An Ecological Characterization of South Carolina Wetland Impoundments

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AN ECOLOGICAL CHARACTERIZATION
OF SOUTH CAROLINA WETLAND IMPOUNDMENTS

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PREFACE

In recent years, there has been a dichotomy of management interests in reference to impoundments. This is especially true in the case of newly created impoundments, where wetlands are diked off. On the one hand, there are those who advocate the creation of impoundments, since these areas do, in fact, substantially enhance resting and feeding habitat for waterfowl and wading birds. In contrast, there are those who oppose this practice in the name of conservation because wetlands, in their natural state, are highly productive and supply vital habitat and nursery grounds for many commercial and sport fish and shellfish. When impounded, these wetlands do not function in the same way. The State of South Carolina discourages the impounding of previously undisturbed wetlands.

Waterfowl management, estuarine management and recent advances in aquaculture are placing demands on the same system, and little data are available to assist in formulation of policies, guidelines, and management strategies (see Gresham and Hook 1982). This report attempts to summarize existing data on impoundments to provide a reasonable starting point for further research. This information was synthesized from a large regional characterization that was completed in 1980.[1]

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[1]An Ecological Characterization of the Sea Island Coastal Region of South Carolina and Georgia. Prepared by S.C. Marine Resources Division, S.C. Wildlife and Marine Resources Department. Publications available from U.S. Fish and Wildlife Service, Slidell, LA 70458. Volume I. Physical Features, edited by T. D. Mathews et al., 212 pp. Volume II. Socioeconomic Features, edited by M. D. McKenzie et al., 321 pp. Volume III. Biological Features, edited by P. A. Sandifer et al., 620 pp. Directory of Information Sources, edited by J. V. Miglarese et al., 35 pp. Atlas, edited by J. S. Davis et al., 56 pp. Executive Summary, Edited by M. D. McKenzie and L. A. Barclay, 51 pp.

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CHAPTER ONE

INTRODUCTION

A. HISTORICAL REVIEW

One of the more readily apparent features of the South Carolina coastal region today is the extensive system of rice field dikes, canals, and reservoirs still visible adjacent to many coastal rivers. This system of dikes, etc. is a remnant of South Carolina's rice culture.

Rice culture was introduced into North America during the last quarter of the seventeenth century in the vicinity of Charleston, South Carolina (Courtney 1884, Doar 1936, Salley 1967). After the settlement of Georgia removed the menace of the Spaniards and Indians, the rice industry expanded into both southeastern and northeastern sections of the Carolina province. Rice was at first grown as an upland crop without irrigation; however, it is probable that even the very early colonists recognized the advantage of utilizing low, moist land.

Irrigation is said to have begun about 1724 on the freshwater swamps in the low eastern part of the Province. The swamp bottoms were irrigated by water stored in ponds formed by dams. Drainage was accomplished through ditches into adjacent streams. During this period, water was probably employed only for supplying moisture and not for the systematic destruction of weeds and insects as practiced later. Irrigation systems were not as elaborate or as permanent as they were after the Revolution. Consequently, the industry did not exhibit the great degree of geographic stability which characterized the later period.

Planting continued in the freshwater swamps until the close of the Revolution, although some small transfers of cultivation to the tidewater region had begun earlier. Use of the tidal river swamps is said to have started as early as 1758 on Winyah Bay (Gray 1941). Before 1783, there was considerable use of inland swamps in Georgia. It was asserted that during this period ". . . devastating floods . . ." caused heavy damage to the inland swamp rice fields (Gray 1941). The shift to the tidewater region came during the late eighteenth and early nineteenth centuries. Due primarily to ineffective methods of water control, upland rice was never grown in the large quantities later produced in the tidewater region. The shift to this latter region was induced partly by the grassy condition prevailing in the inland swamp lands, but mostly by the development of the advantageous water culture. Also, as the backcountry was increasingly cleared and cultivated, the problems of unwanted silting and flooding increased. Upland rice fields rapidly developed the condition of too much or too little water at a given time, and the "freshet" became the fear of all planters.

Rapid expansion continued into the tidewater region until the outbreak of the Revolution. Confidence of the merchants had increased and they poured slaves and supplies into the Carolina Province. The relaxation of prohibitions against importing Negro slaves into Georgia, and increased physical security from Spanish intrusion due to the British occupation of Florida, resulted in expansion of the industry into Georgia.

After the Revolution, major developments led to a greater expansion of the industry. About 1786, a system was perfected utilizing tidal action to flood and drain fields. This provided a much greater degree of control than the earlier upland system. Also, Carolina rice had an established reputation for quality and commanded a premium price.

Until the mid-nineteenth century, the land was first prepared for planting by using mules or oxen (Doar 1936). After field hands plowed, they were required to dig the ground with hoes. The fields were then smoothed with a harrow. During the ante-bellum period, cultivation procedures had probably become fairly standardized.

By 1850, it was claimed that some improvement had been made and that ". . . the hoeings, the pickings, and the cutting with the sickle remained unchanged; but lands are better drained, and in the turning, the plough had superseded the hoe; (and) the trenching, . . . is done by animal power; . . ." (Doar 1936).

In about 1787, Johnathan Lucas constructed, at Peachtree Plantation on the South Santee River, the region's first successful rice pounding mill (Courtney 1884, Doar 1936, Wallace 1951). At first the mills were powered by water from reserves such as Blakes Reserve. Steam later supplemented water power. The mechanization of the pounding process allowed a substantial increase in the rate of processing, which encouraged the planters to expand cultivation to the limits of suitable fields.

In view of the technology of the era, it appears all but impossible that the amount of earth moved for dikes and impoundments could have been accomplsihed. The expenditure of labor was enormous, which promoted the acquisition of large numbers of slaves. Some areas required years to reclaim. The major rivers in South Carolina along which rice was planted were the Waccamaw, Black, Sampit, Pee Dee, Santee, Cooper, Edisto, Ashepoo, Broad, and Combahee, as well as the Savannah (Fig. 1-1). Of these regions, the Winyah Bay and Santee River areas exhibited the most outstanding production.

B. RICE FIELD CONSTRUCTION

Because tidewater rice production was unique and because it has left a lasting impression on the natural systems, the following description of rice field construction and operation is presented to promote a better understanding of the impacts that this agricultural practice had on the area. Typically, once a location was selected, a temporary ditch and embankment were constructed, and any natural channels running through the embankment were bridged and later filled. "Trunks" were installed in the embankment, and the clearing of the swamp began (Hayward 1937). Individual fields were then made by constructing "cross banks" within the large embanked area, which served to keep water in, or out of, each field. Normally, the fields were ditched to aid in drainage. New fields were developed in a sequence of stages sometimes requiring years for

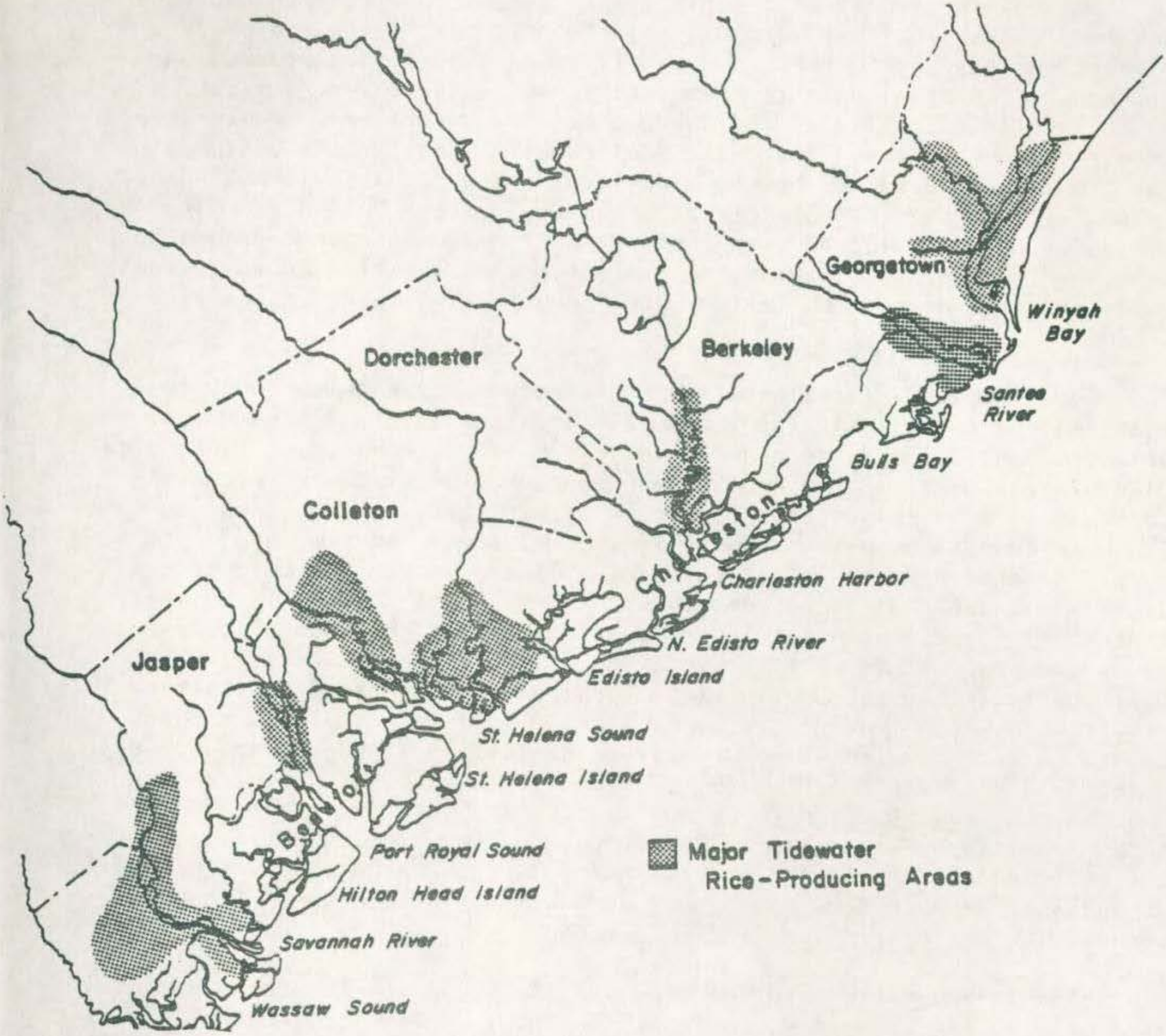

Figure 1-1. Major tidewater rice areas in South Carolina at the close of the nineteenth century (adapted from Hilliard 1975).

completion. After the embankments were completed, flood gates were installed at the ends of trunks, and the field was then ready to be placed into operation. Figure 1-2 illustrates the sequential phases usually required to convert tidal swamp habitat into a functional rice plantation. Figure 1-3 depicts a finalized impoundment arrangement on a large plantation on the Combahee River, South Carolina.

The entire process of clearing, diking, and construction was slow and many years of effort were required to open new fields and place a plantation in proper order. Once a field was placed into production, it required constant attention and maintenance. Moreover, the desired water levels of the fields had to be carefully maintained. Water levels were regulated by the flood gates and trunks. Ideally, the bottom of the trunk was placed at the low tide level. The gates could be locked in position or swung to operate as a one-way valve. During flooding, the outer gate was locked open and the inner gate was opened automatically by tidal pressure through the trunk. When the tide began to fall, water pressure closed the inside gate, thus holding water in the rice field.

The tidewater rice plantation was a complex arrangement and its location and operation raised it to the level of an art. A number of valuable conclusions were drawn by Hilliard (1975) concerning the typical rice plantation: "1) The conditions necessary for tidewater rice culture had to be precise, thus requiring careful attention to location. 2) These conditions were met only in the relatively narrow coastal zone, thus tidewater rice could not expand indefinitely from its core area. 3) The time and labor requirements were substantial, making it unlikely that small farmers with little or no extra-family labor could successfully compete. 4) Knowing the vagaries of coastal environments, with their periodic storms, devastating tides, and occasional freshets from upstream, one can imagine that a substantial amount of maintenance was needed to keep the fields in order. 5) Reclaiming a tidal swamp for a rice field demanded a high level of technical expertise. Leveling embankments, laying off ditches and fields, and setting trunks and gates required considerable engineering knowledge. No other large agricultural regions in the United States during the ante-bellum period demanded such expenditures of labor and such a high degree of technical supervision while bringing land into production."

Georgia and South Carolina produced almost 90% of the total national rice crop during the early nineteenth century. Until 1860, Georgetown, South Carolina was the highest rice producing county in the Nation (Table 1-1). During the period 1850-1860, Doar (1936) listed 39 Santee River plantations in operation, having a total of 16,600 acres (6,700 ha) under cultivation. The average annual yield for these plantations was 30 bushels per acre.

After 1860, production faltered and never recovered. The causes for its decline and ultimate extinction were various. The Civil War caused the destruction of some facilities and, more importantly, the loss of slave labor and adequate capital. These were the first great blows to the planters, for without the full control of a stable labor force and with the general shattered condition of the economy after the Civil War, each storm or other disaster forced curtailment of some production.

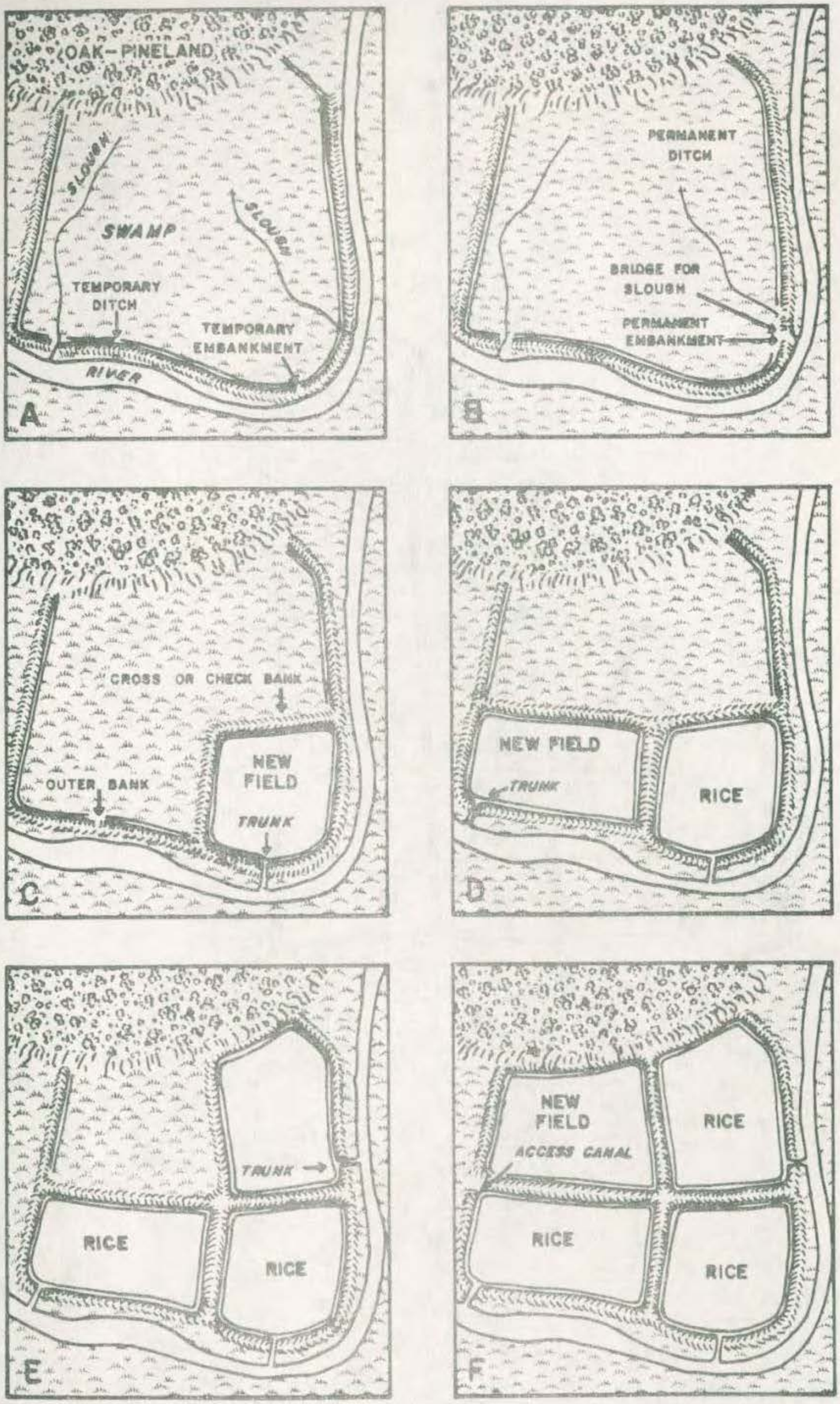

Figure 1-2. Sequential views of a hypothetical rice planation, from initial clearing through several stages, a process sometimes requiring a number of years (adapted from Hilliard 1975).

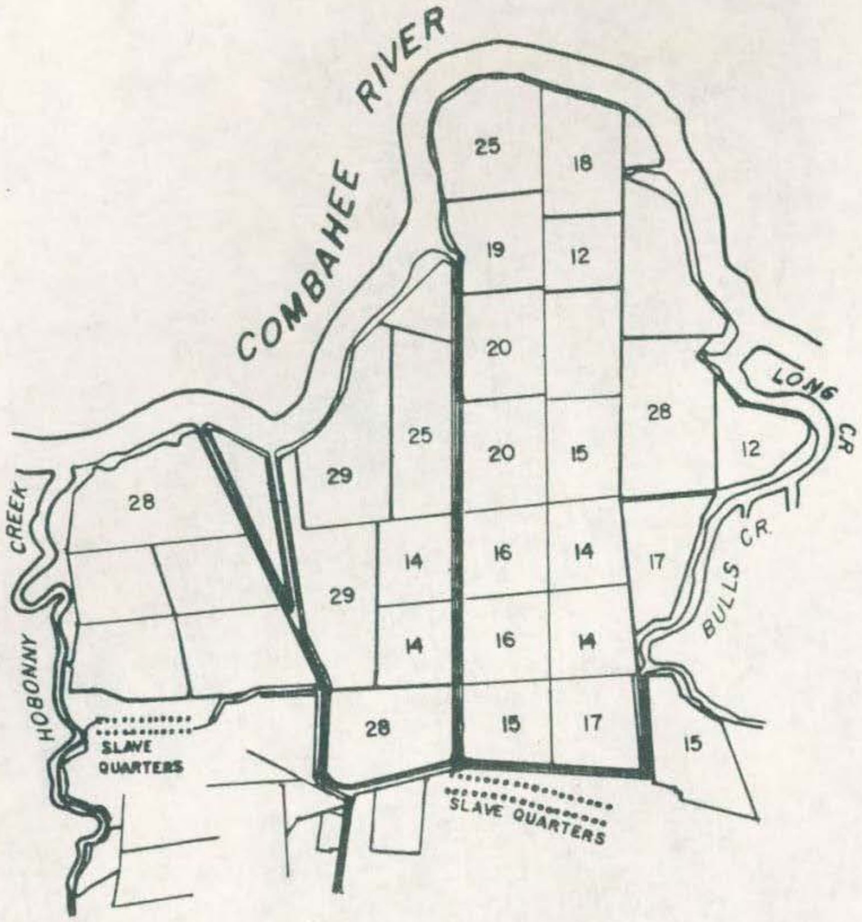

Figure 1-3. A view of a fully developed tidewater rice plantation of the early nineteenth century (Doar 1936).

Later, the final abandonment of commercial rice culture in the South Atlantic States was caused by the introduction of rice into Louisiana and southwestern States on lands where machinery could be used in both cultivation and harvesting. Hand-grown rice was soon priced too high to be competitive and production ceased (Doar 1936).

The rice plantation as a commercial venture lasted only about 200 years; however, at its peak it probably represented the most significant use of the tidewater region for crop agriculture ever attained in the United States (Hilliard 1975). These remnant fields and impoundments of the rice culture have had a tremendous impact on waterfowl management in South Carolina, which will be discussed later.

TABLE 1-1. Rice production for South Carolina during pre-Civil War years (adapted from Hilliard 1975).

County	1839 (Pounds)	1849 (Pounds)	1859[a] (Pounds)
South Carolina			
Beaufort	5,629,000	47,230,000	18,791,000
Charleston	11,939,000	15,701,000	18,890,000
Colleton	5,483,000	45,309,000	22,839,000
Georgetown	36,360,000	46,765,000	55,805,000
Horry	80,000	485,000	238,000

[a]Data after 1859 showed drastic declines in production for all counties.

C. GAME PRESERVES

After the hurricanes of 1893 and early 1900's had destroyed commercial rice culture in Georgia and South Carolina, some fields were unused. During this period, wealthy sportsmen, generally not natives of the area, discovered the value of the abandoned rice fields for duck hunting, both for business promotion and personal use. The attractiveness of these fields for waterfowl gradually diminished as the untended dikes allowed natural succession to convert the fields into needlerush and cordgrasses (Newsom 1968). The development of mechanized construction equipment, especially draglines, soon provided a feasible means of restoration, resulting in the increasing degree of scientific waterfowl management which is now practiced.

Events in the lower Santee River region illustrate typical aspects of the sequential acquisition, consolidation, and development of a waterfowl management area. When E. P. Alexander advertised his North and South island property about 1907, such notables as President Grover Cleveland had hunted there. He persuasively presented them for sale as not being surpassed by lands found elsewhere ". . . with superior attraction for a magnificent and permanent game preserve . . ." (Alexander 1908).

The Santee Gun Club eventually bought 12 rice plantations and controlled about 20,000 acres (8,094 ha) in the Santee Delta (Rogers 1970). In 1975, the Santee Club donated its holdings to the Nature Conservancy for establishment of a refuge now known as the Santee Coastal Reserve. T. W. Yawkey bequeathed his holdings on North and South islands and Cat Island to the State of South Carolina in 1976. They are now administered under the terms of his estate as a game preserve.

D. IMPOUNDMENT DESCRIPTION

In South Carolina, numerous impoundments range in size from a fraction of an acre to several thousand acres. Most of these are former rice fields, although some may consist of newly diked brackish marsh (Johnson et al. 1974, Tiner 1977). Many have been maintained and managed as game preserves since the demise of commercial rice production in this area during the latter half of the last century. Most impoundments were constructed by diking off wetland areas intersected by tidal creeks. In some instances, entire marsh-creek areas were completely encircled by dikes, although the most common practice was to dike off the open end of a marsh slough bounded by high lands. These impoundments are usually equipped with flood gates or other structures for regulating water level and salinity. This is done in most cases to manage plant growth suitable for waterfowl utilization, but salinities in a few are controlled for aquacultural purposes (Morgan 1974, Tiner 1977).

Salinities in impoundments vary from completely fresh to as much as 25 o/oo in those along the lower estuarine reaches. Impoundments with salinities averaging greater than 0.5 o/oo are herein considered salt-water impoundments or estuarine impoundments. Impoundments with salinities averaging less than 0.5 o/oo are herein considered freshwater impoundments.

CHAPTER TWO

SALTWATER IMPOUNDMENTS

A. DESCRIPTION

Because of their brackish nature, the flora and fauna of estuarine impoundments can best be compared and contrasted with biotic communities of the estuarine intertidal system, although technically these enclosures are artificially intertidal (i.e., tidal waters are regulated into and out of the impoundments).

New ecological systems replace old ones when portions of an estuary are impounded (Copeland 1974), and significant changes in hydrography accompany the impoundment of such an area. Water circulation is reduced and may become practically non-existent; increased sedimentation changes the nature of the substrate; smothering of aquatic vegetation may occur; and water salinity, temperature, oxygen, pH, and nutrient levels are altered (Copeland 1974, Dean 1975). Periodic draining and variations in hydrographic parameters limit the number of species occurring within impoundments, particularly in shallow rice field systems. The lack of adequate water circulation may be limiting to many filter feeding benthic organisms. Although such areas are characterized by low species diversity, overall productivity is high (Dean 1975).

In South Carolina, 14% - 16% of coastal marshes [approximately 70,000 acres (28,328.6 ha)] are functional for waterfowl management, their capacity for other uses (e.g., aquaculture, waste treatment, and recreation), as well as their ecological importance as elements of marsh systems, has brought impoundments to the forefront of interest as ecological systems. The unique advantages of saltmarsh impoundments for aquaculture have been known for many years. The use of ponds for bivalve culture can be traced back to the Roman empire in the first century B.C., and may have originated even earlier with the Chinese (Yonge 1960). In the Southeastern United States, research in pond culture was stimulated by the observation of gigantism in blue crabs (*Callinectes sapidus*), and initial experimental success in the polyculture of fish, crabs, and oysters (Lunz 1951, 1968). This initial success was reiterated and quantified in more recent studies at several locations in South Carolina (Anderson 1976, Manzi et al. 1977b).

Despite their abundance and the increased pressure for reclamation, little research is presently underway to study the ecological processes of impounded wetlands. The general lack of knowledge concerning saltmarsh impoundments makes this area of marsh ecology a principal data gap.

B. PRODUCERS

1. Nonvascular Flora

The nonvascular microphytes and macrophytes which inhabit estuarine impoundments, and their role in impoundment processes, have been investigated only marginally. Dominant forms have been documented to some extent (Manzi and Zingmark 1978, Wiseman 1978), and in general seem to be correlated with estuarine/tidal creek population dynamics. Apparent deviations in microphyte population structure between impoundments and their adjacent tidal creeks include larger components of nannoplanktonic flagellata and benthonic blue-green algae in impounded areas (J. J. Manzi, 1978, South Carolina Marine Resources Division, Charleston, unpubl. data). In a recent study of the feasibility of bivalve culture in several South Carolina saltmarsh impoundments, phytoplankton concentrations were found to be generally higher in impounded areas than in adjacent tidal creeks (Manzi et al. 1977b). Fig. 2-1 illustrates this dissimilarity and provides a comparison between the ponds and creeks encompassed by this study. As indicated by this information and other data (Anderson 1976), productivity is relatively high in low marsh impoundments and appears to reflect a classic nitrogen-limiting system.

Salt marshlands, particularly impounded areas with continuous or intermittent access to tidal creeks, normally act as sinks for both matter and energy (Odum and de la Cruz 1967, Odum 1970b, Pomeroy et al. 1972, de la Cruz 1973). The sinks are flushed or diluted regularly by spring tides and irregularly by storms, thus transporting nutrient-rich wastes and detritus to coastal waters (de la Cruz 1973). Periodic outwelling is indeed a primary factor in the high productivity of coastal waters. In a recent study, Manzi et al. (1977b) measured phytoplankton biomass, nutrient concentrations, and rates of primary production. Their data illustrate the concentrating properties of tidal creeks and impoundments (Fig. 2-1), and reflects this fertility in oyster growth and meat yields. Areas characterized by low marshlands and good tidal exchange (Blue Heron and Waring ponds, South Carolina) normally exhibited high concentrations of phytoplankton with resultant decreases in available nitrate. Hitchcocks Pond, while surrounded primarily by maritime forest, was fed by Adams Creek, a long narrow tidal inlet surrounded by extensive low marsh, and subsequently exhibited the same high phytoplankton, low nitrogen concentration characteristic. Orthophosphate was present in high concentrations at all locations and was probably not a limiting factor for phytoplankton populations. Estimates of primary productivity (Fig. 2-2) suggested strongly that increased fertility of saltmarsh impoundments led to increased oyster yields. Potential primary productivity was without exception higher in impoundments than in adjacent creeks or rivers, and was correlated directly with oyster growth among the impoundments.

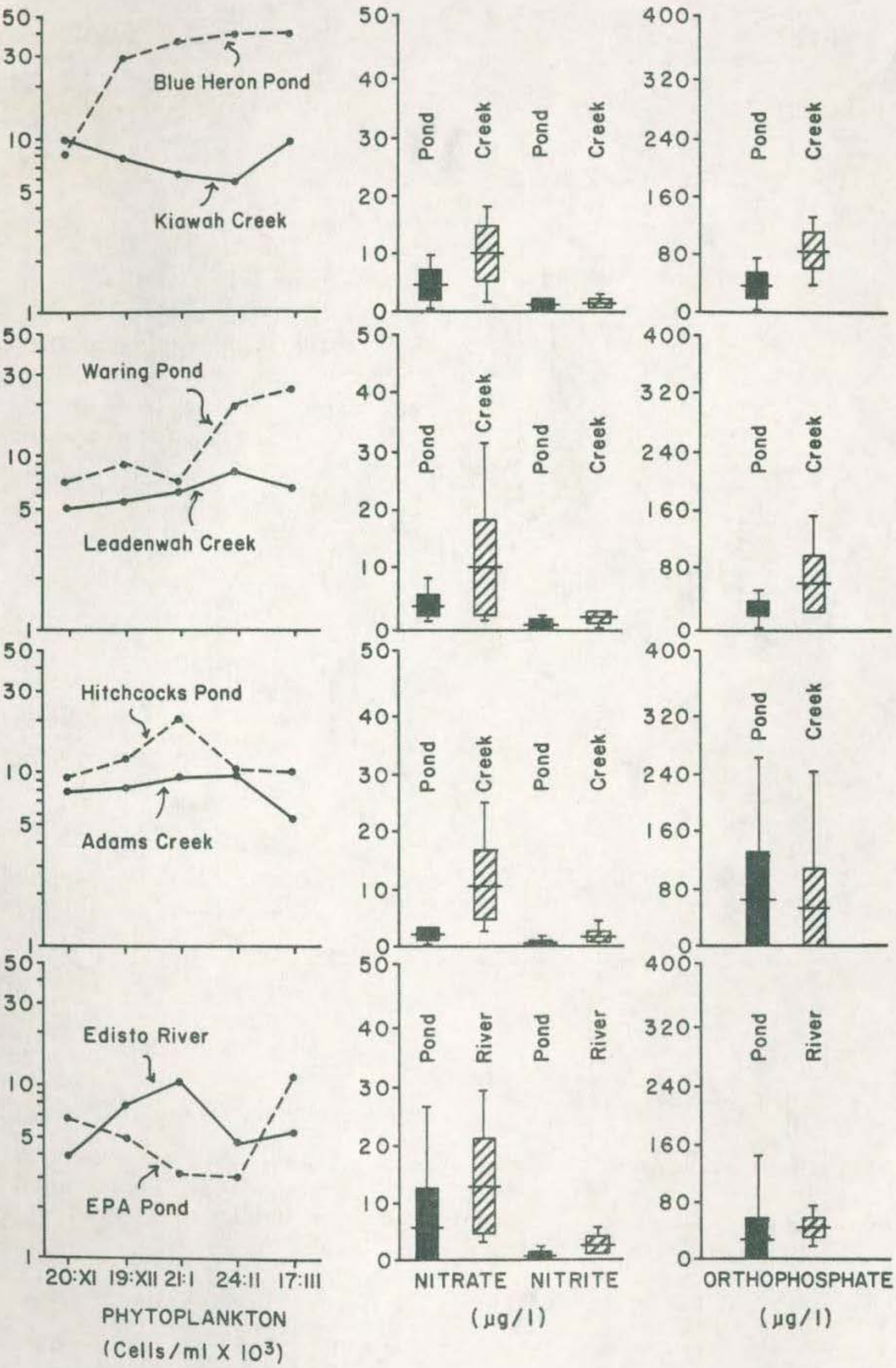

Figure 2-1. Estimates of monthly (ordinate scale) phytoplankton concentrations and means, ranges, and standard deviations of principal nutrients in four tidaly impoundments and their adjacent feeder creeks in South Carolina (Manzi et al. 1977a). (Sampling dates given).

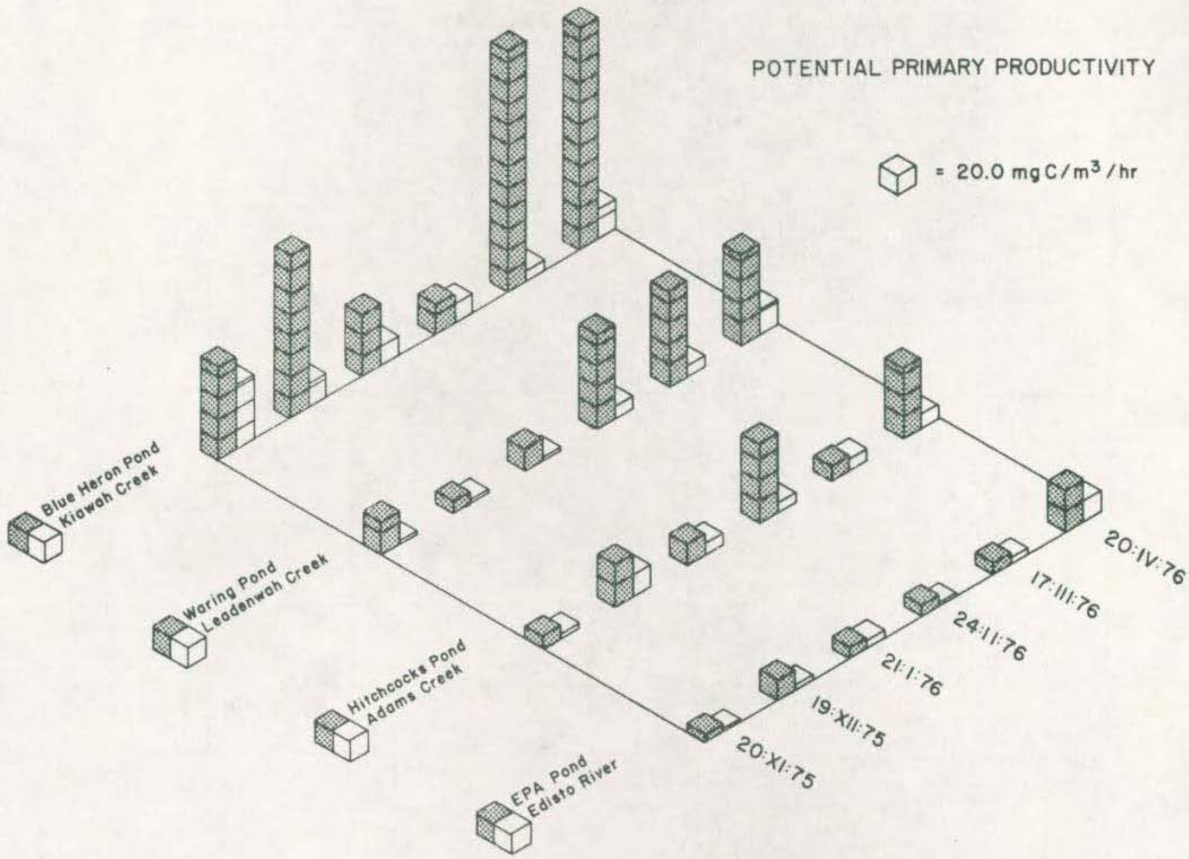

Figure 2-2. Comparative monthly (ordinate scale) estimates of potential primary production in four South Carolina tidal impoundments (shaded) and their adjacent feeder creeks (clear)(Manzi et al. 1977b). (Sampling dates given).

2. Vascular Flora

Because of their value to waterfowl, the desired and usually dominant plant species found in managed brackish water impoundments are widgeon grass, salt-marsh bulrush, and dwarf spikerush (Baldwin 1956, Wilkinson 1970, Tiner 1977). Other desirable plants for waterfowl management are sago pondweed, dotted smartweed, muskgrasses (all non-vascular species), and vascular species such as soft-stem bulrish and common three-square (Baldwin 1956, Johnson et al. 1974). Tiner et al. (1976) interviewed impoundment managers in the Santee River estuary concerning management procedures and dominant plants; results are listed in Table 2-1. A list of plants common to brackish water impoundments in South Carolina is given in Table 2-2.

Baldwin (1968) discussed impoundments in regularly and irregularly flooded salt marshes. He concluded that diked but regularly flooded smooth cordgrass marsh can be managed for widgeon grass with the least effort. In irregularly flooded marshes, impoundments are generally shallower and tend to be vegetated with various bulrushes, dwarf spikerush, wild millets, panic grasses, and giant foxtail grass. Baldwin suggested managing these impoundments for salt-marsh bulrush for maximum waterfowl utilization.

Wilkinson (1970) carefully studied dominance in five newly diked brackish marshes on South Island, Georgetown County, South Carolina. Management procedures for each were as follows:

Impoundment I: "Drawn down in March to keep the marsh soil dry. Flooded in October just prior to the usual time of arrival of waterfowl."

Impoundment II: "Water levels maintained at ground level, which produced a saturated soil condition from March through September. This impoundment was also flooded in October just prior to the usual time of arrival of waterfowl."

Impoundment III: "Water level slowly raised from March through September to a depth of 24 inches, and drained during February of each year."

Impoundment IV: "Water level maintained at full pond depth (approximately 24 inches), except during each February, when it was drained."

Impoundment V: "The inflow and outflow gates were left open to allow the tide to flood and ebb in the impoundment from March through September of each year. During each October the impoundment was flooded to a depth of approximately 24 inches, and held at that depth until the following March."

Table 2-1. Results of a questionnaire survey of several coastal impoundment managers in the Santee River estuary, South Carolina, (Tiner et al. 1976).

Name Of Manager	Area Managed	Brackish-Water Impoundments (acres)	Dominant Plants	Freshwater Impoundments (acres)	Dominant Plants
Phillip M. Wilkinson	South Island Plantation	2,500	Widgeon grass, dwarf spikerush, salt-marsh bulrush, sago pondweed, and muskgrass	500 (dry)	Corn, wheat, barley, rye, Italian rye grass, clover, peas, milo, millet, brown-top millet, soybeans, and grain sorghum
Thomas H. Strange, Jr.	Santee Coastal Reserve	10,500	Widgeon grass, salt-marsh bulrush, dwarf spikerush, and giant cordgrass	1,500	
	Santee Delta Game Management Area				Swamp smartweed, asiatic day-flower, tear-thumbs and giant cordgrass
Kenneth Williams	Kinloch Plantation	4,000	Widgeon grass, dwarf spike-rush, salt-marsh bulrush, giant cordgrass, narrow-leaved cat-tail, and southern cat-tail	150	Not Reported
Graham Reeves	Annandale Plantation	1,500	Dwarf spikerush and widgeon grass		

Table 2-2. List of vascular plants common to brackish water impoundments of South Carolina (adapted from Tiner 1977).

Scientific Name	Common Name
Alternanthera philoxeroides	Alligator-weed
Aster subulatus	Annual salt marsh aster
Baccharis halimifolia	Sea myrtle
Bacopa monnieri	Water hyssop
Borrichia frutescens	Sea ox-eye
Ceratophyllum demersum	Coontail
Cladium jamaicense	Saw grass
Cyperus strigosus	Sedge
Distichlis spicata	Salt grass
Echinochloa walteri	Salt marsh millet
Eleocharis parvula	Dwarf spikerush
Eupatorium capillifolium	Dog fennel
Iva frutescens	Marsh elder
Juncus roemerianus	Black needlerush
Lemna spp.	Duckweeds
Leptochloa sp.	Sprangletop
Myrica cerifera	Wax myrtle
Najas guadalupensis	Bushy pondweed
Nymphaea mexicana	Banana water-lily
Nymphaea odorata	White water-lily
Panicum spp.	Panic grasses
Pluchea purpurascens	Marsh fleabane
Polygonum punctatum	Dotted smartweed
Polygonum sp.	Smartweed
Potamogeton berchtoldii	Narrow-leaved pondweed
Potamogeton pectinatus	Sago pondweed
Ruppia maritima	Widgeon grass
Salicornia europaea	Glasswort
Scirpus americanus	Common three-square
Scirpus olneyi	Olney's three-square bulrush
Scirpus robustus	Salt-marsh bulrush
Scirpus validus	Soft-stem bulrush
Sesbania exaltata	Coffee-weed
Setaria magna	Giant foxtail
Spartina alterniflora	Smooth cordgrass
Spartina cynosuroides	Giant cordgrass
Spartina patens	Saltmeadow cordgrass
Spirodela polyrrhiza	Big duckweed
Typha angustifolia	Narrow-leaved cat-tail
Typha domingensis	Southern cat-tail
Typha glauca	Blue cat-tail
Typha latifolia	Common cat-tail

Table 2-3. Vegetative analysis of Impoundment I (basically dry; see text for explanation of management procedures used in this impoundment) (adapted from Wilkinson 1970).

Plant Species	Percent Occurrence		
	1967	1968	1969
Smooth cordgrass	42.0	33.3	15.3
Bare	40.0	28.5	27.0
Giant cordgrass	8.0	13.8	36.3
Salt grass	4.0	+	0.9
Saltmeadow cordgrass	2.0	9.9	7.4
Glasswort	2.0	+	0.0
Salt-marsh bulrush	1.6	0.6	6.1
Black needlerush	0.4	1.1	0.0
Marsh fleabane	0.0	0.0	2.2
Sedge	0.0	0.0	3.1
Panic grasses	0.0	0.0	1.3
Marsh elder	0.0	0.0	0.4

Table 2-4. Vegetative analysis of Impoundment II (saturated soil; see text for explanation of management procedures used in this impoundment) (adapted from Wilkinson 1970).

Plant Species	Percent Occurrence		
	1967	1968	1969
Bare	65.3	35.6	24.3
Giant cordgrass	10.0	12.0	18.0
Soft-stem bulrush	5.8	0.0	0.0
Salt-marsh bulrush	5.0	26.5	4.6
Narrow-leaved cat-tail	5.0	0.0	0.0
Dwarf spikerush	3.8	10.7	16.7
Salt grass	3.2	7.4	14.9
Marsh fleabane	1.9	7.0	17.0
Smooth cordgrass	0.0	0.8	4.5

Table 2-5. Vegetative analysis of Impoundment III (slowly rising water level; see text for explanation of management procedures used in this impoundment) (adapted from Wilkinson 1970).

Plant Species	Percent Occurrence		
	1967	1968	1969
Salt grass	45.3	33.8	29.5
Narrow-leaved cat-tail	13.8	1.5	2.2
Giant cordgrass	13.3	16.6	13.4
Bare	5.3	0.5	11.2
Widgeon grass	14.6	33.3	15.2
Saltmeadow cordgrass	2.6	+	4.0
Smooth cordgrass	1.7	7.6	20.5
Salt-marsh bulrush	1.3	2.2	4.0
Marsh fleabane	1.3	0.0	0.0
Dwarf spikerush	0.4	4.5	0.0
Sedge	0.4	0.0	0.0

Table 2-6. Vegetative analysis of Impoundment IV (fully flooding; see text for explanation of management procedures used in this impoundment) (adapted from Wilkinson 1970).

Plant Species	Percent Occurrence		
	1967	1968	1969
Open water, nothing growing	25.8	2.4	1.1
Narrow-leaved cat-tail	25.8	13.3	20.5
Giant cordgrass	15.8	12.1	2.1
Dwarf spikerush	14.3	23.0	9.7
Widgeon grass	10.8	30.3	45.0
Salt grass	6.2	2.4	+
Salt-marsh bulrush	5.0	14.5	21.6
Algae (*Cladophora* spp.)	4.3	2.0	0.0

Impoundment I was therefore basically dry, Impoundment II was saturated, Impoundment III was characterized by a slowly rising water level, Impoundment IV was fully flooded, and Impoundment V was open to normal tidal fluctuation. These procedures are representative of the possible methods of managing brackish impoundments in the characterization area.

In Impoundment I, giant cordgrass increased its dominance dramatically, while salt-marsh bulrush, saltmeadow cordgrass, and other species increased in lesser proportions (Table 2-3). Changes in the saturated impoundment are presented in Table 2-4; here, dwarf spikerush very rapidly increased in abundance, although giant cordgrass maintained dominance. In Impoundment III, widgeon grass and smooth cordgrass both increased considerably in abundance, while dwarf spikerush declined (Table 2-5). In impoundment IV widgeon grass and salt-marsh bulrush become dominant (Table 2-6). Narrow-leaved cat-tail also increased in dominance, although most other species declined. Impoundment V was dominated by giant and smooth cordgrass (Table 2-7). Wilkinson's conclusions support the management strategies of most local managers of brackish waterfowl impoundments in that Impoundments III and IV were most successful in attracting waterfowl.

Morgan (1974) described the three basic methods by which the plant composition of brackish water impoundments in the Ashepoo-Combahee-Edisto area of South Carolina is managed. Cyclical fluctuations in water level produce salt-marsh bulrush dominance, while slowly rising water level and permanent flooding favor widgeon grass. Neely (1960) described in detail how careful fluctuations of impoundment water levels at 4 - 6 in (10 - 15 cm) intervals up to 12 in (30 cm) in depth produce salt-marsh bulrush dominance, with dwarf spikerush sometimes dominating former bare spots in the impoundments.

If the flood gates of the brackish water impoundment remain intact and the water level is no longer managed, the impoundment will gradually change into a fresher water environment with sago pondweed and other pondweeds appearing first, and southern cat-tail and water-lily quickly following. In irregularly flooded, shallow impoundments, exposed soil species invade the unmanaged impoundment, with alligator-weed and various cat-tails asserting dominance (Baldwin 1968). If the water-control structures of the impoundments are no longer operable, or if the dikes are broken, the impoundment will gradually change into marsh environment corresponding with those of similar elevation and salinity. Baden et al. (1975) studied two abandoned rice fields in Georgetown County, South Carolina. In Thousand Acre Rice Field, they found a brackish marsh with plant zonation according to elevation; smooth cordgrass dominated the lower portions of the marsh, while giant cordgrass and black needlerush were dominants in the higher areas. Further inland, the much fresher upper marsh was found to be dominated by narrow-leaved cat-tail, giant cordgrass, common three-square, and softstem bulrush. These marsh types correspond closely to other marshes of similar salinities and elevations that have never been impounded.

Table 2-7. Vegetative analysis of Impoundment V (normal tidal fluctuation; see text for explanation of management procedures used in this impoundment) (adapted from Wilkinson 1970).

Plant Species	Percent Occurrence		
	1967	1968	1969
Narrow-leaved cat-tail	0.0	3.4	4.0
Giant cordgrass	38.0	49.1	48.3
Salt-marsh bulrush	0.0	10.1	9.2
Smooth cordgrass	0.0	1.1	22.7
Bare	62.0	36.3	15.8

Fritz (1975) studied aquatic primary productivity in an impoundment in Georgetown County, South Carolina, and measured the standing crop biomass of another impoundment dominated by black needlerush, widgeon grass, and salt grass. Fritz compared its total biomass to that of a nearby unimpounded smooth cordgrass marsh and concluded that the smooth cordgrass marsh was 1.3 to 1.8 times more productive than the impounded marsh (Fritz 1975). Further comparative studies are needed to gain a better understanding of nutrient cycles, total biomass, and primary productivity in estuarine impoundments.

C. CONSUMERS

1. Zooplankton

No in-depth studies of the zooplankton of estuarine impoundments of the South Carolina coastal region have been completed to date. However, certain parallels may be inferred from the work of Deevey (1948), who studied Great Pond, Massachusetts, an impoundment periodically opened and closed to the sea. When free exchange occurred, the pond fauna clearly resembled that present in adjacent open waters. Salinity alterations brought on by periodic closure to the sea restricted numbers of some zooplankters in the pond. In general, Deevey found that successful pond zooplankters were highly euryhaline and that temperature was most important in controlling seasonal succession.

Overall, the degree of similarity between zooplankton of impoundments and adjacent open estuarine waters probably depends upon the following factors: 1) the time of year the impoundment is flooded, 2) the amount and frequency of water exchange permitted between impoundment and open estuary, 3) the mean salinity maintained in the impoundment and the variation about that mean, and 4) the amount and frequency of rainfall. Since the most successful estuarine holoplankters are strongly euryhaline, dominant zooplankters in impoundments may well be the same as those in adjacent estuarine waters. However, differences in abundance of individual species between the two habitats might be great because factors such as predation, or those mentioned above, could selectively favor one species over another.

Impoundments may enhance productivity of estuarine areas by providing protected nursery grounds and spawning sites for zooplankton, which are then periodically released into the open estuary when water is released. This would serve to concentrate food for planktivorous animals, and would permit zooplankters to reach larger size prior to dispersion by currents.

Recent studies indicate that phytoplankton production is higher in coastal brackish ponds than in their feeder creeks (Anderson 1976). Thus, impoundments may support large zooplankton populations. The zooplankton, in turn, may play a major role in recycling nutrients such as nitrogen, which is believed to limit primary production in estuarine impoundments during summer (Anderson 1976).

Predators such as small fishes, American eel, and juvenile crabs may enter impoundments when they are initially flooded and whenever additional water is taken in. These organisms probably control the abundance of zooplankton in impoundments. In summer, low levels of dissolved oxygen, which often result in fish kills, probably also reduce zooplankton numbers significantly.

In a recent study of a flooded former rice field adjacent to the North Santee estuary, Dean (1975) reported that a copepod Acartia (presumably Acartia tonsa), grass shrimp (Palamonetes sp.), and several decapod crustacean larvae (Uca pugnax, Sesarma reticulatum, and Eurypanopeus depressus) were important zooplanters. He noted that density and diversity of zooplankton were low in this brackish impoundment, but gave no numerical data. Molluscan larvae were not reported from this habitat.

Knott (1980) compared zooplankton populations of two man-made ponds filled from the North Edisto River with those of the North Edisto estuary itself. The impoundments were completely isolated from the river; water input from the river was accomplished by pumping. Knott (1980) reported that the annual mean density of zooplankton was much greater in the river (10,148 organisms/m^3) than in either of the ponds (3,417/m^3 and 5,450/m^3). Further, the river zooplankton community was more diverse and more stable over the year than those of the impoundments. The copepod Acartia tonsa was the dominant zooplankter in both environments, but was more important, and frequently more abundant, in the impoundments than in the river (Table 2-8). It also exhibited a marked seasonal variation in abundance in the impoundments, but such variation was much less pronounced in the river. Other important zooplankters in these environments are listed in Table 2-8.

Table 2-8. Numerically abundant zooplankters collected from the North Edisto River and two adjacent impoundments over a 1-year period (from Knott 1980).

Overall Rank	% Of Total Fauna	% Of Total Number Pond 1	Pond 3	Edisto River
1. *Acartia tonsa*	65.88	79.22	93.97	41.36
2. *Euterpina acutifrons*	5.34	0.12	0.09	11.04
3. *Pseudodiaptomus coronatus*	4.38	6.37	1.36	5.62
4. *Parvocalanus crassirostris*	4.12	0.63	0.35	8.12
5. Copepod nauplii	3.69	1.94	0.78	6.40
6. Rotifera	3.67	0.02	< 0.01	7.66
7. Cirripedia larvae	3.05	1.25	0.75	5.35
8. *Tortanus setacaudatus*	1.77	1.09	1.36	2.33
9. Gastropod veligers	1.21	0.88	0.12	2.08
10. *Oithona colcarva*	1.14	1.62	0.14	1.62
11. Decapod larvae	1.07	0.53	0.15	1.92
12. "*Saphirella tropica*"	0.98	0.14	0.03	1.97
13. *Metis* sp.	0.60	2.69	0.16	0.05
14. Polychaete larvae	0.50	0.08	0.20	0.88
15. Foramenifera	0.48	0.04	0.01	0.97
16. *Oikopleura* sp.	0.36	0.00	0.00	0.77
17. Nematoda	0.28	1.20	0.02	0.08
TOTALS	98.52	97.82	99.49	98.22

The impact on zooplankton of environmental alterations in brackish-water ponds has not been investigated and can be predicted at present only from studies of open estuarine systems. The same degree of alteration would be expected to have a more pronounced effect in an impoundment than in an open estuary because: 1) animals have less chance to avoid a contaminant because of areal constraints, 2) dilution proceeds more slowly because of less circulation, and 3) temperatures often are higher, tending to accelerate response of organisms to toxic substances.

2. Benthic Meiofauna

No studies of the meiobenthos of impoundments have been conducted in the South Carolina coastal region. See the section on meiofauna of estuarine intertidal wetlands for information most likely to be pertinent to this environment, in Sandifer et al. (1980).

3. Benthic Macroinvertebrates

Over the last three decades, impoundments have been studied with a view toward intensive cultivation of commercially important species of aquatic invertebrates and fishes in South Carolina. Studies on the rearing of shrimp, crabs, and oysters in ponds were undertaken at Bears Bluff Laboratories between 1946 and 1969. These investigations demonstrated that growth of shrimp was rapid in ponds and that high quality oysters could be grown in such areas (Lunz 1951, 1952a, 1955, 1956, 1957, 1958, Lunz and Bearden 1963). Ballard (1975a,b) studied growth and survival of oysters (*Crassostrea virginica*) and clams (*Mercenaria mercenaria*) in a 250 acre (101.2 ha) pond at Annandale Plantation, Georgetown County, South Carolina. Intensive studies also have been conducted by the South Carolina Marine Resources Research Institute (Charleston) on pond culture of the Malaysian prawn, *Macrobrachium rosenbergii*, at various locations in South Carolina, including Cayce (Richland County), Bonneau (Berkeley County), and Bears Bluff (Charleston County). Smith et al. (1976) observed low mortality and rapid growth of prawns. Duration of grow-out season varied from 5 to 6.5 months, depending upon the site.

An extensive data base exists on water quality and productivity of ponds used for fish culture, particularly for freshwater systems. However, little information is available on the benthos of estuarine impoundments, particularly for the coastal plains of Georgia and South Carolina. Ballard (1975a) observed high densities of *Palamonetes* in a pond at Annandale Plantation. Also present were planktonic larvae of the decapods *Uca pugnax*, *Sesarma reticulatum*, and *Eurypanopeus depressus*. The absence of natural oyster beds in the pond was attributed to the lack of suitable substrate and to periodic draining of the impoundment. Blue crabs (*Callinectes sapidus*) and penaeid shrimp (*Penaeus* spp.) were shown to thrive in ponds at Bears Bluff Laboratories (Bears Bluff Laboratories, Inc. 1956).

Results of studies on culture of oysters in impounded environments along the Atlantic and Gulf coasts are described by Lunz (1951), Shaw (1965), and May (1969). Comprehensive reviews of early oyster culture and artificial propagation of larvae can be found in Dean (1892a, 1893), Baughman (1948), Loosanoff and Davis (1963), Galtsoff (1964), and Joyce (1972).

Oyster culture in enclosed tidal areas (Dean 1892, 1893) was first reported in South Carolina by Colson (1888) in his history of the mill pond oyster, a delicacy which proliferated in large sawmill ponds from 1830 to 1869. Successful production was attributed to tidal flushing and the presence of floating logs bearing oysters (Colson 1888). Battle (1892) proposed tidal pond cultivation in South Carolina during his comprehensive investigation for the U. S. Fishery Commission. However, cultivation of oysters and fishes in marsh impoundments using an experimental approach was not initiated in South Carolina until 1943 (Lunz 1968). Further experimentation illustrated congruent polyculture of fish, crabs, and oysters in the same pond. Ponds dug in the marsh appeared to be less productive than impounded marshlands. In one annual study, oyster yield was estimated to be 35.2 m^3 of shell stock/0.4 ha (Lunz 1968).

Not all attempts to culture oysters in saltwater ponds of South Carolina have been successful. Lunz (1955) reported a disastrous mortality resulting from what was later thought to be the pathogenic fungus, Perkinsia marina, and possibly other predators. Boring sponges (Cliona) and oyster drills (Urosalpinx cinera and Eupleura caudata) are sometimes reported in impoundments where salinities are suitable. Other high salinity predators, such as whelks and starfishes, are less frequently observed due to the characteristically reduced impoundment salinities. Mussels (Brachidontes spp.) are often found growing on oysters in ponds, as are barnacles (Balanus eburneus, Balanus improvisus) and blisters of mud worms (Polydora websteri). Blue crabs (Callinectes sapidus) and occasionally stone crabs (Menippe mercenaria) inhabit the impoundments but are not usually found inside oyster trays (Anderson 1976). Lunz (1968) indicated that predators such as the boring sponge could be controlled by lowering the salinity or draining the pond and allowing the oysters to be exposed to air.

MacGregor (1970), using two groups of 2 - 3 year old Crassostrea virginica in a 0.27 ha (0.67 acre) pond at Sapelo Island, in a 4-week experiment reached no conclusions concerning the feasibility of commercial pond culturing of oysters in Georgia salt marshes. Ballard (1975a) speculated on techniques and the potential of impoundment oyster culture in South Carolina.

Recent studies in impoundments located on Wadmalaw and Kiawah islands, South Carolina (Anderson 1976, Manzi et al. 1977b) have substantiated the accelerated growth rates and favorable survival observed by others (Lunz 1955, 1956, 1968, Badger 1968). These experiments, however, were not designed to establish the economic feasibility of oyster culture in impoundments.

Use of saltwater ponds for aquaculture has the following advantages over open estuarine areas: 1) protection from strong waves and adverse currents, 2) easier access to bottoms for planting and management, 3) predator control, 4) modification of tidal exchange, and 5) artificial fertilization (Bouchon-Brandely 1882, Gaarder and Spärck 1932, Turner 1951, Lunz 1955, Carriker 1956, 1959, Korringa and Postuma 1957, Binmore 1964, Loosanoff 1964, Shaw 1965).

4. Insects

The insect fauna of coastal impoundments in the South Carolina coastal region has not been studied in detail but is expected to be similar to that of marshes. No one venturing into impoundments has escaped the wrath of the biting insect species. Mosquitoes, horse flies, gnats and deer flies are very abundant. See Chapter 4, Sandifer et al. (1980) for additional information on insects of estuarine areas.

5. Fishes

Dean (1975) investigated the mariculture potential of several marine and estuarine fishes, including Atlantic croaker and ladyfish, in impoundments at Annandale Plantation, South Carolina. Theiling and Loyacano (1976) studied the age and growth of red drum from a saltwater marsh impoundment at South Island. In Georgia, investigations of the fisheries of natural brackish ponds occurring on coastal islands have been carried out by Hillestad et al. (1975).

The mariculture potential of saltwater impoundments for fishes was investigated at Bears Bluff Laboratories over a number of years (Lunz 1951, 1956; Bearden 1967; Bears Bluff Laboratories, Inc., Wadmalaw Island, South Carolina, unpubl. data). During the period of 1947 - 1967, 1-acre (0.4 ha) marsh impoundments at Bears Bluff Laboratories were stocked annually with marine fishes and invertebrates by tidal flooding through water control structures, and drained each fall. Biomass of fishes harvested from these ponds ranged from 61.5 to 382 lb/acre (68.9 to 428.1 kg/ha), averaging approximately 200 lb/acre (224.2 kg/ha). Mullet, spot, ladyfish, and mummichog were the most abundant species. Biomass of smaller fishes (mummichog, silverside) was not normally recorded. These data suggested that during certain times the mean biomass of fishes in impoundments may be greater than that of natural, unimpounded tidal marsh areas. Turner and Johnson (1974), for example, found a mean biomass of 92 lb/acre (103.1 kg/ha) for estuarine fishes in tidal creeks of the Cooper River estuary, with a range of from 7.3 to 257.1 lb/acre (8.2 to 288.2 kg/ha) during April through November. This does not imply that impoundments are necessarily more productive on an annual basis than are natural tidal marsh creeks, since the former are semi-enclosed systems from which little emigration may take place, whereas recruitment and emigration take place continually in the latter zone.

Sixty-one species of marine and estuarine fishes (Table 2-9) have been identified from saltwater impoundments in South Carolina (Bears Bluff Laboratories, Inc., Wadmalaw Island, South Carolina, unpubl. data). Such impoundments are typically inhabited both by year-round resident fish species and species which enter periodically from outside waters as larvae or postlarvae but are not capable of reproducing there. Resident fishes are usually numerically dominated by the mummichog, sheepshead minnow, mosquitofish, sailfin molly, and Atlantic silverside. The most abundant species introduced during the flooding of such impoundments are striped mullet, American eel, spot, Atlantic croaker, red drum, spotted seatrout, silver perch, Atlantic menhaden, bay anchovy, mojarras, pinfish, southern flounder, and ladyfish. Impoundments also provide prime habitat for the young of several species of fishes not commonly found in adjacent estuarine waters, including snook and tarpon. Large numbers of juvenile tarpon, ranging from 59 to 300 mm SL, have been collected from saltwater impoundments in South Carolina during late summer and fall. One collection of 130 juvenile tarpon was made from an 8-acre (3.2 ha) impoundment near Adams Creek, South Carolina, in 1965 (C. M. Bearden, 1978, South Carolina Marine Resources Division, Charleston, unpubl. data). Juveniles of red drum and spotted seatrout are often more common in impoundments than in adjacent natural areas (Bears Bluff Laboratories, Inc., Wadmalaw Island, South Carolina, unpubl. data). Some of the low salinity impoundments in the South Carolina coastal region also contain populations of carp. These fish have been observed in impoundments on the Santee estuary and have apparently adapted to brackish water conditions.

On many of the South Carolina and Georgia coastal islands, naturally occurring ponds formed in shallow depressions and influenced by tidal action occasionally contain numbers of euryhaline fish species. In Georgia, Hillestad et al. (1975) sampled the aquatic systems on Cumberland Island, including brackish and freshwater ponds and their drainage outflows. Several of these ponds are closely associated with the ocean and are subject to occasional tidal flooding. Eight species of euryhaline fishes were found in the brackish water ponds. Large numbers of the sheepshead minnow, sailfin molly, mosquitofish, and striped mullet were present, feeding on the abundant organic detritus of pond bottoms. Mosquitofish occurred in the saline and freshwater ponds of the island as well as in the drainage outflow systems. Sailfin mollies also occurred in the drainage systems and were found in eutrophic pools of water beneath oak trees along the drainage channels. The lower, tidally influenced portions of the pond drainage outflows contained mullets, mojarras, mummichogs, marsh killifish, and American eels.

Impoundments provide a rich habitat and an abundant food supply for many fish species. Growth rates of many species appear to be higher in impoundments than in surrounding waters (Bearden 1967, Dean 1975). Average growth rates for four fish species commonly found in impoundments are given in Table 2-10.

Table 2-9. Systematic listing of fish species known to occur in salt and brackish water impoundments in South Carolina (Bears Bluff Laboratories, Inc., Wadmalaw Island, South Carolina, unpubl. data).

- Order Elopiformes
  - Family Elopidae
    - Ladyfish
    - Tarpon
- Order Anguilliformes
  - Family Anguillidae
    - American eel
- Order Clupeiformes
  - Family Clupeidae
    - Atlantic menhaden
    - Gizzard shad
  - Family Engraulidae
    - Bay anchovy
- Order Cypriniformes
  - Family Cyprinidae
    - Carp
- Order Siluriformes
  - Family Ariidae
    - Sea catfish
- Order Batrachoidiformes
  - Family Batrachoididae
    - Oyster toadfish
- Order Gadiformes
  - Family Gadidae
    - Spotted hake
  - Family Ophidiidae
    - Striped cusk-eel
- Order Atheriniformes
  - Family Belonidae
    - Atlantic needlefish
  - Family Atherinidae
    - Atlantic silverside
- Order Atheriniformes (Cont.)
  - Family Cyprinodontidae
    - Sheepshead minnow
    - Mummichog
    - Striped killifish
  - Family Poeciliidae
    - Sailfin molly
    - Mosquitofish
- Order Gasterosteiformes
  - Family Syngnathidae
    - Chain pipefish
- Order Perciformes
  - Family Percichthyidae
    - Striped bass
  - Family Serranidae
    - Rock sea bass
  - Family Pomatomidae
    - Bluefish
  - Family Carangidae
    - Crevalle jack
    - Atlantic bumper
  - Family Gerreidae
    - Irish pompano
    - Mojarras
  - Family Lutjanidae
    - Gray snapper
  - Family Pomadasyidae
    - Pigfish
  - Family Sparidae
    - Pinfish
    - Sheepshead
  - Family Sciaenidae
    - Silver perch
    - Weakfish
    - Spotted seatrout
    - Banded drum
    - Spot
- Order Perciformes (Cont.)
  - Family Sciaenidae
    - Southern kingfish
    - Northern kingfish
    - Black drum
    - Atlantic croaker
    - Red drum
  - Family Ephippidae
    - Atlantic spadefish
  - Family Mugilidae
    - Striped mullet
    - White mullet
  - Family Blenniidae
    - Feather blenny
    - Striped blenny
  - Family Gobiidae
    - Sharptail goby
    - Naked goby
    - Marked goby
    - Highfin goby
  - Family Eleotridae
    - Fat sleeper
    - Spinycheek sleeper
  - Family Triglidae
    - Striped searobin
    - Leopard searobin
- Order Pleuronectiformes
  - Family Bothidae
    - Ocellated flounder
    - Bay whiff
    - Fringed flounder
    - Summer flounder
    - Southern flounder
  - Family Soleidae
    - Hogchoker
  - Family Cynoglossidae
    - Blackcheek tonguefish

Food habits and trophic relationships of fishes occurring in salt or brackish water impoundments are not well understood, and additional research along these lines is needed. Predominantly herbivorous species such as mullets, Atlantic menhaden, sheepshead minnows, and sailfin mollies would presumably feed primarily upon the large quantities of phytoplankton, benthic algae, and vascular plant material present. Odum (1975) estimated that striped mullet in a brackish pond fed largely on living algae and to a lesser extent upon plant detritus. Primary and mid-level carnivores, such as mummichog, mosquitofish, spot, and Atlantic croaker, would be expected to feed largely on smaller fishes, Palaemonetes shrimp, insects, and benthic invertebrates such as polychaete worms, as well as organic detritus and plant material. In brackish ponds on the Santee estuary, South Carolina, young Atlantic croaker were found to feed largely on insects, insect larvae, and crustaceans (Dean 1975). Top level carivores, including ladyfish, tarpon, red drum, black drum, spotted seatrout, and flounders, are known to feed extensively on Palaemonetes and penaeid shrimp, mummichogs, mosquitofish, sailfin mollies, mullets, silversides, and other small fishes (Bearden 1967; Dean 1975, Bears Bluff Laboratories, Inc., Wadmalaw Island, South Carolina, unpubl. data). Table 2-11 presents trophic levels of the most abundant fish species commonly found in coastal saltwater impoundments.

Fluctuations of several environmental factors (e.g., temperature, salinity, dissolved oxygen) in coastal impoundments are more extreme than in nearby estuarine waters. Mortalities due to low dissolved oxygen and low temperatures are commonplace in impoundments. Fish kills associated with pesticide applications on adjacent agricultural lands have frequently occurred in impoundments in past years in South Carolina (South Carolina Marine Resources Division, Charleston, unpubl. data), and the U. S. Environmental Protection Agency (1971) conducted a study of the movement of the pesticide mirex in small impoundments near Charleston. The major limiting factor of shallow natural ponds on coastal islands is water level fluctuation. Alterations in drainage brought about by development could have disastrous effects on this habitat.

While salt and brackish water impoundments provide valuable habitat for many marine and estuarine fish species, unless properly managed with respect to water manipulation (flooding and lowering at strategic times), many introduced species cannot survive the rigorous extremes of temperature and dissolved oxygen supply found within these areas. The drawdown or draining of coastal impoundments in the fall, provided such measures are compatible with waterfowl or mariculture activities, could result in the release of large numbers of fishes and invertebrates to the natural estuarine system.

6. Amphibians and Reptiles

Salinities in estuarine impoundments vary widely, depending on their location and how they are managed. Numbers and diversity of

Table 2-10. Average growth rates of four fish species in brackish ponds of South Carolina (Bearden 1967).

	Age in Years					
	I		II		III	
Species	Total Length (inches)[a]	Weight (pounds)[b]	Total Length (inches)	Weight (pounds)	Total Length (inches)	Weight (pounds)
Red drum	14.5	1.5	20.5	3.5	26.0	7.1
Spot	7.5	0.3	9.8	0.5	11.5	0.8
Black drum	9.3	0.6	15.0	1.8	18.5	3.8
Atlantic croaker	8.5	0.3	10.5	0.5	--	--

a. 1 in = 2.54 cm.
b. 1 lb = .45359 kg.

Table 2-11. Trophic levels of predominant fish species found in saltwater impoundments in the Sea Island Coastal Region (C. M. Bearden 1978, South Carolina Marine Resources Division, Charleston, unpubl. data).

I. HERBIVORES
- Sheepshead minnow
- Sailfin molly
- Atlantic menhaden
- Striped mullet

II. PRIMARY CARNIVORES
- Mosquitofish
- Silverside
- Bay anchovy

III. MID CARNIVORES
- Mummichog
- American eel

MID CARNIVORES (Cont.)
- Pinfish
- Spot
- Atlantic croaker
- Silver perch

IV. TOP CARNIVORES
- Ladyfish
- Tarpon
- Weakfish
- Spotted seatrout
- Red drum
- Black drum
- Southern flounder

amphibians and reptiles are much higher in low-salinity (<5°/oo) impoundments. For purposes of this section, however, discussion of amphibians and reptiles will be limited to impoundments exhibiting estuarine characteristics.

Amphibians are the only class of vertebrates which have not adapted to saline waters, and only a few reptiles have adapted to estuarine conditions. The only characteristically estuarine reptile along the Georgia and South Carolina coast is the Carolina diamondback terrapin, which inhabits the estuarine zone throughout its entire range (Conant 1975). This turtle is relatively common and feeds on mollusks and crustaceans (Coker 1906, 1920); the natural history of a Gulf coast subspecies was reviewed by Cagle (1952). North and south of the South Carolina coastal region, two subspecies of water snakes have adapted to saline conditions and, within their range, are characteristic saltmarsh fauna. The Carolina salt marsh snake is found along the Outer Banks and adjacent mainland of North Carolina (Conant and Lazell 1973), and the Atlantic salt marsh snake is found along the north-central poriton of Florida's east coast (Conant 1975).

The herpetofauna of estuarine impoundments in South Carolina has not been investigated. Thus, much of this discussion is restricted to animals recorded from impoundment-like situations or their probable occurrence in such habitats. Anurans (frogs and toads) are the only group of amphibians found with some regularity in areas similar to estuarine impoundments. Pearse (1936) observed the southern leopard frog in salinities of greater than 21°/oo near Beaufort, North Carolina. Most records of this species, however, were in salinities of less than 5°/oo. Ruibal (1959) observed that salinities of greater than 5°/oo were lethal to the eggs of the closely related northern leopard frog. Other records of this species occurring in low-salinity waters along the Atlantic and Gulf coasts of the Southeastern United States have been published by Viosca (1923), Carr (1940), Hardy (1953), Liner (1954), Neill (1958), and Blaney (1971). On the west coast of Florida, a population of exceptionally large leopard frogs occurs, individuals of which commonly ingest fiddler crabs and are capable of swallowing week-old alligators (Springer 1938). Another distinct population of leopard frogs, but of diminutive size, exists in the same general area and caused Neill (1958) to stress the need for a study of the herpetofauna of saltwater areas. Other anurans reported from saline habitats of the South Atlantic and Gulf coasts include the southern toad, oak toad, green treefrog, squirrel treefrog, southern cricket frog, and the eastern narrowmouth toad (Viosca 1923, Allen 1932, Carr 1940, Burger et al. 1949, Hardy 1953, Smith and List 1955, Neill 1958).

The two-toed amphiuma has been recorded several times from the front beach on Hatteras Island, North Carolina, but in each case the occurrence appeared accidental, i.e., just after a hurricane or heavy rains. The specimens were probably washed from drainage canals along roads or from typically freshwater ponds (J. R. Bailey, 1978, Duke University, Durham, North Carolina, pers. comm.).

The American alligator is the only naturally occurring crocodilian in South Carolina, although the Florida crocodile is found elsewhere in the Southeast. Alligators frequent saltmarsh impoundments (Obrecht 1946, Allen and Neill 1949, Engels 1952), but successful nesting is probably limited to impoundments where salinities are less than 10°/oo. A salinity of 17°/oo was determined to be lethal to newly hatched alligators (Joanen et al. 1972). Dietary and physiological changes resulting from increased salinities are not known, but Chabreck (1972) found significantly less food in stomachs of alligators taken in salinities of 3°/oo to 16°/oo, compared to those of alligators taken in fresh water. He suggested that alligator growth may be reduced in saline waters because of low food intake. Alligator survival and reproduction can be affected by management of impoundments for waterfowl (e.g., through flooding of nests and changes in salinity). Adults are also subject to shifts in reproduction due to thermal loading around nuclear power production reactors (T. Murphy, 1978, South Carolina Wildlife and Marine Resources Department, Green Pond, unpubl. data).

Where salinities are low, as on Kinloch and South Island plantations, Georgetown County, South Carolina, impoundments provide optimum habitat for alligators. Bara (1971) consistently observed the highest concentrations of alligators in canals within marsh impoundments. Abundant food supply, deep and shallow water, and creation of nesting sites on dikes are several benefits of these impoundments (Chabreck 1960). In addition, private lands and game management areas provide protection from illegal hunting. Of 17 nests studied by Bara (1976), 12 were associated with diked impoundments. Most of the 12 nests were located on a dike berm or directly on an old abandoned dike. Principal nest materials of these 17 nests reflected the brackish nature of the habitat.

Impoundments at the Savannah National Wildlife Refuge (SNWR) are managed for waterfowl, and salinities in the feeder creeks typically range from fresh water to about 10°/oo (R. H. Dunlap, Jr., 1978, South Carolina Marine Resources Division, Charleston, pers. comm.). For several successive years, Bara (1976) cruised a line 24 mi (38.6 km) in length within the SNWR, and the mean number of alligators sighted per mile was as follows: 1971-9.38; 1972-8.33; 1973-7.54; 1974-10.21; 1975-8.02 [only 9.6 mi (15.4 km) of the transect were surveyed in 1975]. The largest number of individuals observed was 245 for the 24-mi (38.6 km) transect (Bara 1976).

Newly hatched alligators weigh less than 2 oz (62 g) and measure about 8 in (10.3 cm) long. The young usually remain in the natal area for 2 or 3 years, feeding mainly on insects but also on crayfish and snails when they are available (Valentine et al. 1972). They are opportunistic feeders, shifting to larger prey as they mature. After attaining a length of 4 ft (1.2 m), they usually disperse from the natal area. Growth of alligators varies from 4 to 6 in/yr (10.2 to 15.2 cm/yr) in South Carolina (Bara 1976), or about half the rate observed in Louisiana and Florida (McIlhenny 1934). The slower growth rate in South Carolina results in greater juvenile mortality because the young are exposed to predators, such as herons, egrets, and predacious fish, for a longer period. Major predators on young alligators are herons, egrets, and predacious fish. Predators of lesser importance include raccoons, bobcats, and adult alligators (Neill 1971).

Alligators reach sexual maturity upon attaining a length of about 6 ft (1.8 m). Growth slows to about 2 in/yr (5.1 cm/yr) thereafter, and becomes negligible on approaching maximum length. The normal maximum length is 9 ft (2.7 m) for females and 12 ft (3.7 m) for males. Weight gain is rapid until sexual maturity is reached. Age to sexual maturity in South Carolina alligators is delayed due to the slower growth rate; such information is unavailable for specimens from Georgia. Information on growth rates and the time required to reach sexual maturity is necessary to determine the possibility of a regulated harvest (Bara 1976). The reproductive cycle is seasonal and related to temperature; a cool spring may delay reproduction, while a warm one may initiate the process early. The onset of spermatogenesis usually occurs during the last 2 weeks of May and the first 2 weeks of June. Open waters are necessary for successful courtship and breeding (Nichols et al. 1976).

Nest construction and egg laying take place during the first 2 weeks of July. Secluded areas are sought for nesting. The nests, constructed from vegetation at the site, are approximately 3 ft (0.92 m) in diameter at the base and 2.5 ft (0.76 m) tall. The nest interior provides a microhabitat having a stable, high relative humidity as well as some heat generated through decomposition of plant material (Joanen 1969). Clutch size averages 40 eggs, and incubation takes about 60 days depending on the nest site, construction, and temperature. Eggs deposited in shaded or poorly constructed nests require a longer incubation time. Most eggs hatch during the first 2 weeks in September, and females may be aggressive around the nest site. Stable water level is an important factor affecting the hatching success; both drought and flooding are detrimental. The raccoon is the major predator on nests, and the number destroyed may exceed 50% where there is land access, as on the side of impoundment dikes and levees. Should misfortune befall a nest, reproduction by that female is lost for the year, for renesting is unknown.

Alligators generally become semidormant from the second week of October to the second week of March, although there may be limited basking on mild days in winter. Feeding activity begins again in spring only after water temperatures exceed $\sim 25^{\circ}C$ ($\sim 77^{\circ}F$).

According to Chabreck (1966), large adults constitute a small portion of the alligator population [e.g., only 20% exceed 6 ft (1.8 m) long]. Juveniles should comprise at least 80% of an expanding population, with a 60:40 sex ratio favoring males. Size class distribution and sex ratios are unknown for mature, stable populations.

Range requirements must be considered when habitat needs for the species are evaluated. In Louisiana, the home range of an adult male is 2,200 acres (890.3 ha); of nesting females, 21 acres (8.5 ha); and of

3 - 6 ft (0.92 - 1.83 m) animals, 500 acres (202.3 ha) (Joanen and McNease 1970, 1973). These figures may not necessarily apply to populations in South Carolina, but such data are unavailable.

The standing crop of alligators probably exceeds that of any other large carnivore because of the wide extremes in size (8 in to 12 ft)(20.3 cm to 3.7 m), and the different habitat utilization and niche requirements for different size classes.

Ecologically, alligators function as a top carnivore on many prey species. Chabreck (1972) found that vertebrates were important food items in freshwater areas, with birds comprising one-third of the diet by weight. Other prey organisms include fishes, turtles, snakes, and various mammals. In addition, alligators maintain open, deep water areas and open trails in the marsh that are utilized by other wildlife. Because of their longevity (some may live 40 years), alligators can be useful as an indicator species for monitoring natural systems.

Alligators are important to man aesthetically and economically. In recent years, alligator hides have brought as much as $17/linear foot, but fashion demands cause prices to fluctuate ocnsiderably. Commercial harvesting for hides reached a peak in the late 1800's (McIlhenny 1935), and by 1960 the alligator had been practically eliminated from its original range (Chabreck 1968). During the 1960's, protective legislation was enacted by all States within its range, and the alligator now receives full Federal protection under the 1973 Endangered Species Act. In recent years, numbers of alligators have increased in the Southeast (Powell 1971), including South Carolina (Bara 1971) and Georgia (Joanen 1974).

In February 1977, the status of alligator populations in South Carolina and Georgia south of Winyah Bay, east of highways 17A and Interstate 95, and north of the Florida State line was changed from "endangered" to "threatened." This change in status was based on population estimates. The status of other alligator populations in South Carolina and Georgia is still classified as endangered. (See Sandifer et al. 1980, Chapter One, for additional information on endangered species.) However, census data alone do not provide all the information needed to manage the species. Areas of research that need to be addressed include: 1) ways of accurately aging individuals, 2) mortality rates and factors, 3) the importance of size distribution on reproduction, 4) habitat suitability, especially as it affects reproduction, and 5) the northern extent of its range.

As alligator and human populations continue to expand, there are certain to be interactions between the two species, some of which will be negative. Increased development, especially in coastal areas, is likely to be a limiting factor on alligator populations through direct habitat destruction. Research is presently underway to determine the type and amount of habitat needed to maintain healthy alligator populations and to ensure that this top carnivore does not suffer as it did in years past.

Population data for South Carolina coastal counties in 1973 (Table 2-12) show stable populations in Dorchester, Berkeley, and Georgetown counties, and increasing populations in Colleton, Beaufort, Jasper, and Charleston counties (Joanen 1974). The Non-game and Endangered Species Section of the South Carolina Wildlife and Marine Resources Department is conducting surveys of alligator populations on South, Murphy, and Cedar islands, and in the Bear Island Game Managment area. Results of these surveys will provide information on the size and structure of alligator populations in intertidal estuarine impoundments in South Carolina.

Other reptile species indigenous to the South Carolina coast, and recorded in habitats similar to estuarine impoundments, include the common snapping turtle, eastern mud turtle, striped mud turtle (see Conant 1975), chicken turtle, Florida softshell turtle, striped crayfish snake, cottonmouth, yellow rat snake, banded water snake, eastern garter snake, and the eastern mud snake (Viosca 1923, Engels 1942, 1952, Neill 1958, Conant 1975, Gibbons and Harrison 1975, Gibbons 1978). These species are not characteristic of estuarine impoundments, and their occurrence in this habitat is considered marginal. Neill (1958) provided a detailed discussion and literature review of herpetofauna in saline areas.

7. Birds

The habitats formed by numerous impounded wetlands in South Carolina are among the most dramatic and active ecological units for birds. Some 68 species commonly or occasionally occur in impoundments (Table 2-13). Trophic relationships of these birds are illustrated in Figure 2-3. Specific groups of birds use rather distinct areas within the impoundments. Waterfowl, for instance, use the open water areas for feeding, whereas shorebirds concentrate along the edges and adjacent shallow flats. Earthen dikes delimit the habitat and provide an excellent "edge effect" when fully stabilized with vegetation. Species such as the sparrows, long-billed marsh wren, and common snipe are found in border vegetation and ecotonal communities.

Impoundment border vegetation is a fundamental link among nearly all species and provides for feeding, roosting, nesting, and cover. Impoundments in coastal South Carolina are generally managed for waterfowl and are characterized by the dominance of brackish or freshwater vegetation, especially desirable duck food plants. The management of coastal impoundments for attracting waterfowl has been documented by Chabreck (1960), Neely (1960, 1962), Baldwin (1968), and Morgan et al. (1975).

Waterfowl occurring in impoundments of the South Carolina coastal region can be divided into four major groups: 1) swans and true geese, 2) surface-feeding or puddle ducks, 3) diving ducks or pochards, and 4) sea ducks. Among these four groups, there are some 19 species which occur regularly in the impoundments each year.

Table 2-12. Alligator population estimates by county for coastal South Carolina (Joanen 1974).

SOUTH CAROLINA

COUNTY	NO. OF ALLIGATORS	NO. OF SQUARE MILES IN COUNTY	NO. OF SQUARE MILES OF ALLIGATOR HABITAT	NO. OF ALLIGATORS PER SQUARE MILE OF HABITAT	POPULATION TREND	SOURCE OF INFORMATION
Dorchester	1,500	569.00	150.0	10.0	Stable	Mark Bara
Colleton	10,000	1,048.00	500.0	20.0	Increasing	Mark Bara
Beaufort	4,000	637.00	200.0	20.0	Increasing	Mark Bara
Jasper	7,000	662.00	350.0	20.0	Increasing	Mark Bara
Charleston	3,000	945.00	200.0	15.0	Increasing	Mark Bara
Berkeley	2,500	1,100.00	250.0	10.0	Stable	Mark Bara
Georgetown	4,500	813.00	300.0	15.0	Stable	Mark Bara

Table 2-13. Birds of estuarine intertidal impoundments (Sprunt and Chamberlain 1949, 1970, Burleigh 1958, Audubon Field Notes 1967 - 1970, Chamberlain 1968, American Birds 1971 - 1977, Shanholtzer 1974b, Forsythe 1978).

DOMINANT				MODERATE				MINOR			
Pied-billed grebe	C	PR		Horned grebe	C	WR		Brown pelican	C	PR	
Great blue heron	C	PR		Green heron	FC	PR		Double-crested cormorant	C	PR	
Louisiana heron	C	PR		Little blue heron	C	PR		Yellow-crowned night heron	FC	PR	
Great egret	C	PR		Black-crowned night heron	C	PR		Wood stork	FC	PR	
Snowy egret	C	PR		Least bittern	FC	SR	Mar.-Sept.	Canada goose	C	WR	
White ibis	C	PR		Glossy ibis	FC	PR		Fulvous whistling duck	U	WR	Nov.-Jan.
Blue-winged teal	C	WR	Aug.-May	Mallard	C	WR	Sept.-April	Wood duck	C	PR	
Baldpate	C	WR	Nov.-April	Black duck	C	WR	Sept.-April	Redhead	U	WR	Nov.-Mar.
Scaup	C	WR	Oct.-April	Gadwall	FC	WR	Oct.-April	Canvasback	FC	WR	Nov.-Mar.
Bufflehead	FC	WR	Nov.-April	Pintail	C	WR	Sept.-April	Osprey	U	PR	
Hooded merganser	C	WR	Nov.-April	Green-winged teal	C	WR	Oct.-April	Black-bellied plover	C	PR	
Red-breasted merganser	C	WR	Oct.-April	Shoveler	C	WR	Oct.-Mar.	Ruddy turnstone	C	PR	
Clapper rail	C	PR		Ring-necked duck	C	WR	Oct.-April	Dowitcher	C	PR	
American coot	C	PR		Ruddy duck	C	WR	Oct.-April	American avocet	U	WR	Oct.-June
Spotted sandpiper	C	PR		Virginia rail	FC	WR	Aug.-Mar.	Black-necked stilt	U	SR	Mar.-Aug.
Willet	C	PR		Sora	FC	WR	Aug.-April	Gull-billed tern	FC	SR	Mar.-Sept.
Greater yellowlegs	C	PR		Common gallinule	C	PR		Common tern	FC	PR	
Herring gull	C	PR		Semipalmated plover	C	PR		Bald eagle	U	PR	
Ring-billed gull	C	PR		Lesser yellowlegs	FC	WR	July-May				
Laughing gull	C	PR		Least sandpiper	C	PR					
Forster's tern	C	PR		Dunlin	C	PR					
Least tern	C	SR	Mar.-Oct.	Semipalmated sandpiper	C	PR					

Table 2-13. Concluded

DOMINANT				MODERATE				MINOR			
Belted kingfisher	C	PR		Western sandpiper	C	PR					
				Bonaparte's gull	C	WR	Oct.-May				
				Royal tern	C	PR					
				Black tern	FC	SR	May-Oct.				
				Black skimmer	C	PR					

Note: Dominance indicates relative importance of the species as a group in the community. This concept is not based necessarily on taxonomic relationships but rather on numbers, size, and trophic dynamics.

KEY: C - Common, seen in good numbers
FC - Fairly common, moderate numbers
U - Uncommon, small numbers irregularly
PR - Permanent resident, present year around
WR - Winter resident
SR - Summer resident

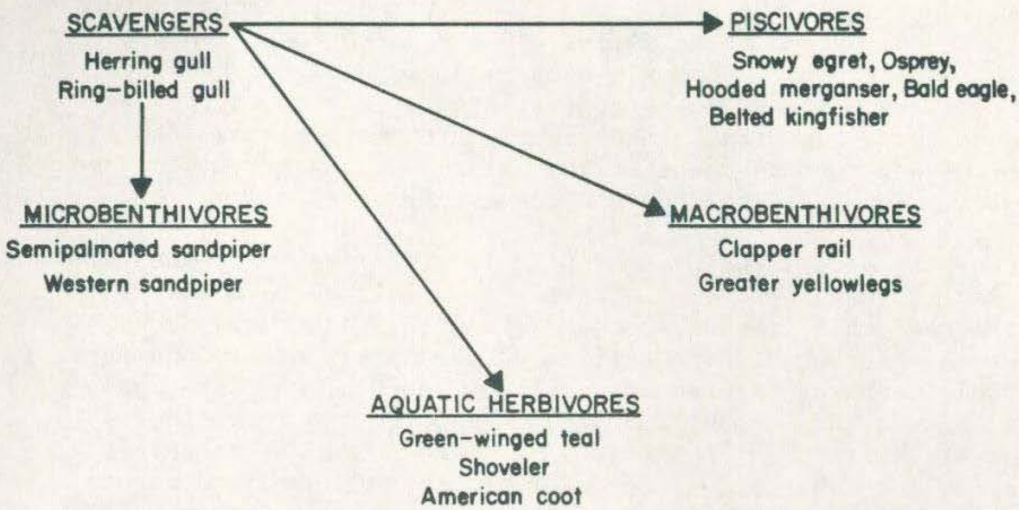

Figure 2-3. Generalized trophic relationships of representative birds of estuarine impoundments.

Swans and true geese are represented by only one major species, the Canada goose. This species, a common visitor to coastal South Carolina and Georgia, has become more abundant in recent years due to intensive management. Geese forage in water and on land, and large crops of grain in agricultural fields have attracted them.

Puddle ducks, probably the most abundant waterfowl group in coastal impoundments, include mallards, blue-winged teal, green-winged teal, gadwall, baldpate, wood ducks, and shovelers. Among the favorite food plants of puddle ducks are wild rice, spikerush, pondweeds, smartweeds, bulrushes, widgeon grass, acorns, cyprus balls, and various fruits (Kerwin and Webb 1972). Animals such as mollusks, insects, small fish, crayfish, and small crabs are also utilized for food to a lesser extent by the puddle ducks (Sprunt and Chamberlain 1970).

Pochards, or diving ducks, occupy a different niche in coastal impoundemnts from that of the puddle ducks. They feed in deeper waters of open bays, sounds, and coastal waters and are gregarious, tending to raft up in large flocks. Commonly occurring pochards include the ring-necked duck, canvasback, lesser scaup, greater scaup, and redhead. The ring-necked duck, canvasback, and redhead are more herbivorous than carnivorous and consume seeds of the water-lily, water-shield, and spikerush. Scaup, however, feed on a wide variety of animal matter.

Sea ducks play a relatively minor role in estuarine impoundments. Like the pochards, they spend most of their time in open bays and sounds and the sea. Buffleheads, hooded mergansers, and ruddy ducks are common winter residents which utilize deeper waters of impoundments. They are largely carnivorous, feeding on fish, insects, mollusks, and crustaceans. Sprunt and Chamberlain (1970) reported two records of hooded mergansers nesting in South Carolina. The hooded merganser is also more common than the common merganser and the red-breasted merganser and seldom mixes with these other two species, since they generally feed in different areas. The red-breasted merganser and common merganser include more fish in their diets than does the hooded merganser.

Rails, gallinules, and coots are commonly found in estuarine impoundments. The king rail is rarely seen in areas other than those characterized by freshwater vegetation, such as cat-tails and rushes, and is therefore not considered to be a resident of estuarine impoundments. Conversely, the clapper rail is commonly found at the water margins of estuarine impoundments where smooth cordgrass grows. This species is a common, permanent salt-marsh resident. The common gallinule is another common permanent resident, occurring in both brackish and freshwater impoundments. Gallinules frequently intermingle with coots and ducks and feed on plant and animal matter. The American coot, also a permanent resident, is extremely abundant in estuarine impoundments. Its food consists primarily of seeds, roots, vegetative parts of aquatic plants, smartweed, small fish, snails, tadpoles, and insects. The Virginia rail and the sora are other common winter residents which frequent the marshes and marsh edges within impoundments, consuming mixtures of animal and vegetable matter.

The herons, storks, and ibises constitute another group of birds which are abundant throughout much of the coastal ecosystem but especially in estuarine impoundments. Among the dominant or characteristic species within this habitat are the great egret, the snowy egret, the Louisiana heron, and the white ibis. Also occurring, but playing a moderate-to-minor role in ecological interactions, are the great blue heron, little blue heron, glossy ibis, green heron, black-crowned night heron, yellow-crowned night heron, and the wood ibis or wood stork.

Both the great and snowy egrets are common permanent residents in coastal impoundments. These "plume birds" have made a dramatic comeback since the days of Wayne (1910), when they were slaughtered for millinery purposes. Both species nest in rookeries within coastal South Carolina and feed in shallow water impoundments. The snowy egret appears to venture out into saltwater marshes and creeks more than does the great egret, which prefers freshwater ponds, marshes, and impoundments. These birds are commonly seen in communal roosts in trees adjacent to impoundments. The great egret is a still hunter and can be observed in a motionless stance seeking its prey. Its diet consists of small fishes such as gizzard shad, minnows, and sunfishes. Sprunt and Chamberlain (1970) reported that frogs, mice, lizards, fiddler crabs, grasshoppers and other insects, and even small alligators are consumed. In contrast, the snowy egret is an active hunter, always moving and stabbing at fiddler crabs, shrimp, snails, small fish, insects, frogs, and lizards. No other egret or heron feeds in this manner.

The Louisiana heron is perhaps the most abundant heron in the coastal area. It is a common permanent resident which nests in rookeries with other herons and ibises, as well as in dissimilar locations such as washed oyster shell banks and cypress lagoons. Its diet consists of killifish, shrimp, crayfish, spiders, and insects.

The little blue heron, also a common permanent resident, exhibits nesting and feeding habits similar to those of the Louisiana heron and also eats frogs, turtles, and snakes. The green heron and black-crowned night heron also are common permanent residents of impoundments. The yellow-crowned night heron is a common summer resident, but it is not as numerous around impoundments as are the other herons. The latter three herons feed on small fishes, crustaceans, and insects in the impoundments and congregate with other herons in nesting.

One of the most distinctive shorebirds occurring within impoundments is the willet. This species is a permanent resident of the South Carolina coast, occurring in great abundance during summer. These birds can often be seen feeding on small mollusks, fiddler crabs, and insects along the banks, flats, and shorelines of estuarine impoundments. Willets frequently nest along sandy overgrown impoundment dikes, as well as on barrier islands or in open pastures. They generally prefer areas where vegetation is tall enough to conceal the nests. Bent (1962a) gave a detailed description of willet nesting habits near Bulls Bay, South Carolina.

The greater yellowlegs, a permanent resident, is also a typical shorebird of impoundments and waterways throughout the coastal region. Although this bird feeds in the shallow like other shorebirds, its long legs enable it to use deeper waters in catching minnows, insects, and snails.

A number of other shorebirds, including the lesser yellowlegs, semipalmated plover, black-bellied plover, ruddy turnstone, dowitcher, and sandpipers, occur commonly in estuarine impoundments. However, two relatively rare birds, the American avocet and black-necked stilt, are undoubtedly among the most spectacular of impoundment shorebirds. Wayne (1910) never observed an avocet in coastal South Carolina, but in recent years this bird has been observed on numerous occasions in impoundments. Sprunt and Chamberlain (1970) reported that one specimen was taken in the Santee River in 1923, with the greatest number (about 50) observed on South Island in 1946. Apparently, these birds over-wintered there (Sprunt and Chamberlain 1970). American avocets are now observed annually in the South Island impoundments (Wilkinson 1970).

The black-necked stilt, a rare resident, is one of the most distinctive shorebirds in the coastal area. Wayne (1910) observed one pair of these birds during his many years in the field. Today, the stilt appears regularly in small numbers within the coastal area, and breeding records are now established (Sprunt and Chamberlain 1970).

The gulls and terns are represented in estuarine impoundments by the herring, ring-billed, and laughing gulls, and the common, least, royal, and Caspian terns. These birds feed to some extent in impoundments, particularly during summer fish kills caused by oxygen deficiencies. These birds also rest on open waters within impoundments.

The osprey and bald eagle, although uncommon in this habitat, have been observed to forage these impoundments in the Cape Romain-Santee Delta area of South Carolina (G. R. Garris, 1979, U. S. Fish and Wildlife Service, Awendaw, South Carolina, pers. comm.).

During the past 2 decades, there have been many ecological objections raised over the diking and impounding of wetlands. These objections are based on the following rationale: the blocking of tidal exchange results in a reduction of nutrient export; valuable marsh nursery grounds are lost for marine organisms; public interest factors are not considered. The objections could go further and in many cases the above rationale is reasonable. However, there are certain advantages to consider in evaluating coastal saltmarsh impoundments. Perhaps the greatest ecological advantage is the valuable habitat created for certain birds. Waterfowl, wading birds, shorebirds, and song birds find compatible niches in this ecosystem. As for adverse impacts, the use of pesticides in nearby agricultural areas (e.g., soybean fields, tomato crops, etc.) would appear to be the most damaging to avifauna. According to C. M. Bearden (South Carolina Marine Resources Division, 1978, Charleston, pers. comm.), there are fish kills annually in the coastal impoundments of lower South Carolina. Available evidence points to the use of pesticides in nearby agricultural lands as a leading cause. Many times, various birds are observed feeding on the dead fish, and occasionally a dead bird is found near the impoundments. The biological magnification of pesticides in avian populations is probably the greatest impact. These effects have been well documented over the years (U. S. Department of Interior, Fish and Wildlife Service 1962, 1963, 1964, 1965, Keith 1968). Borthwick et al. (1973) found mirex residues in 78% of birds collected from a study area near Charleston, South Carolina. The highest level of mirex was found in the belted kingfishers and demonstrated the fate of organochlorides in the estuarine environment.

Another important impact on birds in estuarine impoundments is hunting. Annually, there are thousands of waterfowl harvested from coastal impoundments in South Carolina.

8. Mammals

The mammals of saltwater impoundments have not been investigated. However, because mammal movement in the marsh is common, but controlled largely by the stage of the tide, this discussion will consider the role of mammals in estuarine marshes similar to their role in saltwater impoundments.

The herbivorous mammal most closely associated with the estuarine marsh, and the one of greatest ecological significance, is the marsh rabbit. This species occurs throughout the coastal region of South Carolina and feeds on a variety of herbaceous materials, including cordgrass (Golley 1962). Nevertheless, only a minor component of marsh plant material is consumed and routed through the food web via this pathway, and it is doubtful that the marsh rabbit is ever sufficiently abundant to control marsh plant levels.

Young and adult marsh rabbits constitute an important link in the food chain to birds of prey. Bent (1961), citing unpublished reports from Tomkins, reported that the marsh hawk in saltmarshes of South Carolina depends primarily on marsh rabbits during winter. In summer, other hawks no doubt exert considerable predation pressure. It is likely that predation rather than food supply is the principal population control on marsh rabbits. Specific population estimates have not been attempted, to our knowledge, but the marsh rabbit is known to be abundant in all coastal counties.

The marsh rabbit nests on the mainland adjacent to marsh, or on small brushy islands of dredged material scattered within the marsh, rather than within the intertidal portion of the marsh itself. The nest is usually concealed within dense brush or under fallen logs.

Breeding may occur year around, but in Georgia, Tomkins (1935) found peak reproductive activity in late winter, with a depressed period in the fall. The gestation period in Louisiana is reported by Lowery (1974) to be 28 - 32 days. Lowery stated that up to six litters per year may be produced by a single female. Tomkins (1935) estimated an average litter size in Georgia of three young. Even with a litter size that is small for rabbits in general, the frequency of breeding is sufficient to insure a high reproductive capacity.

A marsh herbivore that one might expect in the coastal marshes is the muskrat, but it is entirely absent. One reason for its absence may be the tidal range, because it occurs inland in South Carolina (Golley 1962, 1966). This species is present in coastal areas and is sufficiently abundant in coastal Louisiana marshes to provide the basis of a valuable fur industry. The U. S. Fish and Wildlife Service attempted to establish a muskrat colony on Cape Island in the Cape Romain National Wildlife Refuge in 1950 but, according to Golley (1966), the population did not survive. An ecologically related exotic mammal, the nutria, was introduced about the same time on Blackbeard Island in Georgia. Neuhauser and Baker (1974) indicated that nutria survived into the late fifties, but were extirpated by 1960. Wilson (1968) suggested that a few nutria may exist in the marshes around Brunswick, Georgia.

The meadow vole is not generally associated with the South Carolina coastal region, but a population was found in Charleston County near the Santee River. Skulls of 59 individuals were found in barn owl pellets (Nelson 1934), and specimens were taken in low stands of saltmeadow cordgrass on Cape Island in 1939; the latter record is based on museum records and is cited by Sanders (1978).

White-tailed deer often graze in the high marsh, feeding on saltmeadow cordgrass and on several species of glasswort. This is most common where the marsh is adjacent to dense cover. Unless pursued, deer seldom venture into the lower marsh due to its soft substrate. However, deer are excellent swimmers and will cross large marsh creeks. In addition to deer, several large domesticated herbivores such as horses, cattle, and goats, may utilize the upper elevations of the salt marsh. Florida manatees have also been observed grazing in Georgia marshes (M. Hardisky, 1978, Georgia Department of Natural Resources, Brunswick, pers. comm.).

The principal omnivorous mammal of the saltmarsh community is the marsh rice rat, which is also among the most highly aquatic of the coastal rodents. Unlike most other marsh mammals in this area, the marsh rice rat may remain permanently in the marsh. Nests are often made of cordgrass, but marsh rice rats also utilize abandoned nests of marsh wrens (Golley 1962). The most detailed study of the ecology of this species is that of Negus et al. (1961) on Breton Island in the Gulf of Mexico; no quantitative studies have been conducted in this area. Although regularly flooded salt marsh was not a major habitat on

Breton Island, much of the information provided by Negus et al. (1961) would be applicable to the coastal region of South Carolina.

Although many rodents are predominantly herbivorous, such is not necessarily the case with the marsh rice rat. Certainly, plant material is less important in its diet during some months than others (Fig. 2-4). Golley (1962) reported that marsh rice rats feed on cordgrass in Georgia coastal marshes, but they also utilize crabs (probably fiddler and other marsh crabs) and insects. Kale (1965) noted extensive predation by marsh rice rats on the eggs and young of the marsh wren. Sharp (1962) reported that the major portion of the diet of the marsh rice rat consisted of crabs and insect larvae. Such studies indicate that the marsh rice rat is an opportunistic omnivore.

Not only is the marsh rice rat an important predator within the estuarine wetlands, it is also an important prey species, especially for for birds. In addition to the recognized birds of prey (hawks and owls) which seek rodents in less densely vegetated sections of the marsh (Sprunt and Chamberlain 1970), many of the larger wading birds (e.g., great blue heron, great egret, night herons, wood stork) will also prey on rodents whenever they have the opportunity to do so (Bent 1963c).

Marsh rice rats seldom live more than 1 year, and they undergo dramatic seasonal changes in abundance (Negus et al. 1961). On Breton Island, decreases in population density appeared to be related to the duration and severity of the winter, and Negus et al. speculated that harsh winters influenced rat populations by controlling the food supply. These authors provided a simple model to show the relationship of environmental factors to population density (Fig. 2-5).

In most habitats, the raccoon is properly considered an omnivore, but it functions exclusively as a carnivore in the salt marsh. Raccoons utilize practically all coastal plains habitats, but their populations appear to be especially high in marshes and in woodlands adjacent to marshes. The raccoon is predominantly nocturnal, generally spending the day in its den in a large tree and leaving to forage at night. This behavior pattern may be somewhat modified in estuarine wetlands because of the tides. It is not unusual to see raccoons feeding in the marsh in full daylight on isolated coastal islands, but such observations are much less common near human habitations even though raccoon populations may be quite large there. The raccoon is without doubt the most characteristic medium-sized mammal of the coastal marshes. Within the marsh, it depends rather heavily on crustaceans (fiddler crabs, marsh crabs, juvenile blue crabs), competing with the clapper rail and white ibis for the same food resources. In addition to crustaceans, marsh mollusks are important food items, especially small intertidal oysters and mussels. Kale (1963) reported predation by raccoons on the nests and young of marsh wrens. Raccoons also constitute a source of mortality for clapper rail eggs and young.

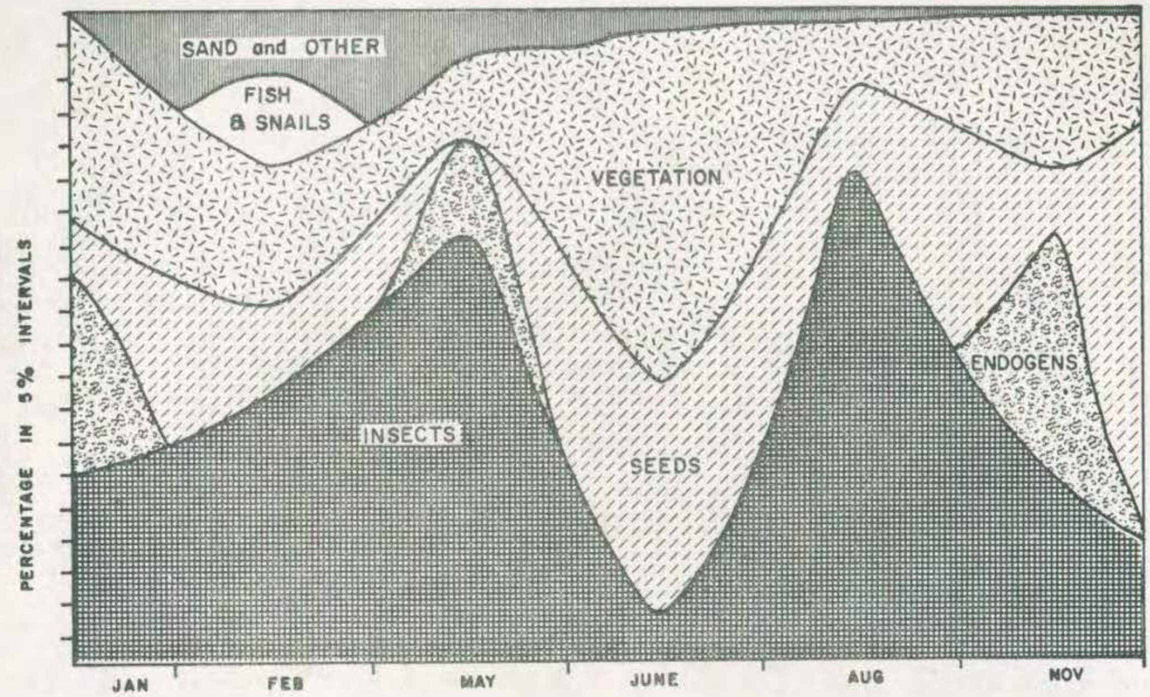

Figure 2-4. Food habits of marsh rice rat on Breton Island, Gulf of Mexico, as determined by stomach analyses of 61 animals from various seasons, 1957-1959 (Negus et al. 1961).

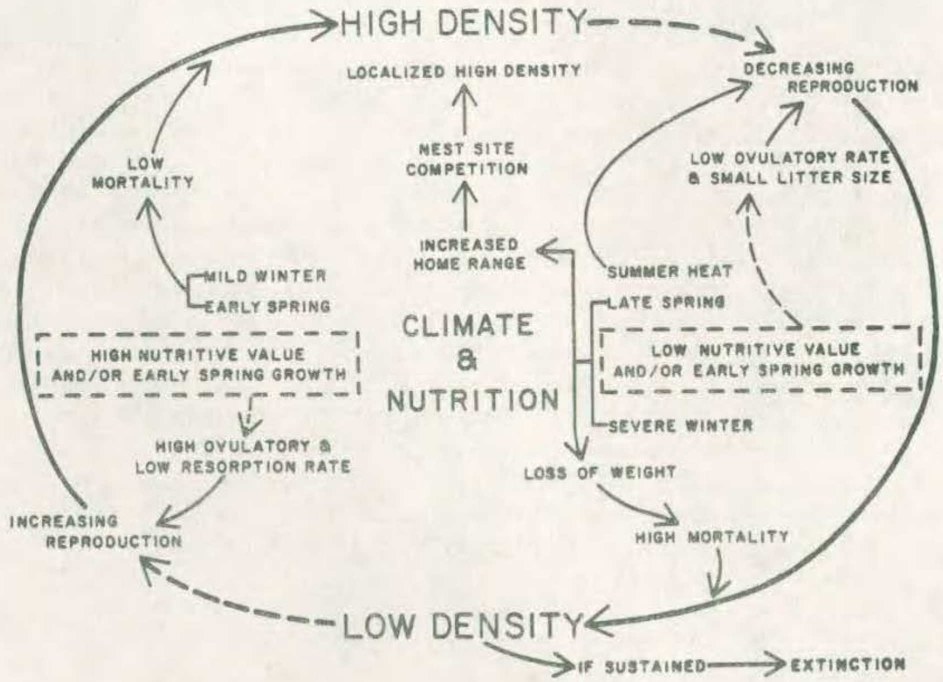

Figure 2-5. Schematic diagram of the Breton Island marsh rat population and its response to the environment. Dotted lines represent hypothetical aspects of the scheme (Negus et al. 1961).

The raccoon has few or no predators in high salinity wetlands, but alligators may cause significant mortality in low salinity marshes. Coastal areas and wetlands provide the raccoon a virtually unlimited food supply, so factors other than food must control its population levels. Hunting and trapping pressures on raccoons in coastal areas are rather light. The marsh or low country raccoon is considered to have a low quality pelt compared to upland populations. Probably the greatest single souce of raccoon mortality, other than disease, is the automobile. Yet, on many coastal islands this ceases to be an important element of mortality because automobile traffic is either nonexistent or extremely limited. At present, disease is probably the principal factor controlling raccoon populations. Raccoons are quite susceptible to a distemper-like respiratory disease, which is almost certainly density dependent.

In South Carolina and Georgia, the raccoon breeding season may range from late February into August, but the raccoon does not breed within the marsh because den trees are generally required for nesting. The gestation period is 63 days, and usually a single litter is produced each year. About 50% of females will breed when 1 year of age, but full size and maturity may not be attained until the second year. The young remain with the mother for several months after they are weaned, and they are given close attention and training.

The river otter is relatively abundant in salt marshes of the coastal region. Johnson et al. (1974) list this species as occurring on virtually all of the Georgia coastal islands. Sanders (1978) cited records from most South Carolina coastal counties, but it undoubtedly occurs in all. The river otter is entirely carnivorous in the marsh habitat and probably depends more on fishes and crabs than do the other marsh mammalian predators (Wilson 1954). Its numbers are too low to exert significant population controls on any of its prey organisms, and the otter itself is not subject to significant predation in this habitat. Factors controlling its population size are not known.

Like the river otter, the mink is a semi-aquatic mammal that frequently occupies coastal marshes, but it too is far from restricted to this environment. The diet of the mink is more varied and is likely to include marsh birds and marsh rodents along with fish and crustaceans (Golley 1966). Like the otter, this species occurs in relatively low population densities and is unlikely to control prey population levels.

Habitat destruction of the marsh would generally have the same effects on mammals as on other faunal components, except that most mammals are not permanent residents of the marsh. A few exceptions, however, should be noted. Most mammals, except for the most aquatic, make more extensive use of the high marsh than they do of the low marsh. Thus, partial filling which converts low marsh to high marsh may be a favorable change for mammals, despite the resulting loss of productivity to the aquatic system. Likewise, the former practice of building small islands within the marsh with dredge spoil material may create more favorable conditions for mammals.

With the notable exception of promoting or allowing domestic animals to graze in the marsh, most mammals on this coastline have little direct effect on the marsh habitat. Analyses of grazed and ungrazed transects suggest that grazing may not only crop down the vegetation but also may alter the zonation. Trampling by heavy mammals such as cattle and horses may have a direct unfavorable impact on some marsh plant species.

CHAPTER THREE

FRESHWATER IMPOUNDMENTS

A. DESCRIPTION

Freshwater coastal impoundments occur in tidal areas where salinity due to ocean-derived salts is below 0.5‰ (Cowardin et al. 1977). Biologically, freshwater environments have many similarities due to their common aquatic nature.

The primary producers in freshwater environments are vascular and non-vascular macrophytes and phytoplankton. These groups, along with detritus, form the trophic foundation of the freshwater food web. Bacteria and fungi decompose organic matter from the system, regenerating new nutrients. Rivers frequently bring large nutrient supplies into lake and impoundment systems. Floodplain systems fed by rivers sometimes have extremely high productivity rates (Wharton 1970, Kitchens et al. 1975). However, diversity in freshwater environments is not directly related to productivity. Highly productive systems may produce natural monocultures of aquatic vegetation (such as water-lily ponds, water hyacinth beds, or Porazilia elodea) with low faunal species diversities. Table 3-1 identifies common organisms occupying freshwater trophic levels and Figure 3-1 illustrates their relationships. Figure 3-2 is a modification of the Rawson Diagram (Rawson 1939). Although prepared many years ago, this diagram accurately portrays the physical characters of freshwater systems that directly or indirectly influence the biotic and abiotic cycles.

B. PRODUCERS

1. Nonvascular Flora

The nonvascular plants of freshwater environments in South Carolina have not been well studied. The earliest work in South Carolina and Georgia was performed by Ravenel, who did not publish until 1882. Bailey (1851) made collections from 60 sites in a trip through South Carolina, Georgia, and Florida, including many in Charleston and Jasper counties. He listed over 80 freshwater species from South Carolina and Georgia. Wood (1874) attempted the first comprehensive treatise on American freshwater algae, including many of his own collections from South Carolina as well as the records of Ravenel. Philson (1939) published a systematic survey of algae in South Carolina, listing 15 species of Cyanophyta; later, Philson (1940) added six new species of Oedogonium. Brown (1930) included South Carolina and Georgia in his listing of desmids from the southeastern coastal plain, and Frohne (1942) published a report on the occurrence of Phymatodocis in Jasper County, South Carolina, and several counties in Georgia. Corbin (1951) identified 15 new species of Myxophyceae in South Carolina, and Metcalf (1947) published a list of 54

Table 3-1. Trophic levels of freshwater consumers.

I. PRIMARY CONSUMERS (Feed directly on producers)	
Zooplankton	(cladocerans, rotifers, copepods)
Herbivorous invertebrates	(amphipods, mayfly larvae)
Granivorous and herbivorous birds	(Savannah sparrow, mallard)
Omnivorous vertebrates	(carp)
Granivorous and herbivorous mammals	(mice, shrews, deer)
II. SECONDARY CONSUMERS (Feed on primary consumers)	
Omnivorous invertebrates	(dragonfly larvae, isopods)
Omnivorous vertebrates	(salamanders, frogs)
Insectivorous birds	(short-billed marsh wren, northern parula)
Predacious fish	(crappie, bluegill)
Predacious reptiles and amphibians	(water snakes)
Mammals	(otter, raccoon, mink)
III. TERTIARY CONSUMERS (Feed on some secondary consumers)	
Omnivorous vertebrates	(salamanders, frogs)
Predacious reptiles and amphibians	(alligators, cottonmouths)
Predacious fish	(largemouth bass)
Piscivorous birds and birds of prey	(osprey, hawks, eagles)
Mammals	(bobcat, man)

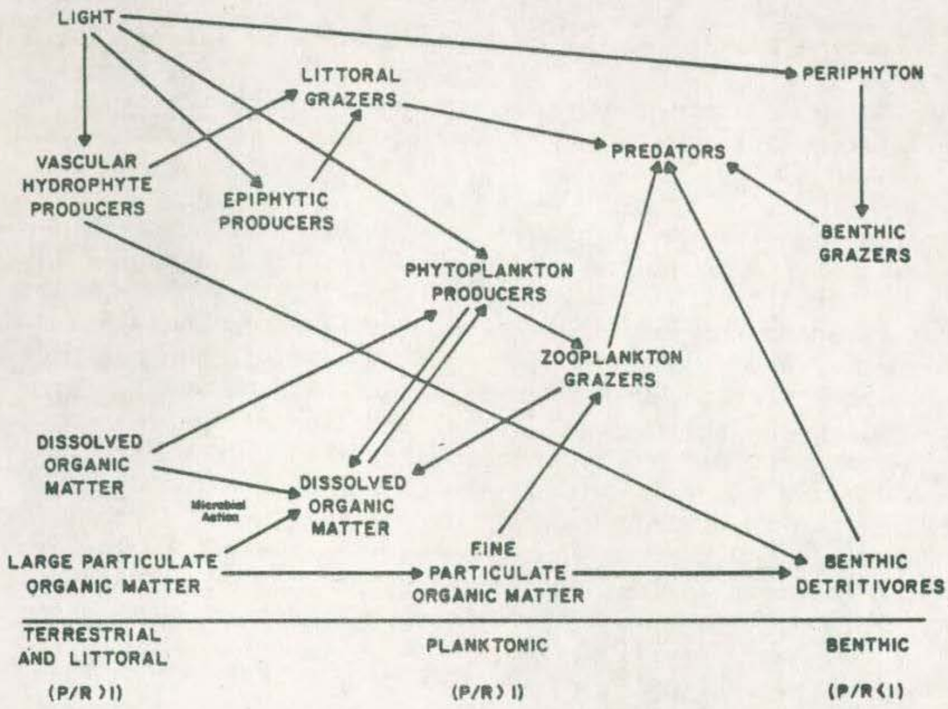

Figure 3-1. Simplified functional compartmentalization of freshwater ecosystems, with general production/respiration ratios (adapted from Cummins 1975).

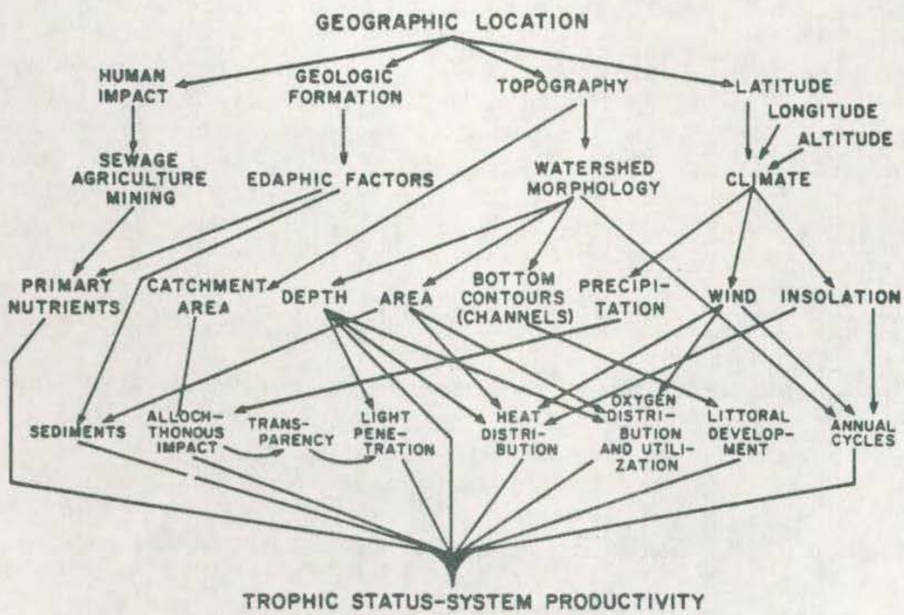

Figure 3-2. Productivity cycle of a freshwater system (adapted from Rawson 1939).

algal genera collected from a freshwater pond on Wadmalaw Island, South Carolina. In a study of the algae of the Savannah River Plant area, Macfie and Swails (1957) discovered a new species of Micrasterias. Dillard (1967) listed 44 algal taxa in a summary of his records for South Carolina.

In more recent studies, Jacobs (1968, 1971) listed 585 taxa in her preliminary survey of the freshwater algae of the Baruch Plantation in Georgetown, South Carolina. Zingmark (1975) listed 114 taxa from a freshwater pond in an environmental inventory of Kiawah Island, and Grant (1974) reported a dominance of diatoms (105 taxa) in the periphyton/phytoplankton component of the upper Cooper River-Tailrace Canal system in South Carolina. In an environmental assessment report for the Amoco Chemicals Corporation (Dames and Moore Associates 1975), four divisions of algae were collected as periphyton in the Cooper River area of South Carolina. Included in the four divisions were 33 species of diatoms, 8 species of chlorophytes, 2 species of cyanophytes, and 1 euglenoid. In the same study, a total of 35 phytoplankton species were identified, with diatoms the most abundant form in both periphyton and phytoplankton samples. Goldstein and Manzi (1976) listed a total of 259 taxa identified from freshwater fish culture ponds in South Carolina. Identified taxa included 146 Chlorophyta, 11 Pyrrophyta, 46 Cyanophyta, 45 Chrysophyta, 9 Euglenophyta, and 1 Rhodophyta. Numerous cryptophytes were noted, but none were identified to species. Among nonvascular flora, diatoms have received only limited detailed study in freshwater systems of the Southeast. In a study of haptobenthic algal flora in two North Carolina streams, Dillard (1966) reported a total of 70 diatom taxa. In his review of algal research in South Carolina (Dillard 1967), he reported only 25 diatom taxa. The Savannah River, which serves as both a political and natural boundary between South Carolina and Georgia, has been the site of intensive diatom research by the Academy of Natural Sciences of Philadelphia (Reimer 1966, Patrick et al. 1967). In a recent study (Camburn et al. 1978), haptobenthic diatom flora were studied in Long Branch Creek, South Carolina, to provide a detailed floristic survey of the diatom flora in an area of North America where few such studies have been conducted. They reported 268 diatom taxa representing 31 genera, the most numerous of which included Eunotia, Achanthes, Navicula, Pinnularia, Gomphonema, and Nitzschia. A complete listing of all freshwater species identified to date in the coastal counties of South Carolina has been published by Manzi and Zingmark (1978).

Algae that inhabit freshwater environments constitute a diverse assemblage with differing physiological requirements and variations in terms of tolerance to physical and chemical environmental parameters. The open water algae, phytoplankton, are regulated both spatialy and temporally by several major classes of environmental factors. Light, temperature, and turbidity interact with a number of inorganic and organic nutrient factors in the succession of algal populations. Unlike marine systems, successional periodicity in undisturbed freshwater systems is fairly constant. Seasonal changes are muted in lower latitudes, although periodicity of phytoplankton biomass and productivity are often out of phase, e.g., growth rates of blue-greens are rapid and turnover times are shortened during summer months in South Carolina.

Aside from the descriptive studies listed above, little is known about nonvascular plant associations and population dynamics in freshwater habitats of South Carolina.

2. Vascular Flora

Most freshwater impoundments in coastal South Carolina occur upstream from the river estuary in the freshwater zone. Water control structures are present for purposes of manipulating the impoundment water level and keeping out brackish water (if the impoundment is located near the brackish-fresh transition zone of the river). The principal use of these impoundments is for waterfowl feeding; however, some may be used for cattle pasturage, snipe hunting, planting cypress, or wildlife sanctuaries (Morgan 1974).

Morgan (1974) lists four possible types of wetlands that may occur in freshwater impoundments: 1) open water, 2) submerged plants, 3) pad plants, and 4) emergent plants. Baldwin (1956) lists four slightly different types: 1) summer drawdown edge; 2) shallowly flooded marsh; 3) pad plants, surface mats, and floating plants; and 4) submerged aquatics. Baldwin's type 1 and type 2 are generally emergents and coincide with Morgan's type 4; and, although Baldwin does not include an open water category, his type 3, which includes floating plants, seems to be broad enough to contain the open water type.

Emergent communities in freshwater impoundments are dominated by the smartweeds, spikerushes, red root, wild millet, Asiatic dayflower, giant cutgrass, panic grass, duck potato, cat-tails, alligatorweed, wild rice, and soft-stem bulrush (Baldwin 1956, Conrad 1966, Morgan 1974).

The submergent dominants are the pondweeds, coontails, bladderworts, fanwort, and proliferating spikerush (Baldwin 1956, Morgan 1974). Floating communities (pad, surface, and floating plants) are dominated by duckweeds and water-shield in open water areas, and by water-lily, white water-lily, frog's bit, pennyworts, and alligator-weed near shore (Baldwin 1956, Morgan 1974). (See Table 3-2 for a list of common marsh plants associated with freshwater impoundments in South Carolina.) Percival (1968) studied the ecology of six plant species commonly found in freshwater impoundments: Asiatic dayflower, water-shield, jointed spikerush, square-stem spikerush, tearthumb, and swamp smartweed. Here the influence of water level and soil acidity on species dominance can be seen. Table 3-3 presents summarized data from Percival (1968), the only available work on nutrients in freshwater impoundments in the coastal region. Quantitative nutrient information is available in other tables in that work.

Table 3-2. List of vascular plants associated with freshwater impoundments in South Carolina (adapted from Tiner 1977).

SCIENTIFIC NAME	COMMON NAME
Alternanthera philoxeroides	Alligator-weed
Aneilema keisak	Asiatic dayflower
Baccharis spp.	Sea myrtles
Brasenia schreberi	Water-shield
Cabomba caroliniana	Fanwort
Cephalanthus occidentalis	Button bush
Ceratophyllum spp.	Coontails
Cyperus erythrorhizos	Redrooted nutgrass
Cyperus odoratus	Sedge
Cyperus polystachos	Sedge
Cyperus spp.	Sedges
Echinochloa crusgalli	Wild millet
Echinochloa spp.	Millets
Egeria densa	Water-weed
Eichhornia crassipes	Water hyacinth
Eleocharis baldwinii	Proliferating spikerush
Eleocharis equisetoides	Jointed spikerush
Eleocharis quadrangulata	Square-stem spikerush
Elodea spp.	Water-weeds
Erianthus spp.	Plume grasses
Hydrochloa caroliniensis	Water grass
Hydrocotyle spp.	Pennyworts
Juncus effusus	Soft rush
Lachnanthes caroliniana	Redroot
Leersia hexandra	Rice cutgrass
Leersia oryzoides	Rice cutgrass
Lemna spp.	Duckweeds
Limnobium spongia	Frog's bit
Ludwigia peploides	Water-primrose
Melochia corchorifolia	Chocolate-weed
Myriophyllum heterophyllum	Water milfoil
Najas guadalupensis	Bushy pondweed
Nelumbo lutea	Lotus
Nelumbo pentapetela	Lotus
Nuphar advena	Spatter-dock
Nymphaea odorata	White water-lily
Panicum bisulcatum	Asiatic panic grass
Panicum dichotomiflorum	Fall panic grass
Panicum hemitomon	Maidencane
Paspalum boscianum	Bullgrass
Peltandra virginica	Arrow-arum
Pluchea spp.	Marsh fleabanes
Polygonum arifolium	Tearthumb
Polygonum densiflorum	Southern smartweed
Polygonum hydropiperoides	Swamp smartweed
Polygonum pensylvanicum	Large-seed smartweed
Polygonum portoricense	Southern smartweed
Polygonum sagittatum	Tearthumb
Polygonum setaceum	Swamp smartweed
Polygonum spp.	Smartweeds
Pontederia cordata	Pickerelweed
Potamogeton berchtoldii	Narrow-leaved pondweed
Potamogeton diversifolius	Variable-leaved pondweed
Potamogeton pectinatus	Sago pondweed

Table 3-2. Concluded

SCIENTIFIC NAME	COMMON NAME
Sagittaria graminea	Delta duck potato
Sagittaria latifolia	Duck potato
Sagittaria spp.	Arrowheads
Salix spp.	Willows
Scirpus validus	Soft-stem bulrush
Sesbania macrocarpa	Seban
Spartina cynosuroides	Giant cordgrass
Spirodela polyrrhiza	Big duckweed
Typha latifolia	Common cat-tail
Typha glauca	Blue cat-tail
Utricularia spp.	Bladderworts
Zizania aquatica	Wild rice
Zizaniopsis milliacea	Giant cutgrass

Table 3-3. Ecology of six common freshwater impoundment plants in the coastal plain of South Carolina (adapted from Percival 1968).

Taxa	Flood Regime	Ferrous Iron	Nitrate	Ammonium Nitrogen	Sulfate	pH	P	K	C	Mg	Dissolved Oxygen
Aneilema keisak (Asiatic dayflower)	flooded occasionally during growing season	low[a]	high[a]	high	low	slightly acidic[a]	low	low	high	low	*
Brasenia schreberi (Water-shield)	standing water throughout growing season	-	high	high	-	acidic	low	low	low	low	*
Eleocharis equisetoides (Jointed spikerush)	shallow flooding	low	low	high	low	slightly acidic	low	low	low	low	*
						slightly basic	*	*	*	*	
Eleocharis quadrangulata (Square-stem spikerush)	variable	low	low	low	low	slightly acidic	*	*	*	*	low
Polygonum arifolium (Tearthumb)	dry site	*	*	*	*	acidic	low	low	low	low	*
Polygonum hydropiperoides (Swamp smartweed)	saturated to slightly above soil level	*	*	*	*	acidic	*	*	*	*	*

a. Terms low, high, and slightly are comparative terms taken from the text of the study. For quantitative information, see data in the original source (Percival 1968).

* Results were indeterminate.

Succession in managed freshwater impoundments rarely proceeds in a natural sequence because of water level manipulations by impoundment managers. However, impoundments with constantly maintained water levels become dominated by floating and submergent vegetation. The dominants vary according to depth of impoundment, but white water-lily, duckweeds, coontails, and bladderworts are usually the most common species. Succession here is comparable to succession in shallow lakes.

The most widespread utilization of successional trends by the impoundment manager is summer drawdown. Drawdown (the lowering or removal of water) insures germination of many annuals, allows for seasonal burning, and permits grazing or cultivation (Baldwin 1950). Cultivated crops, such as corn, brown-top millet, wheat, barley, rye, soybean, and grain sorghum may be planted after drawdown (Tiner 1977). If cultivation is not the desired use, the period of drawdown may be shortened, promoting growth of various smartweeds. Prolonged drawdowns sometimes allow for germination of cat-tails, willows, and button bush, all undesirable plants to waterfowl management. Fanwort-pondweed beds, also undesirable, may be controlled by prolonged drawdown, with the more desirable muskgrass, a nonvascular plant, gaining dominance upon reflooding (Baldwin 1950).

In summary, successional trends are manipulated by impoundment managers to produce desired vegetation for the specific use the manager envisions, be it waterfowl management, grazing, or cultivation.

C. CONSUMERS

1. Zooplankton

Water pH greatly influences zooplankton communities. Separate faunas are found in acidic (as in lakes) and in alkaline (or basic) waters (as in rivers). Zooplankton assemblages of temporary ponds are characterized by groups which have very short life cycles and often exhibit desiccation-resistant stages. Such species are generally successful in temporary water bodies until predators become established in them. For example, the fairy shrimp *Streptocephalus seali* is a very common inhabitant of drainage ditches and other temporary waters but is rarely found in the stable, predator-rich waters of other coastal habitats (Moore 1955). N. A. Chamberlain (1978, College of Charleston, Charleston, South Carolina, pers. comm.) has found this species in two ponds in the Francis Marion National Forest (Berkeley County, South Carolina), and Coker (1938) reported it from a ditch near Society Hill, South Carolina. The freshwater decapod shrimp *Palaemonetes paludosus* is common in coastal South Carolina (P. A. Sandifer, 1978, South Carolina Marine Resources Division, Charleston, pers. comm.). Although larval development in this shrimp is abbreviated, it still exhibits a meroplanktonic larval phase. Certain zooplanktonic copepods are associated with bogs, swamps, and temporarily flooded areas. Robertson (1972), in studies of Oklahoma calanoid copepods, found that the preferred habitat of *Osphanticum laboronectum* was swampy areas. He also reported *Diaptomus salticulinus* present in temporary ponds, and *D. saskatchewanensis* present in swampy areas. Coker (1938) found *Cyclops crassicaudi* regularly occurred in wagon ruts near Chapel Hill, North Carolina. Insect larvae are also present in freshwater zooplankton but will be treated below.

Studies of the zooplankton of freshwater impoundments have not been conducted. Any research conducted on zooplankton in tidal freshwater areas is limited to Turner (1910). He listed 4 species of calanoid copepods, 10 cyclopoids, 1 harpacticoid, and 24 species of Cladocera from temporary and permanent ponds, ditches, and "holes fed by creeks" in the vicinity of Augusta, Georgia. While most Entomostraca were collected in submerged vegetation, many of these species would likely be planktonic on occasion. The copepod Cyclops serulatus and the cladoceran Simocephalus serrulatus were the most widely distributed species in Turner's samples. No Cladocera bearing "winter eggs" were found in these samples, even though temperatures were on occasion just above zero.

2. Insects

In the South Carolina coastal region, various insects of freshwater environments have a number of common life patterns and requirements, regardless of the habitat. Much of the following introductory material, which holds true for all of these environs, is summarized from Pennak (1953), Borror and Delong (1964), and Gosner (1971). Table 3-4 summarizes orders of hydrophilic insects, their basic life history patterns, and whether any species of each order are associated with salt or fresh waters, or both.

Eleven of the 30 to 35 orders of insects (depending upon the classification system followed) contain species that are partially or totally limnetic. Among the primitive insects that have no metamorphosis, Collembola (springtails) is the only order in which freshwater species occur. A few of these occur on the surface of ponds and pools.

The Hemiptera (true bugs) is the only paurometabolous (gradual metamorphosis) order containing freshwater forms. In this group, metamorphosis is gradual and the series of immature forms (nymphs) resemble adults except in size, body proportions, and wing development. Many species of Hemiptera occur below the surface in both nymphal and adult stages, while others move about the surface film.

The mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), and stoneflies (Plecoptera) are hemimetabolous insects. The adults are terrestrial, but a series of aquatic nymphs (naiads) occurs, usually possessing accessory gills.

The remaining six aquatic orders are holometabolous, with development stages consisting of the egg, active larva, acquiescent pupa, and adult. A few lacewings (Neuroptera), moths and butterflies (Lepidoptera), numerous beetles (Coleoptera), flies, mosquitoes, and midges (Diptera), and all alderflies, dobsonflies, and fishflies (Megaloptera), and caddisflies (Trichoptera) have aquatic larvae. All caddisflies and many dipterans have aquatic pupae. A very few hymenopterans are egg

Table 3-4. Summary of hydrophilic insect life history patterns and habitat distribution (adapted from Gosner 1971).

CLASS INSECTA	COMMON NAME	FRESH[a]	SALINE[b]	LIFE HISTORY[c]
Subclass Apterygota				
Order Collembola	Springtails	+	+	am
Order Thysanura	Bristle tails	shorelines		am
Subclass Pterygota				
Order Plecoptera	Stoneflies	+	-	he
Order Odonata	Dragonflies	+	+	he
Order Ephemeroptera	Mayflies	+	+	he
Order Hemiptera	True bugs	+	+	pa
Order Trichoptera	Caddisflies	+	+	ho
Order Megaloptera	Alderflies	+	-	ho
Order Neuroptera	Lacewings	+	-	ho
Order Lepidoptera	Butterflies, moths	+	+	ho
Order Diptera	Flies, mosquitoes	+	+	ho
Order Coleoptera	Beetles	+	+	ho
Order Hymenoptera	Wasps	Parasitic		ho

[a]Fresh = riverine, lacustrine, or palustrine waters and associated environs.
[b]Saline = marine or estuarine waters and associated environs.
[c]am = ametabolous; pa = paurometabolous; he = hemimetabolous; ho = holometabolous.

parasites, entering water only long enough to find and ovideposit on eggs of their aquatic hosts.

With few exceptions, aquatic insects are found near shorelines, in shallow waters, and where an adequate supply of oxygen exists. Only a few dipterans are consistently found in deeper lakes and in waters possessing reduced oxygen supplies. The free-moving plankton has evolved only in some of the midge (Diptera) larvae. The majority of insects aquatic in the adult stage are nektonic, as exemplified by the water beetles (Coleoptera) or neustonic and pleustonic as exemplified by the water striders (Hemiptera).

Hillestad et al. (1975) provided a listing of orders and families of insects from freshwater shrub marsh on Cumberland Island, Georgia (Table 3-5). Included in their collections were representatives of the insect orders Orthoptera, Hemiptera, Homoptera, Coleoptera, Diptera, and Hymenoptera. The Orthoptera were dominated by crickets (Gryllidae), followed by short-horned grasshoppers (Acrididae), roaches (Blattidae), and long-horned grasshoppers (Tettigoniidae). These were undoubtedly found in and around aerial portions of emergent vegetation, as these insects are not aquatic in any life stage (Pennak 1953, Borror and Delong 1964). This would also be true of the homopteran leafhoppers (Cicadellidae), froghoppers and spittlebugs (Cercopidae), and the hemipteran assassin bugs (Reduviidae). Toad bugs (Hemiptera: Gelastocoridae) were also present and are generally associated with moist shores of ponds, marshes, and streams (Pennak 1953). The beetles (Coleoptera) were the most diverse in numbers of families (9), with the ground beetles (Carabidae) being predominant. Dipterans (true flies) and hymenopterans (ants and sawflies) were also common.

3. Benthic Invertebrates

Commonly occurring benthic invertebrates of freshwater pond and impoundment ecosystems include sponges, hydrozoans, turbellarians, nematodes, rotifers, bryozoans, oligochaetes, leeches, pelecypods, gastropods, ostracods, harpacticoid and cyclopoid copepods, isopods, amphipods, crayfish, numerous larval insects, several species of adult bugs and beetles, and arachnids such as water mites and fisher spiders.

Invertebrates of temperate ponds undergo pronounced seasonal patterns of activity and faunal density. Activity is minimal during the winter, and the fauna is variously adapted for survival of cold water temperatures. Several types of "resting stages" are known, particularly in the lower invertebrate phyla. Gemmules, consisting of a mass of cells protected by a hard inner membrane and an outer layer of columnar spicules, are formed by sponges during autumn. Certain hydroids and entoprocts lose their hydranths and calyces, respectively, during late autumn or winter and enter a dormant stage. Species in a number of taxa, including the Hydrozoa, Turbellaria, and Rotifera, produce "winter eggs" which survive the cold. Freshwater bryozoans form dormant statoblasts, consisting of a cell mass covered by chitinous valves. Produced in enormous numbers

Table 3-5. Numbers of orders and families of insects collected from freshwater shrub marsh on Cumberland Island, Georgia (adapted from Hillestad et al. 1975).

INSECTS	COLLECTION DATA (1973)											
	June 14	June 26	July 3	July 10	July 17	July 24	July 31	Aug. 7	Aug. 14	Aug. 22	Aug. 27	TOTAL
ORTHOPTERA												
Acrididae	-	1	-	2	-	-	5	-	7	-	-	15
Gryllidae	7	2	25	18	30	17	15	18	-	18	13	163
Tettigoniidae	1	-	-	-	-	-	-	-	-	-	-	1
Blattidae	-	-	-	-	-	2	-	-	-	-	1	3
HEMIPTERA AND HOMOPTERA												
Cicadellidae	1	-	-	-	-	-	-	-	-	-	-	1
Reduviidae	-	-	-	-	-	-	-	1	-	-	-	1
Cercopidae	-	-	-	1	1	2	-	1	-	2	-	7
Gelastocoridae	-	1	-	-	2	1	-	1	-	-	-	5
COLEOPTERA												
Histeridae	4	-	-	-	-	-	-	1	1	-	-	6
Carabidae	18	4	9	13	12	11	13	4	8	1	3	96
Curculionidae	4	-	-	1	1	-	1	2	2	-	-	11
Elateridae	2	-	-	2	2	3	2	1	-	-	-	12
Scarabaeidae	-	-	1	1	1	2	3	1	2	2	-	13
Staphylinidae	-	1	1	-	-	-	-	1	1	1	-	5
Hydrophilidae	-	-	-	1	-	-	-	-	-	-	-	1
Tenebrionidae	-	-	-	-	-	-	-	2	-	-	-	2
Cicindelidae	-	-	-	-	-	-	-	1	-	-	-	1
DIPTERA	1	-	8	5	-	4	3	2	6	-	5	34
HYMENOPTERA												
Formicidae	1	-	5	7	7	15	12	6	12	14	8	87
Pompilliidae	-	1	-	-	-	1	-	1	-	-	-	3
TOTAL	39	10	49	51	56	58	54	43	39	38	30	467

during summer and autumn, these statoblasts provide an important means of dispersal as well as being tolerant of both low temperatures and desiccation. With the return of favorable environmental conditions, each of these "resting stages" opens and begins development. Other species, including some annelids, mollusks, and arthropods, burrow into the sediments and hibernate. A few, such as certain oligochaetes, mollusks, insect larvae, isopods, and amphipods, may remain active all winter. As temperatures rise in late winter and early spring, faunal activity increases markedly and reproductive cycles commence for many species. Insects such as mayflies, caddisflies, and dragonflies, which constitute an important part of this freshwater benthos as larvae, metamorphose into adults and leave the water. In contrast, several other insects, including water bugs (Notonectidae, Corixidae, Belostomatidae, Naucoridae) and water beetles (Haliplidae, Dytiscidae, Noteridae, Gyrinidae, Hydrophilidae), are common pond inhabitants as adults.

Water levels frequently drop in these environments during summer, and some periodically dry up. Despite this, such ponds support a community of benthic invertebrates made up of both temporary and permanent residents. Many temporary residents are insect larvae whose development is sufficiently rapid to ensure metamorphosis prior to the time when such ponds normally go dry. Permanent residents either burrow in sediments and aestivate, or survive as cysts or other stages adapted to withstand drying. Species numbers are usually lower in these habitats than in "permanent" ponds, and are also reduced in ponds having low levels of dissolved oxygen. Nevertheless, species adapted to such conditions are often present in large numbers.

Dragonflies (Odonata) and other invertebrates of a 1-ha (2.5 acre) farm pond at the Savannah River Plant near Aiken, South Carolina, were studied by Cross (1955), Benke (1972, 1976), and Benke and Benke (1975). Benke (1976) observed a density of 10,000 larval midges (Chironomidae)/m^2 in Ekman grab samples taken from May to September. Biomass of larval midges and mayflies (largely Caenis sp.) amounted to 0.6 g/m^2 (dry weight), or about two-thirds of the total macrobenthos other than dragonflies. The remaining third consisted mostly of beetles (Coleoptera) and horseflies and deer flies (Tabanidae), although caddisflies (Trichoptera), biting midges (Ceratopogonidae), damselflies (Zygoptera), predacious bugs (Hemiptera), and various microcrustaceans were also present. Biomass of the dominant larval dragonflies (Ladona deplanata, Eiptheca spp., and Celithemis fasciata) during May-September was about 6 g/m^2, while total odonate biomass was estimated at 8 g/m^2. Such high predator-to-prey ratios were possible because of high turnover rates in prey populations. Sufficient refuges were also believed by Benke (1976) to be responsible for preventing the annihilation of prey populations. Since high populations of larval dragonflies have been observed elsewhere on the Savannah River Plant and in a lagoon near Athens, Georgia, Benke and Benke (1975) suggested that they may be a predominant feature of pond ecosystems in the Southeastern United States.

The ecology and community structure of benthic invertebrates in freshwater ecosystems of the South Carolina coastal region have generally been ignored and constitute a major data gap.

4. Fishes

Most freshwater impoundments in the coastal region, as stated previously, are former rice fields with dikes in varying stages of erosion, allowing free exchange of water and ichthyofauna with the various other subsystems such as palustrine emergent wetlands. The small portion of former rice fields that have maintained dikes are managed primarily for waterfowl. Shallow water impoundments managed for waterfowl average 30-45 cm (12-18 in) in depth and are dry at varying intervals, some annually, others no more than once every 10 years (R. J. Rhodes, 1978, South Carolina Marine Resources Division, Charleston, pers. comm.). Centrarchids are by far the dominant fish family occurring here. Redfin and chain pickerel, bowfin, largemouth bass, carp, longnose gar, mosquitofish, golden shiner, bullheads, gizzard shad, and threadfin shad are the most prominent species of this impoundment type (Table 3-6).

The vast majority of fish species inhabiting freshwater impoundments are nest building spawners. Carp, redfin pickerel, and longnose gar are among the few exceptions. The sunfish family is especially successful in reproducing in this habitat and is susceptible to overpopulation (Swingle 1950, Lagler 1956). Most species prefer to nest near or among submerged vegetation or obstructions, though spawning will occur throughout the habitat.

During periods of drawdown in former rice fields, or during low water in small impoundments, piscivorous birds, mammals, reptiles, and amphibians concentrate in large numbers around these canals and pools. Vultures, foxes, bobcats, and opossums regularly feed on dead fish washed ashore during periods when die-off occurs.

5. Amphibians and Reptiles

Because of their juxtaposition to riverine systems, herptiles inhabiting freshwater tidal impoundments do not differ substantially from those of the river itself. Combinations of abundant food, diverse aquatic vegetation, restricted water flow, and proximity of dry land in impoundments, however, tend to create an ecotonal effect. Thus, certain species such as greater sirens, dwarf waterdogs, and two-toed amphiumas find this habitat more favorable than the adjacent river. These aquatic amphibians are generally found among subtidal vegetation, bottom debris, or roots of floating aquatics (Conant 1975, Harrison 1978). Food items of amphiumas and sirens include crustaceans, mollusks, worms, insects, small fish, etc. (Conant 1975). Freshwater impoundments also provide good habitat for the aquatic rainbow snake and eastern mud snake, which feed primarily on the American eel and eel-like salamanders, respectively (Conant 1975, Wharton 1978).

Several species of turtles exhibit relatively generalized requirements for aquatic habitats and are found regularly in impoundment communities. Such species include the common snapping turtle, eastern mud turtle, and stinkpots (Conant 1975). These species are nocturnal and seldom bask

Table 3-6. Habitat utilization by 82 species of freshwater fishes inhabiting impoundments of the coastal counties of South Carolina. (C-Common, F-Frequent, 0-Occasional, R-Rare)

Species	Lacustrine		Palustrine			Riverine
	Littoral	Limnetic	Forested Wetlands	Emergent Wetlands	Impoundments	Open Water
Lepisosteidae						
Longnose gar	F	C	R	O	C	C
Florida gar	O	F	R	O	O	F
Amiidae						
Bowfin	C	O	C	C	C	F
Clupeidae						
Gizzard shad	F	C	F	O	C	C
Threadfin shad	O	C	O	O	C	C
Umbridae						
Eastern mudminnow	C	R	C	C	C	R
Esocidae						
Redfin pickerel	C	R	C	O	R	R
Chain pickerel	C	O	C	C	C	O
Cyprinidae						
Goldfish	C	O	C	C	C	F
Carp	C	O	C	C	C	C
Cypress minnow	O	O	C	C	O	O
Silvery minnow	C	C	O	O	O	O
Rosyface chub	R	R	F	F	R	F
Bluehead chub	O	O	C	C	O	C
Golden shiner	C	C	C	C	C	C
Ironcolor shiner	O	O	C	C	F	O
Dusky shiner	C	O	C	O	O	F
Pugnose minnow	F	F	F	F	F	F
Ohoopee shiner	R	R	R	R	R	F
Taillight shiner	F	F	F	F	F	O
Whitefin shiner	C	F	O	O	O	C
Coastal shiner	C	C	F	F	F	C
Fathead minnow						
Catostomidae						
Creek chubsucker	C	C	O	C	C	C
Lake chubsucker	C	C	O	C	C	C
Spotted sucker	F	F	C	C	F	C
Black jumprock	O	O	F	F	O	F
Suckermouth redhorse	O	O	F	F	O	F
Ictaluridae						
Snail bullhead	F	O	O	O	F	C

Table 3-6. (Continued).

Species	Lacustrine		Palustrine			Riverine
	Littoral	Limnetic	Forested Wetlands	Emergent Wetlands	Impoundments	Open Water
Icataluridae (Continued)						
White catfish	C	C	C	C	C	C
Blue catfish	C	C	O	F	F	C
Yellow bullhead	C	C	F	C	C	C
Brown bullhead	C	C	F	C	C	F
Flat bullhead	C	C	F	F	C	C
Channel catfish	C	C	F	C	C	C
Black madtom	O	R	C	C	O	O
Tadpole madtom	O	R	C	C	O	O
Margined madtom	O	R	C	C	O	O
Speckled madtom	O	R	C	C	O	O
Flathead catfish	O	O	F	F	R	C
Amblyosidae						
Swampfish	F	R	F	F	F	R
Aphredoderidae						
Pirate perch	O	R	C	C	C	R
Cyprinodontidae						
Golden topminnow	F	O	C	C	F	R
Banded topminnow	O	R	F	F	O	F
Marsh killifish	O	O	O	O	F	R
Starhead topminnow	C	O	C	C	C	F
Spotfin killifish	O	O	O	O	F	R
Pygmy killifish	F	R	C	C	F	R
Bluefin killifish	F	R	R	F	F	R
Rainwater killifish	C	R	F	C	C	R
Poeciliidae						
Mosquitofish	C	C	C	C	C	F
Least killifish	C	O	C	C	F	O
Sailfin molly	F	O	C	C	C	O
Atherinidae						
Brook silverside	C	F	F	C	C	F
Percichthyidae						
White perch	C	C	O	O	C	C
White bass	C	C	O	O	C	C
Centrarchidae						
Mud sunfish	C	O	C	C	C	R
Flier	C	F	C	C	C	O
Everglades pygmy sunfish	C	O	F	C	C	R

Table 3-6. (Concluded).

Species	Lacustrine		Palustrine			Riverine
	Littoral	Limnetic	Forested Wetlands	Emergent Wetlands	Impoundments	Open Water
Centrarchidae (Continued)						
Okefenokee pygmy sunfish	C	O	F	C	C	R
Banded pygmy sunfish	C	O	F	C	C	R
Blackbanded sunfish	F	R	F	C	F	R
Bluespotted sunfish	F	O	C	C	F	R
Banded sunfish	C	R	F	C	F	R
Redbreast sunfish	F	O	C	C	F	F
Green sunfish	C	F	F	C	C	C
Pumpkinseed	C	F	F	C	C	O
Warmouth	C	O	C	C	C	O
Bluegill	C	F	C	C	C	F
Dollar sunfish	C	F	C	C	C	F
Longear sunfish	C	F	C	C	C	F
Redear sunfish	C	C	F	C	C	F
Spotted sunfish	C	F	C	C	C	F
Largemouth bass	C	C	C	C	C	C
White crappie	C	C	C	C	C	F
Black crappie	C	F	C	C	F	C
Percidae						
Swamp darter	O	O	C	C	O	O
Tessellated darter	O	O	C	F	F	O
Sawcheek darter	O	O	C	F	F	O
Yellow perch	F	F	O	C	F	C
Logperch	O	R	C	O	O	O
Blackbanded darter	F	R	C	O	O	R

(J. R. Harrison, 1978, College of Charleston, Charleston, South Carolina, pers. comm.). The striped mud turtle is found in extreme southern Georgia and would probably inhabit impoundments found within its range. Other turtles which occupy impoundments include Florida cooters, yellowbelly sliders, eastern chicken turtles, Florida softshells, and Gulf Coast spiny softshells (Conant 1975, Mount 1975, Gibbons 1978). Young Florida cooters are omnivorous, whereas the young of yellowbelly sliders are primarily carnivorous; adults of both species are herbivorous. Eastern chicken turtles, Florida softshells, and Gulf Coast spiny softshells are carnivorous (Mount 1975). Turtles lay eggs above the normal high-water line, with the emydids and trioncychids preferring sandy, friable soil, while kinosternids select soil of high organic content for nesting sites (Mount 1975). Levees provide nesting substrates.

Aquatic vegetation in impoundments is relatively abundant with many emergent (pickerelweed, arrowhead, cat-tail, cutgrass), floating (alligator-weed), and floating-leaved plants (water-lily, floating heart). These plants often occur in dense stands or mats and, if not too expansive, improve the habitat for many frogs and water snakes. Hylids occuring among emergent or floating vegetation in freshwater impoundments throughout the coastal region include southern cricket frogs, Cope's gray treefrogs, green treefrogs, and squirrel treefrogs (Conant 1975, Harrison 1978). The Florida cricket frog is found throughout peninsular Florida and along the immediate Georgia coast north to the Savannah River, while the southern cricket frog is found throughout most of the remaining coastal plain of Georgia and all of that of South Carolina (see Conant 1975 for distribution). In the Savannah National Wildlife Refuge, the northern cricket frog has invaded old rice fields along the Savannah River (J. R. Harrison, 1978, College of Charleston, Charleston, South Carolina, pers. comm.). This species is considered rare in the coastal zone (Harrison 1978).

Floating vegetation and levees provide temporary habitat for ranid frogs. Common inhabitants include bullfrogs, pig frogs, bronze frogs, and southern leopard frogs. Presently within the South Carolina coastal region, freshwater impoundments are perhaps the most ideal habitat for pig frogs. It is in this habitat that they are most abundant, and males can be heard calling among floating and herbaceous emergent vegetation day and night during spring and summer (Wright and Wright 1949).

The close proximity of dry land, water, abundant vegetation, and food contribute to make freshwater impoundments prime habitat for aquatic serpents. Redbelly water snakes, banded water snakes, brown water snakes, and cottonmouths are common or even locally abundant (Conant 1975, Gibbons 1978). Floating vegetation near levees also provides good habitat for rough green snakes and eastern ribbon snakes (Conant 1975). The green anole is abundant among vegetation near aquatic environments (Gibbons 1978) and would not be unexpected among emergent aquatics in impoundments. Species uncommon or rare in impoundments are generally uncommon or rare throughout the coastal zone. These species include the Florida green water snake, glossy crayfish snake, and the Carolina and north Florida swamp snakes (Martof 1956, Conant 1975, Gibbons 1978). In extreme southeastern Georgia, adjacent to Florida, the striped crayfish snake is found in impoundment-type habitats, albeit uncommonly (Martof 1956, Conant 1975).

The area immediately north and south of the Savannah River is a transition zone for several subspecies of herptiles common to freshwater impoundments. In addition to the southern cricket frogs already mentioned, subspecies of ribbon snakes, swamp snakes, and cottonmouths differ between most of coastal Georgia and most of coastal South Carolina. The peninsula ribbon snake, north Florida swamp snakes, and Florida cottonmouth inhabit most of coastal Georgia, whereas the eastern ribbon snake, Carolina swamp snake, and eastern cottonmouth inhabit most of coastal South Carolina (Conant 1975).

6. Birds

Colonial Wading Bird Rookeries. Supported by an abundance of estuarine and freshwater swamp habitat, the coastal region of South Carolina maintains a high population of colonial wading birds. Reinforced by large food supplies, stable water regimes, and freedom from disturbance, colonial wading birds continue to thrive and reproduce in nesting colonies scattered throughout the area.

Although colonial wading bird rookeries have been known from this area for well over 100 years, little documentation existed prior to 1975 for comparisons of present and past populations. However, recent studies by Odom (1976), Custer and Osborn (1977), Osborn and Custer (1978), and Sprunt et al. (1978) have located and censused approximately 291 colonies of egrets, herons, and their allies along the Atlantic coast of the United States. (See Davis et al. (1980) for rookery locations.)

Twelve avian species are commonly associated with wading bird rookeries, as indicated in Table 3-7. Of these, four species are considered dominant: the white ibis, cattle egret, Louisiana heron, and snowy egret. All are common residents that occur most frequently in rookeries.

There are eight types of colonies based on the selection of habitat. These can be broadly classed as upland sites, inland swamps, estuarine islands, and small ponds. Upland sites are the least common of wading bird rookeries, as their use is largely confined to the great blue heron and the great egret. This type of colony is typically small, with less than 150 pairs of birds, and has no standing water. Nests are usually constructed in tall pine trees (loblolly pine and slash pine) with a very dense understory often composed of myrtle (wax myrtle), cabbage palmetto, or saw palmetto.

Inland swamp sites can be divided into two distinct types, natural swamps and man-made swamps or reserves. Natural swamp locations are commonly sloughs where standing water has accumulated. Nests are often constructed in bald cypress, black gum, sweet bay, water tupelo, or willows. Nesting success and site tenacity are highly variable in this type and are highly dependent on the availability of standing water.

Man-made or artificial swamps are primarily the remnants of early attempts to cultivate rice in the eighteenth century. Old rice fields gradually undergoing succession are sometimes utilized, if standing water is present and adequate nesting platforms are provided by water-tolerant

Table 3-7. Colonial wading birds commonly associated with rookeries in the South Carolina coastal region (Sprunt and Chamberlain 1949, 1970, Burleigh 1958, Audubon Field Notes 1967-1970, Chamberlain 1968, American Birds 1971-1977, Shanholtzer 1974b, Forsythe 1978).

DOMINANT			MODERATE			MINOR		
White ibis	C	PR	Great egret	C	PR	Great blue heron	FC	PR
Cattle egret	C	PR	Little blue heron	C	PR	Yellow-crowned night heron	FC	PR
Louisiana heron	C	PR	Glossy ibis	FC	PR	Green heron	C	PR
Snowy egret	C	PR	Black-crowned night heron	C	PR	Anhinga	C	PR

Note: Dominance indicates relative importance of the species as a group in the community. This concept is not based necessarily on taxonomic relationships but rather on numbers, size, and trophic dynamics.

KEY: D - Common, seen in good numbers.
FC - Fairly common, moderate numbers.
PR - Permanent resident, present year around.

trees. Most commonly, old reserves or water storage areas provide the rookery sites. These areas are often large, up to several hundred acres, and constantly maintain standing water several feet deep through a system of dikes and ditches. Long abandoned, old rice field reserves frequently contain dense old growth stands of bald cypress, water tupelo, swamp tupelo, and red maple. The understory is sparse, limited chiefly to button bush, sweet bay, and fetter-bush. The stability of the reserve rookery made it the most favored site for many wading birds prior to the advent of spoil islands in the 1940's. Populations in reserve colonies were typically large, with thousands of pairs of herons, egrets, and ibises a common sight. All locally breeding species of colonial wading birds were represented, with the exception of the great blue heron, which is locally distributed.

Small ponds are also utilized by colonial wading species, although in reduced numbers. As a general type, small ponds can be divided into alligator holes, island sloughs, and artificial ponds. Alligator holes are commonly found throughout the lower coastal plain and can be characterized by their small size and presence of a hole 5-10 ft (1.5 - 3.0 m) deep created by the alligator in times of drought. Vegetation around these holes is typically composed of willows, wax myrtle, and cabbage palmetto. Alligator holes are often used by such species as the green heron, anhinga, black-crowned night heron, and yellow-crowned night heron, which often form small isolated colonies. For this reason, there are doubtlessly many more colonies of this type than are currently known.

Island sloughs are limited to barrier islands where they are formed between dune ridges. Also known as cat-eye ponds (Hayes et al. 1975), these sloughs are frequently without standing water and are subject to rapid succession. Vegetation may be composed of cat-tails, willows, wax myrtles, popcorn trees, or cabbage palmettos. Island sloughs often support a variety of wading birds in moderate numbers (Chamberlain and Chamberlain 1975). Artificial or man-made ponds include farm ponds, waterfowl impoundments, and diggings of the remnant phosphate industry of the latter portion of the last century. These ponds vary widely in size and shape and in the numbers of birds using them. Vegetation is primarily wax myrtle, willow, cabbage palmetto, and button bush.

Estuarine islands also play an important role in rookery site selection, and these may be classed as natural islands or dredge spoil islands. Natural islands afford isolation and reduced predation, but they are also subject to storm overwash and erosion. Vegetation is often sparse, dominated by smooth cordgrass, black needlerush, saltmeadow cordgrass, seabeach panic grass, and occasionally wax myrtle. Man-made spoil islands are a recent addition to nesting sites selected in estuarine areas. Beginning in the late 1940's, these areas received periodic spoil disposal until they were significantly higher than surrounding marsh islands. As vegetation became established, spoil islands became attractive to colonial wading species. Such islands are utilized highly by wading birds in the early stages of vegetative succession when sea myrtle and wax myrtle are dominant. Utilization continues as species such as sugarberry and white mulberry dominate, but bird populations decline as these species develop a closed canopy (T. A. Beckett, 1978, Charleston, South Carolina, pers. comm.; E. Cutts, 1978, Charleston, South Carolina, pers. comm.).

In South Carolina, the greatest numbers of wading birds are concentrated on spoil islands, natural swamps, and old reserves. Individual colony locations with estimates of species composition and population levels are given in Table 3-8.

The distribution of wading bird colonies in the coastal zone of South Carolina is subject to yearly fluctuation. Small colonies are more vulnerable to such factors as disturbance and predation than are large, well-established rookeries that have been active for several years (Buckley and Buckley 1976). In support of this observation, one small colony studied in coastal Georgia suffered a minimum nestling mortality of 50% in four of its five species. Predation resulted in nest destruction, and when no attempt to re-nest was made, the colony was abandoned (Teal 1958a). Weather conditions are also a major cause of colonial fluctuation, particularly when drought reduces the available food supply. The white ibis is extremely sensitive to drought and often responds with massive population shifts (Dusi and Dusi 1968). Tidal overwash can also force population shifts on estuarine islands, particularly when eggs are washed during the critical incubation period (P. J. DeCoursey, 1978, University of South Carolina, Columbia, pers. comm.). White ibis are also known to make dramatic shifts in nesting locations without apparent cause. In 1950, about 1,000 pairs of white ibis deserted a well-known South Carolina rookery that had been occupied continuously for 28 years (Sprunt 1922, Denton et al. 1950). Yearly fluctuations between rookeries are also common, as noted between Drum Island and Pumpkinseed Island in South Carolina (T. A. Beckett, 1978, Charleston, South Carolina, pers. comm; P. J. DeCoursey, 1978, University of South Carolina, Columbia, pers. comm.). A more unusual shift in populations was noted in 1975 when the white ibis from the two above-mentioned rookeries relocated in the Okefenokee Swamp, Georgia, over 200 miles (322 km) in distance (Ogden 1978).

In spite of yearly population shifts, several large rookeries have been in continuous use for over a half century. Blake's Reserve, known to be an active rookery since 1823, had a population of five species with 1,125 pairs in 1922, not radically different in size from its present population (Sprunt and Chamberlain 1949; Charleston Museum, 1922, Charleston, South Carolina, unpubl. data).

Variation in rookery populations is closely tied to both species composition and history. At the turn of the century, wading birds were under extreme pressure from plume hunters and egg collectors. Breeding populations were reduced to the point that formerly abundant species such as the great egret and snowy egret were almost extinct (Wayne 1910). By the 1930's, these birds had made a strong comeback, with the little blue heron the most abundant breeder (Sprunt and Chamberlain 1949, Burleigh 1958, Ogden 1978). Beginning in the 1920's, the gradual northern range extension of the white ibis began. This massive population movement was

Table 3-8. Wading bird colonies in South Carolina and Georgia (compiled from Chamberlain and Chamberlain 1975; Odom 1976; Custer and Osborn 1977; T. A. Beckett, 1978, Charleston, pers. comm.; L. Blue, 1978, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, pers. comm.; L. L. Gaddy, 1978, South Carolina Marine Resources Division, Charleston, pers. Comm.; J. Shuler, 1978, South Carolina Wildlife and Marine Resources Department, Columbia, pers. comm.; P. M. Wilkinson, 1978, South Carolina Wildlife and Marine Resources Department, Charleston, pers. comm.).

LOCATION	COORDINATES	SPECIES FEATURED	ESTIMATED NESTS (ADULTS)	COMMENT
South Carolina 1 Pumpkinseed Island Georgetown County	33°17'0 " 79°12'30"	Little blue heron	200 (400)	1978 down due to overwash
		Cattle egret	250 (500)	
		Great egret	500 (1,000	
		Snowy egret	450 (900)	
		Louisiana heron	1,000 (2,000)	
		Black-crowned night heron	40 (80)	
		Glossy ibis	125 (250)	
		White ibis	19,500 (39,000)	
South Carolina 2 Cat Island Plantation Georgetown County	33°14'0 " 79°15'30"	Great blue heron	25 (50)	
South Carolina 3 Esterville Plantation Georgetown County	33°15'30" 79°17'00"	Great egret Anhinga	UNKNOWN	
South Carolina 4 Kinloch Plantation Georgetown County	33°12'42" 79°19'32"	Great blue heron Great egret Little blue heron Yellow-crowned night heron Anhinga	200 total nests. Specifics unknown	
South Carolina 5 Blake's Reserve Charleston County	33°08'30" 79°23'0 "	Great blue heron Great egret Snowy egret White ibis Black-crowned night heron Yellow-crowned night heron Anhinga Cattle egret Glossy ibis	200 pairs of GBH and GE. No recent population figures available	
South Carolina 6 Marsh Island Charleston County	32°58'00" 79°37'00"	Great egret	26 (52)	Louisiana heron and snowy egret figures combined
		Louisiana heron } Snowy egret }	398 (796)	
		Glossy ibis	1 (2)	

Table 3-8. Continued

LOCATION	COORDINATES	SPECIES FEATURED	ESTIMATED NESTS (ADULTS)	COMMENT
South Carolina 7 White Banks Charleston County	33°01'00" 79°30'00"	Cattle egret	2 (4)	Figures for snowy egret and Louisiana heron combined
		Glossy ibis	9 (18)	
		Little blue heron	3 (6)	
		Louisiana heron }	730 (1,460)	
		Snowy egret }		
South Carolina 8 Awendaw Charleston County	33°03'00" 79°33'15"	Snowy egret	200	Estimates now out of date
		Great egret	300	
		Little blue heron	UNKNOWN	
		Louisiana heron	UNKNOWN	
South Carolina 9 Penny Dam Charleston County	32°58'50" 79°44'15"	Great egret Snowy egret Little blue heron Anhinga White ibis	UNKNOWN	No recent surveys
South Carolina 10 Richmond Plantation Berkeley County	33°03'0 " 79°58'0 "	Great blue heron	UNKNOWN	No recent surveys
South Carolina 11 Daniel's Island Berkeley County	32°50'15" 79°55'30"	Louisiana heron Little blue heron Black-crowned night heron Yellow-crowned night heron White ibis	UNKNOW	No recent surveys
South Carolina 12 Drum Island Charleston County	32°48'45" 79°55'30"	Great egret	200 (400)	Largest rookery in S.C. No recent accurate survey-population figures given are 1974. Cattle egrets were well into the hundreds in 1978.
		Snowy egret }	2,000 (4,000)	
		Louisiana heron }		
		Little blue heron	UNKNOWN	
		Cattle egret	UNKNOWN	
		Black-crowned night heron	200 (400)	
		Yellow-crowned night heron	25 (50)	
		Green heron	UNKNOWN	
		White ibis	20,000 (40,000)	
		Glossy ibis	100 (200)	

Table 3-8. Continued

LOCATION	COORDINATES	SPECIES FEATURED	ESTIMATED NESTS (ADULTS)	COMMENT
South Carolina 13 Castle Pinckney Charleston County	33°48'40" 79°55'30"	White ibis	25 (50)	
South Carolina 14 Magnolia Gardens Charleston County	32°52'17" 80°04'17"	Snowy egret	350 (700)	
		Louisiana heron	12 (24)	
		Little blue heron	10 (20)	
		White ibis	6 (12)	
		Black-crowned night heron	7 (14)	
		Cattle egret	350 (700)	
		Anhinga	50 (100)	
South Carolina 15 Kiawah Island Charleston County	32°27'0 " 80°02'30"	Great egret	7 (14)	An additional 28 nests were probably cattle egrets
		Snowy egret } Little blue heron }	50 (100)	
		Louisiana heron		
		Green heron	5 (10)	
		Cattle egret	50 (100)+	
		Anhinga	5 (10)	
South Carolina 16 Deveaux Bank Charleston County	32°32'30" 80°10'0 "	Snowy egret	350 (700)	
		Louisiana heron	400 (800)	
		Cattle egret	12 (24)	
		Glossy ibis	2 (4)	
South Carolina 17 St. Helena Beaufort County	32°18'05" 80°38'20"	Great egret	15 (30)	
		Little blue heron	4 (8)	
		Cattle egret	25 (50)	
		Black-crowned night heron	4 (8)	
		Anhinga	3 (6)	
South Carolina 18 Buckfield Plantation Beaufort County	32°42'55" 80°50'40"	White ibis Snowy egret Great egret Cattle egret Little blue heron Black-crowned night heron Anhinga	UNKNOWN	No recent survey

Table 3-8. Continued

LOCATION	COORDINATES	SPECIES FEATURED	ESTIMATED NESTS (ADULTS)	COMMENT
South Carolina 19				
Pinckney Island Plantation	32°17'0 "	Great egret	2 (4)	
Beaufort County	80°47'30"	Cattle egret	15 (30)	
		Black-crowned night heron	2 (4)	
		Yellow-crowned night heron	12 (24)	
		Anhinga	2 (4)	
South Carolina 20				
Daufuskie Island	32°7 '0 "	UNKNOWN	UNKNOWN	Small rookery known to have herons and egrets but no recent survey available
South Carolina 21				
Whooping Crane Pond	32°14'07"	White ibis	1,000 (2,000)	White ibis estimates range to 2,000 pairs; however all nesting reduced during 1978 season
Hilton Head Island	80°43'11"	Great egret	100 (200)	
Beaufort County		Cattle egret	UNKNOWN	
		Snowy egret	500 (1,000)	
		Louisiana heron	UNKNOWN	
		Green heron	UNKNOWN	
		Anhinga	12 (12)	
South Carolina 22				
Cypress Pond	32°14'07"	White ibis	UNKNOWN	No survey available but activity reduced in 1978 season
Hilton Head Island	80°44'17"	Cattle egret		
Beaufort County				
South Carolina 23				
Taylor Property	32°12'30"	White ibis	UNKNOWN	No recent survey
Hilton Head Island	80°42'24"	Cattle egret		
Beaufort County		Great blue heron		
		Yellow-crowned night heron		
		Green heron		
		Anhinga		
South Carolina 24				
Arcadia Plantation	33°23'30"	UNKNOWN	(+ 100)	No recent survey but large numbers of herons are known to breed
Georgetown County	79°18'55"			

an important influence on the character of present-day rookeries in South Carolina. While Florida was the recognized center for breeding white ibis, this species was known to breed as far north as the Altamaha Swamp region of Georgia in the 1860's (Burleigh 1958, Bent 1962a). By 1922, however, the white ibis was breeding in South Carolina and was increasing in numbers from the original discovery of a few hundred to nearly 3,000 birds in 1947 (Sprunt 1922, Sprunt and Chamberlain 1949). Today, the white ibis is the dominant breeding colonial wading bird in South Carolina and Georgia, with a total population estimated at 65,000 birds (Ogden 1978).

The number of wading birds breeding in the Southeast was also supplemented by the natural introduction of the cattle egret from Africa via South America. Although this species arrived in North America about 1942, the first breeding record for Florida was 1953 (Sprunt 1954). The cattle egret extended its range rapidly, reaching Georgia in 1954 and South Carolina in 1953 (Burleigh 1958, Burton 1970). The first record of the cattle egret breeding in South Carolina was in 1956, when two pairs were found on Drum Island in Charleston Harbor (Burton 1970). The present breeding population is estimated at 25,000 individuals for both Georgia and South Carolina, while in Florida the cattle egret population exceeds all other wading birds in the eastern United States by 70,000 individuals (Custer and Osborn 1977, Ogden 1978).

The cattle egret has not only extended its range north along the Atlantic coast, but has also moved inland to become a dominant breeding wader in the upper coastal plain and Piedmont regions of South Carolina and Georgia (Davis 1960, Post 1970). In inland areas, the cattle egret does not compete with other waders to any significant level since the other species are less common. However, it has been accused of competing successfully against the little blue heron in coastal areas, although there is currently little evidence to support such a belief (Ogden 1978).

One other species, the glossy ibis, is also a recent addition to the wading birds breeding in the coastal area. Arriving in South Carolina in 1947 and Georgia in 1949, the glossy ibis populations have remained well below that of the white ibis and cattle egret (Sprunt and Chamberlain 1949, Burleigh 1958).

The breeding season for wading species in the South Carolina coastal region begins in late February and early March when the larger species begin concentrating as a prelude to the actual nesting process. Depending on the severity of winter, great blue herons begin nesting from mid-to-late March. Great egrets follow in late April to early May, as do the other species with the exception of the little blue heron. Nesting of the little blue heron normally occurs in late May or June, resulting in increased competition with the final arrival of the cattle egret in June or July (Sprunt and Chamberlain 1949, Burleigh 1958). Competition in the rookery commonly involves nest site selection and stealing of nesting material.

Although there are several types of rookeries based on habitat, there are only three general types based on composition: upland colonies, mixed species colonies, and night heron colonies. Upland colonies are dominated by the great blue heron and occasionally include nesting great egrets. Mixed species colonies usually contain great blue herons or great egrets which occupy taller nest sites throughout the colony (Burger 1978, Wiese 1978). Smaller species fill out the balance of the colony, with green herons and yellow-crowned night herons occupying the outer edge, if they are present (Sprunt and Chamberlain 1949). Due to the solitary nature of the yellow-crowned and black-crowned night herons, they often nest in small, remote colonies. This is particularly common of the yellow-crowned night heron, which is much less social than the black-crowned night heron (Wayne 1910, Sprunt and Chamberlain 1949, Bent 1963c).

Several species are commonly found in small numbers in association with colonial waders. The most common is the anhinga or snake bird. The anhinga was found in 46% of South Carolina's colonies, as listed in Table 3-8. Common gallinules are also found in freshwater rookeries, as are clapper rails in estuarine colonies (T. A. Beckett, 1960-1977, Charleston, South Carolina, unpubl. data). Common grackles are also commonly associated with wading bird colonies where they nest at the fringe of the colony and occasionally prey on the eggs of unguarded nests (Sprunt and Chamberlain 1949).

Two of the more unusual species associated with wading bird colonies are the osprey and the great horned owl. The osprey has colonized Blake's Reserve for many years and now boasts a population of approximately 39 pairs (P. M. Wilkinson, 1978, South Carolina Wildlife and Marine Resources Department, Charleston, pers. comm.; T. A. Beckett, 1978, Charleston, South Carolina, pers. comm.). On rare occasions, the great horned owl has also been known to inhabit wading bird colonies, rebuilding abandoned great blue heron or osprey nests (Bent 1963c; T. A. Beckett, 1969, Charleston, South Carolina, unpubl. data).

One of the principal causes of low productivity in wading birds is the loss of eggs and young to predators. Figure 3-3 gives a simplistic view of the trophic relationships commonly associated with wading bird colonies. Avian predators include such raptors as the red-tailed hawk and the barred owl, but the fish crow is commonly the most destructive (Sprunt and Chamberlain 1949; Dusi and Dusi 1968; T. A. Beckett, 1978, Charleston, South Carolina, pers. comm.). Roving in large flocks, fish crows can virtually eliminate a rookery by destroying unguarded eggs. Such behavior was responsible for the loss of one South Carolina rookery in the 1950's (Cutts 1955). At the intermediate level, two predators are also members of wading bird colony. Both the black-crowned night heron and yellow-crowned night heron are known to prey on young of other herons, egrets, and ibis. On Drum Island in South Carolina, the ground beneath the nests of night herons is often strewn with partially digested nestling white ibis and cattle egrets which the young night herons are unable to swallow (T. A. Beckett, 1978, Charleston, South Carolina, pers. comm.). External predators include such familiar animals as raccoons and American alligators, but snakes and even man also play important roles (Teal 1958a, Bent 1963c, Dusi and Dusi 1968). In the recent past, local crabbers had to be prevented from using young herons

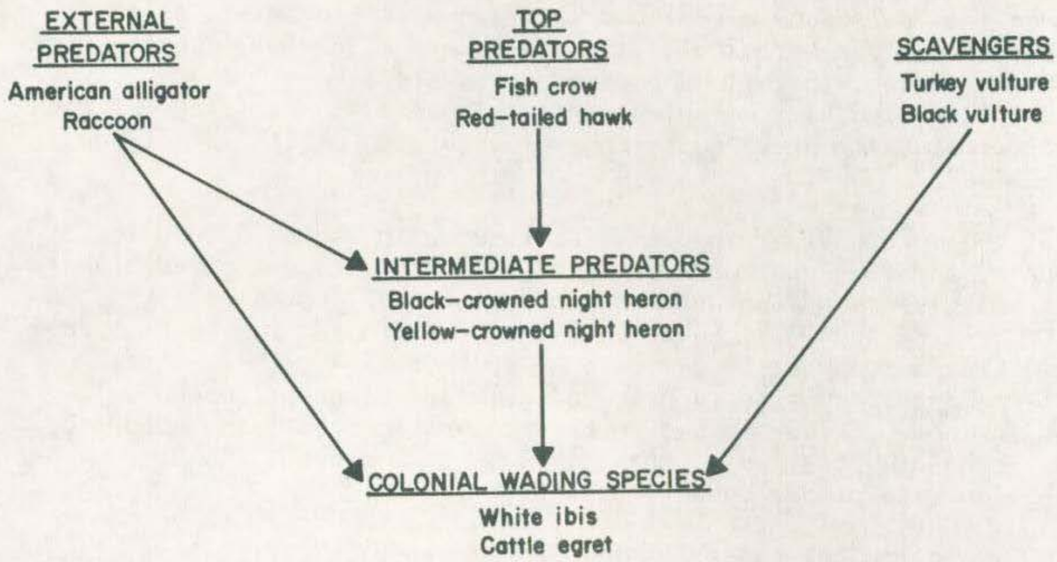

Figure 3-3. Trophic levels associated with colonial wading birds.

and egrets for bait in South Carolina (T. A. Beckett, 1978, Charleston, South Carolina, pers. comm.).

Although predation takes a heavy toll on young wading birds, other factors reduce breeding productivity. Poor nest site selection and poor nest construction result in the loss of some eggs and young, as does cannibalism in some species such as the cattle egret (Dusi and Dusi 1970). On a much greater scale, site disturbance during the early, critical portion of the breeding season can cause nest desertion and wholesale loss of young (Buckley and Buckley 1976). Introduction of certain environmental pollutants has also caused infertility and eggshell thinning, further contributing to low reproductive success (Ohlendorf et al. 1978).

The future of wading birds in South Carolina is generally projected to be good. If the application of chlorinated hydrocarbon pesticides remains under strict control, there should be no reduction of nesting productivity as experienced in the 1950's and 1960's. While coastal (particularly estuarine) colonies are expanding in numbers, inland sites are undergoing population reductions as freshwater swamp habitat is coming under increased developmental pressure (Ogden 1978). Although the range extension of the cattle egret has masked this problem to a degree, the cattle egret has also expanded at such a rate that it may seriously threaten native species such as the little blue heron and snowy egret through nesting competition (Dusi and Dusi 1970, Ogden 1978).

Impoundments. To separate out birds of freshwater impoundments from those of freshwater emergent wetland areas would be purely artificial. In reality, they are inseparable,and ecological disturbance which might affect birds in one habitat inevitably affect birds in the other habitat. Therefore, the following section will discuss birds of impoundments and emergent wetlands as one ecological unit.

The freshwater nonforested wetlands of the upper Santee, Edisto, Combahee, and Savannah Rivers of the South Carolina coastal plain are ideally suited to the needs of a variety of birds. The subtle transition from brackish water to fresh water produces an abundant natural food supply through a diversity of vegetation (Tomkins 1958, Wharton 1978). The emergent wetland plants, together with those in adjacent natural upland and man-made levees, create habitat and structural foundations for feeding, roosting, and breeding activities of many birds. Peak periods of utilization of freshwater nonforested wetlands by birds occur during spring and fall migrations.

Feeding habitats may be quite seasonal, coinciding with shifts in diet. For example, diets of the red-winged blackbird and seaside sparrow shift from a carnivorous diet in spring and summer to a granivorous diet in fall and winter when wild rice seed is readily available. Meanley (1972) studied the importance of wild rice and other freshwater marsh plants to the red-winged blackbird and found that seeds of smartweed, wild rice, millet, and corn formed the bulk of its diet during late summer and fall.

Often, nesting occurs in wetland areas where feeding also occurs; the long-billed marsh wren is a prime example. Other birds, such as herons, assemble in nesting colonies but feed primarily in a variety of locations some distance away. Both breeding and non-breeding species use the freshwater nonforested wetlands as roosting and/or resting sites. Swallows, marsh wrens, and red-winged blackbirds are examples of plant roosting species, whereas the king rail is a ground roosting species. Racks of dead marsh grass also act as resting sites for shorebirds.

There is an obvious overlap of habitat requirements for many of the birds found in salt, brackish, and freshwater wetlands. Birds of prey such as the marsh hawk, osprey, and bald eagle are frequently observed soaring over estuarine and freshwater emergent wetlands and impoundments. Perching birds such as the red-winged blackbirds, long-billed marsh wren, sparrows, and grackles, are also found in both kinds of wetlands. On the other hand, some species are more habitat selective. For instance, the boat-tailed grackle is a familiar bird in the estuarine area, but it rarely overlaps with the common grackle, a permanent resident of the coastal plain which nests in colonies near freshwater marshes. Macgillivray's seaside sparrow provides another interesting example of habitat selectivity. This species is a permanent resident of the coastal plain and, because of its prevalence in the salt marshes during fall and winter, Wayne (1910) looked in these areas for nesting birds. However, Wayne's efforts were fruitless. Later, Sprunt (1924) accidentally found this species nesting in a brackish/freshwater marsh area. Since then, the nesting habitats of Macgillivray's seaside sparrow have been well documented in freshwater nonforested wetlands rather than in salt marshes.

Approximately 78 species of birds occur in this habitat (Table 3-9). Of these, only 22 species should be considered as dominant, based on relative abundance and their ecological roles in this habitat. Dominant permanent residents include the belted kingfisher, barn swallow, long-billed marsh wren, great blue heron, great egret, white ibis, yellowthroat, eastern meadowlark, common grackle, and red-winged blackbird. Dominant winter residents include the marsh hawk, American kestrel, eastern phoebe, tree swallow, short-billed marsh wren, Savannah sparrow, and the swamp sparrow.

Ecologically, avifauna of the freshwater nonforested wetlands can be divided into seven trophic levels. These are the predators, omnivores, granivores, insectivores, herbivores, piscivores, and scavengers (Fig. 3-4). The marsh hawk and sparrow hawk are the more common birds of prey in this habitat. However, the osprey and bald eagle occupy the highest avian trophic levels in the coastal plain.

While the osprey is fairly common in both South Carolina and Georgia, the bald eagle is reportedly observed more in South Carolina than in Georgia. Recently, there have been few reports of bald eagles nesting in Georgia. One of the last reported active bald eagle nests in Georgia was on St. Catherines Island in 1970 (W. D. Chamberlain, 1978, South Carolina Marine Resources Division, Charleston, unpubl. data). However, Burleigh (1958) reported bald eagles nesting previously on the Georgia coast at St. Marys, Cumberland Island, Blackbeard Island, Darien, Savannah,

Table 3-9. Dominant, moderate, and minor bird species of palustrine nonforested wetlands in the Sea Island Coastal Region (Sprunt and Chamberlain 1949, 1970, Audubon Field Notes 1967 - 1970, Chamberlain 1968, American Birds 1971 - 1977, Forsythe 1978).

DOMINANT		MODERATE		MINOR	
Marsh hawk	C WR	Black vulture	C PR	Swallow-tailed kite	U SR
American kestrel	C WR	Turkey vulture	C PR	Mississippi kite	FC SR
Chimney swift	C SR	Sharp-shinned hawk	FC WR	Bald eagle	R PR
Belted kingfisher	C PR	Red-tailed hawk	C PR	Osprey	FC PR
Eastern phoebe	C WR	Red-shouldered hawk	C PR	Merlin	U WR
Tree swallow	C WR	King rail	FC PR	Yellow rail	R WR
Barn swallow	C PR	Field sparrow	C PR	Black rail	R SR
Long-billed marsh wren	C PR	Sora	FC WR	Short-eared owl	FC WR
Short-billed marsh wren	FC WR	Rough-winged swallow	C SR	Bank swallow	U T
Great blue heron	C PR	Purple martin	C SR	Cliff swallow	U T
Great egret	C PR	White-throated sparrow	C WR	House wren	C WR
Green heron	C PR	Song sparrow	C WR	Virginia rail	FC WR
Snowy egret	C PR	Black-crowned night heron	C PR	Purple gallinule	FC SR
White ibis	C PR	Least bittern	FC SR	Common gallinule	FC PR
Louisiana heron	C PR	Glossy ibis	C SR	Yellow-crowned night heron	FC SR
Little blue heron	C PR	Mallard	C WR	American bittern	U SR
Yellowthroat	C PR	Blue-winged teal	C WR	Wood stork	FC PR
Eastern meadowlark	C PR	Green-winged teal	C WR	Black duck	C WR
Red-winged blackbird	C PR	Palm warbler	C WR	Gadwall	U WR
Common grackle	C PR	Bobolink	C T	Pintail	C WR

Table 3-9. Concluded

DOMINANT		MODERATE		MINOR	
Savannah sparrow	C WR	Rusty blackbird	C WR	Shoveler	C WR
Swamp sparrow	C WR	Painted bunting	C SR	Ring-necked duck	C WR
				Greater scaup	C WR
				Lesser scaup	C WR
				Bufflehead	C WR
				Ruddy duck	C WR
				Hooded merganser	C WR
				Red-breasted merganser	C WR
				American coot	C WR
				Grasshopper sparrow	FC WR
				Henslow's sparrow	FC WR
				Le Conte's sparrow	U WR

Note: Dominance indicates relative importance of the species as a group in the community. This concept is not based necessarily on taxonomic relationships but rather on numbers, size, and trophic dynamics.

KEY: C - Common, seen in good numbers
FC - Fairly common, moderate numbers
U - Uncommon, small numbers irregularly
PR - Permanent resident, present year around
WR - Winter resident
SR - Summer resident
T. - Transient

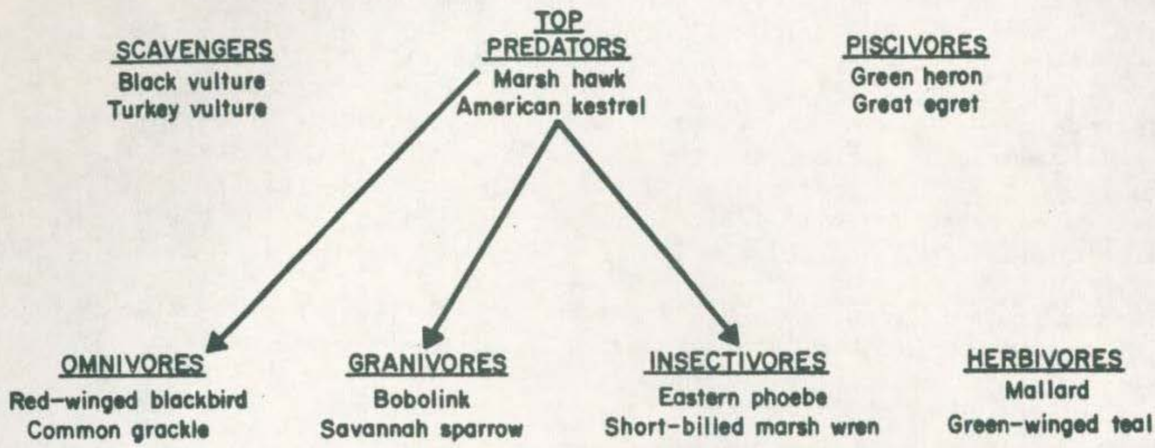

Figure 3-4. Generalized trophic relationships of representative birds of freshwater nonforested wetlands of the South Carolina Coastal Region.

and little Tybee Island. Hebard (1941) cites a number of records for the Okefenokee Swamp in Georgia. The large number of impoundments in South Carolina has been suggested as a major factor in the number of nesting eagles in that State.

The bald eagle is a piscivore as well as a raptor, preferring fish as a stable diet item when available, although carrion is also readily taken. The bald eagle also catches some birds, especially waterfowl and American coots, and some mammals. Bald eagles will often force ospreys to drop fish, which then are caught in mid-air by the eagle (Burleigh 1958). In the coastal plain, nests are usually constructed in living pines, mainly slash or loblolly. Large, old trees with big crowns are usually selected. Such trees are seldom less than 70 years old (Chamberlain 1974). Perch trees are apparently a necessary component of the nesting habitat. They may be located as far as one-quarter mile from the nest and, generally, define the nesting territory. The territory size varies from 28 to 112 acres (12 to 47 ha), with an average of 57 acres (24 ha). There are approximately 18 nesting territories in the South Carolina coastal region (Table 3-10).

A number of factors have contributed to the decline in bald eagle populations (e.g., shooting, electrocution, loss of suitable nesting areas, and severe weather). The greatest single factor at this time, however, seems to be the lowering of reproduction caused by pesticide build-up in the food chain. The effect of such accumulation in bald eagles has caused an almost complete lack of reproduction in many nests. Key habitat requirements for the bald eagle include suitable nest trees and roost sites, and water areas which can provide adequate supplies of suitable food, mainly fish. During migration, the bald eagle will travel considerable distances from water and is then sometimes seen in the mountains, but at all other times the eagle shows a strong preference for coastal areas or for large inland bodies of water. It does not tolerate intense human activity, hence requiring relatively large areas with little disturbance (Chamberlain 1974).

As shown in Figure 3-4, there is a common ecological bond between the marsh hawk and American kestrel and the typical omnivores, grainivores, and insectivores in the freshwater nonforested habitat. The bobolink, or ricebird, a rather abundant granivore in the spring and fall, is a target species for the birds of prey. The bobolink has been characterized as a destructive bird in the lower coastal plain, due to its depredations on the rice crops in the mid-1800's. The Eastern phoebe, an insectivore, is also linked to the birds of prey. This species is a flycatcher and consumes mostly insects in its diet. The red-winged blackbird and common grackle (omnivores) are also common components of the freshwater nonforested trophic structures.

Waterfowl are well represented in this habitat by dabbling ducks such as the mallard, gadwall, blue-winged teal, green-winged teal, pintail, and wood duck. For these ducks, the freshwater vegetation present in nonforested wetlands is more important for feeding than that of salt marsh areas (Kerwin and Webb 1972). Of the pochards, the ring-necked duck

Table 3-10. Active Southern bald eagle nesting territories in South Carolina coastal region during 1978 season[a] (T. M. Murphy, 1979, South Carolina Wildlife and Marine Resources Department, Green Pond, unpubl. data).

Savannah River east of Highway I-95
Hunting Island
Two on Combahee River between Highway 17 and Highway 17-A
Combahee River east of Highway 17
Chehaw River
Two on Ashepoo River east of Highway 17
Dawhoo Creek
Four on Cooper River north of the Tee
Two in Santee Coastal Reserve
South Island
Cat Island
Winyah Bay, east of Highway 17

[a]Lake Marion and Lake Wateree are probable nesting territories outside the coastal region.

is more commonly found in freshwater areas. This is probably due to its food preferences, as it feeds on seeds of the water-lily, water-shield, etc. The canvasback is also commonly found in this habitat, where it feeds on vegetable matter.

Closely associated with the waterfowl are the American coot, king rail, yellow rail, Virginia rail, and sora. All of the above species have similarities but also major differences in their diets. According to Horak (1970), the sora, having a short heavy beak, consumes about 73% seeds in its diet. The Virginia rail, with its long, slender decurved beak, eats approximately 62% insects. These differences in food habits demonstrate that avian fauna in this habitat can live together without serious food competition. The king rail occupies a unique niche in this habitat and is considered to be nonspecific with the clapper rail (a saltwater resident), as they both freely interbreed in coastal areas where fresh and salt water mix.

The gallinules, close relatives of the rails and coots, are also well represented in the freshwater nonforested habitat. Both the purple gallinule and common gallinule nest in freshwater marsh of this habitat.

The wading birds, particularly the herons, are quite euryphagous and frequently feed in the nonforested wetlands on frogs, fish, snakes, field mice, and insects. All three of the common permanent residents (Louisiana heron, great blue heron, and little blue heron) occupy large rookeries in the coastal region. Although herons and egrets are more commonly found in salt marshes, they do feed along the shorelines and tidally exposed banks of this freshwater habitat. The white ibis is a common summer resident of freshwater wetlands and feeds on crayfish and insects. However, in late fall, the white ibis feeds more in salt marshes (on fiddler crabs) than in freshwater areas. Many of these rookeries, which may also include ibises and night herons, are located near the rice field-marsh-swamp-land complex. Here, one needs to consider the indirect relationships between the avifauna and the wetlands. For example, the herons must cycle large amounts of organic matter and nutrients from impounded waters to the marshes, swamps, and land (Shanholtzer 1974b). This enrichment process may be locally significant and may partially account for large standing crops of southern wild rice, cattails, etc. A similar situation probably exists in the estuarine impoundments and emergent wetlands.

7. Mammals

The mammals associated with freshwater impoundments can be considered in two groups. First, and most numerous, are those which utilize the dikes and the emergent or shrub areas of the land-water-interface; the second group consists of a few species which enter the water and feed on aquatic prey.

The principal herbivores of this habitat include the marsh rabbit and a variety of small rodents. Marsh rabbits are good swimmers and will not hesitate to enter water; however, their feeding activities are largely confined to grasses and herbaceous plants of the moist edges. Pelton (1975) trapped a number of rodents along the edge of an impoundment on Kiawah Island. These included eastern wood rats, cotton rats, cotton mice, and marsh rice rats. The presence of these small mammals attracts a number of predators, including reptiles and raptorial birds.

The principal omnivores of this habitat are the raccoon and opossum. The raccoon, of course, enters the water to feed on aquatic forms. If the water is fresh, crayfish and frogs constitute significant portions of the raccoon's diet. In estuarine impoundments, fiddler crabs, marsh crabs, and blue crabs assume great importance in the diet.

Several small carnivorous mammals are common to the emergent impoundment edge environment. These include the eastern mole, the star-nosed mole, and all three native species of shrews: the short-tailed, least, and southeastern shrew.

The principal predatory mammals, and the only ones to feed extensively within impoundment waters, are the mink and the river otter. The predatory habits of both species were studied extensively by Wilson (1954) in eastern North Carolina, and his findings would almost certainly be appropriate to the South Carolina coastal region. The mink is a more generalized predator than the river otter, utilizing a wide selection of small mammals, birds, reptiles, amphibians, arthropods, and fishes. The river otter, on the other hand, feeds almost exclusively on fishes and crustaceans in the same general environment.

CHAPTER FOUR

WATERFOWL MANAGEMENT

The waterfowl resources of South Carolina are dynamic and constitute an important component of the coastal ecosystem. Included are over 30 species of waterfowl and thousands of acres of several types of natural and managed habitats. Since impoundments are heavily managed for waterfowl, an overview of the status, seasonal occurrence, and habitat preference of waterfowl that utilize the coastal areas of South Carolina is presented in Table 8-1. This is followed by a brief description (in phylogenetic order) of the most important species of waterfowl that utilize this area. Subsequent sections discuss waterfowl habitats, management practices, population dynamics, and harvest characteristics.

A. WATERFOWL SPECIES ACCOUNTS

Wood duck - The wood duck is the only species of migratory waterfowl whose breeding range includes South Carolina, as well as the entire Southeastern region. Because of its resident status, it is one of the most important species of waterfowl in the study area. Winter populations are estimated at 235,000 for South Carolina and 190,000 for Georgia (Bellrose 1976). During the 1972-73 waterfowl season, it was the number one species harvested in both states (Benning et al. 1975). Southerland (1971) estimated the breeding population of wood ducks in South Carolina at 40,000 and in Georgia at 30,000.

Preferred breeding habitat for wood ducks consists of freshwater areas such as bottomland sloughs, slow moving rivers, and shallow ponds which are characteristic of many of the major drainages in the study area. This breeding habitat must contain suitable cover of shrubs and trees, adequate food resources which are high in protein, water levels which persist throughout incubation, and suitable brood rearing locations as well as the presence of usable nesting cavities (McGilvrey 1968).

Proper brood rearing habitat is composed of an interspersion of herbaceous aquatic plants, shrubs, and open water (75% cover and 25% open water). There should be an abundance of aquatic insects and water levels should remain fairly constant throughout the fledging period (Bellrose 1976). In the South, beaver impoundments provide excellent brood rearing habitat (Hepp and Hair 1977).

Favored winter habitats include secluded freshwater swamps and marshes (Johnsgard 1975). In the study area, wood duck numbers increase steadily from September through December due to the influx of northern migrants (Fig. 4-1). Spring migration begins in early February and continues into April in the Southeast region.

Landers et al. (1977) demonstrated the importance of habitat diversity for meeting the year-round nutritional requirements of wood ducks. They noted the importance of animal matter in the diet during the spring which supports other results indicating the importance of invertebrates

Table 4-1. Status, seasonal occurrence, and habitat preferences of waterfowl reported for the coastal region of South Carolina and Georgia (adapted from Johnson et al. 1974).

Common Name	Status		Seasonal Occurrence				Preferred Habitat						
	SC	GA	Permanent Resident	Summer Resident	Winter Resident	Uncertain	Offshore	Beaches, Dunes, Mud Flats	Forests	Fields, Pastures	Freshwater Marshes, Ponds	Salt Marshes	Estuaries, Sounds
Whistling swan	T	T			X								X
Canada goose	FC	FC			X					X	X		
	loc.	loc.		X									
Brant	T	T			X								X
Snow goose	T	T									X		X
Blue goose	T	T			X			X					
Fulvous tree duck	T	T			X			X					
Mallard	C	FC			X						X		X
		loc.		X									
Black duck	C	FC			X						X		X
Mottled duck	T	T		X						X	X		
Gadwall	C	C			X						X		X
Pintail	C	FC			X						X		
Green-winged teal	C	C			X						X		X
Blue-winged teal	FC	FC			X						X		X
European wigeon	T	T			X								
American wigeon	C	FC			X						X		
Shoveler	FC	FC			X						X		
Wood duck	C	C	X								X		
Redhead	UNC	UNC			X								X
Ring-necked duck	C	FC									X		X
		C			X								
Canvasback	FC	FC			X								X
Greater scaup	T	T			X								X
		loc.											
Lesser scaup	C	C			X						X		X
Common goldeneye	UNC	UNC			X								X
Bufflehead	UNC	C			X								X
Oldsquaw	UNC	C			X								X
King eider	T	T			X								X
White-winged scoter	T	T			X		X						X
Surf scoter	UNC	UNC			X		X						X
Common scoter	C	C			X		X						X
		loc.											
Ruddy duck	FC	FC			X						X		X
Hooded merganser	UNC		X										X
		C			X								
Common merganser	UNC	UNC			X						X		X
Red-breasted merganser	UNC	C			X						X		X

C - common; FC - fairly common (30-70%); UNC - uncommon (less than 30%); T - transient; loc. - locally.

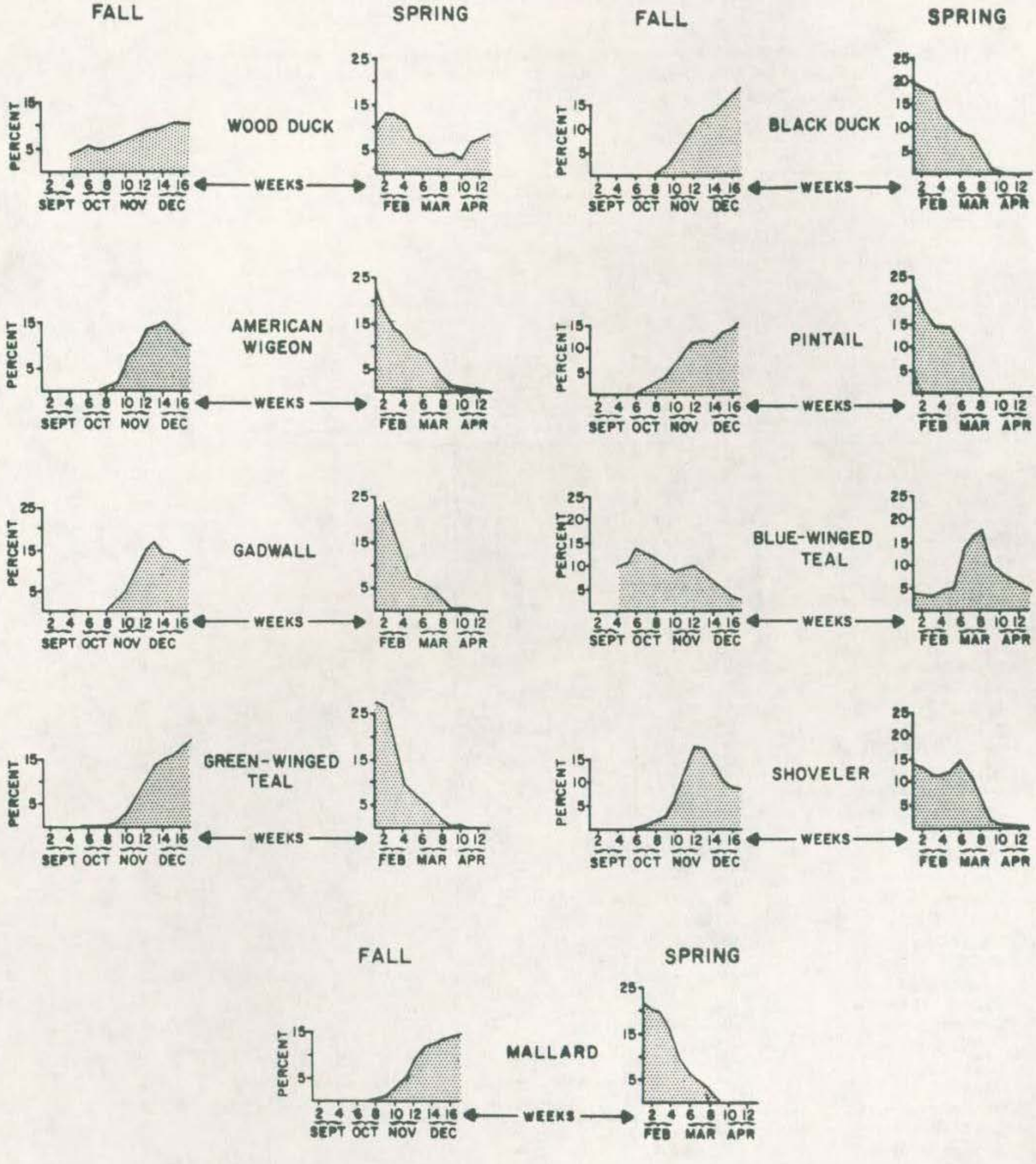

Figure 4-1. The chronology of dabbling duck migration on the Southeastern coast during the fall and spring migratory periods, based on weekly censuses at national widlife refuges - 1957, 1962, and 1967 (adapted from Bellrose 1976).

to breeding waterfowl. Fleshy fruits (e.g., blackberry and black cherry) are important in the summer. Acorns are important fall and winter food when they are abundant, but Asiatic dayflower is the food taken most consistently during late fall and winter. Bellrose (1976) indicated that acorns are the favored food of wood ducks in more places than any other food. McGilvrey (1966a) reported that fruits from oaks, bald cypress, sweet gum, and water hickory are important foods of wood ducks in South Carolina.

American wigeon - Along the Atlantic coast, wigeon winter in fresh and brackish areas from Long Island southward, particularly in Maryland, South Carolina and Florida (Johnsgard 1975). The marshes of South Carolina overwinter almost 60,000 wigeon, the largest concentration in the Atlantic flyway (Bellrose 1976). In coastal areas, the preferred foods of wigeon include eel grass, widgeon grass, pondweed, and *Chara* spp. (muskgrass). Wigeon prefer the stems and leafy portions of these aquatic plants.

In managed tidal impoundments of South Carolina, Landers et al. (1976) reported that widgeon grass and red root were the most important components of the wigeon's diet. McGilvrey (1966a), in a food habits study on Lake Marion, South Carolina, demonstrated that rice cutgrass, spikerush, and water grass were the plant foods of most importance to wigeon. Kerwin and Webb (1972) demonstrated the importance of southern naiad and widgeon grass in the diet of this species.

The wigeon is one of the earliest species of waterfowl to migrate southward; they begin to arrive on the wintering grounds in late September and early October (Fig. 4-1). Spring migration commences in early February and proceeds through March.

Gadwall - Gadwalls are found on slightly brackish marshes and ponds with submerged aquatic vegetation (e.g., pondweeds, southern naiad, widgeon grass, coontail, *Chara* spp. (muskgrass), and eel grass). Like wigeon, they prefer the stems and leaves of plants for food, and the two species often frequent the same habitats. The wintering gadwall population in the Atlantic Flyway numbers 40,000 birds, 75% of which occur in South Carolina (Bellrose 1976).

Landers et al. (1976) showed that sedges, red root, and widgeon grass were consumed in large quantities by gadwalls. Soft-stem bulrush and southern naiad were found to be the most important food items in a study by Kerwin and Webb (1972). McGilvrey (1966b) reported that the seeds of soft-stem bulrush, the vegetative parts of southern naiad and leafy pondweed were principal food items.

The peak of fall migration on the southeast coast is in mid-November (Fig. 4-1). Spring migration begins in February, but not until late April have most of the gadwall dispersed from the wintering grounds.

Green-winged teal - Coastal marshes are the preferred winter habitats of green-winged teal. They also utilize creeks and ponds that are bordered by mud flats at low tide; tidal creeks and marshes near estuaries are preferred over salt marshes (Johnsgard 1976). The Atlantic flyway winters approximately 77,000 green-winged teal. Seventy percent of of these winter along coastal South Carolina, whereas only 5% winter along Georgia's coast (Bellrose 1976).

Green-winged teal prefer to search for food on mud flats, but will also seek food on the shallow marshes and/or temporarily flooded agricultural lands. They prefer seeds of moist soil plants, as well as insects and mollusks. Bellrose (1976) reported that seeds of panic grasses, bulrush, pondweeds, Olney's three-square bulrush, and widgeon grass were preferred food items. Landers et al. (1976) and Kerwin and Webb (1972) also showed that panic grasses, sedges, smartweeds, and bulrushes were important foods for wintering teal.

Most green-winged teal do not arrive at their more southerly wintering areas until late November. In the spring, migration begins in early February and continues through April (Fig. 4-1).

Mallard - The mallard is the most abundant and widely distributed duck in North America. The Atlantic flyway attracts a relatively small portion (200,000) of the total population and over half of these (110,000) winter in southeastern South Carolina (Bellrose 1976).

Mallards are highly adaptable in their utilization of natural and cultivated foods. McGilvrey (1966b) reported that in South Carolina the winter diet of mallards consisted of rice cutgrass seeds, water grass, sweet gum, button bush, and swamp smartweed. In managed tidal impoundments, the seeds of smartweeds were favored by mallards, as were red root and panic grasses (Landers et al. 1976). Kerwin and Webb (1972) found smartweeds, bulrush, and sedges to be of great importance as winter foods.

The mallard has the most prolonged fall migration of any duck (Fig. 4-1). In the South, mallards begin to arrive in early October and continue into the month of December. In the spring, mallards depart their wintering grounds by early February and continue their migration through March.

Black duck - In coastal South Carolina black ducks tend to concentrate in tidewater areas. Estuarine bay marshes, particularly those with salt water, receive high utilization, as do coastal salt marshes and impoundments. Black ducks tend to use saltwater habitats more so than mallards. Fifty thousand black ducks winter in areas south of Virginia (Bellrose 1976).

Eel grass, widgeon grass, and various species of animal matter are the more important food items of black ducks that utilize coastal estuaries. Animal foods (e.g., periwinkles, blue mussels, and various snails) become increasingly important during the winter. Smartweed and saltmarsh bulrush seeds were of high importance to black ducks on managed tidal impoundments (Landers et al. 1976). McGilvrey (1966b) found corn and sweet gum seeds to be important foods for wintering black ducks. Kerwin and Webb (1972), however, showed that pickerelweed, jointed spikerush, swamp smartweed, and saltmarsh bulrush were preferred food items.

Black ducks generally arrive in the coastal areas of South Carolina and Georgia in late November to early December (Fig. 4-1). Their migration into this region is usually delayed until more northern habitats freeze over (Bellrose 1976). Black ducks start their spring migration in early February and continue into early April.

Pintail - Wintering pintails utilize shallow, fresh or brackish estuarine waters with scattered impoundments and adjacent agricultural areas. The pintail is able to winter almost anywhere that a combination of open water and available food may be found (Johnsgard 1975). Approximately 200,000 of these birds winter in the Atlantic flyway. Of these, 87,000 (43.5%) winter in South Carolina (Bellrose 1976).

Pintails consume a variety of foods in the coastal region of the Atlantic flyway. Pintails wintering in South Carolina utilized bulrush, widgeon grass, and redtop (McGilvrey 1966b). Landers et al. (1976) discussed their preference of red root, panic grasses, and smartweeds in managed tidal impoundments. In Kerwin and Webb's (1972) study, saltmarsh bulrush, redtop, and widgeon grass were shown to be the most important foods of pintails.

In South Carolina and Georgia, pintails begin to arrive during fall migration in mid-October and the population continues to increase until a peak population is reached in late December. They are one of the first ducks to migrate north in the spring. Spring migration begins in late January or early February and continues through March (Fig. 4-1).

Blue-winged teal - In the winter, blue-winged teal utilize areas similar to those preferred by green-winged teal (i.e., marsh habitats and/or mud flat areas). It is, however, an early migrant and few remain in the continental United States during the winter. Most spend the winter months in South America and Mexico. Approximately 5,000 blue-winged teal overwinter in South Carolina and small numbers have been found during winter surveys in Georgia (Bellrose 1976).

The blue-winged teal prefers to feed in shallow water when floating and shallowly submerged vegetation and aquatic invertebrates are abundant (Palmer 1976). Twenty-five percent of their diet is comprised of animal matter. They also feed on the vegetative parts of aquatic plants (e.g., muskgrass, duckweeds, widgeon grass, coontail, and pondweeds). Wintering blue-winged teal also prefer Olney's three-square bulrush, sedges, smartweeds, and wild millet (Landers et al. 1976). Kerwin and Webb (1972) found a preference for corn, Asiatic dayflower, jointed spikerush, swamp smartweed, and sedges.

Blue-winged teal are generally the first ducks to migrate south in the fall and the last to migrate north in the spring. Large numbers appear in South Carolina and Georgia during September but diminish rapidly during October with small numbers remaining the rest of winter (Fig. 4-1). The peak of spring migration on the southeast coast is during late March. It is usually late April before the first blue-winged teal arrive on the Canadian breeding grounds.

Northern shoveler - In the winter, shovelers generally utilize freshwater meadows and avoid saltwater habitats. They are most common on still-water ponds subject to slight tidal variations. The Atlantic coast winters approximately 20,000 shovelers (Bellrose 1976). The majority (15,000) of these winter in South Carolina; a small number of shovelers overwinter in Georgia (Bellrose 1976).

The shoveler consumes a considerable amount of small aquatic animal life (e.g., ostracods, copepods, aquatic beetles, and small mollusks) (Bellrose 1976). In coastal South Carolina, the seeds of panic grasses, bulrushes, and spikerush are heavily utilized (McGilvrey 1966b). Landers et al. (1976) showed the importance of panic grasses, red root, saltmarsh bulrush, and smartweeds to wintering shovelers. Fall panic grass, Asiatic dayflower, softstem bulrush, and squarestem spikerush are also preferred foods of shovelers (Kerwin and Webb 1972).

In the fall, peak numbers are not reached on southern wintering grounds until mid- to late November (Fig. 4-1). Spring migration commences in February and continues into early April.

Canvasback - Approximately half of the North American population of canvasbacks overwinter along the Atlantic flyway. Wintering birds occur as far south as central Florida, but the largest concentrations have been reported from the Chesapeake Bay area (75% of the Atlantic flyway population). Brackish estuarine bays are the principal wintering habitats for canvasbacks; saltwater and freshwater estuarine bays are not utilized extensively.

Historically, the winter distribution of canvasbacks has been associated with the distribution of wild celery. In recent years, the abundance of this food resource has been reduced and the food habits of canvasbacks have changed accordingly. In the Southeast, the vegetative parts of arrowhead and banana water-lily are preferred foods (Johnsgard 1975). Recently a study in South Carolina indicated the importance of baltic clams (Macoma baltica) in estuarine bay habitats and banana water-lily in coastal impoundments to wintering canvasbacks (Alexander and Hair 1977). It seems that with the decline in the abundance of plant foods, canvasbacks have changed to a molluscan diet (Perry 1975).

The peak of fall migration along the southeast coast occurs in late November to early December (Bellrose 1976). Spring migration commences in early February and proceeds at a steady rate through March (Fig. 4-2).

Redhead - Redheads prefer fresh and slightly brackish estuarine bays during spring and fall migration. Typical wintering areas include large bodies of water along the coast that are well protected and fairly shallow; they can range from brackish to saline (Johnsgard 1975). Approximately 60,000 redheads winter along the Atlantic coast, but very few (approximately 300) have been reported from coastal areas of South Carolina and Georgia (Bellrose 1976).

Redheads forage more commonly in marshes, sloughs, and ponds than other diving ducks, and feed extensively on aquatic plants (90% plant, 10% animal matter). Along the southeast coast, redheads reach peak numbers during fall migration in late November and early December (Fig. 4-2). Redheads begin to depart from their wintering grounds in early February and continue until mid-March.

Ring-necked duck - Throughout the Southeast, ring-necked ducks utilize marshes, lakes, ponds, and reservoirs as winter habitat. During this time they generally favor shallow, acid marshes and coastal lagoons, and

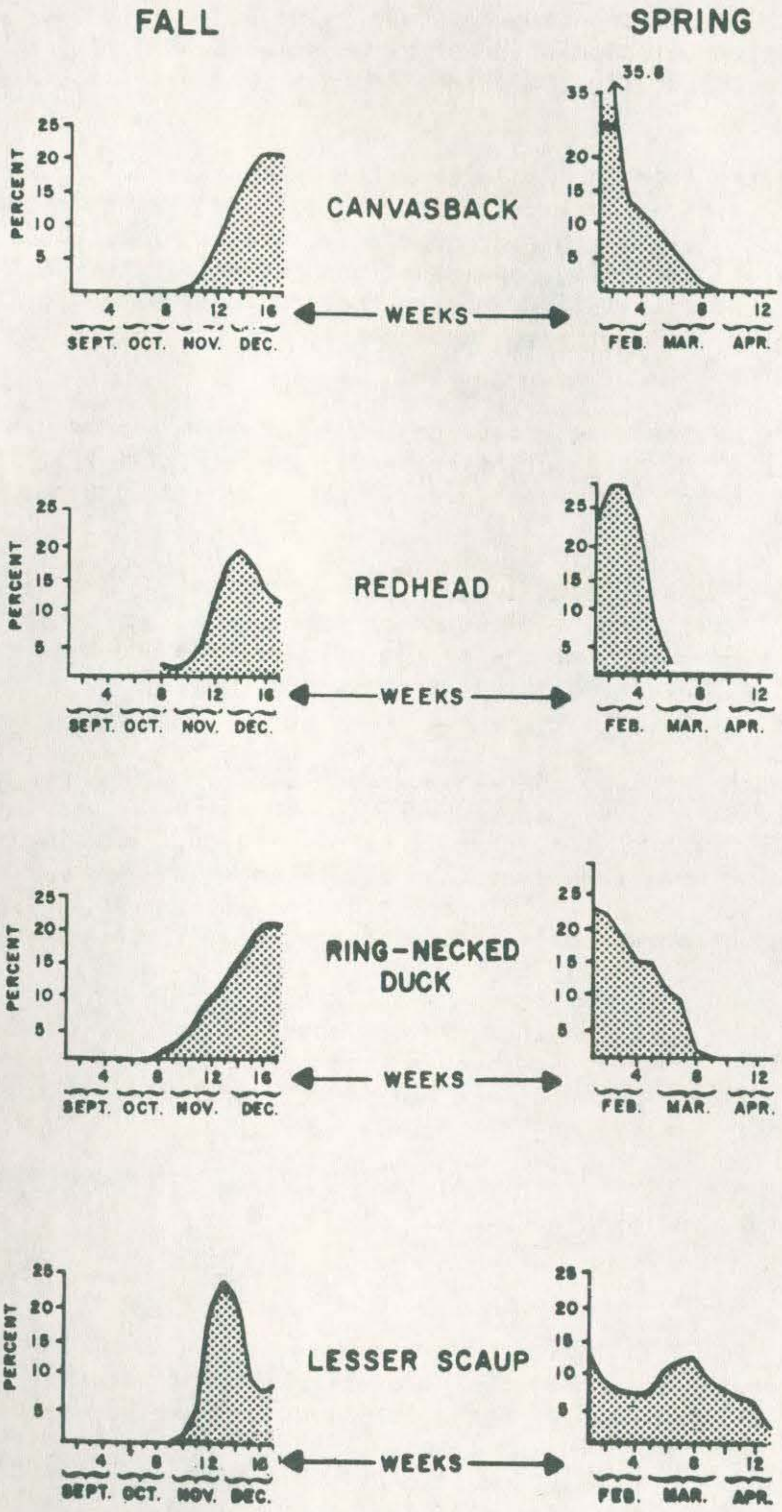

Figure 4-2. The chronology of diving duck migration on the Southeastern coast during fall and spring migratory periods, based on weekly censuses at national wildlife refuges - 1957, 1962, and 1967 (adapted from Bellrose 1976).

prefer less brackish conditions than do scaup. The Atlantic flyway winters 44% of the continental population of ring-necked ducks, with major concentrations in South Carolina, Florida, Georgia, and Alabama (Bellrose 1976).

Ring-necked ducks feed in shallower water than other diving ducks (less than 6 ft or 1.8 m). Their preferred winter food in the Southeast consists of the seeds of water-shield, pondweeds, sedges, smartweeds, and the leafy structures of coontail, pondweeds, and duckweeds (Kerwin and Webb 1972). Landers et al. (1976) reported that panic grasses, smartweeds, saltmarsh bulrush, and red root were important food items during the winter on tidal impoundments.

Ring-necked ducks begin to arrive on the Southeastern coast in late October and attain peak winter population in December (Fig. 4-2). They start to leave their wintering areas in early February and continue through March.

Lesser scaup - The Atlantic flyway winters 31% (455,000) of the total population of lesser scaup. Most occur in Florida, but South Carolina and Georgia have populations of approximately 20,000 wintering birds (Bellrose 1976). Brackish estuarine bays are their chief wintering habitat (Stewart 1962).

In coastal South Carolina, Kerwin and Webb (1972) noted the importance of seeds of panic grasses, smartweeds, and bulrushes to wintering scaup. Animal matter made up less than 1% of their diet. Other studies show animal life to be more important than plants in scaup diets (Harmon 1962, Rogers and Korschgem 1966). Widgeon grass and saltmarsh bulrush were important foods of scaup collected on managed tidal impoundments in South Carolina (Landers et al. 1976).

Lesser scaup arrive on the southeastern coast in late October and their numbers continue to increase through November and into December (Fig. 4-2). Spring migration is a long drawn-out process; it commences in February and continues through late April.

B. COASTAL WATERFOWL HABITATS

1. Historical Perspectives

Historically, the utilization of the coastal region of South Carolina by wintering waterfowl was limited by the availability of natural foods. In the mid-1600's, this changed with the introduction of rice culture along the coast of South Carolina. As well as being important to the economy of the region, rice culture also provided a "managed" habitat and alternate source of food for winter waterfowl populations. According to Heyward (1937), "... When the ducks came in the fall of those days, they not only came in great numbers, but they stayed in the fields day and night, for then it was the practice of the planters to flood their fields as soon as the crop was harvested and keep them flooded until late in the winter when work for another crop had to be begun. When there was a late fall, from the rice stubble a second crop would grow and mature small heads of rice, so that these, together with the shattered rice from the first crop, afforded an abundance of food for the ducks. Early in November they began to pour into the fields in large flocks, and not being constantly shot at as they are now, they remained until early spring."

By 1690, rice was a well established crop and rice plantations were located near the mouths of the major river systems from North Carolina to southern Georgia. However, South Carolina was by far the most important rice producing State during that era. During the peak years of production (1850 - 1860), over 20,000 acres (8,094 ha) were under cultivation in South Carolina alone (Doar 1936). The principal rivers along which rice was planted in South Carolina were the Waccamaw, Black, Sampit, Pee Dee, Santee, Cooper, Edisto, Ashepoo, Broad, Combahee, and Savannah. Georgia and South Carolina produced almost 90% of the total national rice crop, and until 1860, Georgetown County, South Carolina produced more rice than any other county in the Nation (Hilliard 1975).

The entire process of clearing the land and preparing new fields for rice cultivation was slow and took many years of labor. Even when the operation was completed, it required constant maintenance by a large labor force. After the Civil War, rice production faltered and never recovered because of the physical destruction to the plantations and the loss of slave labor. The final demise of rice culture in the South Atlantic region was caused by the introduction of rice into Louisiana, Mississippi, Arkansas, and Missouri.

As rice culture gradually declined in the late 1800's, the diked fields were abandoned. In the first years of abandonment, rice-producing areas probably achieved maximum performance in serving as winter habitats for waterfowl . Abandoned rice fields were quickly vegetated by desirable freshwater marsh plants, such as wild rice, duck potato, square stem spikerush, Olney's three-square bulrush, wild millet, softstem bulrush, and water hemp. Interspersed in these marshes were functional rice plantations, and the rice produced by these plantations augmented the natural food supply. Almost a perfect balance between food and cover was achieved and an ideal habitat for waterfowl was created.

Soon after the decline of rice culture in South Carolina, some plantations were sold to wealthy northern industrialists who repaired and maintained the dikes and water control structures in order to develop waterfowl hunting areas. Some rice was grown to attract ducks to the plantation and natural foods were encouraged. To facilitate shooting, small ponds were dug in the marsh and were baited with shelled corn or rice. Live decoys were used and hunting occurred in the marshes from morning until night. A hunter seldom went to his blind without a case of shells. Plugging your gun was unheard of and there was no limit to the number one could shoot (R. Wood, 1947, South Carolina Wildlife and Marine Resources Department, Charleston, unpubl. data).

Subjected to such intense hunting pressure, ducks fed in the fresh and brackish waters at night and flew to the salt marshes at daybreak. Devil's Den, just off the coast near McClellanville, South Carolina, and now a part of the Cape Romain National Wildlife Refuge, was a renowned shooting area. Although it offered little food, the ducks were intercepted on their morning flight from the Santee Delta marshes. Murphy and Cedar islands, a part of the old Santee Gun Club, and the marshes of South Island Plantation, located at the tip of the Santee Delta, have always provided good hunting and continue to do so, primarily because they lie in the line of flight between feeding and resting areas.

Through improved management and law enforcement efforts, ducks were held in the impoundments throughout the day, and hunting success was improved. By 1942, about 20,000 acres (8,094 ha) of marsh were diked and privately managed for waterfowl in the Santee Delta. At that time, the Santee River estuary in South Carolina was one of the most important waterfowl areas on the entire coast of the Southeastern United States.

The greatest number of ducks killed in the Santee Delta area occurred during the period from 1920 to 1928. Santee Gun Club members harvested 6,388 birds in 1921-22, while Kinloch Club members bagged 3,082 ducks in 1924 and 3,126 in 1927 (R. Wood, 1947, South Carolina Wildlife and Marine Resources Department, Charleston, unpubl. data). A summary of historical kill records available from hunting clubs in the Santee Delta is shown in Table 4-2.

Prior to diversion of the Santee River (before 1942), the dominant marshes in the Santee Delta area were of the freshwater and brackish types. Natural river fluctuations provided a dependable supply of fresh and salt water, which greatly facilitated waterfowl management. During high flows, fresh water could be impounded to promote growth of desirable duck food plants, as mentioned earlier. At low flows, and with an incoming tide, salt water was available for controlling undesirable freshwater plants such as cut grass, cat-tails and willows. Further down the estuary, brackish marshes could be maintained by proper mixing of waters; in sizable areas this occurred naturally. Salt marshes, less valuable for waterfowl production, were confined to a narrow coastal fringe by the large freshwater outflow.

Following diversion in 1942, conditions changed rapidly. Existing water-control structures were inadequate to properly manage the marshes with the restricted supply of available fresh water. Salt marshes became the dominant type, brackish marshes moved up the estuary, and freshwater marshes were all but eliminated. Over the next 20 years, new dikes and control features were added to aid in management of many areas as brackish marshes. Today, about 19,837 acres (8,028 ha) of marsh are under active management in the Santee Delta area (Tiner 1977).

Since 1965, when the U.S. Army Corps of Engineers proposed to redivert the Santee River to reduce shoaling in Charleston Harbor, there has been great concern over potential impacts on waterfowl resources in the Santee Delta. According to the U.S. Army Corps of Engineers (1974a), about 9,000 acres (3,642 ha) of swamps would be flooded due to increased river flows. These new supplies of water would increase timber growth and mast production, thereby benefiting waterfowl and wildlife in general. Waterfowl habitat would be improved in about 38,000 acres (15,378 ha) of estuarine habitat, according to the Corps of Engineers. These improvements would be largely due to increased freshwater duck food plants in the delta as opposed to mostly brackish water plants at present.

Table 4-2. Summary of waterfowl harvest records (total number of ducks killed/season) for the Santee Delta region, 1922 - 1947 (R. Wood, 1947, South Carolina Wildlife and Marine Resources Department, Charleston, unpubl. data).

Year	Total	South Island	Cat Island	Annandale	Winyah	Kinloch	Doar [a]	Rice Hope	Santee Gun Club
1947	1,883	305	25 [b]	50 [b]	0	201	8	16	1,286
1946		985				372		115	2,647
1945		1,021				528		256	2,112
1944		931				387		147	2,285
1943		1,137				727		40	2,212
1942		918			8	793		105	2,268
1941		886			127	1,000		77	2,774
1940		561			95	585		31	2,367
1939		504			104	690		55	2,113
1938		387			186	495		5	1,634
1937		391			74	390		6	1,223
1936		302			210	146		1	1,242
1935		518			159	465		12	1,792
1934		998				1,012		61	3,760
1933		586				754		50	3,172
1932		647				644		105	1,831
1931		689				856		41	2,945
1930		476				934		188	3,541
1929						1,343		293	2,827
1928						2,869		322	4,720
1927						3,126			4,722
1926						3,059			4,406
1925						2,412			5,822
1924						3,082			5,737
1923									5,956
1922									6,388

a. On Woodside and River Hope, Mr. Doar states that over 700 ducks were killed annually prior to 1924.
b. Estimate only - no records available.

At present, marshes (brackish and freshwater) and man-made impoundments are the most important types of waterfowl habitats in the coastal areas of South Carolina. Based on available information, designated waterfowl habitat in private, State, and Federal ownership in the coastal region of South Carolina is detailed below.

2. Waterfowl Habitat Under Private Control

Along the coast of South Carolina, there are seven major river systems, including the Pee Dee, Black, Santee, Cooper-Ashley, Edisto-Ashepoo-Combahee, and the Savannah. All are important components of the total waterfowl habitat resource base of this region.

Although a comprehensive evaluation of privately owned coastal habitats important to waterfowl has not been made, a detailed study by Morgan (1974) of the Edisto-Ashepoo-Combahee drainage system (in Charleston, Colleton, and Beaufort counties, South Carolina) illustrates the importance of these areas to waterfowl. Of the 335,629 acres (135,827 ha) within the boundaries of Morgan's (1974) study area, 98,451 acres (39,842 ha) (29%) were wetlands. The wetlands consisted of tidelands (defined as any wetland never having been diked that is affected by salt, brackish, or freshwater tidal flow), managed and abandoned rice fields, and managed and abandoned impoundments that were constructed since the era of rice culture. The acreages occupied by these types are presented by river system and by ownership in Table 4-3. All data are from Morgan (1974).

Most of these wetlands (92,346 acres or 37,372 ha) were claimed by 52 private landowners. Two areas encompassing 4,339 acres (1,756 ha) of wetlands were owned and managed by State agencies, and another 1,766 acres (715 ha) were not accounted for in the tax records (Table 4-3). The private claims to ownership of much of these wetlands have been disputed by the State of South Carolina. The privately claimed wetlands were generally parts of estates on adjoining high ground. The amount of marsh claimed by each owner ranged from 172 to 839 acres (70 - 340 ha) with an average of 376 acres (152 ha).

In Morgan's study area, there were 213 impoundments comprising 22,536 acres (9,120 ha), of which 15,670 acres (6,342 ha) or 69% were rediked former rice fields. Including abandoned rice fields, a total of 37,070 acres (15,002 ha) of rice fields which were once used in growing rice commercially were present in Morgan's study area (Table 4-3). These are minimum acreages because in some instances older rice fields, especially those in inland swamps, were not discernible on aerial photographs.

Morgan (1974) made an estimate of new dikes and impoundments constructed from 1959 to 1972. The linear extent of dikes, the number of ponds constructed, and the acres of wetlands impounded from 1959 to 1972 within the Edisto-Ashepoo-Combahee drainage are given in Table 4-4. Although data from the Combahee and upper Ashepoo rivers are incomplete, at least 2,015 acres (815 ha) were impounded; 1,562 acres (632 ha) by the State of South Carolina and 453 acres (183 ha) by private landowners. All of this diking was in the brackish zone. See Morgan (1974) for further details.

Table 4-3. Acres[a] of tidal marsh and managed and abandoned impoundments along the South Edisto, Ashepoo, and Combahee rivers, 1972 (Morgan 1974).

Wetland Type	South Edisto River			Ashepoo River		Combahee River	Total Study Area
	Private[b]	State[c]	Untitled[d]	Private[b]	State[c]	Private[b]	
Tidelands never diked:							
fresh	521			396			396
brackish	12,918	148	1,766	512	29		1,062
salt				7,735	608	29,454	52,629
Total							54,087
Abandoned diked areas open to tidal ebb and flow							
Old rice fields:							
fresh	1,752			4,366		8,040	14,128
brackish	3,138			1,054		8,080	7,272
Areas diked since rice culture:							
fresh	4					253	257
brackish	116			55			171
Total abandoned diked areas							21,828
Diked impoundments							
Former rice fields under management in 1972:							
fresh	2,714			1,306		5,182	9,202
brackish	1,643	647		115	878	3,185	6,468
Managed impoundments constructed since rice culture:							
fresh	2,529			358		159	3,046
brackish	782	192		540	1,837	469	3,820
Total under water control							22,536
Total Acres	26,117	987	1,766	16,407	3,352	49,822	98,451

a. 1 acre = 0.405 ha.
b. Those wetlands on which taxes were being paid by private landowners.
c. Those wetlands within the boundaries of the Bear Island Wildlife Management Area and the Edisto Beach State Park.
d. Those wetlands not included in footnotes b and c.

Table 4-4. Construction of new dikes and acres impounded during 1959 - 1972 within the Edisto-Ashepoo-Combahee River drainage, South Carolina (Morgan 1974).

River System	1959 - 1968 Number of Ponds	1959 - 1968 Feet of Dikes	1959 - 1968 Acres[a]	1969 - 1972 Number of Ponds	1969 - 1972 Feet of Dikes	1969 - 1972 Acres[a]
State:						
South Edisto	1	10,736	222			
Ashepoo[b]	6	22,875	1,340			
Private:						
South Edisto	2	1,475	35			
Ashepoo[b]	8	23,135	253	2	7,001	72
Combahee	1	533	29	3	6,347	64
Total for Study Area:						
Private	11	25,143	317	5	13,348	136
State	7	33,611	1,562	--	--	--

a. 1 acre = 0.405 ha.
b. Coverage for Combahee River and upper portion of Ashepoo River is incomplete for the years 1959 - 1968.

Table 4-5. Man-made impoundments and managed waterfowl areas in the Sea Island Coastal Region of South Carolina (Coleman and Dennis 1974).

County	Lakes (≥ 10 acres) Total Number	Lakes (≥ 10 acres) Managed[a]	Surface Area Total	Surface Area Managed[a]	Capacity (acre feet) Total	Capacity (acre feet) Managed[a]
Beaufort	30	10	1,452	232	4,580	706
Berkeley	43	0	64,050	0	1,235,431	0
Charleston	78	31	4,800	3,024	18,949	9,122
Colleton	32	3	2,547	860	6,530	2,580
Dorchester	10	0	388	0	2,245	0
Georgetown	14	5	277	97	511	177
Jasper	27	9	752	283	4,085	987
Totals	234	58	74,266	4,496	1,272,331	13,572

a. Specifically designated as waterfowl or wildlife habitat.

The Santee Delta (Georgetown County) represents another important area in South Carolina where active waterfowl management on privately owned land takes place. For example, Kinloch Plantation, located on the north side of the Santee River, is one of the most important private waterfowl properties along the Southeast Atlantic coast. Kinloch has approximately 5,000 acres (2,023 ha) of marsh with an excellent system of dikes and water control structures, plus a good supply of fresh water. There are a number of other plantations which also manage impoundments for waterfowl, but relevant information is not available.

There are a substantial number of manmade impoundments in private or public ownership along the coast of South Carolina and Georgia. In 1974, the South Carolina Water Resources Commission inventoried all of the man-made lakes greater than 10 acres (4.1 ha) in size (Coleman and Dennis 1974). Collectively, they impound 74,266 surface acres (30,055 ha) of water. Of this total, 58 impoundments (25%) comprising 4,496 acres (1,820 ha) (6%) were specifically designated as waterfowl habitats (Table 4-5).

3. Waterfowl Habitat Under State Control

South Carolina controls eight wildlife management areas in the coastal region (Table 4-6). These areas total approximately 42,000 acres (16,997 ha) (combined upland and wetland habitats) of which 7,054 acres (2,855 ha) (17%) are available for public hunting. The latter figure reflects those areas that will not be made available to public waterfowl hunting until a future date because of various legal agreements made during acquisition, e.g., Santee Coastal Reserve - 24,000 acres (9,713 ha).

4. Waterfowl Habitat Under Federal Control

Four National Wildlife Refuges managed by the U.S. Department of the Interior, Fish and Wildlife Service, and comprised of over 180,000 acres (72,845 ha), are located along the coast of South Carolina. Important features of each, particularly as they relate to waterfowl resources, are discussed in the following paragraphs. Locations have been outlined in Davis et al. (1980).

a. Cape Romain National Wildlife Refuge (Charleston County, South Carolina). Cape Romain was established as a national wildlife refuge in April 1930. It is a diverse area with many low-lying barrier islands and thousands of acres of marsh cut by a maze of tidal creeks and bays. Refuge-owned lands are made up of 1,500 acres (607 ha) of forest lands, 985 acres (399 ha) of freshwater impoundments, 85 acres (34 ha) of farmland or wildlife openings, nearly 20 mi (32.2 km) of sandy beaches and dunes totaling 1,700 acres (688 ha), and approximately 26,960 acres (10,911 ha) of salt marsh (U.S. Department of Interior, Fish and Wildlife Service 1977b). Aquatic plants like banana waterlily, sago pondweed, and widgeon grass grown in the deeper water areas. Excellent stands of foxtail grass, wild millet, smartweed, bulrush, spikerush, and other waterfowl food plants grow on the exposed marsh flats. The management of Cape Romain National Wildlife Refuge is directed toward maintaining a natural island and estuarine environment for wintering waterfowl, nesting shore birds, and sea turtles. With the exception of Bull Island, no habitat improvement practices are considered necessary. Cape Romain National Wildlife Refuge has 28,000 acres (11,331 ha) included in the National Wilderness System.

Table 4-6. Waterfowl habitat controlled by the State of South Carolina (South Carolina Wildlife and Marine Resources Department, Columbia, unpubl. data).

Wildlife Management Area	Acreage Open To Hunting	Total Acreage[a]
Bear Island	2,000	7,500
Hatchery Pool	2,454	2,454
Pee Dee	900	1,275
Santee Coastal Reserve	0	24,000
Santee-Cooper	200	1,275
Santee Delta	1,500	1,500
Turkey Creek	0	2,000
Yawkey Wildlife Center	0	2,356
Total	7,054	42,360

a. 1 acre = 0.405 ha.

Waterfowl wintering on the freshwater impoundments and in the bays often reach peak concentrations of 40,000 birds during migration periods. Totals for 1977 were somewhat lower (Table 4-7). The largest concentrations of waterfowl in 1977 were in Jack's Creek Pond on Bull Island (U.S. Department of Interior, Fish and Wildlife Service 1977b). Lower Summerhouse and Moccasin ponds also were utilized heavily. Bull Island had 20,000 wintering ducks, including approximately 2,500 canvasbacks. There were 200,000 ducks, most of which were diving ducks, on the entire refuge during peak times, but they do not stay for extended periods of time. The refuge also has a successful wood duck nest box program (U.S. Department of Interior, Fish and Wildlife Service 1977b).

b. Santee National Wildlife Refuge (Clarendon and Berkeley counties, South Carolina). The Santee National Wildlife Refuge was established on 31 July 1941. It is situated on the Santee-Cooper Reservoir, lakes Marion and Moultrie. The Santee National Wildlife Refuge is comprised of approximately 75,000 acres (30,352 ha) and is managed specifically for wintering waterfowl. Duck utilization of the refuge has been good in previous years, and black duck use, in particular, is increasing. Corn is planted by refuge personnel and co-operative farmers on a share basis. The refuge's share is mainly left in the fields for the wintering birds. In 1977, the Santee Refuge saw peaks of 173,000 ducks, 15,000 coots, and 6,000 geese (Strange 1977).

c. Pinckney Island National Wildlife Refuge (Beaufort County, South Carolina). Pinckney Island National Wildlife Refuge was acquired by the U.S. Fish and Wildlife Service on 4 December 1975. The refuge, totaling 4,052 acres (1,640 ha) consists of Pinckney Island, Little Harry Island, Big Harry Island, Buzzard Island, and Corn Island, plus another 2,800 acres (1,133 ha) of estuarine salt marsh. The refuge is not officially open to the public. Pending funding for the management of this acquisition, no public use activities are authorized. The refuge's upland habitat provides a breeding ground for the usual complement of game birds and mammals normally associated with the low country of South Carolina.

d. Savannah National Wildlife Refuge (Beaufort County, South Carolina and Chatham and Effingham counties, Georgia). The Savannah National Wildlife Refuge was created on 6 April 1927. On 7 January 1978, 13,480 acres (5,455 ha) comprising Argent Swamp on the Savannah River were acquired from the Union Camp Corporation, doubling the size of the refuge to 26,555 acres (10,747 ha). The majority of the refuge land consists of freshwater marsh and tidal rivers and creeks. Cutgrass is by far the most prevalent marsh plant; however, scattered stands of wild rice, smartweeds, soft-stem bulrush, and other natural waterfowl food plants are common throughout the marshes. Most impoundments now used for migratory waterfowl were formerly rice fields of pre-Civil War rice plantations. There are 3,000 acres (1,214 ha) of freshwater impoundments, managed primarily for wintering waterfowl populations. However, there has been extensive deterioration of water management capabilities and the refuge has fallen far behind its primary waterfowl use objectives. Unless rehabilitation is completed, it is unlikely that the refuge's primary waterfowl use objectives can be realized.

Peak waterfowl populations normally reach 40,000 during the winter season. Mallards, pintails, green-winged teal, ring-necked ducks, and

Table 4-7. The estimated monthly waterfowl populations on the Cape Romain National Wildlife Refuge in 1977; these figures represent an average of four weekly surveys conducted by refuge personnel (U.S. Department of the Interior, Fish and Wildlife Service, Cape Romain National Wildlife Refuge, unpubl. data).

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
American coot	586	225	151							375	3,000	1,557	5,894
Whistling swan	8	15	8								6	22	59
Snow and blue goose	2									12		2	16
Canada goose													--
Mallard duck	125	150	16							10	720	80	1,101
Black duck	43	42	15							40	30	36	206
Gadwall	5	30	22								3,000	18	3,075
Pintail	15	2									1,000	25	1,042
Green-winged teal		5										15	20
Blue-winged teal	55	97	20	20	4			30	30	75	160	132	623
American wigeon	148	4								735	2,000	778	3,665
Shoveler	58	94	40							20	95	23	330
Wood duck	7	200	200	200	250	250	200	200	200	200	110	8	2,025
Redhead	5										100	7	112
Ring-necked duck	35	1,500								35	400	342	2,312
Canvasback	518	77	15								2,500	1,602	4,712
Scaups	135	1,000	5,030	100	10						500	143	6,918
Bufflehead	8	2	6								70	9	95
Ruddy duck	72	39	11							25	150	148	445
Red-breasted merganser		2	11	10	2								25
Hooded merganser	2	20	2	10							25	18	77
Black scoter			5,020										5,020
Total	1,827	3,504	10,567	340	266	250	200	230	230	1,527	13,866	4,965	37,772

wood ducks account for approximately 70% of the waterfowl use on the refuge (Table 4-8). Savannah refuge has a year-round population of wood ducks and peak numbers (10,000) occurred during December 1977.

Waterfowl hunting is permitted on a portion of the refuge's marsh acreage within the State of Georgia. The hunting season on the refuge coincides with the Georgia season. Hunting conditions are classified as poor.

C. WATERFOWL HABITAT MANAGEMENT PROCEDURES

The types of habitats most commonly managed for waterfowl in South Carolina are coastal marshes, hardwood bottomland, inland lakes and ponds, and in some instances, beaver ponds and upland cultivated areas. The following discussion of waterfowl management procedures is restricted to coastal freshwater and brackish marshes and hardwood bottomlands. Unless otherwise noted, the management recommendations are from an unpublished manuscript by P. M. Wilkinson (South Carolina Wildlife and Marine Resources Department, Charleston), presented at the 1976 South Carolina Waterfowl Symposium, held in Columbia, South Carolina, under the joint sponsorship of the South Carolina Wildlife and Marine Resources Department and the South Carolina Chapter of Ducks Unlimited.

1. Coastal Marsh Areas

The objectives of waterfowl impoundment management are to provide an optimum interspersion of open water and cover, and to produce a maximum quantity and quality of food supply. If these objectives are accomplished, waterfowl utilization will be increased. Food is the most important requirement on wintering grounds, and therefore, most management efforts are directed toward the elimination or control of undersirable vegetation. The primary concern for effective management of coastal marsh areas is the stabilization and/or control of water levels. Control of water levels is essential for effective and economical management of vegetation in coastal waterfowl impoundments. Water levels can be raised to reduce emergent vegetative cover, or lowered to increase its density, but submerged aquatic food plants require fairly stable water levels throughout the growing season in order to attain the greatest production. The most common methods used to control water levels in coastal marsh areas are: a) pot holes, b) plugs, c) weirs, and d) diked impoundments.

Pot holes are usually created in well-drain high marsh areas, using explosives or heavy earthmoving equipment. However, the small ponds created in this manner are difficult to manage, and have yielded varying results as waterfowl management tools. Actual control of water levels in these pot holes is difficult, and natural vegetative succession usually reduces the length of time that these impoundments effectively serve as high-quality waterfowl habitat. This method of attracting waterfowl is not practiced extensively in the South Carolina coastal region.

Earthen plugs (small dams) can be placed across natural channels or other drains in marsh areas in order to stabilize water levels, reduce salinity, reduce turbidity, and restrict tioal flow behind the plugs. If

Table 4-8. The estimated monthly waterfowl populations on the Savannah National Wildlife Refuge in 1977; these figures represent an average of four weekly surveys conducted by refuge personnel (U.S. Department of the Interior, Fish and Wildlife Service, Savannah National Wildlife Refuge, unpubl. data).

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
American coot	3,600	2,000	1,400	1,000	150	50	30	45	50	100	600	3,000	12,025
Whistling swan	15	25	25	25									90
Snow and blue goose		4	3										7
Canada goose		10	7										17
Mallard duck	3,600	3,000	900	10							50	1,000	8,560
Black duck	600	600	90	5							25	400	1,720
Gadwall	300	200	500								40	200	1,240
Pintail	2,000	3,000	745	20							50	600	6,415
Green-winged teal	5,000	7,000	2,230	100							10	2,000	16,340
Blue-winged teal	180	200	320	65						25	300	300	1,390
American wigeon	1,000	500	300	50							30	600	2,480
Shoveler	350	800	540	125								150	1,965
Wood duck	4,000	3,500	1,130	550	600	650	1,000	1,000	1,000	1,100	1,500	10,000	26,030
Redhead		5	3								4		12
Ring-necked duck	3,500	1,500	135								200	5,000	10,335
Canvasback	400	650	505	5							5	50	1,615
Scaups	15	20									50	20	105
Bufflehead	5												5
Ruddy duck	50	50	40								5	10	155
Red-breasted merganser													--
Hooded merganser	20	100	10										130
Black scoter													--
Total	24,635	23,164	8,883	1,955	750	700	1,030	1,045	1,050	1,225	2,869	23,330	90,636

these aims are achieved, desired aquatic plant production is favored and waterfowl usage is likely to increase. In areas with relatively large tidal fluctuations, like those found in the South Carolina coastal region, flap gates can be installed in the earthen plugs to improve the water management potential in these marsh areas. Flap gates permit excessive water to drain from the area, while prohibiting undesirable water from entering on the incoming tide.

Weirs are similar in function to earthen plugs in that their main purpose is to stabilize water levels. They are constructed in such a manner that water is held behind the weir during low tides, but passes over the weir and into the impounded area during high tides. Thus, water levels behind weirs can recede to only a fixed level, thereby prohibiting excessive drainage of the area during low tides.

The most common method of impounding marshes in the coastal region is to construct dikes around the desired area. This method allows for the greatest degree of control within the impounded area. Diking, with the appropriate water inlets and drainage outlets, enables the manager to alter conditions within the impoundment so as to encourage desirable plant species and discourage undesirable ones. Most managed waterfowl impoundments in the South Carolina coastal region are diked.

a. Freshwater Marsh. In freshwater marshes, some of the most desirable food plants are annuals which cannot maintain themselves on permanently flooded sites. These require moist or dry ground to grow and produce a good crop. They must be flooded in the fall in order to attract waterfowl. The seeds of many useful marsh plants germinate better when water levels are lowered until only a moist bed remains. Then, better aeration and higher temperatures stimulate germination of the seeds of many food plants that are difficult to establish when land is covered with water. This aeration also releases, by decomposition, nutrients that would remain bound up in submerged plant materials. Plants that are encouraged by this method of water control are smartweeds, wild millet, Asiatic dayflower, tearthumb, spikerushes, panic grasses, red root, rice cutgrass, and arrow-arum.

To encourage these plants, a late winter drawdown is required. This enables the soil to dry out sufficiently to either cultivate or, if possible, to burn before plants turn green in the spring. Once the soil has been either prepared mechanically or the old vegetation burned, the water level is raised even with the bed, but not ponding over the soil. An effort should be made to keep the water at this level during the growing season. If the soil is kept too dry during the growing season, plume grass, beggar ticks, tearthumb, wood awn-grass, foxtail grass, alder, and willow will dominate the plant community. These plants are of moderate value as waterfowl foods. If the impoundment is kept flooded during the growing season, then such undesirable plants as giant cutgrass, cat-tails, pickerel weed, alligator-weed, and even lotus and white water-lily are encouraged. In addition, manipulation of water level, fire, and mechanical disturbance of the soil are probably the most important management tools in freshwater marsh impoundments.

Specific objectives should be established before a marsh is burned. Normally the aims would be one or more of the following.

1. To set back plant succession from an undesirable climax or near-climax to sub-climax plant community that will produce more waterfowl food.

2. To remove or open up dense growths of vegetation to a degree suitable for use as feeding areas by waterfowl.

3. To create ponds and open water areas in a dense marsh by burning into the marsh floor.

Burning helps to cultivate the marshland, and the marsh is fertilized by ash deposits left by fire. Marshes usually have a healthier appearance during regrowth following fire, partly because of the release of nutrients by burning. When and how to burn are important considerations. Healthy shallowwater marshes in the final stages of plant succession sometimes produce vegetative cover too dense for winter use by ducks. A clean cover burn usually done in the fall or winter will produce an immediate change in the habitat because it removes all standing vegetation. Seldom, however, do marked changes in vegetative types result from a cover fire, Root burns are made when the marsh floor is dry and the water table is well below ground level. Such fire damages roots of plants and can change the types of vegetation. A hot root burn can reduce or remove climax vegetation, which generally is useless to waterfowl. A third type of burn involves an extremely dry marsh growing on a layer of dry peat. Marsh soils comprised mainly of organic materials from decaying plants will burn when dry enough. Small potholes, ponds, and even large lakes can be created by means of peat burns.

Mechanical disturbance of the soil can be effective in setting back succession, creating openings for waterfowl feeding and resting areas or for preparing a seed bed for cultivated crops.

b. Saltwater Marsh. The brackish marsh should be managed somewhat differently than the freshwater marsh for optimal production of waterfowl food plants such as widgeon grass, salt-marsh bulrush, and dwarf spikerush. As a matter of convenience, these marsh impoundments can be characterized as those that have water salinities of 0.5°/oo or more.

In brackish marsh impoundments with salinities that normally range above 0.5°/oo, both emergents and submerged aquatic plants can be grown together. Quite often management is aimed as much at discouraging or eliminating undersirable plants as it is directed toward encouraging desirable food plants. A technique that has been successful in low salinity marshes is to de-water the impoundment in late February and keep the bed semi-dry through March. During this period, salt-marsh bulrush and dwarf spikerush will begin to grow. In the spring, the impoundment is re-flooded to a depth of 6 in (15.2 cm). Until late summer, water is added monthly in 6-in increments until a depth of about 2 ft (0.6 m) is reached. During this time, the saltmarsh bulrush and dwarf spikerush will continue to grow; widgeon grass will grow in the more open area.

Once a 2-ft (0.6 m) water level has been reached, it is desirable to keep water gradually moving through an intake structure, across the impoundment, and over a spillway. This helps to keep the salinity up and by moving water through the impoundment, it will flush blooms of undersirable algae out which otherwise remain and limit sunlight penetration through the water. In late summer and early fall, plants such as wild millet, sprangle-top, and fall panic grass will be dominant along the shallow edges of the impoundment.

Often when these impoundments are kept dry, smooth cordgrass will become dominant, and, once established, it may take several years to eliminate unless mechanical means are used. If an impoundment of this type is allowed to remain permanently flooded, the salinity will evenually be lowered and narrow-leaved cat-tail will dominate the saltmarsh bulrush as well as take over in the shallow margins. In the deeper open water areas, an algae called Cladophora will usually form solid mats that practically exclude other submerged aquatics.

Widgeon grass is one of the more desirable plant species found in brackish marsh impoundments. No single factor is more detrimental to the establishment or maintenance of stands of widgeon grass than water fluctuation. When water fluctuations are great and pond bottoms are periodically exposed, widgeon grass will not become established or, if established, the stand will quickly disappear. In large open ponds, wave action can be detrimental to stands of well-established widgeon grass. The establishment of wind breaks, either by encouraging natural stands of emergent vegetation or by the construction of some physical wave barrier, is helpful in this situation.

Another desirable type of submerged aquatic that grows well in brackish marsh impoundments is the nonvascular muskgrasses (Chara spp.) Large numbers of ducks can be attracted by this food plant. Muskgrass does best in salinities of $15^o/oo$ or less. Muskgrass requires "hard" water as it becomes encrusted with calcium carbonate, and the continued presence of this type of plant from year to year may result in the deposition of considerable calcareous material upon the pond bottom. It does well where the water is clear and very poorly where the water is turbid.

Sago pondweed is a very valuable waterfowl food plant commonly found in hardwater lakes. Generally sago pondweed grows best in fresh water, but tuber production is at an optimum at about $3^o/oo$ salinity. Sago plants show different tolerances to salt at different ages. For instance, 1 week old plants will tolerate $9^o/oo$ but die at $12^o/oo$. Four week old plants will tolerate $12^o/oo$ but die at $15^o/oo$, and 8 week old plants tolerate $15^o/oo$ but die at $18^o/oo$.

A final management consideration concerning brackish marsh impoundments is associated with large populations of fish. In ponds that are kept fairly fresh from year to year, carp populations can become a problem. Carp, and sometimes mullet, can affect vegetation in at least three ways: a) by uprooting vegetation while searching for food, b) through consumption of plants for food, and c) by causing increased turbidity, which limits sunlight penetration, which in turn limits plant growth. Also, when these fish keep nutrients in suspension through rooting or otherwise digging up bottom sediments, heavy blooms of bluegreen algae often result.

2. Hardwood Bottomlands

Hardwood bottomlands can be managed very successfully to attract waterfowl. Wood ducks, mallards, and black ducks can be attracted in a flooded hardwood bottom that has a good stand of mast-producing trees. Flooded hardwood bottomlands do not have to be of great size to be effective. Even small areas containing oaks, hickory, black gum, tupelo, sweet gum, and bald cypress will attract ducks when properly flooded.

The essentials for managing hardwood bottomland areas for waterfowl are suitable terrain and soil, a source of water, and mast producing trees. The most suitable terrain is large expanses of flat land where a relatively inexpensive low dike can impound several inches of water over a large areas. If such topography is not available, then a series of steps can be constructed to flood a series of smaller impoundments. An important consideration is to design the dikes low with a wide base to reduce damage to them when flood waters overflow them. The water control structures should be adequate to handle the volume of water in the drainage. The structure should be placed to permit an impoundment depth of from 1 to 15 in (2.5 - 76.2 cm), plus have the capability to permit the complete drainage of the area.

A dependable and adequate source of water is desirable. Storage reservoirs from which the bottomland can be flooded by gravity flow are ideal. Pumping is another method that allows water control; however, this method can be expensive when large acreages are involved. Pumping is sometimes useful in supplementing other sources of water.

A timing of flooding and drainage is important to the survival and vigor of mast-producing trees. Flooding can be started safely in the fall just as the leaves begin to turn color, but the area should be drained by the time the buds begin to swell in the spring. Complete drainage before the growing season is important, because summer flooding can damage or kill desirable mast species. The safe period of flooding extends from early October through February in the South Carolina Coastal Region.

Manipulation of water levels may help prevent depletion of the acorn crop by other species of wildlife before the waterfowl arrives in the fall. A periodic lowering of water levels during the fall and winter may prove necessary to obtain a more complete use of the acorns by ducks.

Quite often the stand of timber in a hardwood impoundment can be improved to have maximum value for waterfowl. The goal for waterfowl management should be to achieve a forest with a preponderance of vigorous, large-crowned, mast-producing species. Stagnated and slow growing stands of desirable trees should be thinned to give the crowns a chance to grow.

D. ECONOMIC CONSIDERATIONS OF WATERFOWL MANAGEMENT

Morgan (1974) and Morgan et al. (1975) reported on the biological and economic aspects of wetlands management within the Edisto-Ashepoo-

Combahee drainage system along the coast of South Carolina. Of the 335,629 acres (135,827 ha) in the study area, 98,451 acres (39,842 ha) were wetlands. This included 1) 54,087 acres (21,889 ha) of undiked marsh and tidal swamp, 2) 21,828 acres (8,834 ha) of abandoned impoundments (98% of which were former rice fields), and 3) 22,536 acres (9,120 ha) of managed impoundments. Of the 213 impoundments, 154 (72% totaling 19,064 acres (7,715 ha) (85%), were managed to attract waterfowl.

Capital investments and annual costs of managing diked impoundments for waterfowl were estimated. The following summarizes the results of this economic evaluation; refer to Morgan (1974) for further details.

1. Capital Investments

The initial investment involved in marsh management is the purchase of the marsh. Cost of marsh in the area varied widely, depending on the location, presence or absence of impoundments, relation to adjoining high ground, and total acreage involved. Estates are usually sold as a unit with no distinction being made between costs of marsh and high ground. Consequently, it is difficult to establish a market value for marshland alone. The major investment in developing diked impoundments is constructing the dikes and associated water control structures. Capital values for these investments were based on replacement costs.

a. Dikes. The cost of building an average sized dike (7 feet high, 12 feet wide at the top, and 30 feet wide at the base) was \$1.65 per linear foot if built on stable soils. This was assuming no major problems occurred, and diking could proceed unimpeded. Usually 2 years after a dike was built, an additional "pass" was needed to bring the dike up to grade, at an additional cost of \$1.25 per linear foot. An extra cost of \$400 - \$800 was often incurred when dikes were built across creeks or when broken dikes needed repair; the above estimate does not include these figures. Therefore, a conservative estimate of cost per linear foot is about \$3.00. This low cost could only be met when the following conditions existed: good stable soils, absence of creek beds, and favorable weather conditions.

b. Other Water Control Structures. Drag-line operators and individuals who built water control structures were interviewed. Their cost figures and charges were used to calculate replacement costs for all water control structures in the study area.

Replacement costs of wooden water control structures, except very small and simple ones, were based on a "standard" size trunk (i.e., 2 feet high, 5 feet wide, and 36 feet long) with two flap gates and one flash-board riser. The replacement cost for this trunk was \$2,290.

Metal water control structures were usually made of heavy gauge steel pipe with bronze flap gates. Replacement costs for most of these were based on a standard size trunk 36 inches in diameter and 36 feet long with two bronze flap gates and one flash-board riser. The cost of such a trunk was $1,460. Replacement costs for smaller, simpler trunks ranged from $395 to $875 each.

A replacement cost of $1,920 each for the 10 concrete water control structures in the study area was determined from cost lists of concrete pipe companies in the Charleston area.

2. Annual Costs

Questionnaires were sent to 23 of the 52 property owners. Fourteen returned these forms which provided various types of information on annual costs. The following estimates of annual costs are based on maintenance of dikes and other water control structures, habitat manipulations, and taxes. Only labor related directly to these operations is included; labor costs for mowing dike vegetation and for maintenance of access roads, barns, storage building, equipment and other indirect labor costs are not included, nor are costs of equipment not used solely for management of impoundments.

a. Maintenance of Dikes - Eleven of the 14 forms returned contained specific information relating to intervals between necessary dike retopping. The average interval for retopping was 6 years, with some landowners retopping at 2 years and others at 10 years. An average cost of $1.25 per linear foot for retopping is based on interviews with drag-line operators. Continually sinking dikes or numerous bad breaks ("blow-outs") would increase this costs considerably. Another factor in dike maintenance cost was mowing, but no estimate of this cost was made.

b. Maintenance of Other Water Control Structures. Cost records provided by six landowners indicated the actual cost of annual water control structure maintenance to be $72.00 each.

c. Habitat Manipulation. Nine of the returned forms contained details on annual cost of habitat manipulation within impoundments, including flooding, burning, water-level manipulation, disking, plowing, planting of commercial crops, cattle grazing, and herbicide application. Extremes of habitat management costs for these nine property owners ranged from $1.85 to $17.44 per acre per year ($4.57 to $43.09/ha/yr), with six reporting costs between $7 and $11 per acre ($17.30 and $27.18/ha). The average cost of annual habitat manipulation for privately managed areas was $8.25 per acre ($20.37/ha). The South Carolina Wildlife and Marine Resources Department spent an average of $8.44 per acre ($20.84/ha) for annual habitat maintenance of the Bear Island Game Management Area.

The annual cost of habitat management per acre of impoundment depended on the ecological situation, the intensity of management, management goals, and the amount of capital an owner is willing to invest to achieve his objectives. There were extreme variations in operational costs, and simple averages of management and maintenance costs are misleading. Each property had peculiarities that made it unique and the resulting costs varied.

d. Taxes. The tax assessor from each county in the study area furnished information on the 1973 land taxes, which was the same for undeveloped uplands and wetlands in the study area. The property tax for each 100 acres of wetlands was as follows: Charleston County--$11.56; Colleton County--$37.10; and Beaufort County--$5.10.

e. Summary of Management Costs. The unit costs, capital and annual, given above were used to construct a model cost table for 100 acres (40.5 ha) of diked impoundment over a 20-year period (Table 4-9). It should be emphasized that the values in Table 4-9 are averages, and actual costs varied greatly with the individual situation.

Based on an extrapolation of data in Table 4-9, total annualized cost for the 19,064 acres (7,715 ha) of diked impoundments managed for waterfowl was $516,846. From this figure and the estimated annual harvest of 11,438 ducks, the cost per duck harvested was $45. From the same cost figure and the 3,432 man-days of hunting previously calculated, the cost per man-day of hunting was $151. For those impoundments in which cattle were grazed, management costs may be reduced by the value of the grazing provided, based on appropriate rates for each grazing day.

The financial investment in the management of diked impoundments for the entire study area was large. Total replacement costs for all functioning dikes and water control structures in the area were calculated to be $2,048,774. Total annual costs of management of all diked impoundments were calculated to be $405,427 including $22,777 in property taxes.

Although the above economic evaluation is specific to the area studied and not necessarily characteristic of other coastal areas, it does provide an important evaluation of the costs associated with waterfowl management. Clearly, when lands under private, State, and Federal ownership are considered collectively, the capital and annual investments for waterfowl habitat management represent significant economic investments.

Table 4-9. Average cost of managing 100 acres of diked impoundment in the lower Edisto, Combahee, and Ashepoo drainage basins, South Carolina (Morgan 1974)[a].

Cost Category	Capital Cost[b]	Annual Cost	Total Capital and Annual Cost
Dike construction	$7,340	$ --	$ 748
Water control structures (wooden)	2,290	--	233
Maintenance			
dikes	--	764	764
water control structures	--	72	72
Habitat manipulation	--	852	852
Taxes (Colleton County)	--	37	37
Total	$9,630	$1,725	$2,706

a. Does not include costs of land, estate labor, facilities, and equipment which are primarily used in management of uplands.

b. Capital cost annualized at 8% for 20 years.

REFERENCES CITED

Alexander, E. P. 1908. Game preserves of E. P. Alexander - North and South islands, Winyah Bay, South Carolina. Herald Publ. Co., Hagerstown, Md. 19 pp.

Allen, E. R. and W. T. Neill. 1949. Increasing abundance of the alligator in the eastern portion of its range. Herpetologica 5: 109-112.

Allen, M. J. 1932. A survey of the amphibians and reptiles of Harrison County, Mississippi. Am. Mus. Novit. 542. 20 pp.

American Birds. 1971. Seventy-first Christmas bird count. Am. Birds 25(2): 287-295.

American Birds. 1972. Seventy-second Christmas bird count. Am. Birds 26(2): 287-295.

American Birds. 1973. Seventy-third Christmas bird count. Am. Birds 27(2): 286-295.

American Birds. 1974. Seventy-fourth Christmas bird count. Am. Birds 28(2): 297-306.

American Birds. 1975. Seventy-fifth Christmas bird count. Am. Birds 29(2): 324-332.

American Birds. 1976. Seventy-sixth Christmas bird count. Am. Birds 30(2): 334-344.

American Birds. 1977. Seventy-seventh Christmas bird count. Am. Birds 31(4): 584-596.

Anderson, W. D. 1976. A comparative study of a salt water impoundment with its adjacent tidal creek pertinent to culture of Crassostrea virginica (Gmelin). M.S. Thesis. Old Dominion Univ., Norfolk, Va. 65 pp.

Audubon Field Notes. 1967. Sixty-seventh Christmas bird count. Audubon Field Notes 21(2): 184-191.

Audubon Field Notes. 1968. Sixty-eighth Christmas bird count. Audubon Field Notes 22(2): 203-209.

Audubon Field Notes. 1969. Sixty-ninth Christmas bird count. Audubon Field Notes 23(2): 229-235.

Audubon Field Notes. 1970. Seventieth Christmas bird count. Audubon Field Notes 24(2): 228-236.

Baden, J. III, W. T. Batson, and R. Stalter. 1975. Factors affecting the distribution of vegetation of abandoned rice fields, Georgetown County, South Carolina. Castanea 40(3): 171-184.

Badger, A. G. 1968. Oyster research in South Carolina, pp. 67-69. In: Proc. oyster culture workshop. Ga. Game Fish Comm. Contrib. Ser. 6. Atlanta.

Bailey, J. W. 1851. Microscopical observations made in South Carolina, Georgia and Florida. Smithson. Contrib. Knowledge 2(8): 1-48.

Baldwin, W. P. 1950. Recent advances in managing coastal plain impoundments for waterfowl. Presented Southeast. Assoc. Game & Fish Comm. Conf., Richmond, Va. 12 pp. (unpubl.)

Baldwin, W. P. 1956. Food supply key to attracting ducks. S.C. Wildl. 3(1): 5-12.

Baldwin, W. P. 1968. Impoundments for waterfowl on South Atlantic and Gulf coastal marshes, pp. 127-133. In: J. D. Newsom, ed. Proceedings of the marsh and estuary management symposium. La. State Univ., Baton Rouge.

Ballard, G. S. 1975a. A consideration of oyster culture in old rice fields, pp. 13-17. In: J. M. Dean, ed. The potential use of South Carolina rice fields for aquaculture. S.C. State Dev. Board, Columbia.

Ballard, G. S. 1975b. The ecology of the rice field, pp. 1-12. In: J. M. Dean, ed. The potential use of South Carolina rice fields for aquaculture. S.C. State Dev. Board, Columbia.

Bara, M. O. 1971. Alligator research project. Annu. progress rep. Aug. 1970 - Dec. 1971. S.C. Wildl. Mar. Resour. Dep., Columbia. 39 pp.

Bara, M. O. 1976. American alligator investigations. Final study rep. Aug. 1970 - Dec. 1975. S.C. Wildl. Mar. Resour. Dep., Columbia. 39 pp.

Battle, J. D. 1892. An investigation of the coast waters of South Carolina with reference to oyster culture. Fish. Bull. 10: 303-330.

Baughman, J. L. 1948. An annotated bibliography of oysters with pertinent material on mussels and other shellfish and an appendix on pollution. Tex. Agric. Mining Res. Found., Rockport Pilot College Stn. Tex. A&M Univ., College Stn. 794 pp.

Bearden, C. M. 1967. Salt-water impoundments for game fish in South Carolina. Prog. Fish-Cult. 29(3): 123-128.

Bears Bluff Laboratories, Inc. 1956. Annual report 1954-1955. Contrib. Bears Bluff Lab. No. 18. Wadmalaw Ilsand, S.C. 15 pp.

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole, Harrisburg, Pa. 540 pp.

Benke, A. C. 1972. An experimental field study on the ecology of co-existing larval odonates. Ph.D. Dissertation. Univ. Ga., Athens. 112 pp.

Benke, A. C. 1976. Dragonfly production and prey turnover. Ecology 57: 915-927.

Benke, A.C. and S. S. Benke. 1975. Comparative dynamics and life histories of co-existing dragonfly populations. Ecology 56: 302-317.

Benning, D. S., M. W. Smith, and S. L. Rhodes. 1975. Waterfowl status report, 1973. U.S. Fish Wildl. Serv. Spec. Sci. Rep.--Wildl. No. 188. 105 pp.

Bent, A. C. 1961. Life histories of North American birds of prey. 2 pts. Dover Publ., Inc., New York. (First publ. 1937, 1938.)

Bent, A. C. 1962a. Life histories of North American shore birds. 2 pts. Dover Publ., Inc., New York. (First publ. 1927, 1929.)

Bent, A. C. 1963c. Life histories of North American marsh birds. Dover Publ., Inc., New York. 392 pp. (First publ. 1926.)

Binmore, T. V. 1964. Oyster seed farming proves good venture. Natl. Fishermen - Maine Coast 45(9): 24-28.

Blaney, R. M. 1971. An annotated checklist and biogeographic analysis of the insular herpetofauna of the Appalachicola region, Florida. Herpetological 27: 406-430.

Borror, D. J. and D. M. Delong. 1964. An introduction to the study of insects. Holt, Rinehart, and Winston, Inc., New York. 819 pp.

Borthwick, P. W., T. W. Duke, A. J. Wilson, Jr., J. I. Lowe, J. M. Patrick, Jr., and J. C. Oberheu. 1973. Accumulation and movement of mirex in selected estuaries of South Carolina, 1969-71. Pestic. Monit. J. 7(1): 6-26.

Bouchon-Brandely, M. 1882. De la sexualite chez l'huitre ordinaire (O. edulis) et chez l'huitre Portugaise (O. angulata). Fecondation artificielle de l'huitre Portugaise. C. R. Hebd. Seances Acad. Sci. 95(5): 256-259. Translated by J. A. Ryder. Bull. U.S. Fish Comm. 1882(2): 339-341.

Brown, H. J. 1930. The desmids of the southeastern coastal plain region of United States. Trans. Am. Microsc. Soc. 49(2): 97-137.

Buckley, P. A. and F. G. Buckley. 1976. Guidelines for the protection and management of colonially nesting waterbirds. U.S. Dep. Inter., Natl. Park Serv., North Atlantic Regional Off., Boston, Mass.

Burger, J. 1978. The pattern and mechanism of nesting in mixed-species heronries, pp. 45-58. In: A. Sprunt, J. C. Ogden, and S. Winckler, eds. Wading birds. Natl. Audubon Soc. Res. Rep. 7. New York.

Burger, W. L., P. W. Smith, and H. M. Smith. 1949. Notable records of reptiles and amphibians in Oklahoma, Arkansas, and Texas. J. Tenn. Acad. Sci. 24: 130-134.

Burleigh, T. D. 1958. Georgia birds. Univ. Okla. Press, Norman. 746 pp.

Burton, E. M. 1970. Supplement, pp. 573-642. In: A. Sprunt, Jr. and E. B. Chamberlain. South Carolina bird life. Univ. S.C. Press, Columbia. (First publ. 1949.)

Cagle, F. R. 1952. A Louisiana terrapin population (Malaclemys), Copeia 1952: 74-76.

Camburn, K. E., R. L. Lowe, and D. L. Stoneburner. 1978. The hapto-benthic diatom flora of Longbranch Creek, South Carolina. Nova Hedwigia, Band 30: 149-279.

Carr, A. 1940. A contribution to the herpetology of Florida. Univ. Fla. Publ. Biol. Sci. Ser. 3(1): 1-118.

Carriker, M. R. 1956. Biology and propagation of young hard clams, Mercenaria mercenaria. J. Elisha Mitchell Sci. Soc. 72: 57-60.

Carriker, M. R. 1959. The role of physical and biological factors in the culture of Crassostrea and Mercenaria in a salt-water pond. Ecol. Monogr. 29(3): 219-266.

Chabreck, R. H. 1960. Coastal marsh impoundments for ducks in Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 14: 24-29.

Chabreck, R. H. 1966. The movement of alligators in Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 19: 102-110.

Chabreck, R. H. 1968. The relation of cattle and cattle grazing to marsh wildlife and plants in Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 22: 55-58.

Chabreck, R. H. 1972. The foods and feeding habits of alligators from fresh and saline environments in Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 25: 117-124.

Chamberlain, E. B. 1968. Birds of the Francis Marion National Forest. U.S. Dep. Agric., Forest Serv., Atlanta. 32 pp.

Chamberlain, E. B. 1974. Rare and endangered birds of the southern national forests. U.S. Dep. Agric., Forest Serv., Atlanta, Ga.

Chamberlain, W. D., Jr. and E. B. Chamberlain. 1975. Avifauna of Kiawah Island, pp. AV1-AV107. In: W. M. Campbell, J. M. Dean, and W. D. Chamberlain, eds. Environmental inventory of Kiawah Island. Environmental Research Center, Inc., Columbia, S.C.

Coker, R. E. 1906. The natural history and cultivation of the diamond-back terrapin. N.C. Geol. Surv. Bull. No. 14. 69 pp.

Coker, R. E. 1920. The diamond-back terrapin: past, present and future. Sci. Mon. N.Y. 11: 171-186.

Coker, R. E. 1938. Notes on the peculiar crustacean fauna of White Lake, North Carolina. Arch. Hydrobiol. 34: 130-133.

Coleman, F. D. and J. A. Dennis. 1974. Inventory of lakes in South Carolina ten acres or more in surface area. S.C. Water Resources Comm. Physical Inventory Rep. No. 119. Columbia. 222 pp.

Colson, C. B. 1888. History of the mill pond oyster and cause of its disappearance. Elliott Soc. Proc. 5 pp.

Conant, R. 1975. A field guide to reptiles and amphibians of Eastern and Central North America. Houghton-Mifflin Co., Boston, Mass. 429 pp. (First publ. 1958.)

Conant, R. and J. D. Lazell, Jr. 1973. The Carolina salt marsh snake: a distinct form of Natrix sipedon. Breviora 400: 1-13.

Conrad, W. B., Jr. 1966. A Food habit study of ducks wintering on the lower Pee Dee and Waccamaw rivers. Georgetown, South Carolina. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 19: 93-98.

Copeland, B. J. 1974. Impoundment systems, pp. 168-179. In: H. T. Odum, B. J. Copeland, and E. A. McMahan, eds. Coastal ecological systems of the United States. Vol. III. The Conservation Foundation, Washington, D.C.

Corbin, F. 1951. Notes on the blue-green algae of South Carolina with some additions to the flora of the State. Bios 22: 129.

Courtney, W. A., ed. 1884. Charleston, S.C. - the centennial of incorporation. News & Courier Book Presses, Charleston, S.C. 259 pp.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. Laroe. 1977. Classification of wetlands and deep-water habitats of the United States. An operational draft. U.S. Fish. Wildl. Serv., Off. Biol. Serv., Washington, D.C. 100 pp.

Cross, W. H. 1955. Anisopteran Odonata of the Savannah River Plant, South Carolina. J. Elisha Mitchell Sci. Soc. 71: 9-17.

Cummins, K. W. 1975. The importance of different energy sources in freshwater ecosystems, pp. 50-54. In: productivity of world ecosystems. National Academy of Sciences. Washington, D.C.

Custer, T. W. and R. G. Osborn. 1977. Wading birds as biological indicators: 1975 colony survey. U.S. Fish Wildl. Serv. Spec. Sci. Rep.--Wildl.

Cutts, E. 1955. Depredation at a breeding colony. Chat 19: 70.

Dames and Moore Associates. 1975. Environmental assessment report proposed chemical plant, Berkeley County, South Carolina for Amoco Chemicals Corporation. Park Ridge, Ill.

Davis, D. E. 1960. The spread of the cattle egret in the United States. Auk 77: 421-424.

Davis, J. S., M. D. McKenzie, J. V. Miglarese, R. H. Dunlap, J. J. Manzi, L. A. Barclay. 1980. Ecological Characterization of the Sea Island Coastal Region of South Carolina and Georgia. Resource Atlas. U.S. Dept. Int. Fish Wildl. Serv., Office Biol. Serv. FWS-OBS 79/43. 56 PP.

Dean, B. 1892a. The physical and biological characteristics of the natural oyster-grounds of South Carolina. Fish. Bull. 10: 335-361.

Dean, B. 1893. Report on the European methods of oyster-culture. Bull. U.S. Fish. Comm. 11(1891): 357-406.

Dean, J. M. 1975. The potential use of South Carolina rice fields for aquaculture. S.C. State Dev. Board, Columbia. 96 pp.

Deevey, G. B. 1948. The zooplankton of Tisbury Great Pond. Bull. Bingham Oceanogr. Collect. Yale Univ. 12(1): 1-44.

Denton, J. F., E. B. Chamberlain, and B. R. Chamberlain. 1950. South Atlantic coast region. Audubon Field Notes 4: 270.

Dillard, G. E. 1966. A floristic and ecological study of benthic algae in two North Carolina streams. Ph.D. Dissertation. N.C. State Univ., Raleigh.

Dillard, G. E. 1967. The freshwater algae of South Carolina. I. Previous work and recent additions. J. Elisha Mitchell Sci. Soc. 83: 128-131.

Doar, D. 1936. Rice and rice planting in the South Carolina low country. Charleston Mus. Contrib. No. 8. 69 pp.

Dusi, J. L. and R. T. Dusi. 1968. Ecological factors contributing to nesting failure in a heron colony. Wilson Bull. 80: 458-466.

Dusi, J. L. and R. T. Dusi. 1970. Nesting success and mortality of nestlings in a cattle egret colony. Wilson Bull. 82: 458-460.

Engels, W. L. 1942. Vertebrate fauna of North Carolina coastal islands, a study in the dynamics of animal distribution. I. Ocracoke Island. Am. Midl. Nat. 28(2): 273-304.

Engels, W. L. 1952. Vertebrate fauna of North Carolina coastal islands. II. Shackleford Banks. Am. Midl. Nat. 47(3): 702-742.

Forsythe, D. M. 1978. Birds, pp. 277-295. In: R. G. Zingmark, ed. An annotated checklist of the biota of the coastal zone of South Carolina. Univ. S.C. Press, Columbia.

Fritz, G. 1975. Measurement of the standing crop biomass. Part V. pp. 37-42. In: J. M. Dean, ed. The potential use of South Carolina rice fields for aquaculture. S.C. State Development Board, Columbia.

Frohne, W. C. 1942. Notes on Phymatodocis norostedtiana Wolle (Desmidiaceae) from South Carolina and its var. minor Borgesen from Georgia. Trans. Am. Microsc. Soc. 61: 438-441.

Gaarder, T. and R. Sparck. 1932. Hydrographisch-biochemische untersuchungen in Norwegischen Austern-pollen. Bergeus Mus. Arab. Naturv. Rek. 1: 1-44.

Galtsoff, P. S. 1964. The American oyster Crassostrea virginica Gmelin. Fish. Bull. 64. 480 pp.

Gibbons, J. W. 1978. Reptiles, pp. 270-276. In: R. G. Zingmark, ed. An annotated checklist of the biota of the coastal zone of South Carolina. Univ. S.C. Press, Columbia.

Gibbons, J. W. and J. W. Coker. 1978. Herpetofaunal colonization patterns of Atlantic Coast barrier islands. Am. Midl. Nat. 99(1): 219-233.

Gibbons, J. W. and J. R. Harrison. 1975. Reptiles and amphibians of Kiawah Island, pp. R1-R26. In: W. M. Campbell, J. M. Dean, and W. D. Chamberlain, eds. Environmental Inventory of Kiawah Island. Environmental Research Center, Inc., Columbia, S.C.

Goldstein, A. K. and J. J. Manzi. 1976. Additions to the freshwater algae of South Carolina. J. Elisha Mitchell Sci. Soc. 92(1): 9-13.

Golley, F. B. 1962. Mammals of Georgia. Univ. Ga. Press, Athens. 218 pp.

Golley, F. B. 1966. South Carolina mammals. Charleston Mus., Charleston, S.C. 181 pp.

Gosner, K. L. 1971. Guide to identification of marine and estuarine invertebrates. John Wiley and Sons, Inc., New York. 693 pp.

Grant, R. R., Jr. 1974. Algae, pp. 16-30. In: Cooper River survey 1973 for the E. I. DuPont de Nemours and Company. Acad. Nat. Sci. Philadelphia.

Gray, L. C. 1941. History of agriculture in the Southern United States to 1860. 2 vols. Peter Smith, New York. 1086 pp.

Gresham, C. A. and D. D. Hook. 1982. Rice fields of South Carolina: A resource inventory and management policy evaluation. Coastal Zone Management Journal 9(2): 183-203.

Hardy, J. D., Jr. 1953. Notes on the distribution of Mycrohyla carolinensis in southern Maryland. Herpetologica 8: 162-166.

Harmon, B. G. 1962. Mollusks as food of lesser scaups along the Louisiana coast. Trans. N. Am. Wildl. Nat. Resour. Conf. 27: 132-138.

Harrison, J. R. 1978. Herpetofauna: amphibians, pp. 260-269. In: R. G. Zingmark, ed. An annotated checklist of the biota of the coastal zone of South Carolina. Univ. S.C. Press, Columbia.

Hayes, M. O., S. J. Wilson, D. M. Fitzgerald, L. J. Hulmes, and D. K. Hubbard. 1975. Coastal processes and geomorphology, pp. G1-G165. In: W. M. Campbell, J. M. Dean, and W. D. Chamberlain. Environmental inventory of Kiawah Island. Environmental Research Center, Inc., Columbia, S.C.

Hebard, F. V. 1941. Winter birds of the Okefenokee and Coleraine. Bull. 3. Ga. Soc. of Naturalists. 84 pp.

Hepp, G. R. and J. D. Hair. 1977. Wood duck brood mobility and utilization of beaver pond habitats. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 31: 216-225.

Heyward, D. C. 1937. Seed from Madagascar. Univ. N. C. Press, Chapel Hill. 256 pp.

Hillestad, H. O., J. R. Bozeman, A. S. Johnson, C. W. Berisford, and J. I. Richardson. 1975. The ecology of the Cumberland Island National Seashore, Camden County, Georgia. Ga. Mar. Sci. Cent. Tech. Rep. Ser. No. 75-5. Skidaway Island. 299 pp.

Hilliard, S. B. 1975. The tidewater rice plantation: an ingenious adaptation to nature, pp. 57-66. In: H. J. Walker, ed. Geoscience and man. Vol. 12. La. State Univ., School of Geoscience, Baton Rouge.

Horak, G. J. 1970. A comparative study of the foods of the sora and Virginia rail. Wilson Bull. 82(2): 206-213.

Jacobs, J. E. 1968. A preliminary check list of fresh-water algae in South Carolina. J. Elisha Mitchell Sci. Soc. 84(4): 454-457.

Jacobs, J.E. 1971. A preliminary taxonomic survey of the freshwater algae of the Belle W. Baruch Plantation in Georgetown County, South Carolina. J. Elisha Mitchell Sci. Soc. 87: 26-30.

Joanen, T. 1969. Nesting ecology of alligators in Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 23: 141-151.

Joanen, T. 1974. Population status and distribution of alligators in the Southeastern United States. Presented at Southeast. Regional Endangered Species Workshop. Sept. 1974. Tallahassee, Fla. 44 pp. (Unpubl.)

Joansen, T. and L. McNease. 1970. A telemetric study of nesting female alligators on Rockefeller Refuge, Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 24: 175-193.

Joanen, T. and L. McNease. 1973. A telemetric study of adult male alligators on Rockerfeller Refuge, Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 26: 252-275.

Joanen, T., L. McNease, H. DuPuie, and W. G. Perry. 1972. Salinity tolerance of hatchling alligators. La. Wildl. Fish. Comm., 1970-71 Biennial Rep. 14: 56. New Orleans.

Johnsgard, P. A. 1975. Waterfowl of North America. Indian Univ. Press, Bloomington. 571 pp.

Johnson, A. S., H. O. Hillestad, S. F. Shanholtzer, and G. F. Shanholtzer. 1974. An ecological survey of the coastal region of Georgia. Natl. Park Serv. Sci. Monogr. Ser. No. 3. Washington, D.C. 233 pp.

Joyce, E. A. 1972. A partial bibliography of oysters, with annotations. Fla. Dep. Nat. Resour. Mar. Res. Lab. Spec. Sci. Rep. No. 34. 846 pp.

Kale, H. W. II. 1965. Ecology and bioenergetics of the long-billed marsh wren, Telmatodytes palustris griseus, in a salt marsh ecosystem. Nuttall Ornithol. Club Publ. No. 5. 142 pp.

Keith, J. O. 1968. Insecticide residues in fish-eating birds and their environment. Aves 5(1): 28-41.

Kerwin, J. A. and L. G. Webb. 1972. Foods of ducks wintering in coastal South Carolina, 1965-1967. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 25: 223-245.

Kitchens, W. M., Jr., J. M. Dean, L. H. Stevenson, and J. H. Cooper. 1975. The santee swamp as a nutrient sink, pp. 349-366. In: F. G. Howell, J. B. Gentry, and M. H. Smith, eds. Mineral cycling in southeastern ecosystems. U.S. Energy Res. Dev. Adm. Symp. Ser. Conf-740513.

Knott, D. M. 1980. The zooplankton of the North Edisto River and two artificial saltwater impoundments. M.S. Thesis, College of Charleston.

Korringa, P. and H. Postuma. 1957. Investigations into the fertility of the Gulf of Naples and adjacent salt water lakes with special reference to shellfish cultivation. Pubbl. Stn. Zool. Napoli 29: 229-284.

Landers, J. L., T. T. Fendley, and A. S. Johnson. 1977. Feeding ecology of wood ducks in South Carolina. J. Wildl. Manage. 41(1): 118-127.

Landers, J. L., A. S. Johnson, P. H. Morgan, and W. P. Baldwin. 1976. Duck foods in managed tidal impoundments in South Carolina. J. Wildl. Manage. 40(4): 721-728.

Loosanoff, V. L. 1964. New shellfish farming. Trans. N. Am. Wildl. Nat. Resour. Conf. 29: 332-336.

Loosanoff, V. L. and H. C. Davis. 1963. Rearing of bivalve mollusks. Adv. Mar. Biol. 1: 1-136.

Lowery, G. H., Jr. 1974. The mammals of Louisiana and its adjacent waters. La. State Univ. Press, Baton Rouge. 565 pp.

Lunz, G. R. 1951. A salt water fish pond. Contrib. Bears Bluff Lab. No. 12. Wadmalaw Island, S.C. 12 pp.

Lunz, G. R. 1952a. Oysters in South Carolina grow above low tide level. Atl. Fisherman 18: 42-43.

Lunz, G. R. 1955. Cultivation of oysters in ponds at Bears Bluff Laboratories. Proc. Natl. Shellfish. Assoc. 46: 83-87.

Lunz, G. R. 1956. Harvest from an experimental one acre salt-water pond at Bears Bluff Laboratories, South Carolina. Prog. Fish-Cult. 18(2): 92-94.

Lunz, G. R. 1957. Pond cultivation of shrimp in South Carolina. Gulf Caribb. Fish. Inst. Proc. 10: 44-48.

Lunz, G. R. 1958. Salt ponds can raise shrimp cheaper than sea trawlers can catch them. Quick Frozen Foods 1958: 111-112, 114.

Lunz, G. R. 1968. Farming the salt marshes, pp. 172-177. In: J. D. Newsom, ed. Proceedings of the marsh and estuary management symposium. La. State Univ., Baton Rouge.

Lunz, G. R. and C. M. Bearden. 1963. Control of predaceous fishes in shrimp farming in South Carolina. Contrib. Bears Bluff Lab. No. 36. Wadmalaw Island, S.C. 9 pp.

Macfie, M. E. and L. F. Swails, Jr. 1957. The algae. A new distribution record of a rare variety of Micrasterias. Univ. S.C. Publ., Biol. Ser. III, 2(2): 61-62.

MacGregor, D. S. 1970. Studies of pond culture of oysters, pp. 1-36. In: T. L. Linton, ed. Feasibility study of methods for improving oyster production in Georgia. Completion rep. 2-10-R. Ga. Game Fish Comm., Mar. Fish. Div. and Univ. Ga.

Manzi, J. J., V. G. Burrell, and W. Z. Carson. 1977b. A comparison of growth and survival of subtidal Crassostrea virginica (Gmelin) in South Carolina salt marsh impoundments. Aquaculture 12: 293-310.

Manzi, J. J., P. E. Stofan, and J. L. Dupuy. 1977a. Spatial heterogeneity of phytoplankton populations in estuarine surface microlayers. Mar. Biol. 41: 29-38.

Manzi, J. J. and R. G. Zingmark. 1978. Phytoplankton, pp. 2-22. In: R. G. Zingmark, ed. An annotated checklist of the biota of the coastal zone of South Carolina. Univ. S.C. Press, Columbia.

Martof, B. S. 1956. Amphibians and reptiles of Georgia, a guide. Univ. Ga. Press, Athens. 94 pp.

McGilvrey, F. B. 1966a. Fall food habits of wood ducks from Lake Marion, South Carolina. J. Wildl. Manage. 30(1): 193-195.

McGilvrey, F. B. 1966b. Fall food habits of ducks near Santee Refuge, South Carolina. J. Wildl. Manage. 30(3): 577-580.

McGilvery, F. B. 1968. A guide to wood duck production habitat requirements, U.S. Bur. Sport Fish. Wildl. Resour. Publ. 60. 32 pp.

McIlhenny, E. A. 1934. Notes on incubation and growth of alligators. Copeia 1934: 80-88.

McIlhenny, E. A. 1935. The alligator's life history. The Christopher Publishing House, Boston. 117 pp.

Meanley, B. 1972. Swamps, river bottoms, and canebrakes. Barre Publ., Barre, Mass. 142 pp.

Metcalf, I. S. H. 1947. Preliminary note on algae and protozoa found in a fresh water pond. Contrib. Bears Bluff Lab. No. 3. Wadmalaw Island, S.C. 5 pp.

Moore, W. G. 1955. The life history of the spiny-tailed fairy shrimp in Louisiana. Ecology 36: 176-184.

Morgan, P. H. 1974. A study of tidelands and impoundments within a three-river delta system--the South Edisto, Ashepoo, and Combahee rivers of South Carolina. M.S. Thesis. Univ. Ga., Athens. 92 pp.

Morgan, P. H., A. S. Johnson, W. P. Baldwin, and J. L. Landers. 1975. Characteristics and management of tidal impoundments for wildlife in a South Carolina estuary. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 29: 526-539.

Mount, R. H. 1975. The reptiles and amphibians of Alabama. Auburn Univ. Agric. Exp. Stn., Auburn, Ala. 347 pp.

Neely, W. W. 1960. Managing Scirpus robustus for ducks. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 14: 30-34.

Neely, W. W. 1962. Saline soils and brackish waters in management of wildlife, fish, and shrimp. Trans. N. Am. Wildl. Nat. Resour. Conf. 27: 321-335.

Negus, N.C., E. Gould, and R. K. Chipman. 1961. Ecology of the rice rat, Oryzomys palustris (Harlan), on Breton Island, Gulf of Mexico, with a critique of the social stress theory. Tulane Stud. Zool. 8(4): 93-123.

Neill, W. T. 1958. The occurrence of amphibians and reptiles in salt-water areas, and a bibliography. Bull. Mar. Sci. Gulf Caribb. 8(1): 1-97.

Neill, W. T. 1971. The last of the ruling reptiles; alligators, crocodiles, and their kin. Columbia Univ. Press, New York. 486 pp.

Nelson, A. L. 1934. Two mammal records for South Carolina. J. Mammal. 15: 253-254.

Neuhauser, H. N. and W. W. Baker. 1974. Annotated list of mammals of the coastal islands of Georgia, pp. 197-209. In: A. S. Shanholtzer. An ecological survey of the coastal region of Georgia. Natl. Park Serv. Sci. Monogr. No. 3. Washington, D.C.

Nichols, J. D., L. Viehman, R. H. Chabreck, and B. Fenderson. 1976. Simulation of a commercially harvested alligator population in Louisiana. La. State Univ. Agric. Exp. Stn., Baton Rouge. 59 pp.

Obrecht, G. B. 1946. Notes on South Carolina reptiles and amphibians. Copeia 1946(2): 71-74.

Odom, R. R. 1976. 1975 heronry survey of the Georgia coast. Oriole 41(2/3): 19-35.

Odum, E. P. 1975. Ecology: the link between the natural and the social sciences. Holt, Rinehart and Winston, New York.

Odum, E. P. and A. A. de la Cruz. 1967. Particulate organic detritus in a Georgia salt marsh-estuarine ecosystem, pp. 383-388. In: G. H. Lauff, ed. Estuaries. Am. Assoc. Adv. Sci. Publ. No. 83. Washington, D.C.

Odum, W. E. 1970b. Pathways of energy flow in a south Florida estuary. Ph.D. Dissertation. Univ. Miami, Coral Gables, Fla. 163 pp.

Ogden, J. C. 1978. Recent population trends of colonial wading birds on the Atlantic and Gulf coastal plains, pp. 137-153. In: A. Sprunt, J. C. Ogden, and S. Winckler, eds. Wading birds. Natl. Audubon Soc. Res. Rep. 7. New York.

Ohlendorf, H. M., E. E. Klaas, and T. E. Kaiser. 1978. Environmental pollutants and eggshell thinning in the black-crowned night heron, pp. 63-82. In: A. Sprunt, J. C. Ogden, and S. Winckler, eds. Wading Birds. Natl. Audubon Soc. Res. Rep. 7. New York.

Osborn, R. G. and T. W. Custer. 1978. Herons and their allies; atlas of Atlantic coast colonies, 1975 and 1976. Patuxent Wildl. Res. Cent., Off. Biol. Serv., U.S. Fish Wildl. Serv. 211 pp.

Palmer, R. S., ed. 1976. Handbook of North American birds. Parts 1 and 2 (waterfowl). Yale Univ. Press, New Haven.

Patrick, R., J. Cairns, Jr., and S. S. Roback. 1967. An ecosystematic study of the fauna and flora of the Savannah River. Proc. Acad. Nat. Sci. Phil. 118(5): 109-407.

Pearse, A. S. 1936. Estuarine animals at Beaufort, North Carolina. J. Elisha Mitchell Sci. Soc. 52: 174-222.

Pelton, M. R. 1975. The mammals of Kiawah Island, pp. M1-M45. In: W. M. Campbell, J. M. Dean, and W. D. Chamberlain, eds. Environmental inventory of Kiawah Island. Environmental Research Center, Inc., Columbia, S.C.

Pennak, R. W. 1953. Fresh-water invertebrates of the United States. Ronald Press Co., New York. 769 pp.

Percival, H. F. 1968. Ecological study of selected waterfowl food plants. Job completion rep. Project W-38-R-5, Job XI-A. S.C. Wildl. Mar. Resour. Dep., S.C. Agric. Exp. Stn., and Belle W. Baruch Found. Columbia. 109 pp.

Perry, M. C. 1975. Looking out for the canvasback, Part V. Ducks Unlimited 39: 14-16, 23.

Philson, P. J. 1939. Freshwater algae of North and South Carolina. Part 1. Cyanophyceae. J. Elisha Mitchell Sci. Soc. 55: 83-116.

Philson, P. J. 1940. Species of Oedogonium new to South Carolina. J. Elisha Mitchell Sci. Soc. 56: 106-110.

Pomeroy, L. R., L. R. Shenton, R. D. H. Jones, and R. J. Reimold. 1972. Nutrient flux in estuaries, pp. 274-291. In: G. E. Likens, ed. Nutrients and eutrophication: the limiting-nutrient controversy. Am. Soc. Limnol. Oceanogr. Spec. Sym. Vol. 1. Lawrence, Kans.

Post, W. 1970. Range expansion of the cattle egret into interior South Carolina. Chat 34(2): 31-33.

Powell, J. H., Jr. 1971. The status of crocodilians in the United States, Mexico, Central America, and the West Indies. Proc. working meeting of crocodile specialists, IUCN Suppl. Rap. 32: 72-82.

Rawson, D. S. 1939. Some physical and chemical factors in the metabolism of lakes, pp. 9-26. In: E.P Moulton, ed. Problems of Lake biology. Am. Assoc. Adv. Sci. Publ. No. 10. Washington, D.C.

Robertson, A. 1972. Calanoid copepods: new records from Oklahoma. Southwest. Nat. 17(2): 201-203.

Rogers, G. C., Jr. 1970. The history of Georgetown County, South Carolina. Univ. S.C. Press, Columbia. 565 pp.

Rogers, J. P. and L. J. Korschgen. 1966. Foods of lesser scaup on breeding, migration and wintering areas. J. Wildl. Manage. 30: 258-264.

Ruibal, R. 1959. The ecology of a brackish water population of Rana pipiens. Copeia 1959: 315-322.

Salley, A. S., ed. 1967. Narratives early Carolina, 1650-1708. Barnes & Noble, Inc., New York. 388 pp. (First publ. 1911.)

Sanders, A. E. 1978. Mammals, pp. 296-308. In: R. G. Zingmark, ed. An annotated checklist of the biota of the coastal zone of South Carolina. Univ. S.C. Press, Columbia.

Sandifer, P. A., J. V. Miglarese, D. R. Calder, J. J. Manzi, L. A. Barclay. 1980. Ecological Characterization of the Sea Island Coastal Region of South Carolina and Georgia. Volume III. Biological Features of the Characterization Area. U.S. Dept. Int. Fish. Wildl. Serv., Office Biol. Serv. FWS/OBS 79/42. 1160 pp.

Shanholtzer, G. F. 1974b. Checklist of birds occurring in the coastal region of Georgia: species, abundance and habitat, pp. 171-190. In: A. S. Johnson, H. O. Hillestad, S. F. Shanholtzer, and G. F. Shanholtzer. An ecological survey of the coastal region of Georgia. Natl. Park Serv. Sci. Monogr. Ser. No. 3. Washington, D.C.

Sharp, H. F., Jr. 1962. Trophic relationships of the rice rat, Oryzomys palustris palustris (Harlan), living in a Georgia salt marsh. M. S. Thesis. Univ. Ga., Athens.

Shaw, W. N. 1965. Pond culture of oysters - past, present, and future. Trans. N. Am. Wildl. Nat. Resour. Conf. 30: 114-120.

Smith, P. W. and J. C. List. 1955. Notes on Mississippi amphibians and reptiles. Am. Midl. Nat. 53: 115-125.

Smith, T. I. J., P. A. Sandifer, and W. C. Trimble. 1976. Pond culture of the Malaysian prawn, Macrobrachium rosenbergii (de Man) in South Carolina. Proc. World Mariculture Soc. 7: 625-645.

Springer, S. 1938. On the size of Rana spenocephala. Copeia 1938: 49.

Sprunt, A., Jr. 1922. Discovery of the breeding of the white ibis in South Carolina. Oologist 39(10): 142-144.

Sprunt, A., Jr. 1924. Breeding of MacGillivary's seaside sparrow in South Carolina. Auk 41: 482-484.

Sprunt, A., Jr. 1954. Florida bird life. Coward-McCann, New York.

Sprunt, A., Jr. and E. B. Chamberlain. 1949. South Carolina birdlife. Univ. S.C. Press, Columbia. 567 pp.

Sprunt, A., Jr. and E. B. Chamberlain. 1970. South Carolina birdlife. Univ. S.C. Press, Columbia. 655 pp. (First publ. 1949.)

Sprunt, A., IV, J. C. Ogden, and S. Winckler. 1978. Wading birds. Natl. Audubon Soc. Res. Rep. No. 7. New York. 381 pp.

Stewart, R. E. 1962. Waterfowl populations in the upper Chesapeake Region. U.S. Fish Wildl. Serv. Spec. Sci. Rep.--Wildl. 65: 1-208.

Strange, T. 1977. Waterfowl status report, 1976-1977. S.C. Wildl. Mar. Resour. Dep., Div. Game Freshwater Fish. Columbia. 16 pp. (Unpubl.)

Sutherland, D. E. 1971. A 1965 waterfowl population model. U.S. Dep. Inter., Fish Wildl. Serv., Bur. Sport Fish. Wildl. Flyway Habitat Manage. Unit Project Rep. 4. Washington, D.C. 11 pp.

Swingle, H. S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Ala. Polytech. Inst. Agric. Exp. Stn. Bull. No. 274. 73 pp.

Teal, J. M. 1958a. Additions to the breeding birds of Sapelo Island. Oriole 23: 8.

Theiling, D. L. and H. A. Loyacano, Jr. 1976. Age and growth of red drum from a saltwater marsh impoundment in South Carolina. Trans. Am. Fish. Soc. 105(1): 41-44.

Tiner, R. W., Jr. 1977. An inventory of South Carolina's coastal marshes. S.C. Mar. Resour. Cent. Tech. Rep. No. 23. 33 pp.

Tiner, R. W., Jr., R. H. Dunlap, and J. P. Deveaux. 1976. Interim report on an inventory of South Carolina non-forested tidal wetlands. S.C. Mar. Resour. Cent., Charleston. (Unpubl.)

Tomkins, I. R. 1935. The marsh rabbit: an incomplete life history. J. Mammal. 16(3): 201-205.

Tomkins, I. R. 1958. A Georgia specimen of the manatee. J. Mammal. 39: 154.

Turner, C. H. 1910. Ecological notes on the cladocera and copepoda of Augusta, Georgia, with description of new or little known species. Trans. Acad. Sci. St. Louis 19(10): 151-176.

Turner, H. J. 1951. Shellfish culture in salt water ponds, pp. 9-10. In: Fourth report investigations of shellfisheries. Mass. Dep. Nat. Resour., Div. Mar. Fish., Boston.

Turner, W. R. and G. N. Johnson. 1974. Standing crops of aquatic organisms in tidal streams of the lower Cooper River system, South Carolina, pp. 13-20. In: F. P. Nelson, ed. The Cooper River environmental study. S.C. Water Resources Comm. State Water Plan Rep. No. 117. Columbia.

U.S. Army Corps of Engineers. 1974. Waterborne commerce of the United States. Part 1: waterways and harbors, Atlantic Coast. U.S. Army Eng. Waterways Exp. Stn., Vicksburg, Miss.

U.S. Department of Interior, Fish and Wildlife Service. 1962. Effects of pesticides on fish and wildlife in 1960. U.S. Fish Wildl. Serv. Circ. 143. 52 pp.

U.S. Department of Interior, Fish and Wildlife Service. 1963. Pesticide-wildlife studies: a review of Fish and Wildlife Service investigations during 1961 and 1962. U.S. Fish Wildl. Serv. Circ. 167. 109 pp.

U.S. Department of Interior, Fish and Wildlife Service. 1964. Pesticide-wildlife studies 1963: a review of Fish and Wildlife Service investigations during the calendar year. U.S. Fish Wildl. Serv. Circ. 199. 129 pp.

U.S. Department of Interior, Fish and Wildlife Service. 1965. The effects of pesticides on fish and wildlife. U.S. Fish Wildl. Serv. Cir. 226. 77 pp.

U.S. Department of Interior, Fish and Wildlife Service. (1977b). Cape Romain National Wildlife Refuge, Awendaw, South Carolina. Annu. Narrative Rep. Calendar Year 1976. Natl. Wildl. Refuge System. 44 pp. (Unpubl.)

U.S. Environmental Protection Agency. 1971. Report on pollution of the St. Marys and Amelia estuaries, Georgia - Florida. Southeast Water Lab., Athens, Ga. NTIS #PB-213-394. 52 pp.

Valentine, J. M., J. R. Walther, K. M. McCartney, and L. M. Ivy. 1972. Alligator diets on the Sabine National Wildlife Refuge, Louisiana. J. Wildl. Manage. 36: 809-815.

Viosca, P., Jr. 1923. An ecological study of the cold blooded vertebrates of southeastern Louisiana. Copeia 1923: 35-44.

Wallace, D. D. 1951. South Carolina - a short history. Univ. N.C. Press, Chapel Hill. 753 pp.

Wayne, A. T. 1910. Birds of South Carolina. Charleston Mus. Contrib. 1. Charleston, S.C. 254 pp.

Wharton, C. H. 1970. The Southern river swamp--a multiple-use environment. Ga. State Univ., School Business Adm., Atlanta. 48 pp.

Wharton, C. H. 1978. The natural environments of Georgia. Ga. Dep. Nat. Resour., Off. Planning Res. and Geologic and Water Resour., Atlanta. 227 pp.

Wiese, J. H. 1978. Heron nest-site selection and its ecological effects, pp. 27-34. In: A. Sprunt, J. C. Ogden, and S. Winckler, eds. Wading birds. National Audubon Society Res. Rep. 7. New York.

Wilkinson, P. M. 1970. Vegetative succession in newly controlled marshes. Job completion rep. Project W-38-6. April 1, 1967 - June 30, 1970. S.C. Wildl. Mar. Resour. Dep., Columbia. 37 pp.

Wilson, K. A. 1954. Role of mink and otter as muskrat predators in northeastern North Carolina. J. Wildl. Manage. 18(2): 199-207.

Wilson, K. A. 1968. Fur production on southeastern coastal marshes, pp. 149-162. In: J. D. Newsom, ed. Proceedings of the marsh and estuary management symposium. La. State Univ., Baton Rouge.

Wiseman, D. R. 1978. Benthic marine algae, pp. 23-36. In: R. G. Zingmark, ed. An annotated checklist of the biota of the coastal zone of South Carolina. Univ. S.C. Press, Columbia.

Wood, H. C. 1874. A contribution to the history of fresh-water algae of the United States. Smithson. Contrib. Knowledge 19: 1-202.

Wright, A. H. and A. A. Wright. 1949. Handbook of frogs and toads of the United States and Canada. Comstock Publ. Co., Ithaca, N.Y. 640 pp.

Yonge, C. M. 1960. Oysters. Collins, London. 209 pp.

Zingmark, R. G. 1975. The phytoplankton of Kiawah Island, pp. P1-P38. In: W. M. Campbell, J. M. Dean and W. D. Chamberlain, eds. Environmental Research Center, Inc., Columbia, S.C.

Zingmark, R. G. 1978. An annotated checklist of the biota of the coastal zone of South Carolina. Univ. S.C. Press, Columbia. 364 pp.