Beach (Miller and Jorgenson 1969), are stragglers from offshore.
Antennarius radiosus Garman–singlespot frogfish
Offshore, occasionally inshore.
Histrio histrio (Linnaeus)–sargassumfish
Pelagic, in clumps of sargassum.

OGCOCEPHALIDAE–Batfishes
Ogcocephalus radiatus and *Halieutichthys aculeatus* occur offshore on the Georgia coast. One species reported from inshore is listed below.
Ogcocephalus vespertilio (Linnaeus)–longnose batfish
Abundant offshore, sometimes collected in the coastal and lower reaches habitats (Anderson 1968).

Order GADIFORMES

GADIDAE–Codfishes and Hakes
The Carolina hake *(Urophycis earlli)* and silver hake *(Merluccius bilinearis)* probably occur offshore (Struhsaker 1969).
Urophycis floridanus (Bean and Dresel)–southern hake
Common in estuaries January through May. Abundant offshore.
Urophycis regius (Walbaum)–spotted hake
Common in estuaries January through May. Abundant offshore.

OPHIDIIDAE–Cusk Eels
Species reported from offshore by Struhsaker (1969) include the bank cusk-eel *(Ophidion holbrooki)*, polka-dot cusk-eel *(Otophidium omostigmum)*, blotched cusk-eel *(Ophidion grayi)*, and *Lepophidium* spp.
Rissola marginata (DeKay)–striped cusk-eel
Deeper waters of lower and middle reaches, coastal habitat, and rare in beach habitat.

Order ATHERINIFORMES

BELONIDAE–Needlefishes

In addition to the species listed, *Platybelone argalus* occurs in the Gulf Stream off Georgia.

Ablennes hians (Valenciennes)–flat needlefish

Primarily offshore but may occur inshore.

Strongylura marina (Walbaum)–northern needlefish

Found around docks in the lower and middle reaches, also known from the high marsh and the beach.

Tylosurus acus (Lacépède)–agujon

Primarily offshore but may wander inshore.

Tylosurus crocodilus (Peron and Lesueur)–houndfish

Primarily offshore but may wander inshore.

EXOCOETIDAE–Halfbeaks and Flyingfishes

Three species of halfbeaks apparently occur on the Georgia coast but they have not been collected inshore. They may be restricted to offshore. Flyingfishes do not normally occur in Georgia estuaries or along the beaches although they are common offshore. Listed here is a straggler from offshore and another species likely to occur near shore. Two other flyingfishes probably occur offshore on the Georgia coast. These are *Parexocoetus brachypterus* and *Cypselurus cyanopterus.*

Hemiramphus balao Lesueur–balao

Hemiramphus brasiliensis (Linnaeus)–ballyhoo

Hyporhamphus unifasciatus (Ranzani)–halfbeak

Cypselurus heterurus (Rafinesque)–Atlantic flyingfish

Has not been collected near Georgia shore.

Hirundichthys affinis (Günther)–fourwing flyingfish

One adult reportedly collected from Valona Creek apparently is a straggler from offshore.

CYPRINODONTIDAE–Killifishes

Cyprinodon variegatus Lacépède–sheepshead killifish

In the high marshes, tidal canals, high- and low-salinity tidal pools. Euryhaline.

Fundulus chrysotus (Gunther)–golden topminnow

A freshwater species reported to go into brackish water.

Fundulus confluentus Goode and Bean–marsh killifish

Common in freshwater and low-salinity creeks and pools,

Fundulus heteroclitus (Linnaeus)–mummichog

Beach, high marsh, lower to upper reaches, oligohaline creek, tidal canal and tidal pools. Abundant in shallow waters and not found in deep waters.

Fundulus luciae (Baird)–spotfin killifish

The only definite Georgia records were collected at a marsh near the Meridian dock (Miller and Jorgenson 1969). The spotfins apparently have disappeared since the collecting site became occupied with *Spartina* and *Juncus.*

Fundulus majalis (Walbaum)–striped killifish

Present at beaches throughout the year and occasionally taken in the high marsh, tidal canals, and high-salinity tidal pools.

Lucania parva (Baird)–rainwater killifish

Known from South Carolina and Florida but not from Georgia.

POECILIIDAE–Livebearers

Gambusia affinis (Baird and Girard)–mosquitofish

Most abundant in fresh water but common in the high marsh, oligohaline creeks, tidal pools, tidal canals, and sometimes found at the beach.

Heterandria formosa Agassiz–least killifish

Common in fresh water and known to go into brackish water.

Poecilia latipinna Lesueur–sailfin molly

Common in high marsh, fresh water, tidal canals, tidal pools, and rare at the beach and in oligohaline creeks.

ATHERINIDAE–Silversides

Membras martinica (Valenciennes)–rough silverside

Lower reaches, beach, and high marsh habitats. Present throughout the year.

Menidia beryllina (Cope)–tidewater silverside

Most abundant in oligohaline creek and fresh water near the coast, and also found in the upper reaches and at the beach. Present throughout the year.

Menidia menidia (Linnaeus)–Atlantic silverside

Beach, high marsh, lower and middle reaches, and high-salinity tidal pools. Present throughout the year.

Order BERYCIFORMES

HOLOCENTRIDAE–Squirrelfishes

Four species known from the Georgia coast are collected only in offshore waters.

Order GASTEROSTEIFORMES

AULOSTOMIDAE–Trumpetfishes

One species of trumpetfish *(Aulostomus maculatus)* is known from Georgia offshore waters.

FISTULARIIDAE–Cornetfishes

Fistularia tabacaria Linnaeus–bluespotted cornetfish

Primarily offshore but reported from the coastal habitat by Anderson (1968).

SYNGNATHIDAE–Pipefishes and Seahorses

Three pipefishes are known from the Georgia coast–*Syngnathus fuscus, S. louisianae,* and *Corythoichthys albirostris* (one record). Additional forms which may occur inshore along the Georgia coast are *S. scovelli, S. floridae hubbsi,* and *S. f. mckayi* (Dr. E. Herald, pers. comm.). *S. pelagicus* and *S. springeri* may occur offshore.

Hippocampus erectus Perry–lined seahorse

Rare in estuaries but probably common offshore.

Syngnathus floridae mckayi (Swain and Meek)–key dusky pipefish

Inshore.

Syngnathus floridae hubbsi Herald–Chesapeake dusky pipefish

Inshore.

Syngnathus fuscus Storer–northern pipefish

Often found at the beach, upper and lower reaches, and rare in oligohaline creek.

Syngnathus louisianae Günther–chain pipefish
Common in Georgia estuaries. Known from beach, high marsh, lower to upper reaches, high-salinity tidal pool, and rare in oligohaline creek.
Syngnathus pelagicus Linnaeus–sargassum pipefish
A pelagic species associated with rafts of sargassum.
Syngnathus scovelli (Evermann and Kendall)–Gulf pipefish
Inshore.
Syngnathus springeri Herald–bull pipefish
Ranges from North Carolina to Pensacola, Fla., but not known from Georgia.
Corythoichthys albirostris Heckel–whitenose pipefish
Inshore.

Order PERCIFORMES

CENTROPOMIDAE–Snooks

Centropomus undecimalis (Bloch)–snook
Young occur in tidal pools and tidal ditches from June to November in Georgia.

SERRANIDAE–Sea Basses

Numerous sea bass species occur on live-bottom areas off the Georgia coast. The gag, *Mycteroperca microlepis,* is a straggler to Georgia estuaries. Only two species *(Centropristis)* are common in the estuary. *Centropristis ocyurus* occurs offshore. Two species of *Diplectrum* occur in the coastal habitat and *Diplectrum bivittatum* occurs offshore (Struhsaker 1969). Two more serranids, *Serraniculus pumilio* and *Serranus subligarius,* occur offshore and may be found in reefs in the coastal habitat.
Centropristis philadelphica (Linnaeus)–rock sea bass
Occasionally caught in estuaries. Common offshore.
Centropristis striata (Linnaeus)–black sea bass
Young are commonly in estuarine sounds and rivers throughout the year. Large black sea bass are abundant offshore around reefs.
Diplectrum formosum (Linnaeus)–sand perch
Coastal habitat and offshore.
Diplectrum radiale (Quoy and Gaimard)–aguavina
Coastal habitat and offshore.

PERCICHTHYIDAE

The white perch *Morone americana* occurs in South Carolina (Bearden 1961b) but not Georgia.
Morone saxatilis (Walbaum)–striped bass
Anadromous. Common in Georgia rivers.

PRIACANTHIDAE–Bigeyes

Two species *(Priacanthus arenatus* and *Pristigenys alta)* are found offshore.

APOGONIDAE–Cardinalfishes

Two species *(Apogon maculatus* and *A. pseudomaculatus)* occur offshore.

CENTRARCHIDAE–Sunfishes

Many species of sunfishes enter brackish waters occasionally. I collected four species in the oligohaline Riceboro Creek when the water was fresh. These were the flier (*Centrarchus macropterus*), warmouth (*Lepomis gulosus*), bluegill (*Lepomis macrochirus*), and largemouth bass (*Micropterus salmoides*).

POMATOMIDAE–Bluefish

Pomatomus saltatrix (Linnaeus)–bluefish

The smaller "snapper blues" are commonly caught with fishing poles on beaches, in sounds and estuarine rivers. Large bluefish are caught offshore.

ECHENEIDAE–Remoras

Echeneis naucrates Linnaeus–sharksucker

RACHYCENTRIDAE–Cobia

Rachycentron canadum (Linnaeus)–cobia

Commonly caught around buoys offshore. Found around mouths of sounds and rivers of South Carolina (Bearden 1961a).

CARANGIDAE–Jacks, Scads, Pompanos

Most offshore records of carangids are from Struhsaker (1969). A few additional species may be found in the Gulf Stream.

Alectis crinitus (Mitchill)–African pompano

Coastal habitat.

Caranx bartholomaei Cuvier–yellow jack

Primarily offshore near the Gulf Stream. Juveniles occasionally migrate or drift inshore (Berry 1959).

Caranx crysos (Mitchill)–blue runner

Collected in Georgia estuarine and coastal waters (Anderson 1968) but most abundant offshore.

Caranx hippos (Linnaeus)–crevalle jack

Adult crevalle jack are rarely caught with fishing poles on the Georgia coast. Young are sometimes collected along the beach and in the marsh (Miller and Jorgenson 1969).

Caranx latus (Agassiz)–horse-eye jack

Collected at St. Simons Beach by Miller and Jorgenson (1969).

Chloroscombrus chrysurus (Linnaeus)–Atlantic bumper

Common June-December in waters of beach, lower reaches, and coastal habitat and rare in middle reaches and high-salinity tidal pools.

Decapterus punctatus (Agassiz)–rough scad

Coastal habitat and offshore.

Oligoplites saurus (Bloch and Schneider)–leatherjacket

Common June-November along the beach and also occurring in the high marsh, middle reaches, and high-salinity tidal pools.

Selar crumenophthalmus (Bloch)–bigeye scad

Coastal and offshore. Uncommon.

Selene vomer (Linnaeus)–lookdown

Sometimes collected in waters of the beach, lower reaches, and coastal habitat, May-September.

Trachinotus carolinus (Linnaeus)–Florida pompano

Young pompano are abundant along the beaches in the warmer months. All three species of *Trachinotus* apparently occur offshore.

Trachinotus falcatus (Linnaeus)–round pompano
Young occur along the beach and sometimes in the high marsh, May-November.
Trachinotus goodei Jordan and Evermann–palometa
Young occur along beaches in warmer months. Rare.
Vomer setapinnis (Mitchill)–Atlantic moonfish
Coastal habitat and sometimes collected at the beach.

CORYPHAENIDAE–Dolphins
The common dolphin (*Coryphaena hippurus*) is often caught offshore by sport fishermen and the pompano dolphin *(C. equisetis)* also occurs offshore.

LOBOTIDAE–Tripletail
Lobotes surinamensis (Bloch)–tripletail, sunfish
Sometimes caught in coastal and offshore waters especially around buoys and wrecks.

LUTJANIDAE–Snappers
The snappers are tropical fishes that are represented by at least seven species offshore. The red snapper *(Lutjanus campechanus)* supports a small commercial fisheries off Georgia. Included in the synonymy of the red snapper is *L. aya* and *L. blackfordi* (Anderson 1967, Rivas 1966). One snapper ranges inshore.
Lutjanus griseus (Linnaeus)–gray or mangrove snapper
On the Georgia coast the mangrove snapper occurs primarily offshore. A few juveniles were collected in shallows of the lower reaches, beach, high marsh, low- and high-salinity tidal pools.

GERREIDAE–Mojarras
Diapterus olisthostomus (Goode and Bean)–Irish pompano
Beach, high marsh, low- and high-salinity tidal pools, and rare in oligohaline creeks and tidal canals. Euryhaline. Collected July through November.
Eucinostomus argenteus Baird and Girard–spotfin mojarra
Occasionally collected in waters of beach, lower reaches to oligohaline creeks, high marsh, tidal canals, and low- and high-salinity tidal pools, July-November. Mostly in shallows but some were collected while trawling in the lower reaches.
Eucinostomus gula (Quoy and Gaimard)–silver jenny
Recorded for the beach and high marsh by Miller and Jorgenson (1969). Also reported for the coastal habitat (Bullis and Thompson 1965).
Eucinostomus melanopterus (Bleeker)–flagfin mojarra
Two specimens collected in the oligohaline Riceboro Creek.

POMADASYIDAE–Grunts
The grunts are primarily tropical fishes. The pigfish is the only species common in temperate Atlantic waters and often found in the estuaries. The tomtate occasionally occurs in the coastal habitat and is more common around reefs and offshore. The white grunt *(Haemulon plumieri)* occurs offshore on reefs.
Haemulon aurolineatum (Cuvier)–tomtate
Most abundant offshore in reef and shelf-edge habitats and sometimes collected in coastal habitat.
Orthopristis chrysoptera (Linnaeus)–pigfish
Collected in the lower and middle reaches of the estuary. Also in coastal habitat and open shelf habitat. Collected June through December inshore.

SCIAENIDAE–Drums

Sciaenids are predominantly temperate-water fishes that need estuarine waters for nursery grounds. The diverse and abundant sciaenids of Georgia are the most important group to coastal sport fishermen. They are the most abundant fishes in terms of number available for trawling (Anderson 1968) and probably biomass.

Bairdiella chrysura (Lacépède)–silver perch

Abundant in trawl catches in the coastal habitat and lower and middle reaches. Mostly young are found in waters of the beach, high marsh, oligohaline creeks, tidal canals, and high- and low-salinity tidal pools.

Cynoscion nebulosus (Cuvier)–spotted seatrout, winter trout

A very popular sport fish along beaches and in lower and middle reaches, caught mostly in fall and winter. Also in coastal habitat, high marsh, and high-salinity tidal pools.

Cynoscion nothus (Holbrook)–silver seatrout

Lower reaches from May to August and coastal habitat.

Cynoscion regalis (Bloch and Schneider)–weakfish, summer trout

Most common in lower reaches. Also in waters of coastal habitat, beach, middle reaches, high marsh, tidal canals, and high-salinity tidal pools. Present throughout the year.

Larimus fasciatus Holbrook–banded drum

Lower reaches and rare along the beach. Present throughout the year.

Leiostomus xanthurus Lacépède–spot

Beach, lower reaches up the estuary to oligohaline creeks, high marsh, tidal canal, and high- and low-salinity tidal pools. Present throughout the year.

Menticirrhus americanus (Linnaeus)–southern kingfish

Both young and adults are common to abundant in the lower reaches throughout the year and beach habitat spring through fall. Also known from the coastal habitat, high marsh, and middle reaches.

Menticirrhus littoralis (Holbrook)–Gulf kingfish

Young are common along the beach in warmer months and occur there throughout the year. Also known from the lower reaches and high marsh.

Menticirrhus saxatilis (Bloch and Schneider)–northern kingfish

Young are common along the beach. Young and adults are sometimes caught in the lower reaches. Rare in high marsh. Occurs April through August.

Micropogon undulatus (Linnaeus)–Atlantic croaker

Adults are abundant in the lower reaches. Other habitats are the beach, high marsh, middle reaches, and high-salinity tidal pools. Rare in oligohaline creeks and tidal canals. Present throughout the year.

Pogonias cromis (Linnaeus)–black drum

Large black drum are occasionally collected in the lower reaches. Young occur in beach waters, high marsh, tidal canals, high- and low-salinity tidal pools. Also recorded for the coastal habitat.

Sciaenops ocellata (Linnaeus)–red drum

Large red drum are caught along the beaches and in the lower reaches. Young are occasionally collected in high-salinity tidal pools and rarely in the high marsh, tidal canals, and low-salinity tidal pools.

Stellifer lanceolatus (Holbrook)–star drum

This is the most abundant species in trawl catches in the lower reaches. Most abundant in warmer months. Sometimes occurs in the middle reaches and beach habitats.

MULLIDAE–Goatfishes

Two species were collected at 10-11 fathoms off South Carolina (Bullis and Thompson 1965) and are listed here. The dwarf goatfish *(Upeneus parvus)* occurs offshore.

Mullus auratus Jordan and Gilbert–red goatfish
Offshore, uncommon in coastal habitat.
Pseudupeneus maculatus (Bloch)–spotted goatfish
Offshore, uncommon in coastal habitat.

SPARIDAE–Porgies
Nine species were listed by Struhsaker (1969) for offshore waters. Four species that occur inshore are listed here.
Archosargus probatocephalus (Walbaum)–sheepshead
Sheepshead support a sport fishery in the lower reaches. Young sometimes occur along the beach and in the high marsh. Also offshore on reef habitat.
Calamus leucosteus Jordan and Gilbert–whitebone porgy
Offshore, occasionally in coastal habitat.
Lagodon rhomboides (Linnaeus)–pinfish
Uncommon but widespread. They occupy beach waters, lower reaches, high marsh, tidal canals, and high- and low-salinity tidal pools.
Stenotomus chrysops (Linnaeus)–northern porgy
Coastal and offshore habitats.

KYPHOSIDAE–Sea Chubs
Moore (1962) reported juvenile yellow chubs from the Georgia shore and juvenile Bermuda chub from the South Carolina and Florida shores. Adults occur offshore.
Kyphosis incisor (Cuvier)–yellow chub
Primarily offshore but young occasionally occur inshore as stragglers.
Kyphosis sectatrix (Linnaeus)–Bermuda chub, rudderfish
Primarily offshore but young occasionally occur inshore as stragglers.

EPHIPPIDAE–Spadefishes
Chaetodipterus faber (Broussonet)–Atlantic spadefish
Ranges from reefs and coastal habitat to beaches, lower and middle reaches, and high marsh.

CHAETODONTIDAE–Butterflyfishes
This family includes at least four butterflyfishes of the genus *Chaetodon* and angelfishes of the genus *Holacanthus* off the Georgia coast. Only one is known from within the coastal habitat.
Chaetodon ocellatus Bloch–spotfin butterflyfish
Offshore, occasionally in coastal habitat.

POMACENTRIDAE–Damselfishes
Four species are known from the Georgia coast, mostly from reefs. Only one has been reported inshore.
Abudefduf saxatilis (Linnaeus)–sergeant major
Primarily reefs. Reported by Miller and Jorgenson (1969) from St. Simons Beach.

MUGILIDAE–Mullets

Mugil cephalus Linnaeus–striped mullet

Ubiquitous in shallow waters of the beach, from the lower reaches to the oligohaline creeks, and high-salinity tidal pools. Also found in the high marsh, tidal canals, and low-salinity tidal pools.

Mugil curema Valenciennes–white mullet

Beach, high marsh, lower to upper reaches, tidal canals, and high- and low-salinity tidal pools.

SPHYRAENIDAE–Barracudas

Miller and Jorgenson (1969) reported the southern sennet from St. Simons Beach. Struhsaker (1969) considered the other three species to be coastal, and Bearden (1961b) listed them from South Carolina. I collected one small guaguanche at Sapelo Beach. Barracudas are rarely found inshore along Georgia, and are represented inshore by juveniles

Sphyraena guachancho Cuvier–guaguanche

Generally in turbid waters along silty shores (Randall 1968).

Sphyraena barracuda (Walbaum)–great barracuda

Sphyraena picudilla Poey–southern sennet

Offshore.

Sphyraena borealis DeKay–northern sennet

Offshore.

POLYNEMIDAE–Threadfins

Polydactylus octonemus (Girard)–Atlantic threadfin

Anderson (1968) reported one specimen from an estuary near Brunswick.

LABRIDAE–Wrasses

Seven species apparently occur within depths of the open-shelf and others occur farther offshore. The tautog *(Tautoga onitis)* occurs inshore on the South Carolina coast (Bearden 1961a) but does not range south to Georgia. Two species collected on a reef at a depth of 70 ft off the Georgia coast are listed here.

Halichoeres bivittatus (Bloch)–slippery dick

Primarily reefs in open-shelf habitat and in or near coastal habitat.

Hemipteronotus novacula (Linnaeus)–pearly razorfish

Primarily reefs and in or near the coastal habitat.

SCARIDAE–Parrotfishes

Two species that have been collected offshore are the bucktooth parrotfish *(Sparisoma radians)* and emerald parrotfish *(Nicholsina usta)* (Struhsaker 1969).

URANOSCOPIDAE–Stargazers

Two stargazer species occur off the Georgia coast. The lancer stargazer *(Kathetostoma albigutta)* occurs offshore.

Astroscopus y-graecum (Cuvier)–southern stargazer

Open-shelf, coastal habitat, lower reaches and occasionally beach, high marsh, and middle reaches. Usually on sandy bottoms.

DACTYLOSCOPIDAE–Sand Stargazers

Dactyloscopus tridigitalus Gill–sand stargazers

Several specimens have been collected in the coastal habitat but not within the estuarine or beach waters.

BLENNIIDAE–Combtooth Blennies

Chasmodes bosquianus (Lacépède)–striped blenny

Oyster reefs and probably other cover in the lower reaches and along the beach.

Hypleurochilus geminatus (Wood)–crested blenny

Known from a reef near the coastal habitat and from the lower reaches and beach.

Hypsoblennius hentzi (Lesueur)–feather blenny

Oyster reefs in the lower and middle reaches and rarely off the beach.

Hypsoblennius ionthas (Jordan and Gilbert)–freckled blenny

Range includes Georgia.

ELEOTRIDAE–Sleepers

Dormitator maculatus (Bloch)–fat sleeper

A euryhaline species that I collected only in the low-salinity tidal pools.

GOBIIDAE–Gobies

Evorthodus lyricus (Girard)–lyre goby

Collected only in the high-salinity tidal pools.

Gobioides broussonneti Lacépède–violet goby

Collected in the lower reaches by University of Georgia Marine Institute personnel.

Gobionellus boleosoma (Jordan and Gilbert)–darter goby

High-salinity tidal pools and occasionally waters of beach and high marsh.

Gobionellus hastatus Girard–sharptail goby

Collected in lower reaches and high-salinity tidal pools, and reported from coastal habitat by Anderson (1968).

Gobionellus shufeldti (Jordan and Eigenmann)–freshwater goby

Collected in low-salinity tidal pools. Also reported from St. Simons Beach and Altamaha River (Miller and Jorgenson 1969).

Gobionellus smaragdus (Valenciennes)–emerald goby

Collected only in the high-salinity tidal pools.

Gobionellus stigmaticus (Poey)–marked goby

Recorded from South Carolina (Bearden 1961b) but not Georgia.

Gobiosoma bosci (Lacépède)–naked goby

Common in oyster reefs in the lower reaches. Also collected in the upper reaches, oligohaline creeks, beach waters, high marsh, and high-salinity tidal pools.

Gobiosoma ginsburgi Hildebrand and Schroeder–seaboard goby

Oyster reefs and occasionally in beach waters and deeper waters of lower reaches.

Microgobius thalassinus (Jordan and Gilbert)–green goby

Occurs over a broad salinity range and available data suggest preference for sandy substrates (Dawson 1969). I collected this species only in a muddy high-salinity tidal pool.

ACANTHURIDAE–Surgeonfishes

Two species occur on offshore live-bottom habitats. These are the blue tang *(Acanthurus coeruleus)* and doctorfish *(A. chirurgus)*.

TRICHIURIDAE–Cutlassfishes
Trichiurus lepturus Linnaeus–Atlantic cutlassfish
Lower reaches and coastal habitat. Rarely lower shelf.

STROMATEIDAE–Butterfishes
Peprilus alepidotus (Linnaeus)–southern harvestfish
Coastal habitat, lower and middle reaches, and sometimes collected in beach waters. Inshore throughout the year but uncommon.
Peprilus triacanthus (Peck)–butterfish
Lower shelf, coastal, lower reaches, and sometimes in middle reaches and beach waters. Inshore throughout the year but uncommon.

SCOMBRIDAE–Mackerels and Tunas
The pelagic mackerels and tunas are primarily restricted to offshore waters. Three species of mackerel occasionally occur in the coastal habitat or estuaries. Scombrids occur on the Georgia coast primarily from spring to fall.
Euthynnus alletteratus (Rafinesque)–little tunny
Offshore.
Sarda sarda (Bloch)–Atlantic bonito
Offshore.
Scomber japonicus Houttuyn–chub mackerel
Pelagic but frequently taken in bottom trawls in the coastal and open-shelf habitats (Struhsaker 1969).
Scomberomerus cavalla (Cuvier)–king mackerel
Primarily offshore. Large king mackerel are sometimes caught by fishermen within 5 miles of the Georgia coast. Occasionally found inshore around piers in South Carolina (Bearden 1961a).

Scomberomerus maculatus (Mitchill)–Spanish mackerel
Primarily offshore but adults are often caught in the coastal habitat and sometimes in Georgia estuaries. Miller and Jorgenson (1969) reported young at St. Simons Beach from June to October.
Scomberomerus regalis (Bloch)–cero
Offshore.
Thunnus atlanticus (Lesson)–blackfin tuna
Occasionally found offshore.

ISTIOPHORIDAE–Billfishes
Istiophorus platypterus (Shaw and Nodder)–Atlantic sailfish
Tetrapterus albidus (Poey)–white marlin
Makaira nigricans Lacépède–blue marlin

XIPHIIDAE–Swordfish
Xiphius gladius Linnaeus–swordfish

SCORPAENIDAE–Scorpionfishes and Rockfishes
In addition to the species listed, *Scorpaena calcarata* occurs in the open-shelf habitat (Struhsaker 1969).
Scorpaena brasiliensis Cuvier–barbfish
Coastal habitat and offshore.

TRIGLIDAE–Searobins

Six species of *Prionotus* and three species of *Bellator* are listed for coastal waters by Struhsaker (1969). Of these, he reported only four *Prionotus* from the open-shelf habitat to shore. I reported two additional species.

Prionotus carolinus (Linnaeus)–northern searobin

Offshore to coastal habitat and lower reaches; rarely found along the beach.

Prionotus scitulus Jordan and Gilbert–leopard searobin

Offshore to lower reaches; rare in middle reaches and beach habitats.

Prionotus evolans (Linnaeus)–striped searobin

Offshore to lower and middle reaches and beach; rare in high marsh.

Prionotus tribulus Cuvier–bighead searobin

Occurs from at least 15 fathoms to lower reaches and beach and rare in middle reaches.

Prionotus salmonicolor Fowler–blackwing searobin

Offshore, and one specimen collected in the lower reaches (identified by George C. Miller).

Order PLEURONECTIFORMES

BOTHIDAE–Lefteye Flounders

Listed in this family are 14 species that occur within or are likely to occur within the range of the estuaries and coastal habitat. Struhsaker (1969) lists five additional species which represent three additional genera for offshore waters. On the Georgia coast, the summer flounder and southern flounder are the only flatfishes that are important in the sport and commercial fisheries.

Ancylopsetta quadrocellata Gill–ocellated flounder

Offshore, coastal, lower and middle reaches. Inshore January through May.

Bothus ocellatus (Agassiz)–eyed flounder

Offshore but may enter coastal habitat.

Citharichthys macrops Dresel–spotted whiff

Usually in coastal habitat and offshore. Miller and Jorgenson (1969) report one from St. Simons Beach.

Citharichthys spilopterus Günther–bay whiff

Offshore to lower and middle reaches and rarely collected in waters of the beach and oligohaline creeks. Inshore May through October.

Cyclopsetta fimbriata (Goode and Bean)–spotfin flounder

Offshore.

Etropus crossotus Jordan and Gilbert–fringed flounder

Offshore to lower and middle reaches and sometimes collected along the beach. Inshore throughout the year.

Etropus microstomus (Gill)–smallmouth flounder

Coastal habitat and offshore.

Etropus rimosus Goode and Bean–gray flounder

Coastal habitat and offshore.

Paralichthys albigutta Jordan and Gilbert–Gulf flounder

Known from coastal and lower reaches of Georgia, and ranges offshore. Rare inshore on Georgia coast.

Paralichthys dentatus (Linnaeus)–summer flounder

Offshore, coastal, common in lower and middle reaches, and sometimes collected along the beach. Present inshore throughout the year.

Paralichthys lethostigma Jordan and Gilbert–southern flounder
Coastal and common from the lower reaches to oligohaline creeks and along the beach. Present inshore throughout the year.
Paralichthys squamilentus Jordan and Gilbert–broad flounder
Adults offshore; young have been collected along the beach.
Scophthalmus aquosus (Mitchill)–windowpane
Coastal habitat to middle reaches and sometimes along beach. Present inshore January through May.
Syacium papillosum (Linnaeus)–dusky flounder
Primarily offshore, sometimes coastal habitat.

SOLEIDAE–Soles
Gymnachirus melas Nichols–zebra sole
Offshore and coastal habitat but never occurs in estuaries.
Trinectes maculatus (Bloch and Schneider)–hogchoker
Common from coastal habitat to freshwater habitat and sometimes taken along beach. Young go far upstream in freshwater rivers. Present inshore throughout the year.

CYNOGLOSSIDAE–Tonguefishes
Two species are listed here and three additional species occur offshore (Struhsaker 1969).
Symphurus plagiusa (Linnaeus)–blackcheek tonguefish
Abundant in lower and middle reaches and also found in the coastal habitat, beach waters and high marsh. Only young were found in the oligohaline creeks and high-salinity tidal pools.
Symphurus urospilus Ginsburg–spottail tonguefish
One specimen was collected in the coastal habitat.

Order TETRAODONTIFORMES

BALISTIDAE–Triggerfishes and Filefishes
Eight species occur primarily offshore (Struhsaker 1969). Two are listed below.
Aluterus schoepfi (Walbaum)–orange filefish
Offshore and occasionally in coastal habitat.
Monacanthus hispidus (Linnaeus)–planehead filefish
Offshore to lower and middle reaches and sometimes found in high marsh and beach waters. Only young are found inshore.

OSTRACIIDAE–Trunkfishes
Four species may be found offshore and only one is definitely known from the coastal habitat.
Lactophrys quadricornis (Linnaeus)–scrawled cowfish
Coastal habitat and offshore.

TETRAODONTIDAE–Puffers
Lagocephalus laevigatus (Linnaeus)–smooth puffer
Primarily offshore, sometimes coastal.
Sphoeroides dorsalis Longley–marbled puffer
Offshore.

Sphoeroides maculatus (Bloch and Schneider)–northern puffer
Offshore, coastal habitat.
Sphoeroides nephelus (Goode and Bean)–Florida puffer
Offshore and coastal habitats.
Sphoeroides spengleri (Bloch–bandtail puffer
Offshore.

DIODONTIDAE–Porcupine fishes
Three species are likely to be found offshore and one often occurs inshore.
Chilomycterus schoepfi (Walbaum)–striped burrfish
Lower and middle reaches and in beach waters, April through November, and offshore.

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Appendix II

ANNOTATED LIST OF AMPHIBIANS AND REPTILES OF THE COASTAL ISLANDS OF GEORGIA

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INTRODUCTION

Less is known about the amphibians and reptiles than any other groups of vertebrates on the Georgia coast. A long-range study of the herpetofauna of the barrier islands was begun in 1970. The incomplete list that follows summarizes existing data on the occurrence and distribution of amphibians and reptiles on the islands.

The list was compiled from records in the literature, from public and private collections, from reliable sight observations, and from surveys made during the preparation of this report.

The names of museum and private collections have been abbreviated in the list under the category "Specimens." The names of museum collections are as follows: Auburn University Museum of Paleontology (AUMP), Auburn University Museum of Zoology (AUM), The Charleston Museum (CM), The Florida State Museum (UF), Georgia State Museum (GSM), Savannah Science Museum (SSM), Tall Timbers Research Station (TTRS), and the University of Georgia Museum of Zoology (UG-Z). Private collections cited in the list are: I. L. Brisbin (ILB), C. W. Dopson (CWD), H. O. Hillestad (HOH), J. I. Richardson (JIR), and Mrs. Clifford B. West (CBW).

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Class **AMPHIBIA**
Order CAUDATA

Family SALAMANDRIDAE
Notophthalmus viridescens–newt
Distribution:
Specimens–Sapelo (UG-Z, UF)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)

Family AMPHIUMIDAE
Amphiuma means–two-toed amphiuma
Distribution:
Specimens–Sapelo (UG–Z)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)

Order ANURA

Family PELOBATIDAE
Scaphiopus holbrooki–eastern spadefoot toad
Distribution:
Specimens–Sapelo (UG-Z), Cumberland (TTRS, CM, GSM)
Literature–Sapelo (Martof 1963)
Sight observations–Little Cumberland

Family RANIDAE
Rana grylio–pig frog
Distribution:
Specimens–Sapelo (UG-Z)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Rana sphenocephala–southern leopard frog
Distribution:
Specimens–Wassaw (TTRS), St. Catherines (SSM), Sapelo (UG-Z), Little Cumberland (JIR), Cumberland (CM, GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Blackbeard

Family MICROHYLIDAE
Gastrophryne carolinensis–eastern narrow-mouthed toad
Distribution:
Specimens–Sapelo (UG-Z, UF), Cumberland (GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Little Cumberland

Family BUFONIDAE
Bufo quercicus–oak toad
Distribution:
Specimens–Sapelo (UG-Z)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)

Bufo terrestris–southern toad
Distribution:
Specimens–Tybee (HOH), Wassaw (TTRS), St. Catherines (SSM), Blackbeard (UG-Z, AUM), Sapelo (UG-Z), Cumberland (TTRS, CM, GSM)
Literature–Sapelo (Martof 1963)
Sight observations–Ossabaw, Blackbeard, Little Cumberland
Remarks: A very large specimen has been reported from Blackbeard Island (G. W. Folkerts, pers. comm.)

Family HYLIDAE
Hyla cinerea–green tree frog
Distribution:
Specimens–Wassaw (TTRS), Sapelo (UG-Z, AUM), Jekyll (GSM), Little Cumberland (UG-Z), Cumberland (CM, GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Ossabaw
Hyla femoralis–pine woods tree frog
Distribution:
Specimens–Sapelo (UG-Z, UF)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Hyla squirella–squirrel tree frog
Distribution:
Specimens–Wassaw (TTRS), Sapelo (UG-Z), Jekyll (GSM), Cumberland (CM, GSM)
Literature–Sapelo (Martof 1963, Teal and Teal 1964)
Limnaoedus ocularis–grass frog
Distribution:
Specimens–Sapelo (UG-Z)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Pseudacris nigrita–southern chorus frog
Distribution:
Specimens–Sapelo (UG-Z)

Class **REPTILA**
Order TESTUDINATA

Family CHELYDRIDAE
Chelydra serpentina–snapping turtle
Distribution:
Specimens–Sapelo (UG-Z), Cumberland (CM)
Literature–Sapelo (Martof 1963)
Sight observations–Little St. Simons, Ossabaw
Kinosternon subrubrum–mud turtle
Distribution:
Specimens–Sapelo (UG-Z, HOH), Little Cumberland (HOH)
Literature–Sapelo (Martof 1963)

Family EMYIDAE

Terrapene carolina–eastern box turtle
Distribution:
Literature–Sapelo (Martof 1963)

Malaclemys terrapin–Diamondback terrapin
Distribution:
Specimens–Sapelo (UG-Z), Jekyll (UF)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–The diamondback terrapin is common throughout the salt marsh estuary of Georgia

Pseudemys scripta–yellow-bellied turtle
Distribution:
Specimens–Wassaw (TTRS), Cumberland (CM)

Deirochelys reticularia–chicken turtle
Distribution:
Specimens–Ossabaw (CBW)
Literature–Sapelo (Martof 1963)

Family TESTUDINIDAE

Gopherus polyphemus–gopher tortoise
Distribution:
Sight observations–Cumberland

Remarks: The gopher tortoise was introduced on Cumberland Island.

Family CHELONIDAE

Caretta caretta–loggerhead sea turtle
Distribution:
Specimens (skulls)–Blackbeard (UG-Z, HOH), Ossabaw (CBW), Sapelo (AUMP, UG-Z), Jekyll (UF), Little Cumberland (JIR), Cumberland (CWD, HOH)
Literature–Sapelo (Ragotzkie 1959; Caldwell et al. 1959a,b; Martof 1963; Teal and Teal 1964), St. Simons (Caldwell 1962), Jekyll (Caldwell et al. 1959a,b), Little Cumberland (Caldwell et al. 1959a,b; Carr 1967), Cumberland (Caldwell et al. 1959b), Blackbeard (U.S. Fish and Wildlife Service 1962)
Sight observations–Tybee, Wassaw, St. Catherines, Wolf, Little St. Simons, Sea, St. Simons, Little Cumberland

Lepidochelys kempi–Ridley turtle
Distribution:
Specimens (skulls)–Sapelo (UG-Z), McIntosh Co. (UF, exact locality unknown), Chatham Co. (UF, exact locality unknown)
Literature–Sapelo (Martof 1963)

Remarks: The Ridley is rarely observed on the Georgia coast and has not been reported to nest on the coast.

Chelonia mydas–green turtle
Distribution:
Sight observation–Glenn County

Remarks: A small green turtle was taken by a fisherman near Brunswick and was observed alive on 15 June 1968. Exact locality unknown. The green turtle has not been reported to nest on the coast.

Order CROCODILIA

Family CROCODYLIDAE
Alligator mississippiensis–alligator
Distribution:
Literature–St. Catherines (Baldwin 1966), Blackbeard (U.S. Fish and Wildlife Service 1962), Sapelo (Martof 1963; Teal and Teal 1964), Cumberland (Moore 1934)
Sight observations–Wassaw, Ossabaw, St. Catherines, Blackbeard, Sapelo, Little Cumberland, Cumberland

Order SQUAMATA

Family IGUANIDAE
Anolis carolinensis–green anole
Distribution:
Specimens–Wassaw (TTRS), Sapelo (UG-Z), Jekyll (GSM), Cumberland (TTRS, GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Tybee, Ossabaw, Little Cumberland
Sceloporus undulatus–fence lizard
Distribution:
Specimens–Jekyll (GSM), Cumberland (TTRS, GSM)

Family SCINCIDAE
Lygosoma laterale–ground skink
Distribution:
Specimens–Wassaw (TTRS), St. Catherines (SSM), Sapelo (UG-Z), Cumberland (GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Eumeces fasciatus–five-lined skink
Distribution:
Specimens–Sapelo (UG-Z)
Literature–Sapelo (Teal and Teal 1964)
Eumeces laticeps–broad-headed skink
Distribution:
Specimens–St. Catherines (SSM), Sapelo (UG-Z), Jekyll (GSM), Cumberland (GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Ossabaw, Little Cumberland
Eumeces inexpectatus–southeastern five-lined skink
Distribution:
Specimens–Wassaw (TTRS), St. Catherines (SSM)
Literature–Sapelo (Teal and Teal 1964)

Family TEIIDAE
Cenmidophorus sexlineatus–six-lined racerunner
Distribution:
Specimens–Blackbeard (HOH), Sapelo (UG-Z), Cumberland (GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Little Cumberland

Family ANGUIDAE

Ophisaurus ventralis—eastern glass lizard

Distribution:

Specimens—Tybee (HOH), Blackbeard (UG-Z), Sapelo (UG-Z)

Literature—Sapelo (Martof 1963)

Sight observations—Little Cumberland

Ophisaurus compressus—island glass lizard

Distribution:

Specimens—Sapelo (UG-Z)

Literature—Sapelo (Martof 1963), Wolf (Neill 1948)

Family COLUBRIDAE

Natrix fasciata—banded water snake

Distribution:

Specimens—St. Catherines (SSM), Blackbeard (UG-Z), Sapelo (UG-Z), Jekyll (GSM), Cumberland (GSM)

Literature—Sapelo (Teal and Teal 1964)

Remarks: Martof (1963) reported *N. sipedon* on Sapelo Island. Although he did not list subspecies this snake was probably the currently recognized *N. fasciata,* formerly *N. sipedon fasciata.*

Thamnophis sirtalis—garter snake

Distribution:

Specimens—Blackbeard (UG-Z), Sapelo (HOH), Cumberland (TTRS, CM, GSM)

Literature—Sapelo (Martof 1963; Teal and Teal 1964)

Sight observations—Ossabaw, Little Cumberland

Thamnophis sauritus—ribbon snake

Distribution:

Specimens—Blackbeard (AUM, UG-Z), Sapelo (UG-Z), Little Cumberland (JIR), Cumberland (CM, GSM)

Literature—Sapelo (Martof 1963)

Coluber constrictor—black racer

Distribution:

Specimens—Ossabaw (ILB), St. Catherines (SSM), Blackbeard (AUM), Sapelo (UG-Z, HOH), Cumberland (TTRS, GSM)

Literature—Sapelo (Martof 1963; Teal and Teal 1964)

Sight observations—Wassaw, Little Cumberland

Masticophis flagellum—coachwhip

Distribution:

Specimens—Sapelo (UG-Z), Cumberland (GSM)

Literature—Sapelo (Martof 1963)

Sight observations—Little Cumberland

Opheodrys aestivus—rough green snake

Distribution:

Specimens—Blackbeard (AUM), Cumberland (GSM)

Literature—Sapelo (Martof 1963; Teal and Teal 1964)

Sight observations—Little Cumberland

Elaphe obsoleta quadrivittata–greenish rat snake
Distribution:
Specimens–Blackbeard (HOH), Sapelo (UG-Z, HOH), Jekyll (HOH), Cumberland (TTRS, GSM)
Literature–Sapelo (Martof 1963)
Sight observations–Tybee, Ossabaw, Little Cumberland
Remarks: The form occurring on the islands is the "greenish rat snake." Conant (1958) states that it is an intergrade between the yellow rat snake *(E. o. quadrivittata)* and the black rat *(E. o. obsoleta)*.

Elaphe guttata–corn snake
Distribution:
Specimens–Sapelo (UG-Z)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Little Cumberland

Cemophora coccinea–scarlet snake
Distribution:
Specimens–Ossabaw (ILB), Sapelo (UG-Z), Cumberland (GSM)
Literature–Sapelo (Martof 1963)

Lampropeltis getulus–kingsnake
Distribution:
Specimens–Sapelo (UG-Z), Cumberland (TTRS, GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Wassaw, Ossabaw, Little Cumberland

Family VIPERIDAE

Agkistrodon piscivorus–cottonmouth
Distribution:
Specimens–Wassaw (TTRS), Blackbeard (UG-Z), Sapelo (UG-Z, HOH), Little Cumberland (UG-Z), Cumberland (GSM)
Literature–Sapelo (Martof 1963; Teal and Teal 1964)
Sight observations–Ossabaw

Crotalus adamanteus–diamondback rattlesnake
Distribution:
Specimens–Ossabaw (CBW), Blackbeard (UG-Z), Sapelo (UG-Z), Little Cumberland (UG-Z), Cumberland (GSM)
Literature–St. Catherines (Baldwin 1966), Blackbeard (U.S. Fish and Wildlife Service 1962), Sapelo (Martof 1963; Teal and Teal 1964), Little St. Simons (Anon.), St. Simons (Leigh 1883)

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Appendix III

CHECKLIST OF BIRDS OCCURRING IN THE COASTAL REGION OF GEORGIA: SPECIES, ABUNDANCE AND HABITAT

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INTRODUCTION

A comprehensive checklist of birds occurring in the coastal region of Georgia has been prepared from literature records, museum records, and sight observations. Generalized categories of status, seasonal occurrence, and preferred habitat are included. Seasonal occurrence and preferred habitat categories are self-explanatory. A key to abbreviations used in the status category follows:

C – common, encountered nearly every time one visits preferred habitat.

FC – fairly common, encountered approximately 30-70% of the time one visits preferred habitat.

UNC – uncommon, encountered less than 30% of the time one visits preferred habitat.

R – rare, encountered infrequently in preferred habitat.

Acc – accidental, very few records of occurrence, generally of extra-limital occurrence.
* – known to nest.
EXN – extinct.
EXP – extirpated.
loc – locally (used in combination with other status category).
Irr – irregular.
? – status uncertain.

Order / Family / Species / Common Name	Status	Seasonal Occurrence: Permanent Resident	Summer Resident	Winter Resident	Transient	Uncertain	Preferred Habitat: Offshore	Beaches, Dunes, Mud Flats	Forests	Fields, Pastures	Freshwater Marshes, Ponds	Salt Marshes	Estuaries, Sounds
GAVIIFORMES													
Gaviidae													
Gavia immer	FC			●	●		●						●
Common Loon													
G. stellata	UNC			●			●						●
Red-throated Loon													
PODICIPEDIFORMES													
Podicipedidae													
Podiceps grisegena	UNC			●									●
Red-necked Grebe													
**Podilymbus podiceps*	C			●	●						●		●
Pied-billed Grebe	UNC		●										
PROCELLARIIFORMES													
Procellariidae													
Puffinus gravis	Acc						●						
Greater Shearwater													
P. griseus	Acc						●						
Sooty Shearwater													
P. lherminieri	Acc						●						
Audubon's Shearwater													
Hydrobatidae													
Oceanites oceanicus	Acc						●						
Wilson's Petrel													
PELECANIFORMES													
Pelecanidae													
Pelecanus erythrorhynchos	R				●		●						●
White Pelican													
P. occidentalis	FC	●											●
Brown Pelican													
Sulidae													
Morus bassanus	FC			●			●						
Gannet													
Phalacrocoracidae													
Phalacrocorax carbo	R			●									●
Great Cormorant													
P. auritus	C			●									●
Double-crested Cormorant	FC		●										

Order / Family / Species / Common Name	Status	Seasonal Occurrence					Preferred Habitat						
		Permanent Resident	Summer Resident	Winter Resident	Transient	Uncertain	Offshore	Beaches, Dunes, Mud Flats	Forests	Fields, Pastures	Freshwater Marshes, Ponds	Salt Marshes	Estuaries, Sounds
Anhingidae													
**Anhinga anhinga*	FC		●								●		
Anhinga	UNC			●									
Fregatidae													
Fregata magnificens	Acc				●		●						●
Magnificent Frigate-bird													
CICONIFORMES													
Ardeidae													
Ardea occidentalis	Acc					●							●
Great White Heron													
**A. herodias*	C	●						●				●	●
Great Blue Heron													
**Butorides virescens*	FC										●	●	●
Green Heron	UNC			●									
**Florida caerulea*	FC	●									●		●
Little Blue Heron													
**Bubulcus ibis*	C		●							●			
Cattle Egret	R			●									
Dichromanassa rufescens	Acc												●
Reddish Egret													
**Casmerodius albus*	C	●						●			●	●	●
Common Egret													
**Leucophoyx thula*	C	●						●			●	●	●
Snowy Egret													
**Hydranassa tricolor*	C		●								●	●	●
Louisiana Heron	FC			●									
**Nycticorax nycticorax*	FC		●								●	●	●
Black-crowned Night Heron	UNC			●									
**Nyctanassa violacea*	FC		●								●	●	●
Yellow-crowned Night Heron	R			●									
**Ixobrychus exilis*	FC		●								●		
Least Bittern													
Botaurus lentiginosus	FC				●						●		
American Bittern	UNC			●									
Ciconiidae													
Mycteria americana	FC		●							●	●		
Wood Ibis	UNC			●									
Threskiornithidae													
**Plegadis falcinellus*	FC		●							●	●	●	
Glossy Ibis	R			●									

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**Eudocimus albus*	C		●							●	●	●	
White Ibis	UNC			●									
Ajaia ajaja	Acc					●							
Roseate Spoonbill													
ANSERIFORMES													
Anatidae													
Olor columbianus	R			●	●								●
Whistling Swan													
**Branta canadensis*	FC			●	●					●	●		
Canada Goose	loc		●										
B. bernicla	R			●									●
Brant													
Chen hyperborea	R				●						●		●
Snow Goose													
C. caerulescens	R			●	●			●					
Blue Goose													
Dendrocygna bicolor	R			●				●					
Fulvous Tree Duck													
**Anas platyrhynchos*	FC			●	●						●		●
Mallard	loc		●										
A. rubripes	FC			●	●						●		●
Black Duck	R		●										
A. fulvigula	Acc									●	●		
Mottled Duck													
A. strepera	C			●							●		●
Gadwall													
A. acuta	FC			●	●						●		
Pintail													
A. carolinensis	C			●	●						●		●
Green-winged Teal													
A. discors	FC				●						●		●
Blue-winged Teal	UNC			●									
Mareca penelope	R			●	●								
European Widgeon													
M. americana	FC			●							●		
American Widgeon													
Spatula clypeata	FC			●	●						●		
Shoveler													

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**Aix sponsa*	C	●									●		
Wood Duck													
Aythya americana	UNC			●	●								●
Redhead													
A. collaris	FC				●						●		●
Ring-necked Duck	C			●									
A. valisineria	FC			●	●								●
Canvasback													
A. marila	R			●									●
Greater Scaup	loc												
A. affinis	C			●	●						●		●
Lesser Scaup													
Bucephala clangula	UNC			●									●
Common Goldeneye													
B. albeola	C			●	●								●
Bufflehead													
Clangula hyemalis	UNC			●									●
Oldsquaw													
Somateria spectabilis	R			●									●
King Eider													
Melanitta deglandi	R			●			●						●
White-winged Scoter													
M. perspicillata	UNC			●			●						●
Surf Scoter													
Oidemia nigra	C			●			●						●
Common Scoter	loc												
Oxyura jamaicensis	FC			●							●		●
Ruddy Duck													
Lophodytes cucullatus	R		●										●
Hooded Merganser	C			●	●								
Mergus merganser	UNC			●							●		●
Common Merganser													
M. serrator	C			●	●						●		●
Red-breasted Merganser													
FALCONIFORMES													
Cathartidae													
**Cathartes aura*	C	●						●	●	●			
Turkey Vulture													
**Coragyps atratus*	C	●						●	●	●			
Black Vulture													

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Accipitridae													
Elanoides forficatus	R		●		●				●	●			
Swallow-tailed Kite													
Ictinia misisippiensis	UNC		●							●			
Mississippi Kite													
Accipiter striatus	UNC			●					●				
Sharp-shinned Hawk													
**A. cooperii*	FC	●							●				
Cooper's Hawk													
**Buteo jamaicensis*	FC	●								●			
Red-tailed Hawk													
**B. lineatus*	FC	●							●	●			
Red-shouldered Hawk													
B. platypterus	FC				●				●				
Broad-winged Hawk	R			●									
B. lagopus	?					●				●			
Rough-legged Hawk													
Aquila chrysaetos	?					●				●			
Golden Eagle													
**Haliaeetus leucocephalus*	UNC	●							●	●			●
Bald Eagle													
Circus cyaneus	C			●						●	●	●	
Marsh Hawk													
Pandionidae													
**Pandion haliaetus*	FC		●								●		●
Osprey	UNC			●									
Falconidae													
Falco peregrinus	R			●				●	●	●	●		
Peregrine Falcon													
F. columbarius	UNC			●	●			●		●			
Pigeon Hawk													
**F. sparverius*	C			●						●			
Sparrow Hawk	UNC		●										
GALLIFORMES													
Cracidae													
**Ortalis vetula*	FC	●							●				
Chachalaca		Sapelo Island											

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Phasianidae													
**Colinus virginianus*	FC	●							●	●			
Bobwhite													
Meleagrididae													
**Meleagris gallopavo*	FC	●							●	●			
Turkey	loc												
GRUIFORMES													
Gruidae													
Grus americana	EXP									●			
Whooping Crane													
Aramidae													
Aramus guarauna	R					●					●		
Limpkin													
Rallidae													
**Rallus elegans*	UNC			●							●		
King Rail	C		●										
**R. longirostris*	C	●										●	●
Clapper Rail													
R. limicola	FC			●	●						●	●	
Virginia Rail													
Porzana carolina	FC			●	●						●	●	
Sora													
Coturnicops noveboracensis	R			●	●					●	●	●	
Yellow Rail													
Laterallus jamaicensis	R			●	●							●	
Black Rail													
**Porphyrula martinica*	FC		●								●		
Purple Gallinule	loc												
**Gallinula chloropus*	FC	●									●		
Common Gallinule													
**Fulica americana*	C			●	●						●		●
American Coot	UNC		●										
CHARADRIIFORMES													
Haematopodidae													
**Haematopus palliatus*	C	●						●					
American Oystercatcher													
Charadriidae													
Charadrius semipalmatus	C			●	●			●					
Semipalmated Plover	FC		●										

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C. melodus	FC			●	●			●					
Piping Plover													
**C. wilsonia*	FC		●					●					
Wilson's Plover													
C. vociferus	C			●				●		●			
Killdeer	UNC		●										
Eupoda montana	Acc							●					
Mountain Plover													
Pluvialis dominica	R				●			●					
American Golden Plover													
Squatarola squatarola	C			●	●			●					
Black-bellied Plover	UNC		●										
Arenaria interpres	C				●			●					
Ruddy Turnstone	UNC		●										
Scolopacidae													
Philohela minor	UNC	●							●	●			
American Woodcock													
Capella gallinago	C				●						●		●
Common Snipe	FC			●									
Numenius americanus	R			●	●			●					
Long-billed Curlew													
N. phaeopus	C				●			●				●	
Whimbrel	UNC		●										
Bartramia longicauda	R				●					●			
Upland Plover													
Actitis macularia	C				●			●					
Spotted Sandpiper	UNC			●									
Tringa solitaria	FC				●						●		
Solitary Sandpiper													
**Catoptrophorus semipalmatus*	C	●						●				●	
Willet													
Totanus melanoleucus	C				●								
Greater Yellowlegs	FC			●				●			●		●
	UNC		●										
T. flavipes	C				●						●		●
Lesser Yellowlegs	UNC		●	●									
Calidris canutus	C				●								
Knot	FC			●				●					
	UNC		●										

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Erolia maritima	R			●									
Purple Sandpiper													
E. melanotos	FC				●					●	●		
Pectoral Sandpiper													
E. fuscicollis	FC				●			●					
White-rumped Sandpiper	loc												
E. minutilla	C			●	●			●					
Least Sandpiper	UNC		●										
E. alpina	C			●	●			●					
Dunlin													
Limnodromus griseus	C				●			●					
Short-billed Dowitcher	UNC			●									
L. scolopaceus	?							●			●		
Long-billed Dowitcher													
Micropalama himantopus	UNC				●			●			●		
Stilt Sandpiper													
Ereunetes pusillus	C				●			●					
Semipalmated Sandpiper	UNC		●	●									
E. mauri	C			●	●			●					
Western Sandpiper	UNC		●										
Tryngites subruficollis	R				●					●			
Buff-breasted Sandpiper													
Limosa fedoa	FC			●	●			●					
Marbled Godwit													
Crocethia alba	C			●	●			●					
Sanderling	UNC		●										
Recurvirostridae													
Recurvirostra americana	R				●			●			●		
American Avocet													
Himantopus mexicanus	R				●			●			●		
Black-necked Stilt													
Phalaropodidae													
Phalaropus fulicarius	C				●		●						
Red Phalarope	loc												
Steganopus tricolor	R					●	●	●			●		
Wilson's Phalarope													
Lobipes lobatus	R					●	●						
Northern Phalarope													

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Stercorariidae													
Stercorarius parasiticus	R			●			●						●
Parasitic Jaeger													
S. pomarinus	Acc					●	●						●
Pomarine Jaeger													
Laridae													
Larus hyperboreus	R			●			●						
Glaucous Gull													
L. glaucoides	Acc												●
Iceland Gull													
L. marinus	UNC			●									●
Great Black-backed Gull													
L. argentatus	C			●	●			●				●	●
Herring Gull	UNC		●										
L. delawarensis	C			●	●							●	●
Ring-billed Gull	UNC		●					●					
L. atricilla	C				●								
Laughing Gull	FC		●	●				●				●	●
L. philadelphia	C			●	●			●					●
Bonaparte's Gull													
Xema sabini	Acc												●
Sabine's Gull													
**Gelochelidon nilotica*	FC				●			●					●
Gull-billed Tern	loc												
	UNC		●										
Sterna forsteri	C			●	●			●					●
Forster's Tern													
S. hirundo	FC				●			●					●
Common Tern													
S. fuscata	Acc						●						
Sooty Tern													
S. anaethetus	Acc						●						
Bridled Tern													
**S. albifrons*	FC		●					●					●
Least Tern													
**Thalasseus maximus*	C	●						●					●
Royal Tern													
T. sandvicensis	UNC				●			●					●
Sandwich Tern													

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Hydroprogne caspia	FC			●	●			●					●
Caspian Tern	UNC		●										
Anous stolidus	Acc						●						
Noddy Tern													
Rynchopidae													
**Rhynchops nigra*	C	●						●					●
Black Skimmer													
Alcidae													
Alca torda	Acc						●						
Razorbill													
Plautus alle	Acc						●						
Dovekie													
COLUMBIFORMES													
Columbidae													
Columba livia	C	●								●			
Rock Dove													
Zenaida asiatica	Acc									●			
White-winged Dove													
**Zenaidura macroura*	C	●								●			
Mourning Dove													
Ectopistes migratorius	EXN												
Passenger Pigeon													
**Columbigallina passerina*	C	●								●			
Ground Dove													
PSITTACIFORMES													
Psittacidae													
Conuropsis carolinensis	EXN												
Carolina Parakeet													
CUCULIFORMES													
Cuculidae													
**Coccyzus americanus*	FC		●						●				
Yellow-billed Cuckoo													
C. erythropthalmus	UNC				●				●				
Black-billed Cuckoo													

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STRIGIFORMES													
Tytonidae													
**Tyto alba*	FC	●								●		●	
Barn Owl													
Strigidae													
**Otus asio*	FC	●							●	●			
Screech Owl													
**Bubo virginianus*	FC	●							●				
Great Horned Owl													
Nyctea scandiaca	Acc									●			
Snowy Owl													
Speotyto cunicularia	Acc									●			
Burrowing Owl													
**Strix varia*	UNC	●							●				
Barred Owl													
Asio otus	UNC			●					●				
Long-eared Owl													
A. flammeus	FC			●	●			●		●	●		
Short-eared Owl	loc												
Aegolius acadicus	R								●				
Saw-whet Owl													
CAPRIMULGIFORMES													
Caprimulgidae													
**Caprimulgus carolinensis*	C		●						●	●			
Chuck-will's-widow													
C. vociferus	UNC			●	●				●				
Whip-poor-will													
**Chordeiles minor*	C		●					●	●	●	●	●	
Common Nighthawk													
APODIFORMES													
Apodidae													
**Chaetura pelagica*	C		●						●				
Chimney Swift													
Trochilidae													
**Archilochus colubris*	FC		●						●				
Ruby-throated Hummingbird													

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CORACIIFORMES													
Alcedinidae													
Megaceryle alcyon	FC	●									●		●
Belted Kingfisher													
PICIFORMES													
Picidae													
**Colaptes auratus*	C			●	●				●				
Yellow-shafted Flicker	UNC		●										
**Dryocopus pileatus*	C	●							●				
Pileated Woodpecker													
**Centurus carolinus*	C	●							●				
Red-bellied Woodpecker													
**Melanerpes erythrocephalus*	FC	●							●				
Red-headed Woodpecker	loc												
Sphyrapicus varius	FC			●					●				
Yellow-bellied Sapsucker													
**Dendrocopos villosus*	FC	●							●				
Hairy Woodpecker													
**D. pubescens*	C	●							●				
Downy Woodpecker													
D. borealis	R	●							●				
Red-cockaded Woodpecker													
Campephilus principalis	EXP								●				
Ivory-billed Woodpecker													
PASSERIFORMES													
Tyrannidae													
**Tyrannus tyrannus*	C		●							●		●	
Eastern Kingbird													
**T. dominicensis*	R		●		●					●		●	
Gray Kingbird													
T. verticalis	Acc			●						●			
Western Kingbird													
Muscivora forficata	Acc							●		●			
Scissor-tailed Flycatcher													
**Myiarchus crinitus*	C		●						●				
Great Crested Flycatcher													
Sayornis phoebe	C			●	●				●				
Eastern Phoebe													

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Empidonax flaviventris	R				●				●				
Yellow-bellied Flycatcher													
**E. virescens*	FC		●						●				
Acadian Flycatcher													
**Contopus virens*	FC		●						●				
Eastern Wood Peewee													
Pyrocephalus rubinus	Acc									●	●		
Vermilion Flycatcher													
Hirundinidae													
Iridoprocne bicolor	C			●	●						●	●	
Tree Swallow													
Riparia riparia	UNC				●						●	●	
Bank Swallow													
**Stelgidopteryx ruficollis*	C		●		●						●	●	
Rough-winged Swallow													
**Hirundo rustica*	C				●						●	●	
Barn Swallow	UNC		●										
Petrochelidon pyrrhonota	R				●						●	●	
Cliff Swallow													
**Progne subis*	C		●		●				●		●	●	
Purple Martin													
Corvidae													
**Cyanocitta cristata*	FC	●							●				
Blue Jay	loc												
**Corvus brachyrhynchos*	FC	●							●	●			
Common Crow													
**C. ossifragus*	C	●						●	●	●	●	●	
Fish Crow													
Paridae													
**Parus carolinensis*	C	●							●				
Carolina Chickadee													
Sittidae													
Sitta carolinensis	UNC			●	●				●				
White-breasted Nuthatch													
S. canadensis	UNC			●	●				●				
Red-breasted Nuthatch													
**S. pusilla*	C	●							●				
Brown-headed Nuthatch													

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Certhiidae													
Certhia familiaris	UNC			●	●				●				
Brown Creeper													
Troglodytidae													
Troglodytes aedon	FC			●	●				●				
House Wren													
T. troglodytes	FC			●					●				
Winter Wren													
Thryomanes bewickii	UNC			●						●			
Bewick's Wren													
**Thryothorus ludovicianus*	C	●							●				
Carolina Wren													
**Telmatodytes palustris*	C	●									●	●	
Long-billed Marsh Wren													
Cistothorus platensis	FC			●	●					●		●	
Short-billed Marsh Wren	loc												
Mimidae													
**Mimus polyglottos*	C	●							●	●			
Mockingbird													
**Dumetella carolinensis*	C			●					●				
Catbird	UNC		●										
**Toxostoma rufum*	C	●							●				
Brown Thrasher													
Turdidae													
**Turdus migratorius*	C			●	●				●	●			
Robin	R		●										
**Hylocichla mustelina*	FC	●							●				
Wood Thrush													
H. guttata	C			●					●				
Hermit Thrush													
H. ustulata	C				●				●				
Swainson's Thrush													
H. minima	UNC				●				●				
Grey-cheeked Thrush													
H. fuscescens	UNC				●				●				
Veery													
**Sialia sialis*	C	●							●	●			
Eastern Bluebird													

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Sylviidae													
**Polioptila caerulea*	C		●					●	●	●			
Blue-gray Gnatcatcher	UNC			●									
Regulus satrapa	FC			●					●				
Golden-crowned Kinglet													
R. calendula	C			●					●				
Ruby-crowned Kinglet													
Motacillidae													
Anthus spinoletta	FC			●						●			
Water Pipit													
A. spragueii	Acc									●			
Sprague's Pipit													
Bombycillidae													
Bombycilla cedrorum	C			●					●				
Cedar Waxwing	loc												
Laniidae													
**Lanius ludovicianus*	C	●								●			
Loggerhead Shrike													
Sturnidae													
**Sturnus vulgaris*	C	●								●			
Starling													
Vireonidae													
**Vireo griseus*	FC		●						●				
White-eyed Vireo	R			●									
**V. flavifrons*	UNC		●	●	●				●				
Yellow-throated Vireo													
V. solitarius	FC				●				●				
Solitary Vireo	UNC			●									
**V. olivaceus*	C		●		●				●				
Red-eyed Vireo													
V. philadelphicus	R								●				
Philadelphia Vireo													
Parulidae													
Mniotilta varia	C				●				●				
Black-and-white Warbler	UNC			●									
**Protonotaria citrea*	FC		●		●				●		●		
Prothonotary Warbler													

Order / Family / Species / Common Name	Status	Seasonal Occurrence: Permanent Resident	Summer Resident	Winter Resident	Transient	Uncertain	Preferred Habitat: Offshore	Beaches, Dunes, Mud Flats	Forests	Fields, Pastures	Freshwater Marshes, Ponds	Salt Marshes	Estuaries, Sounds
Limnothlypis swainsonii	UNC		●						●		●		
Swainson's Warbler													
Helmitheros vermivorus	UNC				●				●				
Worm-eating Warbler													
Vermivora chrysoptera	R				●				●				
Golden-winged Warbler													
V. pinus	UNC				●				●	●			
Blue-winged Warbler													
V. bachmanii	Acc								●		●		
Bachman's Warbler													
V. peregrina	UNC				●				●				
Tennessee Warbler													
V. celata	FC			●	●				●				
Orange-crowned Warbler													
**Parula americana*	C		●		●				●				
Parula Warbler	Acc			●									
Dendroica petechia	C				●				●		●		
Yellow Warbler													
D. magnolia	UNC				●				●				
Magnolia Warbler													
D. tigrina	FC				●				●				
Cape May Warbler													
D. caerulescens	FC				●				●				
Black-throated Blue Warbler													
D. coronata	C			●	●				●				
Myrtle Warbler													
D. virens	UNC				●				●				
Black-throated Green Warbler													
D. fusca	UNC				●				●				
Blackburnian Warbler													
**D. dominica*	C		●		●				●				
Yellow-throated Warbler	FC			●									
D. pensylvanica	UNC				●				●				
Chestnut-sided Warbler													
D. striata	C				●				●				
Blackpoll Warbler													
**D. pinus*	C	●							●				
Pine Warbler													
D. kirtlandii	R				●				●				
Kirtland's Warbler													

Order / Family / Species / Common Name	Status	Seasonal Occurrence: Permanent Resident	Summer Resident	Winter Resident	Transient	Uncertain	Preferred Habitat: Offshore	Beaches, Dunes, Mud Flats	Forests	Fields, Pastures	Freshwater Marshes, Ponds	Salt Marshes	Estuaries, Sounds
D. discolor	FC		●		●				●				
Prairie Warbler													
D. palmarum	C				●								
Palm Warbler	FC			●					●	●			
Seiurus aurocapillus	C				●				●				
Ovenbird													
S. noveboracensis	UNC				●				●				
Northern Waterthrush													
S. motacilla	FC				●				●				
Louisiana Waterthrush													
Oporornis formosus	UNC				●				●				
Kentucky Warbler													
O. agilis	UNC				●				●				
Connecticut Warbler													
**Geothlypis trichas*	C	●							●		●		
Yellowthroat													
**Icteria virens*	UNC		●						●	●			
Yellow-breasted Chat	R			●									
**Wilsonia citrina*	FC				●				●				
Hooded Warbler	UNC		●										
W. canadensis	R				●				●				
Canada Warbler													
Setophaga ruticilla	FC				●				●				
American Redstart													
Ploceidae													
**Passer domesticus*	FC	●								●			
House Sparrow	loc												
Icteridae													
Dolichonyx oryzivorus	FC				●					●			
Bobolink													
**Sturnella magna*	FC	●								●			
Eastern Meadowlark													
S. neglecta	Acc									●			
Western Meadowlark													
Xanthocephalus xanthocephalus	Acc									●			
Yellow-headed Blackbird													
**Agelaius phoeniceus*	C	●						●		●	●	●	
Redwinged Blackbird													
**Icterus spurius*	FC		●						●				
Orchard Oriole													

Order Family Species Common Name	Status	Seasonal Occurrence: Permanent Resident	Seasonal Occurrence: Summer Resident	Seasonal Occurrence: Winter Resident	Seasonal Occurrence: Transient	Seasonal Occurrence: Uncertain	Preferred Habitat: Offshore	Preferred Habitat: Beaches, Dunes, Mud Flats	Preferred Habitat: Forests	Preferred Habitat: Fields, Pastures	Preferred Habitat: Freshwater Marshes, Ponds	Preferred Habitat: Salt Marshes	Preferred Habitat: Estuaries, Sounds
I. galbula Baltimore Oriole	R			●	●				●				
Euphagus carolinus Rusty Blackbird	FC				●				●		●		
**Cassidix mexicanus* Boat-tailed Grackle	C	●						●	●	●		●	
**Quiscalus quiscula* Common Grackle	C	●							●	●	●		
Molothrus ater Brown-headed Cowbird	FC loc	●								●			
Thraupidae													
Piranga olivacea Scarlet Tanager	UNC				●				●				
**P. rubra* Summer Tanager	C		●						●				
Fringillidae													
**Richmondena cardinalis* Cardinal	C	●							●		●		
**Guiraca caerulea* Blue Grosbeak	FC		●						●	●			
**Passerina cyanea* Indigo Bunting	FC		●						●	●			
**P. ciris* Painted Bunting	C		●						●	●			
Hesperiphona vespertina Evening Grosbeak	UNC			●					●				
Carpodacus purpureus Purple Finch	UNC			●					●	●			
Spinus pinus Pine Siskin	Irr			●					●				
S. tristis	C			●					●	●			
American Goldfinch	R		●										
Loxia curvirostra Red Crossbill	Acc			●					●				
**Pipilo erythrophthalmus* Rufous-sided Towhee	C	●							●				
Calamospiza melanocorys Lark Bunting	Acc									●			
Passerculus princeps Ipswich Sparrow	R			●				●					

Order Family Species Common Name	Status	Seasonal Occurrence: Permanent Resident	Summer Resident	Winter Resident	Transient	Uncertain	Preferred Habitat: Offshore	Beaches, Dunes, Mud Flats	Forests	Fields, Pastures	Freshwater Marshes, Ponds	Salt Marshes	Estuaries, Sounds
P. sandwichensis Savannah Sparrow	C			●						●			
Ammodramus savannarum Grasshopper Sparrow	R			●	●					●			
Passerherbulus caudacutus Le Conte's Sparrow	Acc									●			
P. henslowii Henslow's Sparrow	R			●						●			
Ammospiza caudacuta Sharp-tailed Sparrow	C			●								●	
**A. maritima* Seaside Sparrow	C	●										●	
Pooecetes gramineus Vesper Sparrow	FC			●						●			
Chondestes grammacus Lark Sparrow	Acc								●	●			
**Aimophila aestivalis* Bachman's Sparrow	UNC	●							●				
Junco hyemalis Slate-colored Junco	C			●					●	●			
Spizella passerina Chipping Sparrow	C			●						●			
**S. pusilla* Field Sparrow	FC	●								●			
Zonotrichia leucophrys White-crowned Sparrow	Acc								●	●			
Z. albicollis White-throated Sparrow	C			●					●	●			
Passerella iliaca Fox Sparrow	FC			●					●				
Melospiza lincolnii Lincoln's Sparrow	R			●	●						●		
M. georgiana Swamp Sparrow	C			●							●		
M. melodia Song Sparrow	C			●					●	●	●		
Calcarius lapponicus Lapland Longspur	Acc									●			
Plectrophenax nivalis Snow Bunting	Acc									●			

Appendix IV

LOCATIONS AND DESCRIPTIONS OF WADING BIRD ROOKERIES ON THE GEORGIA COAST

INTRODUCTION

Georgia's coastal islands play a significant role in the maintenance of populations of wading birds such as herons, egrets, and ibises. Most of the islands have sloughs and ponds which are highly preferred for nesting. In addition to suitable habitat, the islands provide secluded nesting areas with minimal human intrusion.

Several colonies of moderate size occur on the Georgia coast. Ten rookeries and colonies were detected by aerial surveys during the summer of 1970 and are described briefly in the list that follows. Many of the nesting sites were visited by foot or by boat. Previous nesting information on some of the rookeries and colonies is included for historical perspective.

The nesting sites are listed and described from north to south along the coast. The numbers preceding the rookery or colony names indicate the location of that nesting site on Fig. 34.[1]

[1]Fig. 34 is a map located at the back of the book.

1. CROOKED CREEK ROOKERY

Location: lat. 31°55′, long. 81°07′, Petit Gauke Hammock Island, Chatham County, 1.5 miles southwest of Vernon View.

This rookery, which can be seen from the intracoastal waterway, consisted primarily of Great Blue Herons and Common Egrets. Nesting sites were commonly 30-40 feet above ground in pine trees. Nesting was near completion about mid-July.

2. MIDDLE PLACE ROOKERY

Location: lat. 31°47′35″, long. 81°07′, 3.1 miles south of Ossabaw Island Landing on Ossabaw Island, Chatham County.

A 1.5-acre submerged field surrounded by mature live oak and pine trees provided the habitat for this colony. Nests were located in willow, cabbage palmetto, and buttonbush. There was no discernible nesting sequence for the eight species using the rookery during the summer of 1970. Over 90% of the nestlings were fledged by mid-July.

Species	Number of Adult Birds
Snowy Egret	47
Cattle Egret	45
Louisiana Heron	18
Black-crowned Night Heron	14
Little Blue Heron	8
Green Heron	8
Yellow-crowned Night Heron	6
Common Egret	2

3. EGRET POND ROOKERY

Location: lat. 31°47′34″, long. 81°07′, 3.6 miles south of Ossabaw Island Landing on Ossabaw Island, Chatham County.

The largest concentration of nesting wading birds on Ossabaw was located here. This area has been frequently used as a nesting site for wading birds since at least 1915 (Erichsen 1921). Nest sites were in willow trees and myrtle bushes. Egret Pond consists of about three acres of open water surrounded by mature pines and hardwoods. The water depth was from 1-4 feet in the area of the colony. Pickerel weed and duckweed occurred in dense clusters beneath the nests.

High juvenile mortality seemed to occur during the latter stages of nesting. Causes of this mortality were not evident. Excessively low passes by helicopters from nearby Hunter Army Airfield may have contributed to the mortality.

Species	Number of Adult Birds
Snowy Egret	150
Common Egret	100
Black-crowned Night Heron	21
Cattle Egret	20
Louisiana Heron	12
Green Heron	10
Anhinga	6 (one nest found)
White Ibis	35 (no nests found)

4. BLACKBEARD ISLAND ROOKERY

Location: lat. 31°30′40″, long. 81°11′30″, Blackbeard Island, McIntosh County on northeast side of island.

Nearly 250 birds made use of this area as a nesting locale. Nests were located in shrubbery adjacent to and within small freshwater ponds. The estimates below are based on visual observation and photographs.

Species	Number of Adult Birds
Snowy Egret	100
Common Egret	75
Louisiana Heron	30
Little Blue Heron	10

Cattle Egret, White and Glossy Ibis were observed, but there was no evidence of their nesting.

5. MARY HAMMOCK ROOKERY

Location: lat. 31°26′30″, long. 81°17′30″, 3.7 miles southeast of Valona, Ga., on west side of Duplin River.

Despite the presence of a pond near the center of this hammock and its use by many species as roosting sites, nesting took place several yards to the north, high in pine trees. Only Common Egret and Great Blue Heron nests were located. Nests were 30-40 feet above ground. Fledging was completed by the first week of July.

Species	Number of Adult Birds
Great Blue Heron	10
Common Egret	8

Wood Ibis, Yellow-crowned Night Herons, Black-crowned Night Herons, Louisiana Herons, Cattle Egrets, Snowy Egrets, and White Ibis used the vegetation surrounding the nearby pond as roosting sites. Varying numbers of these species were present throughout the summer.

6. DARIEN ROOKERY

Location: lat. 31°20′02″, long. 81°22′29″, 1 mile east of Rabbit Island near the mouth of the Altamaha River, McIntosh County.

This colony was first entered on May 14, 1970. At this time nests of most species contained eggs. Only Common Egret, Anhinga, and Black-crowned Night Heron had well-developed young. Low-level nesting predominated. White and Glossy Ibis made nest depressions from broken and bent *Spartina* grass. These structures were generally 7-18 inches above ground level. The remaining species nested mostly in bushes from 2-5 feet above ground.

Two nesting periods occurred during the summer of 1970. The first White Ibis and Glossy Ibis nests were destroyed by high tides and winds late in May. White Ibis made a second nesting attempt 2-3 weeks later. Young were fledged during mid-July. No Glossy Ibis young were known to survive the storm of late May. (This is the first record of Glossy Ibis nesting in Georgia and is documented by photographs of nests, eggs, and young.) A few late-nesting attempts by Louisiana Herons and Snowy Egrets occurred during late June.

The nesting sequence may loosely be ascribed as follows: (1) Common Egret, Anhinga, Black-crowned Night Herons; (2) Snowy Egret, Louisiana Heron, Cattle Egret; and (3) White Ibis and Glossy Ibis.

Species	Number of Adult Birds
White Ibis	2500
Glossy Ibis	150
Snowy Egret	50
Cattle Egret	38
Louisiana Heron	33
Black-crowned Night Heron	28
Common Egret	25
Anhinga	20

Evidence of heavy mink predation was noticed in this colony. Numerous dead young birds were found on each visit to the rookery. Despite the presence of a small number of "gator holes" no alligators were seen.

7. LITTLE SAINT SIMONS SKIMMER COLONY

Location: lat. 31°16′, long. 81°16′50″, Little St. Simons Island, Glynn County.

The abandoned Black Skimmer colony of Little Egg Island (c.f.) appears to have relocated at this site. Approximately 110 skimmers were observed from the air. Nesting occurred on high beach dunes. On 12 August a small but undetermined number of young could be seen. No evidence of tern nesting was found.

8. SATILLA RIVER ROOKERY

Location: lat. 30°58′, long. 81°29′30″, 4 miles southwest of Jekyll Point on the Satilla River, Camden County.

This island had the largest nesting congregation of wading birds on coastal Georgia. This treeless marsh island is approximately 1200 yards long and 250-300 yards wide. Three-fifths of the island is submerged by spring or storm tides. The figures below are based on aerial photographs and observations prior to a storm in late May which resulted in high tides and winds that destroyed about half of the White Ibis nesting sites. Following this, the number of nesting birds was approximately that of the Darien Rookery. By 16 June 1970 most young were near fledging; however, all species except Black-crowned Night Herons had some late nesting attempts underway. Cattle Egrets and Yellow-crowned Night Herons were not present. The absence of adequate feeding habitat nearby may have prevented Cattle Egret nesting. One Glossy Ibis nest containing one egg provided the second nesting record for this state. Mink predation was evident throughout the rookery. Aerial observation on 8 July revealed several Turkey and Black Vultures, and two young Bald Eagles in the rookery.

Species	Number of Adult Birds
White Ibis	3600
Common Egret	200
Snowy Egret	175
Louisiana Heron	150
Little Blue Herron	30
Glossy Ibis	16
Black-crowned Night Heron	5

9. NORTHWEST CUMBERLAND ISLAND ROOKERIES

Location: Small ponds on the north and west sides of Cumberland Island, Camden County.

Two small pond sites were used as nesting locations by Great Blue Herons and Common Egrets (personal communication of C. William Dopson and James I. Richardson). No estimate of the individual species was given.

10. MAIN CUMBERLAND ISLAND ROOKERY

Location: lat. 30°52′, long. 81°26′, 2-3 miles from the north end of Cumberland Island on the eastern side.

This relatively small colony was located during an aerial survey on 16 May. Nesting sites were in trees and bushes surrounding a 1-acre pond. Species observed included Common Egrets and Snowy Egrets. The colony appeared to include about 160 birds.

11. OYSTER BED ISLAND TERN AND SKIMMER COLONY

Location: lat. 32°02′15″, long. 80°53′20″, Tybee National Wildlife Refuge, Chatham County.

No observations of this site were made during the summer of 1970. In the past, however, Oyster Bed Island has been a nesting site of Least and Royal Terns and Black Skimmers. Periodic deposition on the refuge of spoils from dredging operations by the U.S. Army Corps of Engineers serves to maintain feeding and nesting habitat for these and other migratory birds. Nesting by the above species is most common immediately following spoil deposition. No information is available regarding the size and relative composition of the nesting colony.

12. SAPELO ISLAND ROOKERY

Location: lat. 30°30′40″, long. 81°14′20″, Reynolds Duck Ponds, Sapelo Island, McIntosh County.

R. J. Reynolds, former owner of Sapelo Island, constructed freshwater ponds at the north end of the island which developed into suitable nesting habitat for wading birds. By 1958, 2500 pairs of White Ibis, 75 pairs of Black-crowned Night Herons, 100 pairs each of Common Egrets and Snowy Egrets, and 50 pairs of Louisiana Herons were nesting there (Kale 1965). Since that time, cattails have covered nearly all of the pond, and herons no longer nest there. Proposed programs of the Georgia Game and Fish Commission to restore the area to habitat suitable for waterfowl may result in reestablishment of the rookery.

13. LITTLE EGG ISLAND SKIMMER AND TERN COLONY

Location: lat. 31°19′, long. 81°18′, Little Egg Island between Egg Island and Wolf Island at the mouth of the Altamaha River, McIntosh County.

This small treeless island has been the subject of ornithological observation since the mid-1950s (Kale 1967; Kale and Teal 1958; Kale et al. 1965; and others). Previous observers report the nesting of Black Skimmers, Royal, Least and Gull-billed Terns, American Oystercatcher, Wilson Plovers, Willets, and Boat-tailed Grackles.

Seven trips were made to this island from mid-April to the second week of August 1970. No evidence of nesting by any of the above species was noted. In late April and early May several small, scooped depressions in the sand were observed but no eggs or young were located. This island appears to receive considerable use as a picnic area during the tern and skimmer nesting season. Until this activity is eliminated or reduced, it is doubtful if nesting will occur. The Black Skimmer component of this colony has moved to an isolated beach on Little St. Simons Island.

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Appendix V

ANNOTATED LIST OF MAMMALS OF THE COASTAL ISLANDS OF GEORGIA

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INTRODUCTION

Relatively little information has been published on the mammals of the barrier islands of Georgia, and no attempt to compile a list of resident species has been made since Bangs (1898). The following annotated list attempts to synthesize the available information from divergent sources and present the most complete summary to date of the status of mammals on the coastal islands.

The list covers 44 species of wild mammals (native and introduced) that occur or were known to occur on the barrier islands. The mammals are treated in phylogenetic order following, for the most part, the nomenclature of Hall and Kelson (1959) unless a more recent revision is available. The islands covered are from north to south, Oyster Bed, Cockspur, Tybee, Little Tybee, Wassaw, Ossabaw, St. Catherines, Blackbeard, Sapelo, Wolf, Little St. Simons, St. Simons, Sea, Jekyll, Little Cumberland, and Cumberland. Islands where, on best available evidence, the species is presumed to be extirpated are preceded by an asterisk (*).

Sources of information include museum specimens and records, collections of individuals, field work, a literature review, and personal inquiry. In the text, distribution records are subdivided into three categories in decreasing order of reliability—those based on specimens, literature citations, and sight observations.

Specimens and their accompanying data were examined by the senior author (or indications of specimens' existence were conveyed to us) in the following museums and personal collections:

AMNH	American Museum of Natural History, New York, N.Y.
AUMP	Auburn University Museum of Paleontology, Auburn, Ala.
Carn	Carnegie Museum, Pittsburgh, Penna.
CBW	Private collection of Mrs. C. B. West, Bloomfield Hills, Mich.
CM	Charleston Museum, Charleston, S.C.
CU	Cornell University, Ithaca, N.Y.

FMNH	Field Museum of Natural History, Chicago, Ill.
GSU	Georgia State University, Atlanta, Ga.
HNN	Private collection of Hans N. Neuhauser, Athens, Ga.
JPT	Private collection of James P. Thomas, Seattle, Wash.
MCZ	Museum of Comparative Zoology, Cambridge, Mass.
UF	University of Florida State Museum, Gainesville, Fla.
UG-FR	University of Georgia Forest Resources collection, Athens, Ga.
UG-Z	University of Georgia Museum of Zoology, Athens, Ga.
USNM	United States National Museum, Washington, D.C.
WWB	Private collection of W. Wilson Baker, Tallahassee, Fla.

Supplemental mammal surveys were made in 1970-71 on most barrier islands, with concentrated collecting efforts on Tybee, Wassaw, Sapelo, Jekyll, and Cumberland islands. Most of the specimens collected by the authors and others assisting in these surveys will be housed at either the University of Georgia Museum of Zoology or the Tall Timbers Research Station, Tallahassee, Fla. Collecting was accomplished primarily by trapping, shooting, and an examination of owl pellets. Shooting and 4243 trap nights yielded 135 specimens of 12 species; owl pellets contained a minimum of 329 specimens of 9 species.

Literature records of distribution are given when published by professional biologists; records by others are accepted only for the following easily identifiable species: opossum, raccoon, bear, mink, otter, wild boar, whitetailed deer, and moose. While some effort was made to survey the non-technical literature, there are undoubtedly records contained in it that have been overlooked.

Sight records are accepted with the same reservations as for literature records. They represent field observations by us or by people who have communicated their observations to us. Sight observations are documented only when they represent the only record for the species from any Georgia island.

The information and assistance contributed by the following people during the compilation of this survey are gratefully acknowledged: Mrs. B. Aziz, A. Barbee, R. Bauer, P. C. Berolzheimer, B. Blihovde, H. W. Coolidge, O. Dewberry, J. K. Doutt, F. B. Golley, D. H. G. Gould, A. Graves, F. A. Hayes, H. O. Hillestad, M. Hopkins, Jr., J. H. Jenkins, A. S. Johnson, Mrs. B. LaSalle, C. Marshall, Mrs. R. Newman, E. P. Odum, J. I. Richardson, J. Richardson, C. Schroder, D. J. Shure, W. Sikora, Dr. and Mrs. F. Smith, M. H. Smith, Mrs. C. B. West, C. H. Wharton, and R. Whittington. Especially, we would like to thank C. W. Dopson, Jr., who participated in much of the collecting effort and provided us with much useful data. Special thanks are due to those curators and institutions who allowed the senior author to examine specimens in their care: C. W. Dopson, Jr. (UG-Z); J. H. Jenkins (UG-FR); C. O. Handley, Jr., and C. Jones (USNM); C. Mack (MCZ); J. C. Moore (FMNH); A. E. Sanders (CM); R. G. Van Gelder (AMNH).

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Didelphis marsupialis Linnaeus–opossum
Distribution:
Specimens–Sapelo (USNM), St. Simons (USNM), Jekyll (WWB)
Literature–Sapelo (Teal and Teal 1964; Wilson and Baker in press), *Little Cumberland (Lee et al. 1963), *Cumberland (White 1849; Ober 1880; Lee et al. 1963)
Sight observations–Cockspur, Tybee, Sapelo, Little St. Simons, St. Simons, Sea, Jekyll

Remarks: The opossum is abundant on Sapelo and rare on Jekyll and Little St. Simons. It was abundant on Cumberland (White 1849; Ober 1880) but has since been eliminated there and on Little Cumberland (Lee et al. 1963).

Blarina brevicauda (Say)–short-tailed shrew
Distribution:
Specimens–Ossabaw (MCZ), Sapelo (HNN), Cumberland (WWB)
Literature–Ossabaw (Bangs 1898)

Remarks: The Sapelo and Cumberland specimens were collected from owl pellets.

Cryptotis parva (Say)–least shrew
Distribution:
Specimens–Blackbeard (HNN), Sapelo (GSU, HNN), Cumberland (WWB)

Remarks: The Cumberland specimens were taken from owl pellets, probably barn owl. Bangs (1898) records a single specimen from Skidaway Island. Reexamination of the specimen (MCZ) confirms the original identification.

Scalopus aquaticus (Linnaeus)–eastern mole
Distribution:
Specimens–Ossabaw (MCZ), St. Catherines (MCZ), Blackbeard (UG-Z, HNN), Sapelo (UG-Z, HNN, WWB), St. Simons (USNM), Jekyll (WWB), Cumberland (MCZ, WWB)
Literature–Ossabaw (Bangs 1898; Jackson 1915), St. Catherines (Bangs 1898; Jackson 1915), Sapelo (Golley 1962; Teal and Teal 1964), St. Simons (Jackson 1915), Cumberland (Bangs 1898; Jackson 1915; Harper 1927)
Sight observations–Ossabaw, St. Catherines, Sapelo, St. Simons, Little Cumberland

Myotis austroriparius (Rhoads)–southeastern myotis
Distribution:
Specimens–Sapelo (UG-Z)
Literature–Sapelo (La Val 1967)

Remarks: One specimen (HNN) was collected from Little Sapelo Island (between Sapelo and the mainland). Davis and Rippy (1968) record this species from Butler Island (between Little St. Simons Island and the mainland). Specimens have been collected in April, June, November, and December.

Pipistrellus subflavus (F. Cuvier)–eastern pipistrelle
Distribution:
Specimens–Cumberland (WWB)
Sight observations–Little Cumberland

Eptesicus fuscus (Palisot de Beauvois)–big brown bat
Distribution:
Specimens–Sapelo (UG-Z), Cumberland (WWB)

Remarks: Specimens have been collected in March, May, and August.

Lasiurus borealis (Müller)–red bat
Distribution:
Specimen–Ossabaw (HNN)
Sight observation–Sapelo (3 January 1971, C. W. Dopson, Jr., and J. I. Richardsor pers. comm.)

Lasiurus seminolus (Rhoads)–seminole bat
Distribution:
Specimens–Sapelo (UG-Z), Cumberland (MCZ, WWB)
Remarks: Specimens have been collected in March and April.

Lasiurus intermedius H. Allen–yellow bat
Distribution:
Specimen–Cumberland (WWB)
Remarks: The Cumberland specimen is one of the first records of this species from Georgia's Coastal Plain.

Sylvilagus floridanus (J.A. Allen)–cottontail rabbit
Distribution:
Sight observation–St. Simons (C. Schroder, pers. comm.)

Sylvilagus palustris (Bachman)–marsh rabbit
Distribution:
Specimens–Oyster Bed (UG-Z), Cockspur (UG-Z), Ossabaw (MCZ), St. Catherines (MCZ), Blackbeard (UG-Z, HNN), Sapelo (UG-Z, HNN), Wolf (UG-Z), St. Simons (MCZ, USNM), Sea (UG-Z), Jekyll (WWB), Little Cumberland (HNN), Cumberland (MCZ, CM, WWB)
Literature–Oyster Bed (Tomkins 1935; Narrative Report Tybee Nat. Wildlife Refuge), Cockspur (Tomkins 1946, 1955, 1960), Ossabaw (Bangs 1898; Nelson 1909; Lowe 1958), St. Catherines (Bangs 1898; Nelson 1909; Baldwin 1966), Blackbeard (U.S. Fish and Wildlife Service 1962), Sapelo (Lowe 1958; Teal and Teal 1964; Caldwell 1966), St. Simons (Nelson 1909; Lowe 1958), Cumberland (Bangs 1898; Nelson 1909; Harper 1927)
Sight observations–Cockspur, Tybee, Wassaw, Ossabaw, St. Catherines, Sapelo, Little St. Simons, St. Simons, Jekyll, Little Cumberland
Remarks: Tomkins (1955) reported large populations in the brackish marshes of the Savannah and Altamaha rivers, and smaller populations about the mouths of the Ogeechee, Satilla, and St. Marys rivers. He stated that it is doubtful if any are found in strictly salt marsh. Marsh rabbits were introduced on Oyster Bed in 1925 (Tomkins 1935) and are now very abundant (Narrative Report, Tybee Nat. Wildlife Refuge).

Sciurus carolinensis Gmelin–gray squirrel
Distribution:
Specimens–Wassaw (WWB), St. Catherines (MCZ), Sapelo (UG-Z, HNN, USNM), Jekyll (WWB), Cumberland (MCZ, CM, WWB)
Literature–Tybee (Tomkins 1965), Ossabaw (Jordan and Hayes 1959), St. Catherines (Bangs 1898; Baldwin 1966), Sapelo (Tomkins 1965), Cumberland (Bangs 1898; Harper 1927)
Sight observations–Cockspur, Tybee, Ossabaw, St. Catherines, Sapelo, Little St. Simons, St. Simons, Jekyll
Remarks: Tomkins (1965) said that "the gray squirrel is not native on Tybee (recently introduced), Wassaw, Ossabaw, Blackbeard, Sapelo (introduced), or Little Cumberland."

Gray squirrels have recently been introduced on Wassaw and Ossabaw. A red color phase is found on Wassaw. The Sapelo population is presumably derived from a release of 13 pairs from the mainland in the 1930s (F. Smith, pers. comm.).

Sciurus niger Linnaeus–fox squirrel
Distribution:
Specimens–Ossabaw (UG-Z, UG-FR), Cumberland (Carn)
Literature–Ossabaw (Jordan and Hayes 1959)
Sight observations–Ossabaw, St. Simons
Remarks: Marshall (in litt. 13 Oct. 1970) stated that he was informed that the fox squirrels were caught in Michigan and introduced on Ossabaw for hunting purposes. He also stated that the ratio of fox squirrels to gray squirrels, *Sciurus carolinensis*, was 20:1.

Glaucomys volans (Linnaeus)–southern flying squirrel
Distribution:
Sight observation–St. Simons (C. Schroder, pers. comm.)

Geomys cumberlandius Bangs–Cumberland Island pocket gopher
Distribution:
Specimens–Cumberland (MCZ, AMNH, USNM, CM, UG-Z)
Literature–Cumberland (Bangs 1898; Harper 1927; others)
Sight observations–Cumberland

Remarks: This species is known only from Cumberland Island. It differs from its mainland counterpart, *Geomys pinetis,* in the former's larger size, longer tail, brighter coloration, smaller auditory bullae, narrower ascending arms of the maxilla, and differently shaped zygoma (Bangs 1898).

In Bangs' description of the type specimen, he gave the catalog number as 5015, but his drawing and measurements refer to specimen number (MCZ) B5016. This latter specimen should be regarded as the holotype.

Oryzomys palustris (Harlan)–marsh rice rat
Distribution:
Specimens–Cockspur (USNM), Tybee (HNN), Wassaw (WWB), Ossabaw (MCZ), Blackbeard (HNN), Sapelo (UG-Z, GSU, HNN, WWB), Jekyll (WWB, GSU), Cumberland (MCZ, AMNH, WWB).
Literature–Cockspur (Tomkins 1946), Ossabaw (Bangs 1898; Goldman 1918). Sapelo (Kale 1961; Golley 1962; Sharp 1962; Teal and Teal 1964; Kale 1965; Sharp 1967), Cumberland (Bangs 1898; Goldman 1918)
Sight observations–Blackbeard, St. Simons, Little Cumberland
Remarks: Dopson and Richardson (1968) observed a rice rat on Little Egg Island at the mouth of the Altamaha River.

Reithrodontomys humulis (Audubon and Bachman)–eastern harvest mouse
Distribution:
Specimen–Cumberland (WWB)
Remarks: The single specimen was taken from an owl pellet. It is possible that the owl captured the mouse on the adjacent mainland where the species is known to occur (Golley 1962).

Peromyscus polionotus (Wagner)–oldfield mouse
Distribution:
Literature–Cumberland (Wright 1926)

Peromyscus gossypinus (LeConte)–cotton mouse

Distribution:

Specimens–Ossabaw (MCZ, HNN), Blackbeard (USNM, HNN), Sapelo (HNN), Jekyll (WWB, GSU), Little Cumberland (UG-Z, HNN), Cumberland (MCZ, AMNH, CM, GSU, WWB)

Literature–Ossabaw (Bangs 1898 as *Peromyscus* sp.; determined to species by HNN), Blackbeard (U.S. Fish and Wildlife Service 1962), Little Cumberland (Frankenberg et al. 1971), Cumberland (Bangs 1898; Osgood 1909; Harper 1927; Golley 1962; others)

Remarks: Bangs (1898) described a new species of mouse, *Peromyscus insulanus*, from the north end of Cumberland Island. Osgood (1909), revising the genus, made *P. insulanus* a junior synonym of *P. gossypinus anastasae* Bangs. This subspecies is known from Little Cumberland, Cumberland, and Anastasia (Fla.) islands. The subspecific designation for the mice found on the other islands cannot be determined from the small sample size.

Pournelle and Barrington (1953) trapped extensively for *P. g. anastasae* on Anastasia Island, Fla., but found none. They stated that no cotton mice had been taken on the island since Surber's collection, reported in Elliot (1901). Thus, the present known distribution of the subspecies is restricted to Cumberland and Little Cumberland islands. [*P. gossypinus has* recently been trapped on Anastasia Island (M. H. Smith pers. comm.) but the specimens have not been identified to subspecies yet.]

Four *Peromyscus,* possibly this species, were introduced on Sapelo from the Meridian Dock, McIntosh County, in 1968.

Sigmodon hispidus Say and Ord–hispid cotton rat

Distribution:

Specimens–Cockspur (CM, UG-FR), Tybee (HNN), Ossabaw (MCZ), Blackbeard (UG-Z, HNN), Sapelo (UG-Z, GSU, HNN, WBB), St. Simons (CU), Jekyll (WBB), Cumberland (MCZ, AMNH, CM, WWB)

Literature–Cockspur (Tomkins 1946), Ossabaw (Bangs 1898), Sapelo (Teal and Teal 1964), Cumberland (Bangs 1898; Harper 1927)

Sight observation–Little Cumberland

Neotoma floridana (Ord)–eastern wood rat

Distribution:

Literature–St. Simons (Goldman 1910)

Remarks: This species was listed among the mammals of Wassaw by Francisco et al. (1970), but the record is unsubstantiated.

Rattus rattus (Linnaeus)–black rat

Distribution:

Specimens–Oyster Bed (CM), Cockspur (UG-Z), Tybee (USNM, HNN), Wassaw (HNN), St. Catherines (MCZ), Sapelo (UG-Z, HNN), Jekyll (WWB), Cumberland (MCZ, CM)

Literature–Oyster Bed (Tomkins 1946, 1959), Ossabaw (Bangs 1898), St. Catherines (Bangs 1898)

Rattus norvegicus (Berkenhout)–Norway rat

Distribution:

Specimens–Ossabaw (MCZ), St. Catherines (MCZ)

Literature–Oyster Bed (Narrative Report Tybee Nat. Wildlife Refuge), Ossabaw (Bangs 1898), St. Catherines (Bangs 1898), Blackbeard (U.S. Fish and Wildlife Service 1962)

Mus musculus Linnaeus–house mouse
Distribution:
Specimens–Oyster Bed (CM), Tybee (USNM, HNN)
Literature–Oyster Bed (Tomkins 1946, 1959; Narrative Report Tybee Nat. Wildlife Refuge)

Myocastor coypus (Molina)–nutria
Distribution:
Literature–*Blackbeard (Jenkins 1953; U.S. Fish and Wildlife Service 1962)
Sight observation–*Blackbeard

Remarks: Jenkins (1953) stated that the nutria were introduced on Blackbeard by the U.S. Fish and Wildlife Service in 1949, and that at least some were present in the winter of 1951. Blihovde (in corresp. 10 August 1970) reports the escape of 27 nutria of unknown sex on Blackbeard in December 1951. Very little was seen of the nutria in the next few years and they gradually disappeared. The Narrative Reports of the Blackbeard Island National Wildlife Refuge indicate that 100 nutria were present in 1957 and 1958. An eradication program was started, and none were seen in 1959 or 1960. Presumably, the species has been extirpated from Blackbeard.

Wilson (1968), quoting Hubert Handy, says that a few nutria inhabit the coastal marsh in the Brunswick area.

Ziphius cavirostris G. Cuvier–goose-beaked whale
Distribution:
Specimens–Wassaw (FMNH), Little Cumberland (UG-Z), Cumberland (UF)
Literature–Wassaw (Caldwell et al. 1971), St. Simons (True 1910), Little Cumberland (Caldwell et al. 1971)

Kogia breviceps (Blainville)–pygmy sperm whale
Distribution:
Specimens–Ossabaw (UG-Z), Sapelo (JPT, photos of specimen in UG-Z; USNM, not seen), Little Cumberland (UG-Z), Cumberland (UG-Z)
Literature–Blackbeard (Caldwell et al. 1971), Sapelo (Smalley 1959; Caldwell and Golley 1965; Caldwell et al. 1971), Sea (Caldwell and Golley 1965), Jekyll (Caldwell et al. 1971), Little Cumberland (Zam. et al. 1971; Caldwell et al. 1971)

Kogia simus (Owen)–dwarf sperm whale
Distribution:
Specimen–Ossabaw (CBW, photos of specimen in UG-Z), Cumberland (UG-Z)
Literature–Ossabaw (Caldwell et al. 1971)

Tursiops truncatus (Montague)–Atlantic bottle-nosed dolphin
Distribution:
Specimens–Ossabaw (CBW, UG-Z), Blackbeard (UG-Z, USNM), Sapelo (UG-Z), Wolf (USNM), Little Cumberland (HNN), Cumberland (HNN)
Literature–Wassaw (Caldwell et al. 1971), Blackbeard (Golley 1962; Caldwell and Golley 1965; Caldwell et al 1971), Sapelo (Golley 1962; Caldwell and Golley 1965; Kale 1965; Caldwell et al. 1971), Wolf (Golley 1962; Caldwell and Golley 1965), Jekyll (Golley 1962; Caldwell and Golley 1965)

Pseudorca crassidens (Owen)–false killer whale
Distribution:
Literature–Tybee (Golley 1962; Caldwell and Golley 1965)

Steno bredanensis (Lesson)–rough-toothed porpoise
Distribution:
Specimen–Little Cumberland (UG-Z)

Globicephala macrorhyncha Gray–pilot whale
Distribution:
Specimens–Wassaw (UG-Z), Ossabaw (UG-Z), Little St. Simons (AUMP, HNN), Jekyll (UG-Z), Little Cumberland (UG-Z, HNN)
Literature–Wassaw (Golley 1962; Caldwell and Golley 1965), Ossabaw (Golley 1962; Caldwell and Golley 1965), Little St. Simons (Golley 1962; Caldwell and Golley 1965; Caldwell et al. 1971), St. Simons (Golley 1962; Caldwell and Golley 1965), Jekyll (Golley 1962; Caldwell and Golley 1965), Little Cumberland (Caldwell et al. 1971)
Sight observations–Little St. Simons, St. Simons
Remarks: The pilot whale occasionally strands in large numbers on the Georgia coast. Fifty-three stranded on Little St. Simons in 1968, and between 15 and 25 stranded on St. Simons in 1962.

Megaptera novaengliae (Borowski)–humpback whale
Distribution:
Specimen–Sapelo (UG-Z)

Urocyon cinereoargenteus (Schreber)–gray fox
Distribution:
Literature–*Cumberland (Bent 1940)
Remarks: Bent's observation of a gray fox is the only record, substantiated or otherwise, for this species from any of Georgia's islands. Since Bent's observation was made some years before 1940, the species is presumed extirpated.

Ursus americanus Pallas–black bear
Distribution:
Literature–*St. Simons (Moore 1840; Leigh (1883). *Cumberland (Ober 1880; Bangs 1898; Harper 1927; Sprunt 1936)
Remarks: The St. Simons records are not definite; Moore heard that black bear were on St. Simons but did not see any, and Leigh had two cubs on the island, but did not say where they came from. Sprunt said that the bear was still present on Cumberland in small numbers, and that unmistakable sign was noted. Bears have been reported from areas between Ossabaw and the mainland, and between St. Catherines and Colonels Island within the last 30 years.

Procyon lotor (Linnaeus)–raccoon
Distribution:
Specimens–Wassaw (WWB), Ossabaw (MCZ), St. Catherines (MCZ, HNN), Blackbeard (USNM, UG-Z), Sapelo (UG-Z), Wolf (UG-Z), St. Simons (USNM), Jekyll (WWB), Little Cumberland (HNN), Cumberland (MCZ, WWB)
Literature–Oyster Bed (Narrative Report Tybee Nat. Wildlife Refuge), Wassaw (Francisco et al. 1970), Ossabaw (Goldman 1950; Hall and Kelson 1959; Jordan and Hayes 1959), St. Catherines (Baldwin 1966), Blackbeard (U.S. Fish and Wildlife Service 1962; Narrative Report Blackbeard Island Nat. Wildlife Refuge), Sapelo (Teal and Teal 1964; Kale 1965), Wolf (Narrative Report Wolf Island Nat. Wildlife Refuge), Little St. Simons (Anon. 1923), St. Simons (Moore 1840; Nelson and Goldman 1930; Goldman 1950; Bartram *in* Harper 1958, others),

Cumberland (White 1849; Ober 1880; Sprunt 1936; Bent 1940)

Sight observations –Cockspur, Tybee, Little Tybee, Wassaw, Ossabaw, St. Catherines, Wolf, Little St. Simons, St. Simons, Sea, Jekyll, Little Cumberland

Remarks: *Procyon lotor litoreus* was described from St. Simons by Nelson and Goldman (1930). This subspecies is found along the coastal region of Georgia and South Carolina. The type specimen is #2450 (USNM).

Mustela vison Schreber–mink

Distribution:

Specimens–Ossabaw (MCZ), Sapelo (UG-Z, HNN), Jekyll (UG-Z), Cumberland (UG-Z)

Literature–Oyster Bed (Narrative Report Tybee Nat. Wildlife Refuge), Ossabaw (Bangs 1898; Jordan and Hayes 1959), St. Catherines (Baldwin 1966), Blackbeard (U.S. Fish and Wildlife Service 1962; Narrative Report Blackbeard Island Nat. Wildlife Refuge), Sapelo (Teal and Teal 1964; Kale 1965), Wolf (Narrative Reports Wolf Island Nat. Wildlife Refuge)

Sight observations–Ossabaw, Sapelo, Wolf, Little St. Simons, St. Simons, Little Cumberland

Lutra canadensis (Schreber)–river otter

Distribution:

Specimen–Blackbeard (UG-Z), Little Cumberland (UG-Z)

Literature–Oyster Bed (Narrative Report Tybee Nat. Wildlife (Refuge), Tybee (Jenkins 1953), Little Tybee (Jenkins 1953), Wassaw (Jenkins 1953), Ossabaw (Jenkins 1953; Jordan and Hayes 1959), St. Catherines (Jenkins 1953; Baldwin 1966), Blackbeard (U.S. Fish and Wildlife Service 1962; Narrative Report Blackbeard Island Nat. Wildlife Refuge), Sapelo (Jenkins 1953; Teal and Teal 1964; Kale 1965). Wolf (Jenkins 1953), Little St. Simons (Jenkins 1953), St. Simons (Jenkins 1953), Sea (Jenkins 1953), Jekyll (Jenkins 1953), Little Cumberland (Jenkins 1953), Cumberland (Jenkins 1953)

Sight Observations–Ossabaw, St. Catherines, Sapelo, St. Simons, Little Cumberland, Cumberland

Lynx rufus (Schreber)–bobcat

Distribution:

Specimen–*Ossabaw (CBW)

Literature–*Sapelo (Teal and Teal 1964), *Cumberland (Harper 1927)

Sight observation–*Cockspur

Remarks: John Richardson, Park Ranger-Naturalist at Fort Pulaski National Monument, Cockspur Island, reported a bobcat "passing through" in the 1950's. Moore (1840) described "wildcats or tigers" on St. Simons. Presumably, this was a bobcat, although Backman (*in* White 1849) says that panthers, *Felis concolor coryi*, are found in Glynn County (St. Simons is in Glynn County).

Teal and Teal (1964) stated that wildcats inhabited Sapelo in the past, but died off or were killed off during periods of intense cultivation. Harper (1927) wrote that "Issac F. Arnow stated that the species was common on Cumberland Island up to about 1907, when some disease exterminated it there."

The Ossabaw bobcats died off about 15-20 years ago (Mrs. C. B. West, pers. comm.).

Trichechus manatus Linnaeus–manatee

Distribution:

Literature–Cumberland (Tomkins 1956; Caldwell and Golley 1965)

Remarks: There is a manatee specimen from the mouth of the Altamaha (UG-Z). Tomkins (1956) reported manatees from Jekyll Creek and the Little Satilla River. Tomkins (1958) found a manatee skull in Savannah Harbor.

Sus scrofa Linnaeus–European wild boar

Distribution:

Literature–*Wassaw (Francisco et al. 1970), *Jekyll (Diehl 1965)

Sight observations–*Ossabaw, *Little St. Simons, *St. Simons, *Jekyll, *Little Cumberland, *Cumberland

Remarks: The above distribution does not include domestic or feral pig distributions on the islands. Hanson and Karstad (1959) said that European wild boar were introduced into feral herds of swine to increase the sporting value of the resident forms. Probably no true wild boar exist on the coastal islands today.

Diehl (1965) indicated that 300 wild boar were sent to the Jekyll Island Club by King Humbert of Italy.

Francisco et al. (1970) stated that wild boar were abundant on Wassaw, but a cholera plague in 1916 eradicated the entire population.

Dama dama (Linnaeus)–European fallow deer

Distribution:

Literature–Little St. Simons (Jenkins 1953)

Sight observations–Little St. Simons, St. Simons, Jekyll

Remarks: Berolzheimer (In corresp. July 13, 1971) states that fallow deer were introduced on Little St. Simons between 1900 and 1920.

The fallow deer on Jekyll were introduced from Little St. Simons (D. Gould, pers. comm.).

Cervus elaphus Linnaeus–red deer or European elk

Distribution:

Literature–*Little St. Simons (Anon. 1923?)

Sight observation–*Little St. Simons

Remarks: At least four animals were introduced for hunting (Anon 1923?). Jenkins (pers. comm.) states that the European form were present on Little St. Simons and, according to the caretaker, they were eliminated when the screw-worm infestation appeared in 1930-34.

Odocoileus virginianus (Zimmermann)–white-tailed deer

Distribution:

Specimens–Wassaw (WWB, MCZ), Ossabaw (UG-Z), Blackbeard (USNM, UG-Z, UG-FR), Sapelo (HNN), Cumberland (MCZ, USNM)

Literature–Tybee (Jenkins 1953), Wassaw (Folk 1939; Jenkins 1953; Francisco et al. 1970), Ossabaw (Jenkins 1953; Jordan and Hayes 1959), St. Catherines (Jenkins 1953; Baldwin 1966; Francisco et al. 1970), Blackbeard (Goldman and Kellogg 1940; Jenkins 1953; U.S. Fish and Wildlife Service 1962; Golley 1962; Lund et al. 1962; Narrative Reports Blackbeard Island Nat. Wildlife Refuge; others), Sapelo (Jenkins 1953; Miller and Kellogg 1955; Robert et al. 1956; Hall and Kelson 1959; Golley 1962; Teal and Teal 1964), Wolf (Jenkins 1953), Little St. Simons (Anon. 1923?; Jenkins 1953), St. Simons (Dickinson 1751; Moore 1840; Leigh 1883; Jenkins 1953), Sea (Jenkins 1953), Jekyll (Lanier 1916; Jenkins 1953), Little Cumberland (Jenkins 1953), Cumberland (White 1849; Ober 1880; Barbour and Allen 1922; Harper 1927; Sprunt 1936; Bent 1940; Jenkins 1953; Bartram in Harper 1958; Hall and Kelson 1959)

Sight observations–Wassaw, Ossabaw, St. Catherines, Sapelo, St. Simons, Sea, Jekyll, Little Cumberland, Cumberland

Remarks: *Odocoileus virginianus nigribarbis* was described from Blackbeard Island by Goldman and Kellogg (1940). The subspecies is known to occur on only two islands, Blackbeard and Sapelo but, according to Miller and Kellogg (1955), the subspecies may occur on other islands along the coast of Georgia. The type specimen is #265213 (USNM).

Odocoileus virginianus virginianus (Zimmermann) also occurs on the coast, but to what extent is unknown. Barbour and Allen (1922) and Hall and Kelson (1959) include Cumberland in the range of the subspecies.

Deer populations on most of the larger islands have been genetically mixed with introductions from various parts of the United States.

Alces alces (Clinton)–moose

Distribution:

Sight observation–*Little St. Simons (Mrs. B. Aziz, pers. comm.)

Remarks: Moose were introduced for hunting but have been exterminated.

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Appendix VI

LOCATION OF OYSTER BEDS AND EXTENT OF POLLUTED WATERS CLOSED TO OYSTER HARVESTING

The distribution and acreage of oyster beds along the coast of Georgia were mapped in 1966-67 by Thomas L. Linton for the Georgia Game and Fish Commission. Locations of oyster beds, as revealed by Dr. Linton's survey data made available by the Game and Fish Commission, are shown in black on Figs. 35A-H which are located at the back of the book.

The State Department of Public Health has closed to oyster harvest those areas of the estuary indicated by shading on the map. These areas were closed because of high coliform bacteria counts which serve as indicators of contamination by domestic sewage. The data, corrected to August 1970, were provided by the State Department of Public Health.

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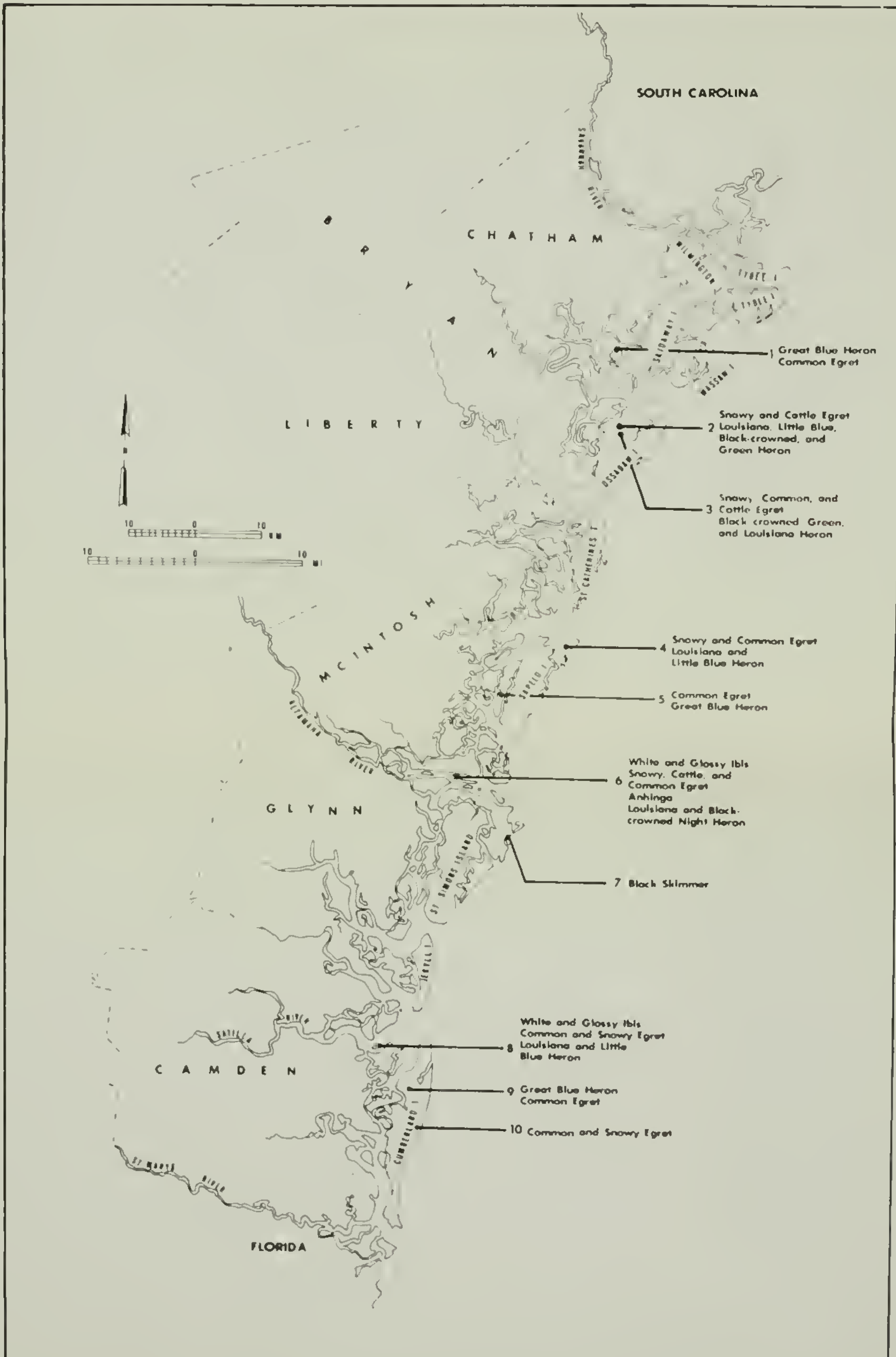
Fig. 1. Map of the coastal region of Georgia. The area covered by this report is the region of islands, marshes, and estuaries lying eastward of the mean high tide level indicated on the map by the heavy, broken line.


SOUTH CAROLINA
Savannah NWR
SAVANNAH RIVER
CHATHAM
Tybee NWR
Ft Pulaski Nat Monument
Savannah Beach
TYBEE I
Wassaw Island NWR
WASSAW
BRYAN
LIBERTY
OSSABAW
MCINTOSH
BLACKBEARD I
Blackbeard Island NWR
R J Reynolds Wildlife Refuge
Sapelo Lighthouse NWR
Wolf Island NWR
ALTAMAHA RIVER
Darien
GLYNN
LITTLE ST SIMONS I
ST SIMONS I
Ft Frederica National Monument
SEA I
Brunswick
St Simons
JEKYLL
Jekyll Island State Park
SATILLA RIVER
LITTLE CUMBERLAND I
CAMDEN
PROPOSED
Cumberland Island National Seashore
CUMBERLAND I
ST MARYS RIVER
St Marys
FLORIDA
ATLANTIC OCEAN
10 0 10 KM
10 0 10 MI

Fig. 31. Map showing decline of artesian water levels in the coastal area of Georgia, 1880–1961. Contour interval 10 ft. Compiled from maps and data of Warren 1944; Wait 1962; Counts and Donsky 1963; McCollum and Counts 1964; and Carver 1968.


FLORIDA
CAMDEN
GLYNN
McINTOSH
LIBERTY
BRYAN
CHATHAM
SOUTH CAROLINA
ATLANTIC OCEAN

Fig. 34. (Appendix IV) Locations and compositions of wading bird and shorebird rookeries on the Georgia coast. Numerals indicate rookery numbers in text of Appendix 4.



SOUTH CAROLINA
CHATHAM
BRYAN
LIBERTY
MCINTOSH
GLYNN
CAMDEN
FLORIDA
1 Great Blue Heron
Common Egret
2 Snowy and Cattle Egret
Louisiana, Little Blue,
Black-crowned, and
Green Heron
3 Snowy, Common, and
Cattle Egret
Black crowned Green,
and Louisiana Heron
4 Snowy and Common Egret
Louisiana and
Little Blue Heron
5 Common Egret
Great Blue Heron
6 White and Glossy Ibis
Snowy, Cattle, and
Common Egret
Anhinga
Louisiana and Black-
crowned Night Heron
7 Black Skimmer
8 White and Glossy Ibis
Common and Snowy Egret
Louisiana and Little
Blue Heron
9 Great Blue Heron
Common Egret
10 Common and Snowy Egret
ST SIMONS ISLAND
ST CATHERINES I
SAPELO I
OSSABAW I

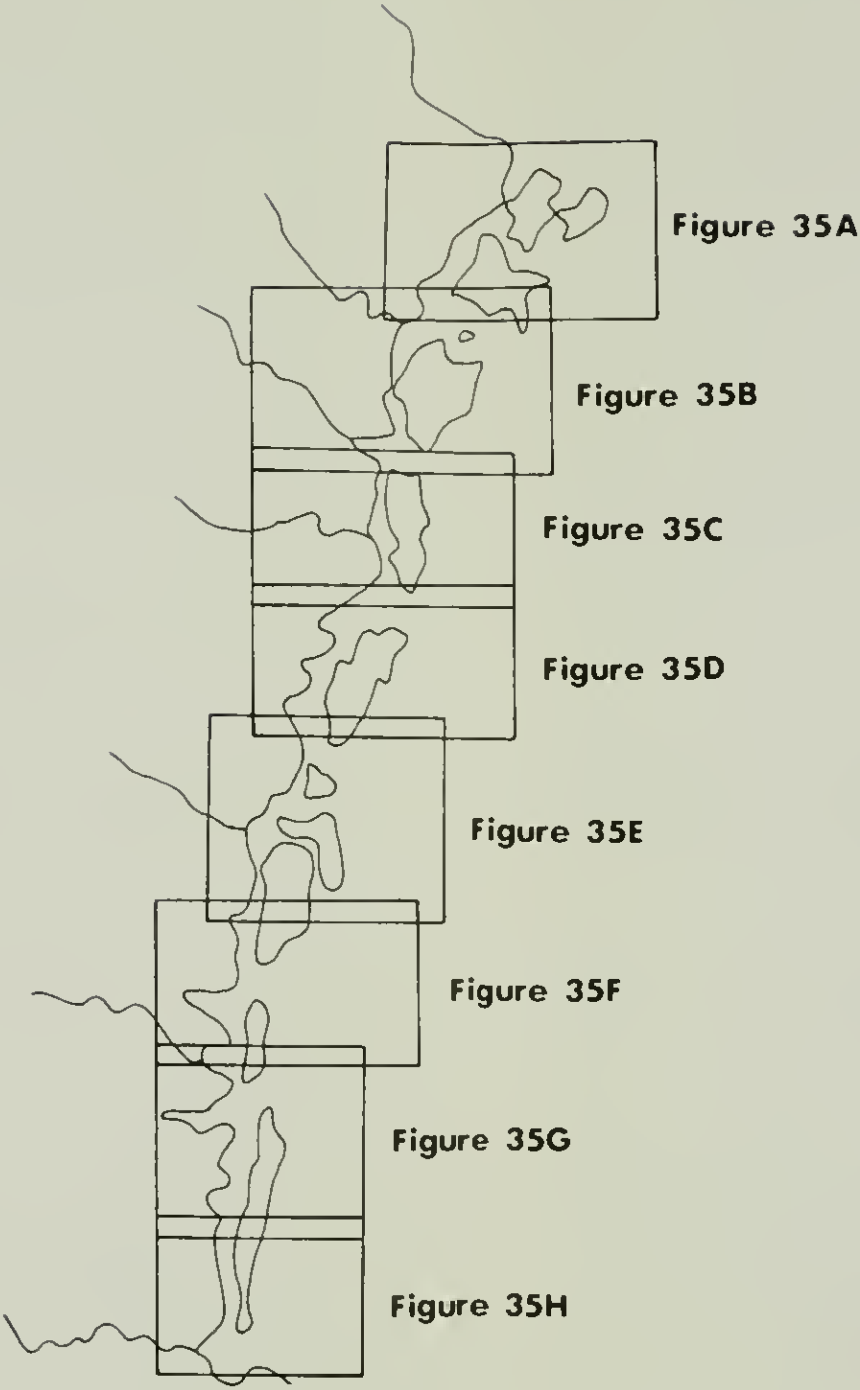
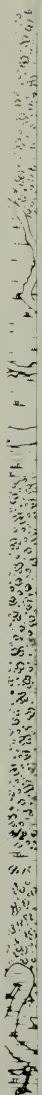


Figure 35A
Figure 35B
Figure 35C
Figure 35D
Figure 35E
Figure 35F
Figure 35G
Figure 35H

Fig. 35A. (Appendix VI).


TYBEE ISLAND
SAVANNAH BEACH
WILMINGTON ISLAND
LITTLE TYBEE ISLAND
WILMINGTON RIVER
SKIDAWAY ISLAND
WASSAW SOUND
ATLANTIC OCEAN
LITTLE OGEECHEE RIVER
LITTLE WASSAW ISLAND
WASSAW ISLAND

Fig. 35B. (Appendix VI)




OSSABAW SOUND
Ogeechee River
OSSABAW ISLAND
ATLANTIC OCEAN
Medway River
COLONELS ISLAND
ST. CATHERINES SOUND

Fig. 35C. (Appendix VI)

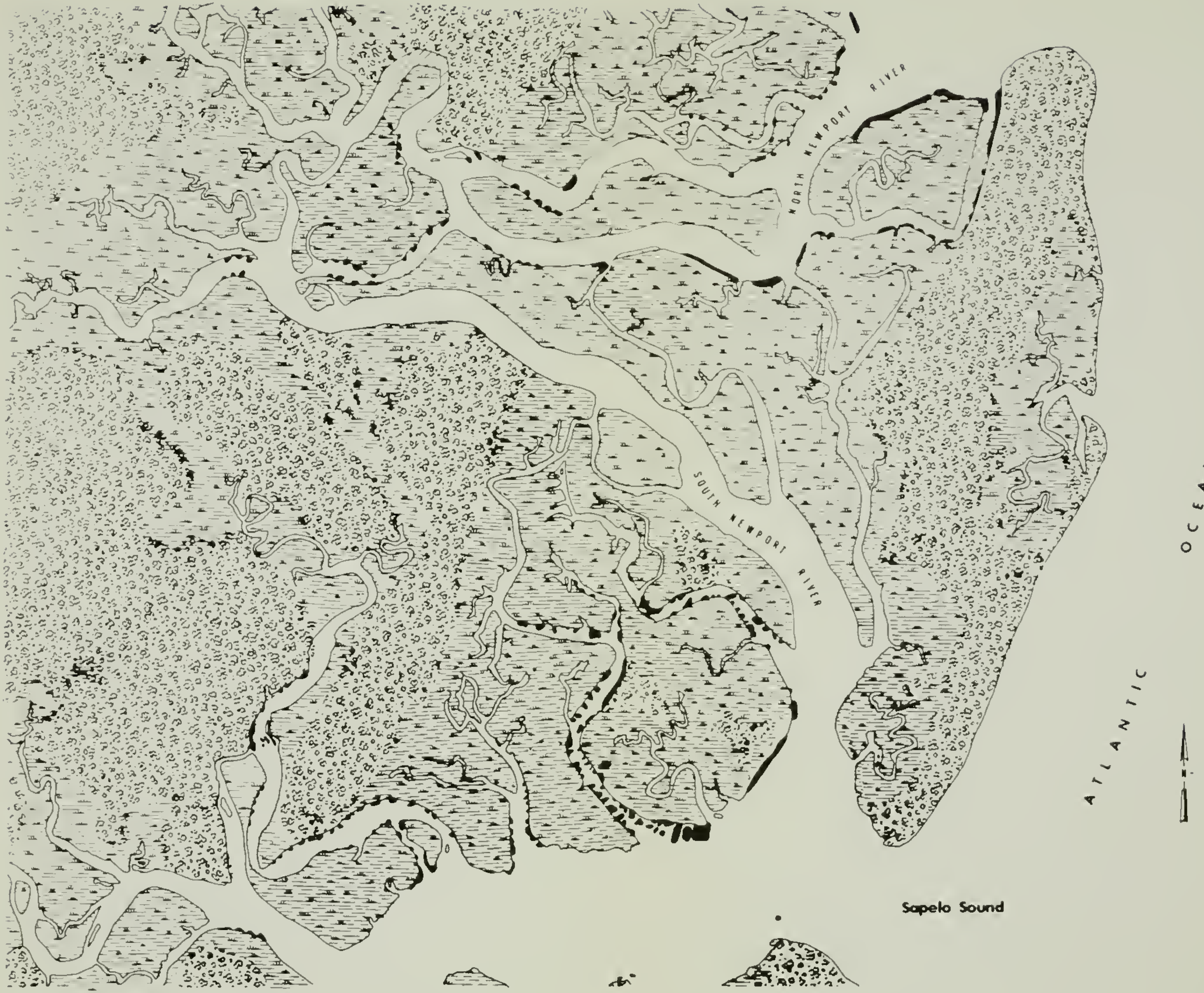
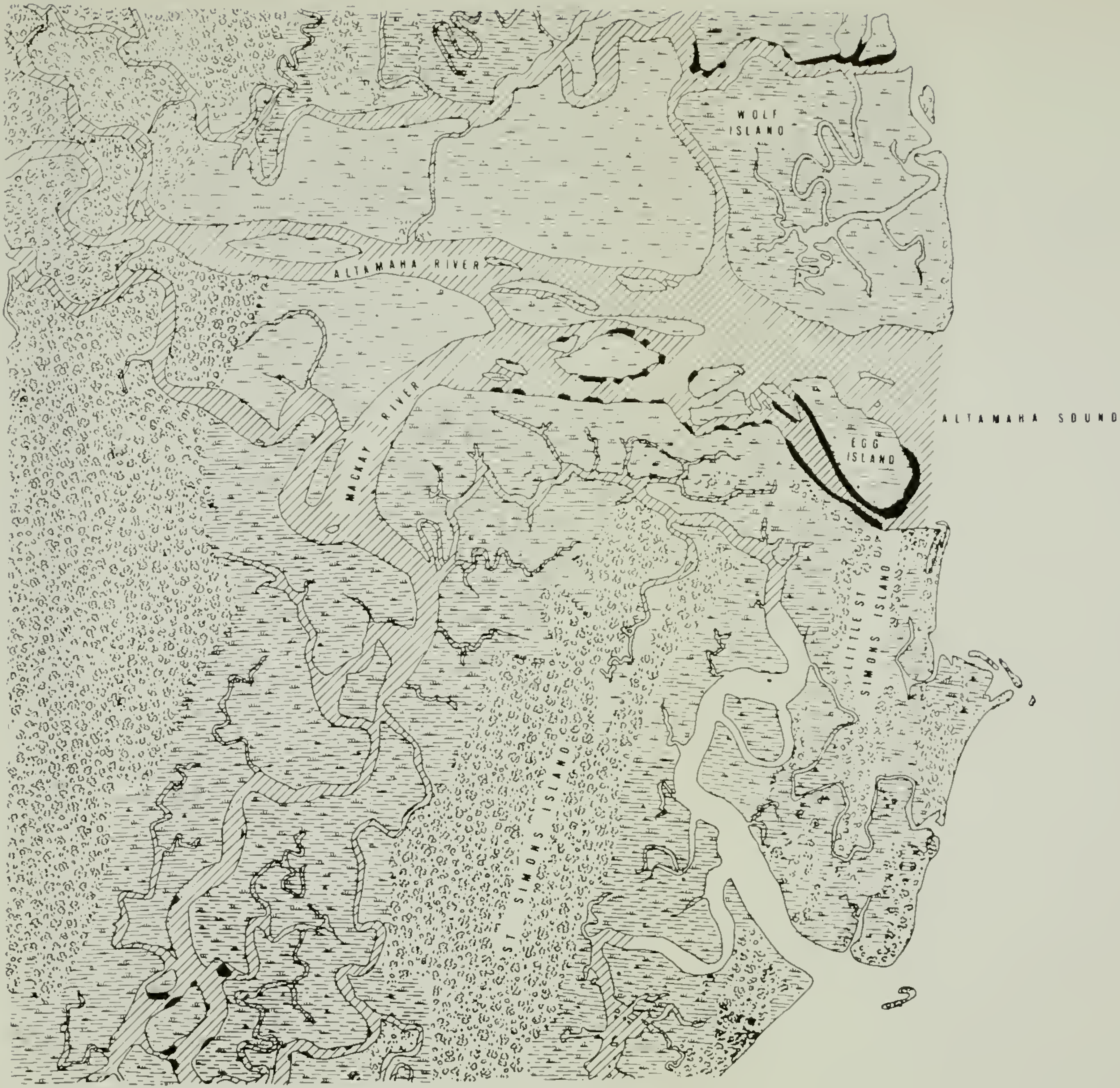

NORTH NEWPORT RIVER
SOUTH NEWPORT RIVER
ATLANTIC OCEAN
Sapelo Sound

Fig. 35D. (Appendix VI)

Mud River
SAPELO ISLAND
BLACKBEARD ISLAND
ATLANTIC OCEAN
DOBOY SOUND
N

Fig. 35E. (Appendix VI)



WOLF ISLAND
ALTAMAHA RIVER
MACKAY RIVER
ALTAMAHA SOUND
EGG ISLAND
LITTLE ST SIMONS ISLAND
ST SIMONS ISLAND
ATLANTIC OCEAN

Fig. 35F. (Appendix VI)


BLYTHE ISLAND
BRUNSWICK
ST SIMONS ISLAND
ST SIMONS
St. Simons Sound
ATLANTIC OCEAN
BRUNSWICK RIVER
COLONELS ISLAND
JEKYLL ISLAND

Fig. 35G. (Appendix VI)


ST. ANDREW SOUND
SATILLA RIVER
CUMBERLAND RIVER
LITTLE CUMBERLAND ISLAND
CUMBERLAND ISLAND
ATLANTIC OCEAN

Fig. 35H. (Appendix VI)

CROOKED RIVER
Cumberland River
CUMBERLAND ISLAND
ATLANTIC OCEAN
ST MARYS
ST MARYS RIVER
GEORGIA
FLORIDA

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