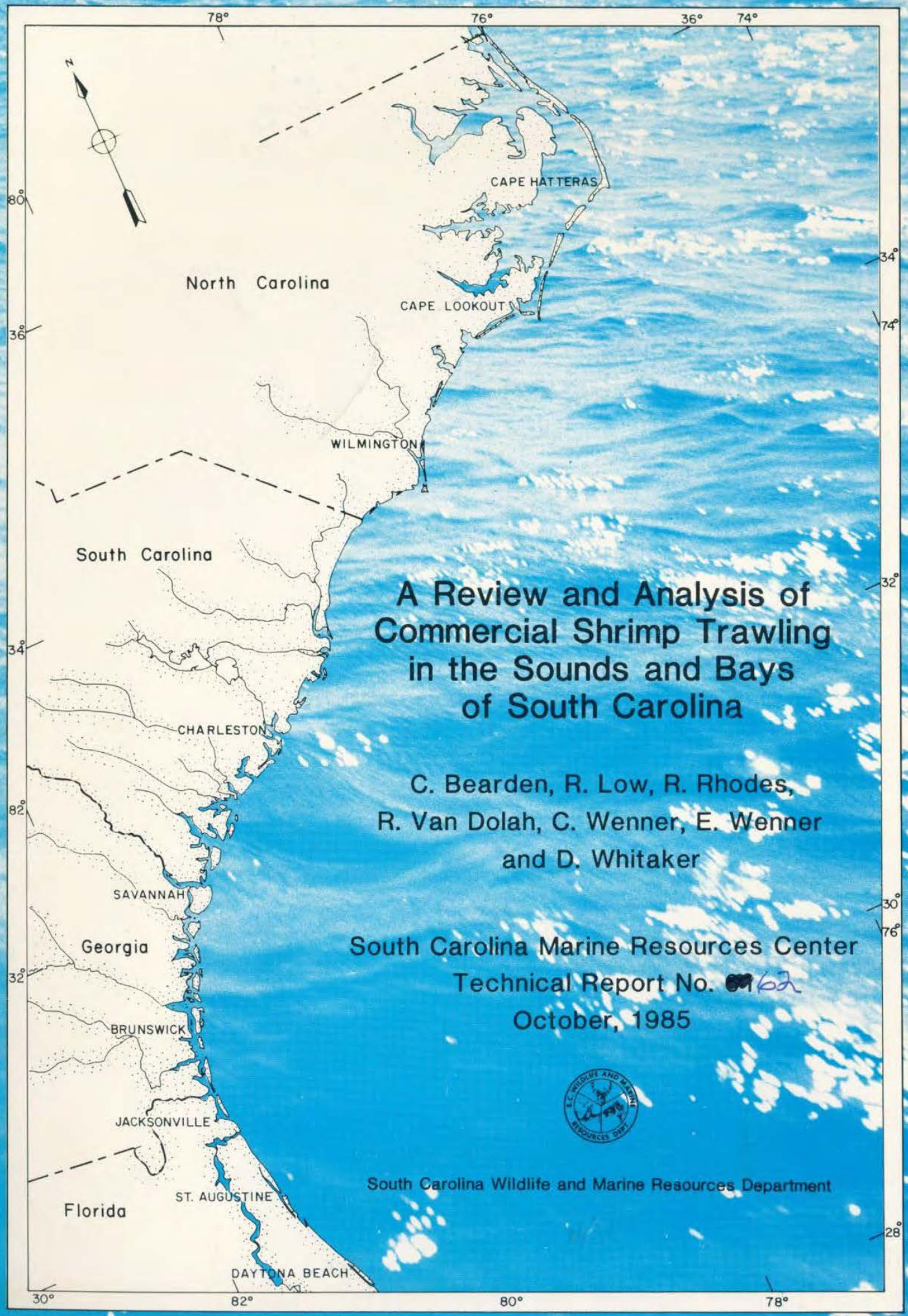

A Review and Analysis of Commercial Shrimp Trawling in the Sounds and Bays of South Carolina

C. Bearden, R. Low, R. Rhodes,
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South Carolina Marine Resources Center
Technical Report No. [redacted]62
October, 1985

South Carolina Wildlife and Marine Resources Department

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by

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Contribution No. 201 from the South Carolina Marine Resources Center

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ACKNOWLEDGEMENTS

The authors greatly appreciate technical assistance provided by N. Peacock, K. Swanson, P. Godsell, and K. DeLiesseline of SCWMRD during preparation of this report. Critical comments on earlier drafts were provided by P. Eldridge (National Marine Fisheries Service), V.G. Burrell, Jr., E. Joseph, A.S. Lachicotte, and M. McKenzie of SCWMRD. Information on S.C. fisheries statistics were kindly provided by D. Theiling and A. Applegate of SCWMRD, while data for analysis of experimental CPUE and size composition were collected during routine monitoring of S.C. sounds and bays by the Crustacean Management Section, SCWMRD.

INTRODUCTION

There has been a commercial trawl fishery for shrimp in South Carolina's sounds and bays for over thirty years, and the controversy surrounding this practice is a longstanding one. Major issues of concern are related to potential ecological effects and impacts upon commercial and recreational fisheries. The prevailing management philosophy has been to permit shrimp trawling at appropriate times in offshore waters, sounds, and bays while prohibiting it in the tidal creeks and rivers that serve as nursery areas. This summary presents the historical background of the sound and bay policy, describes the rationale for allowing inside trawling, provides information on the issues, specifies recommendations, and lists alternatives for the management of the sound and bay resource.

HISTORICAL BACKGROUND

With the exception of a limited period in Beaufort County during World War II, the inside waters of South Carolina, including the sounds, bays and tidal rivers, were generally closed to trawling prior to 1953. Section 28-863 of the S.C. Code of Laws, 1952 (formerly Section 3410, 1942, 1932 Code) stated that "the trawling for shrimp in any stream, bay, sound or river within this State is prohibited."

In December 1952, following requests by shrimp trawler operators that the sounds and bays be re-opened, as they were during World War II in Beaufort County, an investigation was begun by Bears Bluff Laboratories to determine whether it would be biologically appropriate to open inside waters to trawling.

Beginning in 1953, Calibogue, Port Royal and St. Helena Sounds were opened to shrimp trawling on September 1. Crab trawling during December, January, February and March was legal in Port Royal and St. Helena Sounds.

In March 1955, a report entitled "Management Plan for Shrimp Trawling in Rivers, Sounds, and Bays of South Carolina" (Lunz 1955) was submitted to the South Carolina Wildlife Commission. The recommendations in this report, along with findings of trawl sampling during 1953-56, were that the sounds, bays and certain river mouths could be opened to shrimp trawling after August.

During the 1956 session of the S.C. General Assembly, shrimp trawling laws were revised to give Statewide application to the regulations already in effect in the Beaufort County sounds. This Act [Section 28-861(b)] provided for the opening of ten inside areas (sounds, bays and river mouths) to shrimp trawling, beginning August 15 and ending December 15 of each year. The areas were Calibogue Sound, Port Royal Sound, St. Helena Sound, Trenchards Inlet, North Edisto River, lower Stono River, Charleston Harbor, Bulls Bay, Cape Romain Harbor, and lower Winyah Bay.

In 1957, Calibogue Sound was closed to trawling, except for crabs between December 15 and March 15 of the following year. A subsequent survey, however, by Bears Bluff Laboratories (Dawson 1957) indicated no benefits directly related to the cessation of shrimp trawling in Calibogue Sound.

In 1959, shrimp trawling laws again underwent major revisions by the S.C. General Assembly. At that time, Section 28-861.1 was added, which limited shrimp trawling in inside waters to the following areas: Calibogue Sound, Port Royal Sound, St. Helena Sound, Bulls Bay, North Santee Bay and Winyah Bay. This Act also provided for an open season of August 15 through December 15 in all of the above areas except Calibogue Sound, which was from September 1 to November 1.

The 1959 Act re-opened Calibogue Sound, added North Santee Bay, and deleted Trenchards Inlet, the North Edisto River, Stono River, Charleston Harbor and Cape Romain Harbor as legal trawling areas. The legal areas established are the same sounds and bays that are currently opened to trawling each year, although modification to legal boundaries within some of them have been made over the years.

The legal trawling boundaries of Bull Bay, North Santee Bay and Winyah Bay have not changed since 1959 (Figures 1-3). However, during the 1970's, the boundary lines of the three southern sounds were changed by State legislation. In Calibogue Sound, the closed area behind Marsh Island was opened and the upper boundary moved inland (Figure 4). In Port Royal Sound, the inner boundaries were modified to extend up river in the Chechessee and Broad Rivers (Figure 5). St. Helena's seaward boundary was straightened and the inner boundary

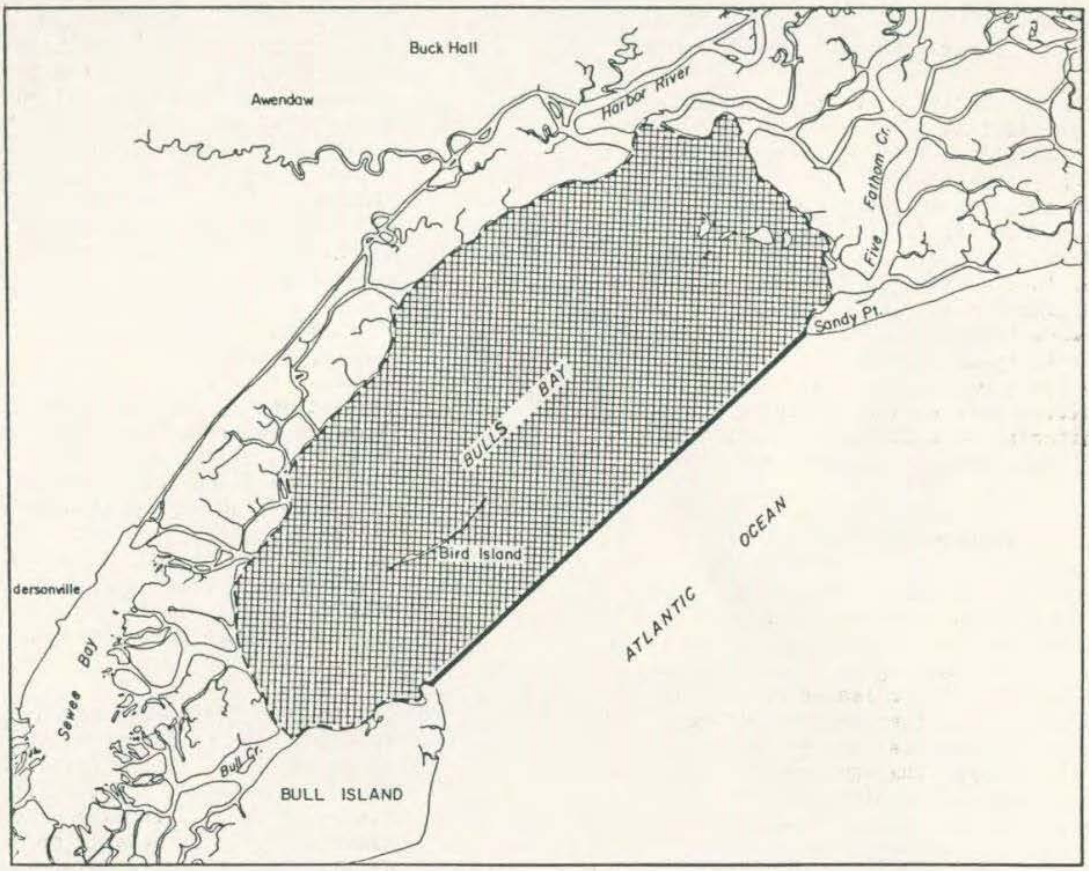

Figure 1. Current legal trawling areas in Bulls Bay.

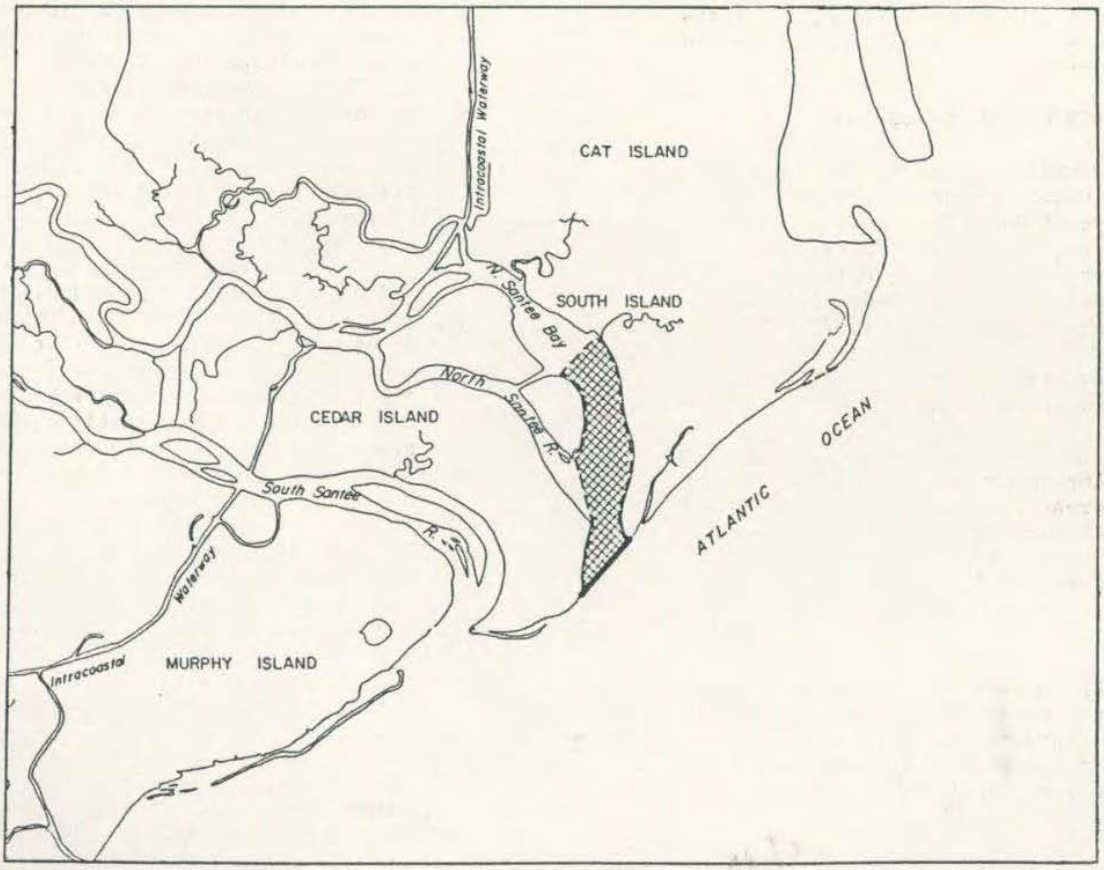

Figure 2. Current legal trawling areas in North Santee Bay.

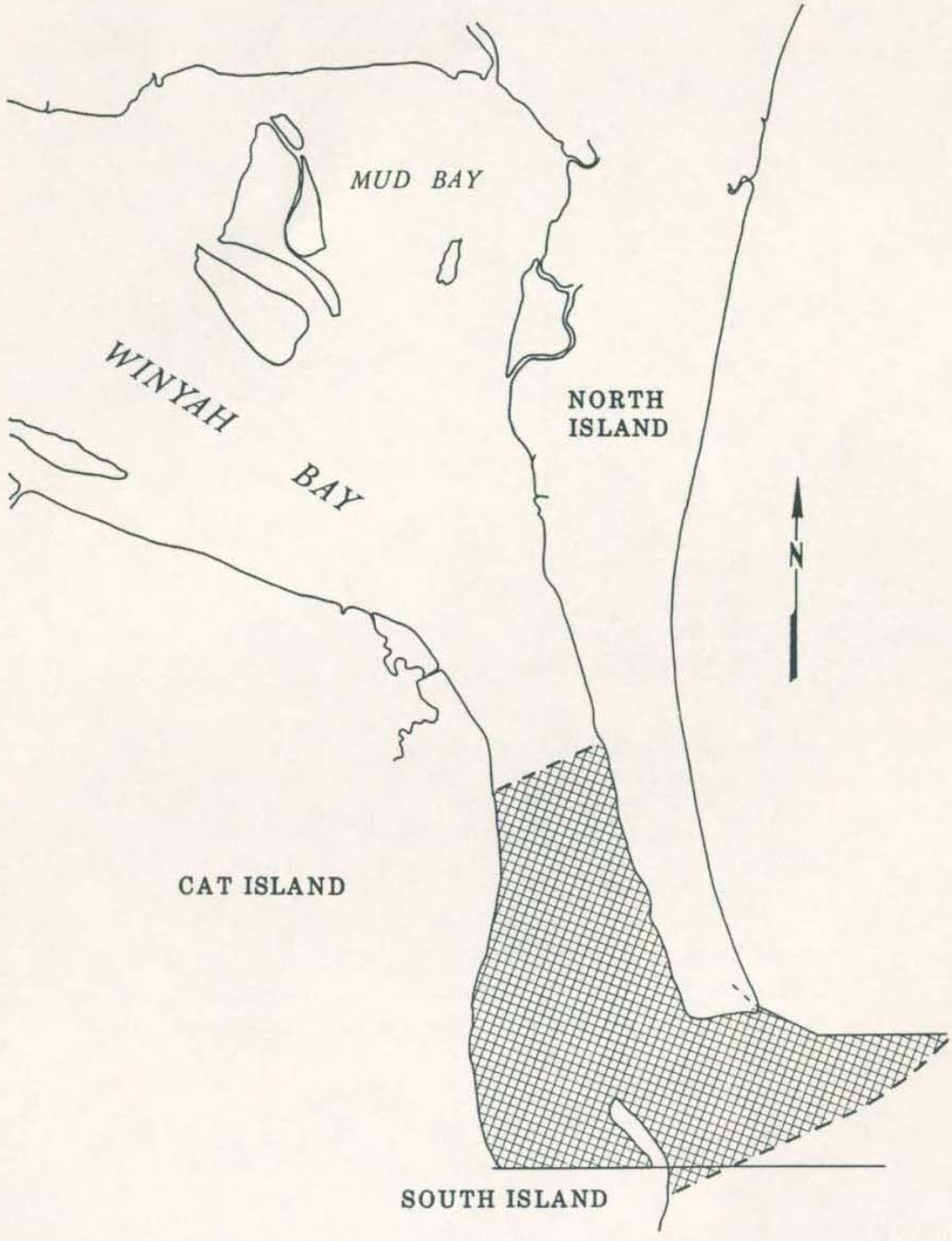

Figure 3. Current legal trawling areas for Winyah Bay.

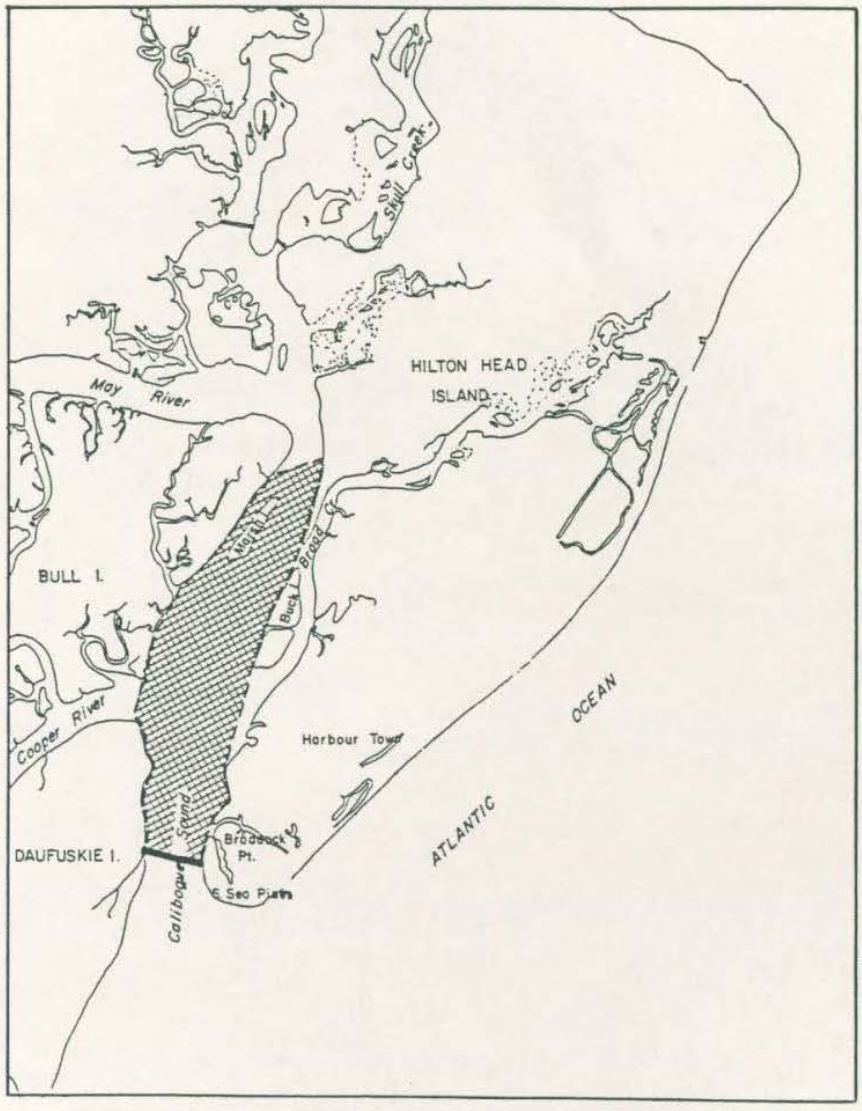

Figure 4. Current legal trawling areas for Calibogue Sound.

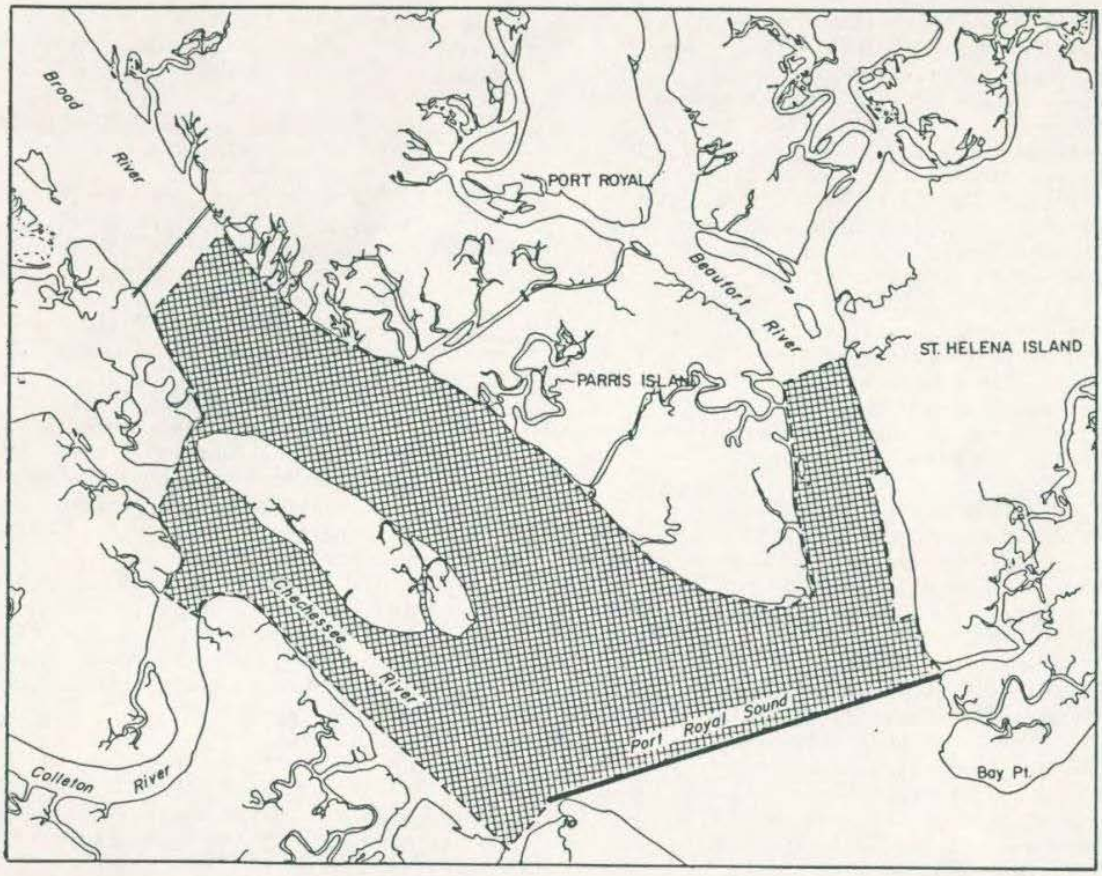

Figure 5. Current legal trawling areas for Port Royal Sound.

moved up the Coosaw River (Figure 6). Most of these modifications were made to straighten boundary lines in order to facilitate compliance with the laws and enforcement. The changes in the boundaries of the sounds were, for the most part, rather minor ones, with the exception of the Broad River area. The latter, which included a rather sizeable acreage, contains a considerable amount of untrawlable rough bottom.

The general seasons for trawling in the sounds and bays established in 1959 remained the same up to the present time (August 15 to December 15, except for Calibogue Sound, which is September 1 to November 1). Crab trawling remained legal in all areas during December through March. The 1959 act also included a Section (28-861.3) authorizing the Chairman of the Commission to shorten or extend the season by not more than 30 days in any of the sounds and bays, following consultation with Bears Bluff Laboratories (later Marine Resources Division). In 1976, this Section was completely rewritten to divide the legal trawling areas into three fishing zones and provided the Commission with authority to open or close any area, including sounds and bays, at any time.

During the 1950's and 1960's, the shrimp trawling season in the sounds and bays (except for Calibogue Sound) was usually opened between July 15 and August 15, depending upon the size and quantity of brown shrimp present. During the 1970's, however, it became common practice to open in July or August for short periods on an area by area basis for brown shrimp, closing the season when small white shrimp began to move seaward, and re-opening when these shrimp had attained marketable size. The general trend since 1974 has been to keep the sounds and bays closed until the fall (usually after September 1) when the white shrimp in those areas reach a suitable commercial size (at least 50-60 heads-on count on the average) (Table 1). The only exceptions to this have been in Bulls Bay, which was opened for very short (one week) periods in July or August of 1975, 1976 and 1981, and in Winyah Bay and North Santee Bay in 1981, when a one week opening was also provided for in August.

The reasons for the shift in opening dates have been: (1) the concern over protection of small white shrimp, which often enter the sounds and bays in August and (2) widespread and increased support by the shrimping industry over the years for later (fall) opening dates.

In recent years, the sounds and bays have generally been opened for shrimp trawling only during the September-December 15 period, although extensions to December 31 have been made in years when large shrimp were predominant. Crab trawling is lawful during December through March, although this activity is limited and carried out primarily in the southern sounds, particularly near the mouth of St. Helena Sound.

The shrimp management concept, although modified somewhat over the years, has remained basically the same --permitting shrimping at appropriate times in offshore waters and the sounds and bays while prohibiting trawling in the tidal creeks and rivers. The sounds and bays are not opened until sampling by the Marine Resources Division indicates that the majority of shrimp are acceptable commercial size.

Description of South Carolina Sounds and Bays Open to Trawling

The legal areas in South Carolina sounds and bays open to trawling (Winyah Bay, North Santee Bay, Bulls Bay, St. Helena Sound, Port Royal Sound, and Calibogue Sound) constitute 58,780 acres or 8.8% of the total 670,000 acres of tidal wetlands and estuarine waters in the state (Table 2).

Winyah Bay and North Santee Bay are the two northernmost bays open to trawling and have the smallest legal trawling areas of the six sounds and bays (Table 2). Winyah Bay is a combination drowned river valley/bar - built estuary, characterized by two-layer flow with partial vertical mixing. Freshwater inflow is normally high (annual average flow is 15,000 cfs) from the Pee Dee, Black and Waccamaw Rivers. Drought conditions in recent years, however, have resulted in much higher than normal salinities.

Bottom types in Winyah Bay consist of silt-clay, sand, shell mixtures. Subtidal clam and oyster beds are found in some areas. Water depth within Winyah Bay ranges from 10-30 ft., except at Mother Norton Shoal which is 1-3 ft at mean low water (MLW).

Annual reported shrimp landings from Winyah Bay in recent years have ranged from about 6,000 to 200,000 pounds, averaging about 80,000 pounds. Only the seaward-most portion of this bay is open to trawling (Figure 3). Channel netting is allowed in a 1100 acre area adjacent and inland of the legal trawling area. During years of high or normal river discharge this bay has commonly had large numbers of very small shrimp, but this pattern has changed with drought conditions in recent years.

North Santee Bay has the smallest legal trawling area of the six sounds and bays and is also the least productive, with annual reported landings of only 6,000-7,000 lbs. in recent years. A channel netting area of about 500 acres is adjacent to the legal trawling area.

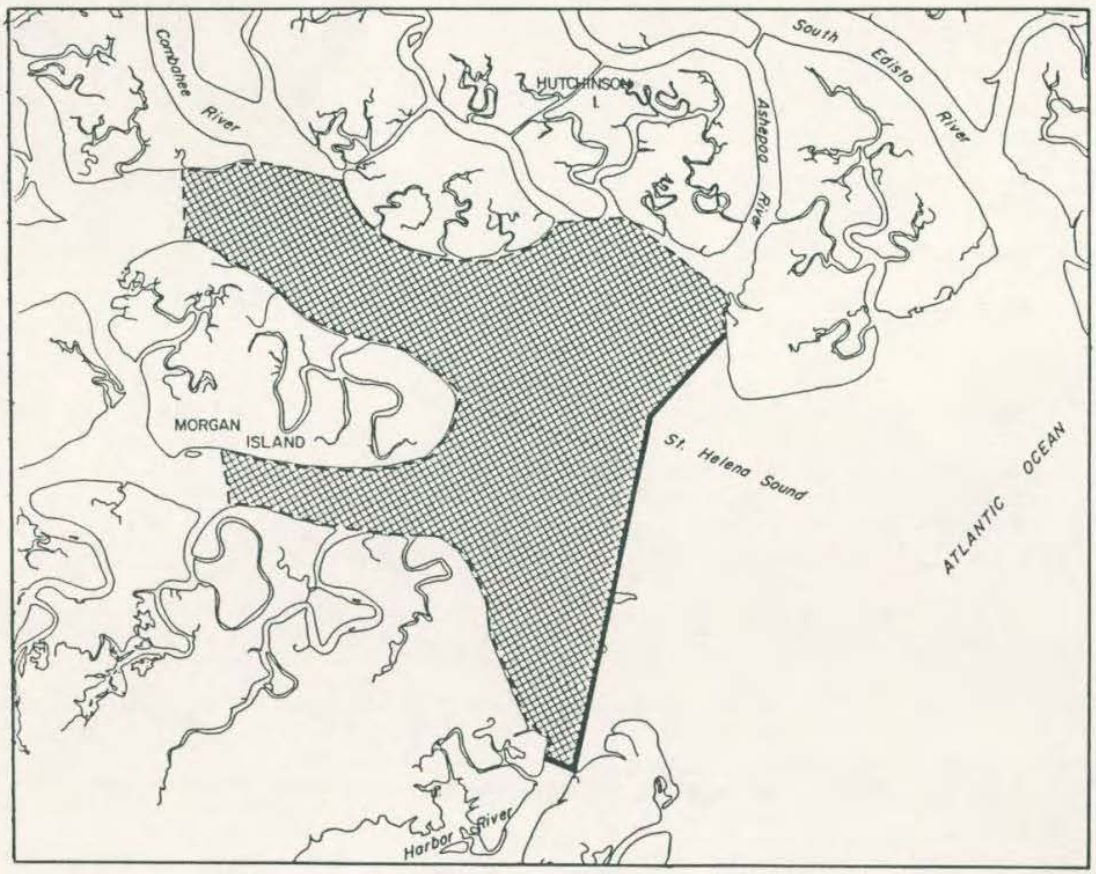

Figure 6. Current legal trawling areas for St. Helena Sound.

Table 1. Opening and closing dates for shrimp trawling in South Carolina's Sounds and Bays

YEAR	CALIBOGUE SOUND	PORT ROYAL SOUND	ST. HELENA SOUND	BULLS BAY	NORTH SANTEE BAY	WINYAH BAY
1970	Sept..1 - Nov. 30	Jul. 16 - Dec. 15	Jul. 16 - Dec. 15	Jul. 16-Dec. 15	Jul. 16 - Dec. 15	Jul. 16 - Dec. 15
1971	Sept. 14 - Nov. 30	Sept. 14 - Dec. 15	Sept. 14 - Dec. 15	Sept.14-Dec. 15	Sept. 14 - Dec. 15	Sept. 14 - Dec. 15
1972	Oct. 1 - Nov. 30	Aug. 15 - Aug. 16 Sept. 25 - Dec. 1	Aug. 15 - Aug. 16 Sept. 25 - Dec. 1	Aug. 15 - Aug.16 Sept.25-Dec. 1	Aug. 15 - Aug. 16 Sept, 25 - Dec. 1	Aug. 15 - Aug. 16 Sept. 25 - Dec. 1
1973	Jul. 16 - Jul. 24 Aug. 30 - Dec. 23	Jul. 16 - Jul. 24 Aug. 30 - Dec. 15	Jul. 16 - Jul. 24 Aug. 30 - Dec. 15	Jul.16-Jul. 24 Aug. 30 -Dec..15	Jul. 16 - Jul. 24 Aug. 30 - Dec. 15	Jul. 16 - Jul. 24 Aug. 30, Dec. 15
1974	Sept. 9 - Dec. 15	Sept. 9 - Dec. 15	Sept. 9 - Dec. 15	Sept. 9- Dec. 15	Oct. 1 - Dec. 15	Not Opened
1975	Sept. 15 - Dec. 15	Sept. 15 - Dec. 15	Sept. 2, Dec. 15	Jul. 18-Jul. 22 Sept. 2-Dec. 15	Sept. 15 - Dec. 15	Sept. 15 - Dec. 15
1976	Sept. 15 - Dec. 8	Sept. 15 - Dec. 8	Sept. 15 - Nov. 26	Jul. 14-Jul. 20 Sept. 15- Dec. 8	Sept. 15 - Nov. 4	Sept. 15 - Nov. 4
1977	Sept. 15 - Sept. 19 Sept. 22 - Dec. 31	Sept. 15 - Sept. 19 Sept. 22 - Dec. 31	Sept. 15 - Sept. 19 Sept. 30 - Dec. 15	Sept. 30 - Dec.15	Sept. 30 - Dec. 15	Sept. 30 - Dec. 15
1978	Sept. 7 - Dec. 15	Sept. 7 - Dec. 15	Sept. 7 - Dec. 15	Sept. 7 - Dec. 15	Sept. 7 - Dec. 15	Sept. 7 - Dec. 15
1979	Oct. 2 - Dec. 11	Oct. 2 - Dec. 11	Oct. 2 - Dec. 11	Oct. 2 - Dec.11	Oct. 2 - Dec. 11	Oct. 2 - Dec. 11
1980	Sept. 3 - Dec. 15	Sept. 3 - Dec. 15	Sept. 3 - Dec. 15	Sept. 3 - Dec.15	Sept. 3 - Dec. 15	Sept. 3 - Dec. 15
1981	Sept. 8 - Dec. 15	Sept. 8 - Dec. 15	Sept. 8 - Dec. 15	Aug. 7-Aug. 15 Sept.8 -Dec. 15	Aug. 7 - Aug. 15 Sept. 8 - Dec. 15	Aug. 7 - Aug. 15 Sept. 8 - Dec. 15
1982	Sept. 17 - Dec. 31	Sept. 17 - Dec. 31	Sept. 17 - Dec. 31	Sept. 17- Dec. 31	Sept. 15 - Dec. 31	Sept. 15 - Dec. 31
1983	Sept. 29 - Dec. 31	Sept. 29 - Dec. 31	Sept. 29 - Dec. 31	Sept. 29 - Dec.31	Sept. 14 - Dec. 31	Sept. 14 - Dec. 31
1984	Aug. 31 - Dec. 4	Aug. 31 - Dec. 4	Aug. 31 - Dec. 4	Aug. 31 - Dec. 4	Aug. 31 - Dec. 4	Aug. 31 - Dec. 4

Table 2. Acreage for Wetlands and Estuarine Areas of South Carolina.

	Total Acreage
Tidal Wetlands	428,000
Estuarine (internal) waters	242,000
Sounds and Bays (Legal Trawling Areas)	58,780
Calibogue Sound	3,480
Port Royal Sound	19,690
St. Helena Sound	13,470
Bulls Bay	18,360
North Santee Bay	980
Winyah Bay	2,800

The Santee River delta closely resembles a sediment-filled drowned river valley estuary and is characterized by two layer flow with vertical mixing. The Santee River freshwater discharge has averaged 500-600 cfs, with an estimated 85% of this entering the North Santee estuary. During flood conditions in the past, however, it has reached over 40,000 cfs. With rediversion, average flow in the Santee will be 15,000 cfs, which is expected to have considerable impact on the ecology and the size of shrimp present. Bottom types in North Santee Bay include sand, mud-sand, silt-clay, organic debris, and large areas of subtidal clams, oysters and shell. North Santee Bay is shallow, with water depth ranging from 1-10 ft. on MLW.

Bulls Bay lies within the Cape Romain National Wildlife Refuge in Charleston County. Traditionally known as being more productive for brown shrimp trawling, this bay has not been opened for such purpose since 1981. During recent years, annual reported landings in Bulls Bay have ranged from 12,000 to 79,000 lbs., averaging around 50,000 lbs.

Bulls Bay is a bar-built estuary and is vertically homogeneous with near sea-strength salinities. No freshwater rivers enter this bay. Bulls Bay is very shallow with depths ranging from 0-5 ft. on MLW, except for areas where tidal streams enter the bay. Bottom sediments are variable and include sand, sand-mud mixtures and shell. Areas with hard shell bottom have attached invertebrate growth with sea whips and sponges dominant.

The three southern sounds are among the most productive in terms of shrimp landings. Landings in St. Helena Sound have ranged from ~ 80,000 to 290,000 lbs. annually in recent years, with an average of 180,000 lbs. Generally, white shrimp are large here during the season, but there are some areas present, such as Coosaw, Bottleneck, mouth of Ashepoo River and Rock Creek, where small shrimp tend to congregate at times. Port Royal Sound has experienced reduced white shrimp catches over the past three to four years, probably because of drought conditions. In recent years, reported shrimp landings for Port Royal Sound have ranged from 37,000 to 217,000 lbs., averaging ~ 118,000 lbs. Although Calibogue Sound is the smallest of the three southern sounds, it and Winyah Bay are the most productive of the six areas in terms of shrimp landings on a per acre basis and are probably the most heavily fished. Calibogue Sound is fished heavily by Georgia boats when opened. Reported annual shrimp landings have ranged from 18,000 to 135,000 lbs. with an average in recent years of 105,000 lbs.

The physical characteristics of the three southern sounds are similar. St. Helena Sound is a drowned river valley/bar-built estuary that is vertically homogeneous with lateral variations in salinity. This sound receives moderate freshwater input from the Combahee, Ashepoo and South Edisto Rivers with combined annual freshwater flow averaging around 3,000 cubic feet per second (cfs). The depth in St. Helena Sound is variable but relatively deep (15-30 ft) except on large banks and flats such as Egg Bank, Pelican Bank, Combahee Bank, and Marsh Spit. Port Royal Sound is a drowned river valley type estuary that is vertically homogeneous with high salinities and low turbidity. Freshwater inflow is very limited, and the only notable upland source of freshwater is from the Coosawhatchie River, with an average flow of 186 cfs. In recent drought years, salinities in Port Royal Sound have been near sea strength throughout the fall. Port Royal is a relatively deep sound, with depths in most areas ranging from 20-45 at MLW. Shoaler areas occur on spits and flats off Parris Island and Daw's Island. Bottom type is similar to that in St. Helena with hard bottom habitat and attached invertebrates in various areas of the sound. Calibogue Sound also has very limited freshwater inflow with input received sporadically from the New, Wright and Savannah Rivers via the Atlantic Intracoastal Waterway. This sound is a bar-built estuary and is vertically homogeneous with high salinities. Calibogue Sound is relatively deep with water depth ranging from 20-50 feet, except for a shoal area near Marsh Island. Bottom type is variable and includes sand, mud, and shell mixtures as well as "live" bottom areas.

BIOLOGICAL AND ECOLOGICAL ISSUES

Lunz (1955), in a report to the South Carolina Wildlife Commission, first discussed the ecological effects of shrimp trawling in the rivers, bays, and sounds. His report attempted to answer questions raised by groups that opposed trawling in these waters. These same issues continue to be of primary concern to groups interested in habitat and resource preservation. Additional studies have been completed to supplement data from experimental trawls conducted by Bears Bluff Laboratories during 1953 to 1955 in an attempt to determine the validity of the issues. The available information, summarized below, strongly indicates that the real issues surrounding the sounds and bays controversy are not of a biological nature, and cannot be resolved by a recitation of damaging biological and ecological effects for which there is no sound scientific basis.

Destruction of spawning grounds and interference with spawning of economically important fishes

One point raised by those advocating closure was that trawling destroys the spawning grounds, and interferes with the spawning of desirable species of fishes. This claim is still voiced by those who support the closure of the bays and sounds to shrimp trawling.

In South Carolina, the main species of fishes that are of commercial and recreational importance in coastal (nearshore and estuarine) waters, as opposed to offshore and anadramous species are:

spot,
Leiostomus xanthurus;
croaker,
Micropogonias undulatus;
spotted sea trout,
Cynoscion nebulosus;
southern kingfish,
Menticirrhus americanus;
gulf kingfish,
Menticirrhus littoralis;
black drum,
Pogonias cromis;
red drum,
Sciaenops ocellatus;
bluefish,
Pomatomus saltatrix;
sheepshead,
Archosargus probatocephalus;
summer flounder,
Paralichthys dentatus;
southern flounder,
Paralichthys lethostigma;
Spanish mackerel,
Scomberomorus maculatus;
king mackerel,
Scomberomorus cavalla; and
cobia
Rachycentrum canadum

Several species spawn in offshore waters so that inshore trawling would have no impact on their reproduction. Furthermore, the eggs of these species are buoyant and the probability of damage to them by demersal trawling is negligible (Lunz 1955). In the South Atlantic Bight from Cape Fear to Cape Canaveral, spot spawn off the coast in moderately deep waters over a protracted period from late fall through early spring (Johnson 1978). The eggs are pelagic and the larvae and post-larvae are transported into the estuarine nursery grounds where they are taken in plankton samples from December through July with peak abundance in January and February (J.C. McGovern, College of Charleston and South Carolina Wildlife and Marine Resources Department (SCWMRD), unpublished data).

Atlantic croaker spawn in offshore waters of the South Atlantic Bight during fall and early winter (Bearden 1964; Powles and Stender 1978). The smallest larvae were found 60-80 km offshore; they were larger in nearshore waters. Large larvae and post-larvae are recruited to the estuarine nursery grounds from October through May (J.C. McGovern, College of Charleston and SCWMRD, unpublished data).

Bluefish spawn offshore near the 100 fm curve during May in the South Atlantic Bight (Powles and Stender 1976). In early summer, small juveniles are found in the estuarine nursery areas where they are associated with schools of prey species such as anchovies and juvenile menhaden.

Sheepshead are associated with "live bottom" areas, oyster bars, wrecks, docks, and jetties in waters of moderate and high salinity. Available information indicates that this species spawns in offshore waters during spring (Johnson 1978). Juveniles are found in high salinity creeks around oyster bars throughout the summer in South Carolina waters (H.R. Beatty, SCWMRD, unpublished data).

Both summer and southern flounder undertake a spawning migration from the estuaries and coastal waters of the southeastern United States to offshore water during fall. The larvae are recruited to estuarine nursery grounds during winter and early spring (J.C. McGovern, College of Charleston, and SCWMRD,unpublished data).

Spanish mackerel spawn along the coast of the southeastern United States during the late spring and summer (Fritzche 1978). This species is primarily neritic and, although adults may sometimes enter the lower reaches of the sounds and bays to forage on anchovies and other small pelagic fishes, there is a low probability that shrimp trawling would impact spawning since the opening of the sounds occurs after the peak of reproductive activity. King mackerel spawn offshore from July to early September along the south Atlantic coast (Fritzche 1978).

The kingfishes are abundant species that are sought by commercial and recreational fishermen. The gulf kingfish, *Menticirrhus littoralis*, is found primarily in the high energy areas along the coast (surf zone) and does not comprise a significant portion of the kingfish by-catch landed by the penaeid shrimp fishery. This species spawns during the summer along the front beaches (Powles and Stender 1978). Southern kingfish spawn throughout the summer (May-September) primarily in the coastal waters (Powles and Stender 1978). This species may spawn in the high salinity reaches of the sounds, but the peak of activity is prior to the opening of the season.

Although few data are available, it appears that black drum spawn in the lower reaches of estuaries and bays throughout its geographical range (Mass. to Brazil). In

South Carolina, larvae have been taken only in May and June, suggesting a late spring spawning time in South Carolina water (J.C. McGovern College of Charleston and SCWMRD). Mature black drum are large fishes and they are seldom taken in shrimp trawl nets. Available information indicates that black drum spawn before the opening of the bays and sounds for shrimping.

Based on the occurrence of larval red drum, spawning occurs in August, September and October in South Carolina (J.C. McGovern, College of Charleston and SCWMRD, unpublished data). The size of the larvae indicates spawning occur very close to the estuarine areas near Winyah Bay. Scanty and frequently conflicting reports from areas throughout the species range do not allow for the exact placement of the spawning areas; however, it appears they are in proximity to estuarine passes and inlets. Spawning, as described in the laboratory, takes place at dusk (Mercer 1984). It should be noted, however, that mature red drum are large, powerful fish that are adept at avoiding trawl nets.

Spotted seatrout spawn in estuarine passes and inlets of South Carolina from late spring through summer (Powles and Stender 1978). Larval spotted trout have been collected from June through September near Winyah Bay (J.C. McGovern College of Charleston and SCWMRD). Although exact spawning locations are not known, it appears that spawning is restricted to the high salinity areas of the nearshore estuarine habitats.

Conflicting reports in the literature present a confusing picture as to the spawning locations of cobia throughout its geographic range. Larvae have been reported from 40 to 64 km offshore in the Gulf of Mexico and up to 925 km offshore of Delaware. Eggs, however, have been taken inside of the Chesapeake Bay (Hardy 1978). Off South Carolina cobia apparently spawn in late spring and early summer. Juveniles are euryhaline and are recruited to estuaries where they are frequently found around docks and floating objects.

Destruction of juveniles of economically important fish

Another point raised by individuals opposed to the trawl fishery for penaeid shrimps in the bays and sounds is that significant quantities of the juveniles of economically important fishes are destroyed. There is little argument that this fishery kills a substantial number of fishes incidentally to harvesting activities. However, available information indicates that these fishes are of little economic importance, and much of the discarded by-catch is recycled; that is, it is consumed by sea birds, porpoises and various fish and invertebrate predators.

Published and unpublished by-catch data show that spotted seatrout are rarely taken in shrimp trawls. The only time that this species is caught is during cold, winter periods. In 18 years of sampling South Carolina estuaries, only 207 young spotted seatrout were taken (Lunz and Schwartz 1969). These were mainly captured in trawls during December through February. The MARMAP program of the SCWMRD captured only three spotted seatrout in 308 trawl tows throughout the South Atlantic Bight along the beach. These were taken in January off Bull's Bay. There are two factors that are possibly in effect. First, the trout may be there during warmer weather but they are able to avoid the nets. Cold water may slow down their metabolic processes so that they are unable to avoid the nets in winter. Second and a more probable situation is that trout are spatially separated from the trawl fishery in warmer periods of the year.

Flounders and southern kingfish taken by shrimp trawlers are culled at sea. Small individuals are discarded and large fishes are landed and sold. Black drum, red drum, sheepshead and cobia are rarely taken by trawlers. The impact of trawling in the bays and sounds to juveniles of these species is either very low or non-existent.

Spot and Atlantic croaker are among the most abundant species of fishes in the by-catch (Keiser 1976, 1977; C.A. Wenner, unpublished data). These are abundant species in all estuaries of South Carolina and it does not appear that shrimp trawling has made any major impact on their population size. They have high reproductive potentials, short life spans and high natural mortalities. On such species, the effects of additional mortality would be minimized (especially when you consider that they have many "sanctuary" areas where they are not exposed to commercial fishing pressure).

Small numbers of juvenile bluefish, Spanish and king mackerel are taken in the by-catch. The impact of shrimping on these species is unknown. Stocks of mackerel appear to have declined, with Atlantic king mackerel stocks remaining relatively stable compared to depressed stocks of Spanish mackerel. This situation has been attributed to over exploitation of these species in the southern part of the South Atlantic Bight.

Destruction of Juvenile Blue Crab

Juvenile and adult blue crab (Callinectes sapidus) are another by-catch of shrimp trawling in the bays and sounds. Lunz (1955) felt that the impact of trawling on juvenile blue crab was minimal for several reasons. Although otter trawl catches offshore account for a portion of South Carolina's commercial crab landings (Eldridge and Waltz 1977), the minimum size

limit of five inches protects juvenile crabs. Those young crabs which are caught as by-catch do not generally die as a result of trawling or culling but are released alive. It is apparent from observations on shrimp trawlers that very few crabs are killed by being captured in shrimp trawls. The few mortalities that are noticed usually occur during summer when high water and air temperatures cause the most stress. As temperature decreases in September, concurrent with the beginning of the sound and bay season, temperature stress is reduced.

The distribution of the subadult crabs also implies that populations will not be deleteriously affected by shrimp trawling (Lunz 1955). Early juvenile stages migrate to lower salinity and shallow waters during summer months. In Chesapeake Bay and Delaware Bay, migration to deeper channels occurs only in colder months (Van Engel 1958; Cronin 1954). In Mississippi, juvenile blue crab distribution is as follows: 1) First and early crab stages (3-10 mm) occurred most often in 15 to 20 °/oo, 2) 10-20 mm juveniles were most frequently found in salinities < 10 °/oo, and 3) maximum number of crabs (20-40 mm) were taken from salinities < 5 °/oo (Perry and Stuck 1982). The peak abundance of juvenile blue crabs does not coincide with the inshore shrimp trawling season. In Core Sound, N.C., juvenile crabs ≤ 4 cm reached greatest numbers between December and April in creeks, followed by migrations to deeper waters, causing low numbers of this size range in May (Dudley and Judy 1973). Lunz (1955) noted that the peak abundance of crabs occurs in the first four months of the year when the sounds and bays in S.C. are closed. Although the movement of crabs to deeper channels in response to cold temperatures may overlap with the sound and bay season of September through December, most of the crabs taken as incidental catch will be mature females (Eldridge and Waltz 1977). Eldridge and Waltz (1977) found that approximately 72% of the commercial blue crab harvest is comprised of males. This is primarily because the larger more valuable males are targeted in the upper reaches of estuaries. The less valuable females move to the higher salinities of river mouths and nearshore areas. With females making up only a small percentage of the total commercial harvest, it appears doubtful that trawling damages the supply of potential spawners to the extent that recruitment would be jeopardized.

Lunz (1955) also observed that a notable portion of the trawl catch was Callinectes danae (=C. similis). Callinectes similis, known as the lesser blue crab, attains a smaller maximum body size than the blue crab, but is frequently confused with the blue crab because of its similar appearance. Callinectes similis is found most abundantly in salinities > 15 °/oo and co-occurs with C. sapidus, often in large numbers (Williams 1984). Wenner et al. (1984) found C. similis to be similar in abundance to C. sapidus in a five year study of the Charleston Harbor - Cooper River estuarine system. In the nearshore coastal zone (< 10 fm), C. similis was much more abundant than C. sapidus (E. Wenner, pers. obser., SCWMRD). This suggests that C. similis may comprise a greater portion of the by-catch in the bays and sounds than C. sapidus. Callinectes ornatus is also occasionally found in high salinity neashore areas. This species is also very similar to C. sapidus but rarely reaches a carapace width of five inches. Therefore, it is rarely marketed.

There was some indication that opening of Georgia's sounds to commercial shrimp trawling would impact the blue crab fishery. As a result of socio-economic conditions, crab landings in Georgia since the sounds were closed have approached the high levels of production in the late 1950's and early 1960's. A greater proportion of landings attributable to pots and thereby having a higher market value has corresponded to closure of the Georgia sounds. A markedly greater number of pots and part-time participation in the blue crab fishery occurred following closure. An economic analysis of the impact on the blue crab fishery of opening Georgia's sounds to commercial shrimp trawling suggested a potential maximum loss of about $86,000. Georgia Department of Natural Resources felt, however, that this impact would be partially mitigated by the entry of part-time crabbers into the shrimp fishery. Furthermore, the opening of sounds during November and December corresponds to the time of emigration of crabs to deeper nearshore water to overwinter[1].

Destruction of Bottom Habitat and Nursery Areas

The destruction of bottom habitat has long been a major concern of commercial and recreational fishermen, environmentalists, and government officials. Knowledge of the effects of trawl gear on the macrobenthos is important since many estuarine fish species depend on these animals as a food source (Thayer et al. 1975). In South Carolina, no scientific studies have been conducted to evaluate the effects of trawling on benthic communities inhabiting the bays and sounds or the nearshore sand bottom areas which are heavily trawled for shrimp. Therefore, conclusions concerning the destruction of bottom habitat in South Carolina waters are

[1]Memorandum to Duane Harris from Susan Shipman, November 1, 1983, Georgia Department of Natural Resources.

speculative and dependent on limited studies conducted elsewhere. Those studies present evidence which supports contrasting views.

The report by Lunz (1955) to the South Carolina Wildlife Commission suggested that available evidence did not support the argument that trawling leads to serious destruction of bottom habitat. In a limited study conducted in the North Sea, Graham (1955) also found that damage by trawl to species preyed upon by fishes was not serious. Trawling with heavy tickler chains broke and flattened the sand-tubes of the polychaete Sabellaria and other fragile highly projecting structures; however, minimal damage was noted on clean, sandy ground. Similarly, a more recent study by Gibbs et al. (1980) concluded through quantitative data and visual observations that otter trawling for shrimp did not cause any detectable changes in the macrobenthic fauna of the trawl grounds. The gear used in this study, however, had no tickler chain and was maximally efficient by having the gear skim lightly over the surface of the sea bed.

Other studies have clearly demonstrated that the effect on the seabed of any trawl will depend on the type of gear used. For example, Bridger (1970) found that even small otter boards and nets equipped with light weight chains caused considerable bottom disturbance and damage was enhanced when tickler chains or heavy chain legs were used. The quantity of benthic marine life brought up in the net was ten times greater when a heavy tickler chain was used, a fact which makes usage of the chain popular among shrimpers seeking to maximize their catches. Due to this disturbance, several investigators have presented indirect evidence that bottom fishing is important in the trophic ecology of groundfish since trawler agitation of the bottom may potentially make a large contribution to the energy budgets of bottom foraging fish (Caddy, 1971, 1973; Arntz and Weber, 1970; Medcof and Caddy, 1971; Margetts and Bridger, 1971).

Bottom type is another important factor in assessing damage by trawls. While variable effects have been noted for soft-bottom habitats, Tilmant (1979) found that the impact to benthic organisms in hard-bottom areas by bait shrimp trawls was substantial. Van Dolah et al. (1983b) also noted that repeated trawling over the same bottom in hard bottom areas would cause considerable damage, not only to the sponge and coral populations but to the invertebrate fauna associated with these species. Hard bottom areas are patchy in their distribution in bays and sounds, and are not considered to be prime habitat for white shrimp, Penaeus setiferus, and brown shrimp, P. aztecus; however, juveniles of commercially important fish species such as groupers inhabit these areas. These areas also harbor several important invertebrates such as stone crabs, spiny lobsters, and a high diversity of ecologically important smaller fauna. Therefore, trawling on hard-bottom areas in the bays and sounds should be minimized to avoid habitat damage. Although trawl damage must also occur in heavily fished sand- and mud-bottom waters of South Carolina, no obvious deterioration in benthic communities has been detected in trawled versus non-trawled areas based on limited benthic surveys conducted by SCWMRD personnel over the past several years (Calder et al. 1975, 1977a, 1977b; Van Dolah et al. 1983a, 1984b). Furthermore, studies evaluating the effects of other destructive activities, such as dredging, suggest that soft-bottom benthic communities can recover from disturbance fairly rapidly (Van Dolah et al. 1979, 1983a, 1984a, 1984b).

Information from the fishery for clams and oysters using an hydraulic escalator suggests that long-term trawling in North Santee and Winyah Bay has had no adverse impacts upon benthic shellfish populations. Sizable and widespread populations of subtidal hard clams and oysters occur in the legal trawling areas of these bays. An hydraulic escalator fishery for clams and oysters has been in operation in North Santee Bay since 1975 and total landings, as well as CPUE, in this area have been as high as that for the South Santee and North Santee River clam areas, which are not open to trawling. In addition, a significant dredge fishery for subtidal oysters has developed over the past few years in North Santee Bay and production has increased each year. These results suggest that populations have not been markedly affected by long-term trawling, through either direct disturbance or as a result of siltation.

Nursery areas which are located in shallow portions of estuaries will not be impacted by trawling. These areas are permanently closed to commercial shrimp trawling. Recent studies on utilization of estuarine nursery areas by penaeid shrimps indicate that densities of P. aztecus are higher in Spartina marshes than adjacent nonvegetated habitat (Zimmerman et al., 1984). Substrate preference experiments confirmed the selection of salt marsh cord grass S. alterniflora, by P. aztecus and P. setiferus, although substrate selection may be influenced by shrimp size, population density, temperature and salinity (Rulifson 1981). Because trawling is limited to

deeper portions of high salinity sounds and bays, it is highly unlikely that shallow vegetated habitats, which are reported to be the primary nursery area for Penaeus spp., would be damaged by such activity.

Based on existing evidence, combined with the fact that trawled areas in bays and sounds are generally not important nursery areas for shrimp and other economically important species during the shrimping season, there appears to be little basis for closure of bays and sounds using arguments of habitat destruction.

Preservation of Overwintering Shrimp

Proponents of closure have stressed that the overwintering population of young shrimp should be protected in order to provide spawning stock the following spring. In terms of the life history of Penaeus spp., the overwintering population consists of those individuals which do not attain a large size during the fall and emigrate from the estuaries. Part of the population remains in the deeper waters of the rivers and sounds throughout the winter; however, during severe winters, large numbers will overwinter offshore near the beaches and move back inside in the spring. Those that survive in the estuaries grow rapidly in late winter and early spring before migrating to the ocean. These migrating roe shrimp comprise a small but valuable spring fishery and form the spawning stocks of white shrimp.

Climatological conditions influence the survival of overwintering white shrimp and, hence, their ultimate contribution to commercial catches. Severe winter weather causes mass mortalities of overwintering shrimp and this has been related to lowered landings (South Atlantic Fishery Management Council, 1981; Williams, 1969). Lindner and Anderson (1956) reported the effects of low winter temperature during 1939-40 on P. setiferus landings the following spring. More recently, Farmer et al. (1978) and Music (1979) have examined the effect of severe winter weather on overwintering white shrimp. They concluded that the winter of 1976-1977 severely damaged white shrimp stocks in South Carolina and Georgia, resulting in much reduced commercial landings in the South Atlantic.

The minimum lethal water temperature for Penaeus spp. is variable and its effects are dependent on salinity and rate of temperature change. Joyce (1965) reported that 20 percent of the white shrimp caught in a bottom trawl in December off Florida were dead after a rapid 4.5°C drop in bottom water temperature to 8.0°C. Dahlberg and Smith (1970) reported that white shrimp were killed in the Duplin River and Doboy Sound when water temperature reached a low of 4.5°C. Farmer et al. (1978) related catches of white shrimp to temperature and found that catches did not reach zero until 28 days after waters were 9.5°C. At 8.5°C, catches fell from an average of 12 lbs. (heads-on) to zero in 13 days. At 7.5°C catches decreased from about 5 heads-on lbs. to zero in 13 days. They concluded that 8.5°C may be near the critical temperature which stimulates migration or causes mortalities of shrimp. In laboratory experiments over a 24-hr. period, Zein-Eldin and Griffith (1976) found that post-larval P. setiferus have a low temperature limit of 7°C at 25 °/oo, following a 12-24 hr. acclimation period. When the acclimation period was lengthened to 48-72 hr. and the test period to one month, low temperatures, except at high salinities, were less well tolerated by P. setiferus over a longer period of time. A similar situation was observed for brown shrimp in which a combination of low temperature and low salinity was not favorable for either growth or survival (Zein-Eldin and Aldrich 1965). Most field and laboratory data indicate that simultaneous decreases in temperature and salinity such as may occur during a very cold, wet winter are detrimental to both P. setiferus and P. aztecus.

White shrimp form the main portion of the overwintering population in South Carolina, since juvenile and adult brown shrimp have either been killed or have moved offshore prior to onset of cold weather (South Atlantic Fishery Management Council 1981). When the majority of white shrimp do not survive the winter, the fisheries of North Carolina, South Carolina and Georgia are apparently dependent on a northward migration of white shrimp from Florida and Georgia to form the spawning stocks. The fact that the offshore commercial fishery begins in late spring, with roe shrimp harvested during this time, indicates that fisheries management scientists believe that there is no necessity to totally protect the roe shrimp during years of high abundance. Overwintering shrimp, however, should be protected as much as possible because there is no way of knowing in advance how severe winter weather conditions will be and to what extent the overwintering stocks will be affected. It appears that climatological conditions will have a great impact on overwintering stocks and ultimately determine the number of roe shrimp that show up in the spring.

The general concensus of biologists traditionally has been that there is no relationship between spawning stocks and recruitment in shrimp. In the case of penaeid shrimp, Neal (1975) noted that a relatively small population of spawners was required in the Gulf of Mexico because high fecundity maintained stock levels, and environmental fluctuations rather than changes in spawner abundance were the primary cause of stock fluctuations. The importance of environmental factors on recruitment was emphasized by Garcia and

LeReste (1981) in their review of the biology and dynamics of penaeids. Recently, however, the National Marine Fisheries Service (NMFS) Southeast Fisheries Center has used new catch data for a review of the fishery, in an effort to address concerns over a trend of declining catches of white shrimp (Nichols 1984; Nichols and Cummings 1984). In 1984, NMFS began gathering more detailed catch information on bay shrimp in an attempt to identify any stock-recruitment relationship for this species. The observations for penaeids suggest either a quasi-linear relationship between stock and recruitment or no relationship at all (Garcia 1983). Furthermore, there is currently no convincing evidence that the positive, quasi-linear relationships observed up to now are related to excessively high levels of fishing. Garcia (1983) concludes that for some shrimp stocks the effect of the environment on recruitment may be at least as important, if not more so, than the effect of fishing. Rothschild and Brunenmeister (1984), however, point out that the risk of recruitment failure increases as populations decline. This coupled with the fact that shrimp are an annual stock intensifies the possibility of a stock collapse. The implications for management are that a conservative policy designed to afford protection to overwintering shrimp should continue until more definitive information is available regarding the spawner - recruit relationship. Heavy fishing on shrimp which move into the sounds during late fall and early winter could subsequently have an impact on the spring spawning population that might prove to be significant in some years.

Increased Weight Yield through Growth and Emigration

An argument used to support opening of bays and sounds is that biological and economic yield is maximized through reduction of the shrimp population in the sounds which triggers the emigration of large shrimp in the lower creeks and rivers[1]. Most available data do not support this idea that emigration is density dependent. Rather, movement from creeks appears to depend on climatological factors and growth rate of shrimp.

Various explanations have been given concerning distribution and movements of Penaeus spp. in estuarine and offshore waters. Postlarvae enter estuaries after water temperatures begin to rise in late winter and early spring and move to wetland nursery areas (Williams 1969; Herke 1971; Weinstein 1979). Laboratory and field efforts strongly suggest that growth and densities of penaeids are associated with temperature, salinity and vegetation (e.g. St. Amant et al. 1963; Gunter et al. 1964; Mock 1967; Trent et al. 1969; Giles and Zamora 1973; Gilmore and Trent 1974; Christmas et al. 1976; Weinstein 1979). Evidence to date suggests that shallow water estuarine habitats such as marsh beds function to provide food, substrate and protection for young penaeids (Zimmerman et al., 1984).

Weinstein (1979) indicated that postlarvae were found in immense numbers at the headwaters of shallow creeks and along the marsh fringe. He suggested that seasonality and spatial distribution mediated by salinity and substrate may reduce competition among recruits. Rulifson (1981) suggested that Penaeus spp. may compete for suitable substrate at times when they co-occur. He found that substrate preferences change with size, so that when shrimp emigrate to lower estuarine areas in fall their affinity for sandy-mud bottoms increases. The substrate preferences of sub-adults exhibited during final emigration activity are retained as adults residing offshore.

Shrimp move from the inshore habitat to higher salinity coastal waters as sub-adults. Weymouth et al. (1933) reported that P. setiferus measuring 20-50mm move seaward through the summer and fall with a gradient of decreasing size from waters of greater salinity toward freshwater. Baisden (1979) reported mean lengths of 84 mm for shrimp from creek headwaters and 109 mm for shrimp taken in areas adjacent to open ocean. Bishop et al. (1980) suggested that as shrimp increase in size, they seek higher, stable salinities because of a decrease in osmoregulatory ability. Joyce (1965) noted that this movement was related to temperature, storms, high tides, and rainfall but size was mainly responsible. Lindner and Anderson (1956) found that shrimp leave inshore areas as they approach adulthood and a drop in water temperature hastens the movement.

Data supporting the idea that emigration is density-dependent was provided by Parker (1970) who found that density was important in regulating time of emigration of brown shrimp in Galveston Bay. By examining brown shrimp size, abundance and distribution, he found that the size of emigrating shrimp differed considerably in the two years of the study. When shrimp were more abundant, they moved offshore at a smaller size. He reasoned that, "if the bay were populated well below its maximum capacity....juveniles could remain in the nursery areas longer because of more available food and consequently, grow to a larger size before emigrating to the Gulf."

For South Carolina, there is no apparent relation between opening the sounds and the size composition of penaeid shrimp that become available to the offshore fishery (Appendix 1). Purvis and McCoy (1974), however, determined that shrimp will reach 16 to 30 heads-off count before migrating

out of Pamlico Sound, North Carolina. They felt that it was reasonable to prohibit shrimping in Pamlico Sound until shrimp approach 46-50 count. In Core and Bogue Sounds and New River, McCoy (1972) found that maximum potential yield, in both weight and value, is attained somewhat before shrimp reach the generally accepted minimum commercial size of 70 count (headless).

The physical yield (i.e., the catch in pounds) obtained from the sounds and bays depends on the natural mortality schedule and the timing of harvest compared to the rate of growth and emigration pattern of the shrimp. During any given time interval, a percentage of the shrimp population dies from natural causes. This percentage is known as the instantaneous rate of natural mortality (M) and includes shrimp that are eaten by fish, killed by environmental factors, die from pollution, etc. In the case of most animals, this rate is high very early in the life cycle, declines with increasing age and size, then accelerates with age as the end of the normal life span is approached or passed. Whether or not this pattern applies to shrimp is not known, but one would suspect that senility (old age) is not an important factor in the natural deaths of older, large shrimp. Predation is probably the most important element. The rate at which shrimp of near-harvestable or harvestable size are dying from natural causes is critically important in determining the most appropriate time to harvest them.

If there is no fishing, then obviously all of the shrimp that die do so from natural causes. The death rate may be related to the number of shrimp in an area because of competition for food, the ease with which fish are able to find and catch them, etc., but this is very difficult to determine in any given situation. Under normal circumstances, the death rate probably is not influenced by the density of the available shrimp. Under conditions in which there is no fishing (e.g. a closure), a certain percentage of the shrimp are lost. This percentage does not change if fishing is allowed. What changes is the number of shrimp that die due to natural causes only, and it will be less than if no fishing was allowed. This is because fishing removes some of the shrimp that would otherwise die due to natural mortality, thus natural causes are working on a smaller population than would exist if there was no fishing. Because fishing acts as an additional source of mortality, both the overall percentage and total number of shrimp killed is higher when fishing occurs.

What becomes critical in the choice of harvest strategies is the trade-off between the number of shrimp lost due to natural causes in the absence of fishing versus the number of shrimp that would be caught if fishing was allowed during the time interval, combined with the growth rate during the interval. If the natural mortality rate is low and the growth rate is high, then relatively few shrimp die. Those surviving gain appreciably in individual weight, and the population shows a substantial net increase in weight at the end of the time period. In this situation, it is desirable to let as many shrimp as possible continue to grow because little potential (weight) yield is being lost in the form of dying individuals. A closure is sound policy when such conditions prevail.

Under adverse environmental conditions, the natural mortality rate may be very high. Conditions conducive to poor survival also tend to retard growth. In such circumstances, large numbers of shrimp are dying and those remaining are not growing much, so the aggregate population weight at the end of the time interval may actually be less than at the start. In this situation, there is little to be gained from a closure. It would be more practical to allow fishing in order to catch some of the shrimp that would otherwise die, particularly since these shrimp are not going to get much larger during a closure. A variant of this scenario, and one that has occurred in the recent past, is when the shrimp do not leave the sounds and bays as they reach a large size. Drought conditions cause shrimp to remain in inside waters. If these waters are closed, the shrimp remain exposed to natural mortality but are not growing very rapidly, and the fishery is losing yield in the form of shrimp that are dying. When the shrimp do move out, they do so quickly and rapidly disperse in offshore waters where they become relatively unavailable to local fishermen. Thus, any potential benefit from the closure is likely to be further decreased.

The economic consequences are difficult to evaluate because of the variable price structure. The availability of medium versus large shrimp and the relative prices by count have an important impact on the economic yield in each of the above situations. In addition to gross revenues, the net revenues also need to be considered. For example, it may prove more profitable to catch medium shrimp at a lower price when they are concentrated in the sounds and bays and less trawling time is required than to catch lesser quantities of larger shrimp offshore when substantially more dragging effort and higher fuel bills are involved.

It must be emphasized that natural mortality rates of shrimp are not well known and are likely to vary over a wide range both spatially and temporally. Because the extent of natural mortality is very difficult to quantify in specific situations, a wide range of values is usually incorporated into yield models. Depending on which end of the range they

occupy, these hypothetical rates will have a significant influence on the choice of an appropriate harvest management strategy.

For example, two studies examined pink (P. duorarum) shrimp harvest on Florida's Tortugas Grounds and yielded different management recommendations. Kutkuhn (1966) used mark-recapture experiments to examine natural and fishing mortality rates (F). Of 2,090 shrimp tagged and released, only 252 recaptures were reported over a fourteen-week period. His work produced very high M's (0.42 weekly, 28.6 annual) and he observed that he had to rely heavily upon certain conditional assumptions that may or may not be warranted. Kutkuhn (1966) suggested that shrimp be harvested when they first reach marketable size (70-count heads-off) and noted that a natural mortality rate of 0.10 or less would be required to justify harvesting larger shrimp.

Linder (1966) also examined pink shrimp yields from the Tortugas area. He estimated M to be about 0.075 to 0.125 (weekly rate) (annual = 3.9-6.5). Using this range of values, he produced two curves illustrating optimal harvest sizes. For the lower M he recommended harvesting between 60- and 40-count (heads-off). The weight yield could be about the same if shrimp were harvested anywhere in this range. (Similar curves for maximum economic yield indicated harvest should be conducted on 38- to 30-count [heads-off] based on prices of $0.86 per lb. for 70-count and $0.21 per lb. for 15 count).

Costello and Allen (1968) worked with pink shrimp on the Tortugas and Sanibel grounds. From 2,496 shrimp tagged at Sanibel (563 recaptures) and 2,350 at Tortugas (784 recaptures), they estimated higher values than Iversen (1962), but lower than those calculated by Kutkuhn (1966). Weekly natural mortality values were 0.03-0.07 (4.2-5.7 annual), as converted by Berry (1970), who noted the wide range of published natural mortality values for Tortugas pink shrimp and the resulting conflicts in management proposals. Using size composition and fishing intensity data, he produced weekly M's of 0.01-0.03 (annual = 1.04) and concluded that there is merit in protecting small shrimp.

Studies in North Carolina have produced differing management recommendations for pink shrimp, instantaneous weekly total mortality rates (Z's) averaged 0.317 and 0.350 (Purvis and McCoy 1972). Z's for brown shrimp were 0.272 and 0.434 in Pamlico Sound (Purvis and McCoy 1974). The authors recommended that pink shrimp be harvested at 70-count, but browns should be harvested at 35 count (heads-off). They explained that brown shrimp in Pamlico Sound grow to relatively large size before moving offshore and being lost to the commercial fishery. Pink shrimp and brown shrimp (in other estuaries) apparently move offshore at a relatively small size and become unavailable to the fishermen.

Studies of Gulf of Mexico white shrimp have produced a wide range of estimates of mortality. Klima (1964) produced a very high Z of 23.9 (annual). Annual M values calculated by Klima and Benigo (1965) and Klima (1974) ranged from 2.1 to 6.3, but Rothschild and Brunemeister (1984) concluded that these were too high; "one conclusion is that shrimp tagged in the Gulf of Mexico have higher mortality rates than untagged shrimp." They further observed that Z's in excess of 10.0 (such as Kutkuhn's 1966) were mathematically improbable. If Z = 10.0, then the average age of the population converges to only about 5 weeks beyond recruitment, meaning that such a population would be composed of very small shrimp (Rothschild and Brunemeister 1984).

Phares (1980) tagged over 36,000 small white shrimp (tail length = 40-70 mm) in Caillou Lake, Louisiana. She calculated weekly M values of 0.214, 0.490, 0.553 and 0.556, but only the lowest value was thought not to be influenced by unequal fishing mortality or emigration.

Rothschild and Brunenmeister (1984) examined natural mortality by analyzing the decline in numbers of shrimp caught per unit effort over time in cases where significant recruitment to the fishery does not occur after a definable point in time. Specifically, they examined white shrimp mortality rates in the offshore Gulf of Mexico shrimp fishery. They estimated M to be 2.6 (annual rate) over the period 1965 to 1980 with fishing mortality (F) ranging from 0.6 to 1.9. These values were considerably lower than previously determined offshore values. Several sources of possible error in previous studies were presented. All of these possible errors involved "phenomena that either increase or decrease the apparent number of shrimp early or later in the season".

Rothschild and Brunenmeister (1984) concluded by stating that catching small shrimp should generally be avoided. Based on their analysis, the relatively low natural mortality rates suggested that "important gains in yield-per-recruit could be derived" by harvesting larger shrimp. They note, however, that this is a "tricky problem" and more detailed work is needed on natural mortality rates.

SOCIOECONOMIC CONSIDERATIONS

Overview of the U.S. Shrimp Market

During 1974-1983, the domestic harvest of penaeid shrimp ranged between 123 and 179 million pounds, with the annual rate of increase in domestic consumption averaging

about five percent (Fig. 7). In 1984, consumption of fresh and frozen shrimp (Fig. 7) reached a record 536 million pounds, about 13% above 1983 and more than one-third higher than the 1979-83 average.

The 1984 aggregate Gulf and South Atlantic shrimp landings, 171 million pounds (heads-off), were about 28 million pounds higher than 1983 (Fig. 7) and approximately 11 percent above the 1979-1983 average. Most of the increased landings came from Gulf ports. Sustainable increases in domestic landings are not expected and, while the long-term growth in real (deflated) prices has partially compensated for catch declines and increased costs, vessel owners have experienced a cost-revenue squeeze in recent years. This has caused many failures in the domestic fleet.

In contrast to domestic production, 1984 imports of fresh and frozen shrimp totaling, 388.1 million pounds were nearly the same as 1983 imports (Fig. 7) but remained two-thirds higher than the 1979-83 average. After increases in nine successive quarters, imports declined in the second half of 1984. Imports from Ecuador, a major exporter of shell-on fresh and frozen shrimp to the U.S., fell off apparently due to a decline in aquaculture production. The world harvest from wild fisheries is not expected to increase appreciably in the future, but the potential for increased imports of cultured shrimp is considerable, despite the short-term slow down in Ecuador. The U.S. market is absorbing the increasing aquaculture production (under 15 thru 36-40 counts, headless) from Ecuador and other countries (e.g. Taiwan).

During the 1974-79 period, apparent consumption of fresh and frozen shrimp fluctuated (Fig. 7) due to several factors: (1) domestic production variations (2) business cycles in the U.S. which partially influenced the restaurant sector and (3) economic conditions in exporting countries (e.g. "strength" of the U.S. dollar). In the 1980-84 period, the growth in the U.S. shrimp markets has been attributed to several factors (Vondruska 1985): (1) recovery of the U.S. economy (2) a strong U.S. dollar, (3) lack of growth in the Japanese market until 1984, (4) greater product promotion in certain market segments, and (5) moderating prices. The development of aquaculture technology and resulting supplies from Ecuador and Taiwan have also contributed to the growth of fresh and frozen consumption in the U.S.

Shell-on headless shrimp, which constitute a large portion of the U.S. primary wholesale sector, are ultimately purchased by restaurants or processors, which process them into a frozen product (IQF) or other shrimp products.

In the shrimp wholesale sector, headless, shell-on shrimp in the 31-50 counts are generally considered "medium" shrimp with the 26-30 counts as a transition size to "larger" shrimp (e.g. 21-25 counts). The medium shrimp sizes are generally considered a desirable size for various restaurant-oriented products.

Published estimates indicate that approximately 85% of frozen shrimp supplies are consumed in restaurants. The remaining 15% are marketed through retail outlets, mainly supermarkets. The current concensus is that the wholesale market demand for frozen shrimp will continue to increase as restaurant seafood sales expand.

Exvessel Prices in South Carolina

South Carolina annual landings averaged about two percent of total U.S. penaeid shrimp production during the 1980-84 period. Consequently, exvessel prices in the Carolinas (Waters et al. 1980) are generally assumed to be perfectly elastic (i.e. relatively unresponsive to quantities landed in South Carolina). Moreover, Waters et al. (1979) concluded that a possible decrease in North Carolina landings due to shrimp fishery regulatory policies, in this case potential regulations to reduce pink shrimp discard, was expected to have only a small impact on North Carolina shrimp prices.

South Carolina exvessel prices are influenced by U.S. Gulf of Mexico exvessel prices (Fig. 8). Since shrimp is an international seafood commodity, Gulf exvessel prices are affected by both domestic and foreign shrimp demand and supplies. At the national level, U.S. exvessel prices appear to be quite responsive (i.e. high price flexibilities) to imports and domestic shrimp landings (Adams and Prochaska, 1985). The 1984 exvessel prices pattern especially for medium shrimp has been characterized as a supply-induced decline due to increasing imports in the first half of 1984 and relatively high Gulf shrimp landings in 1984. Three factors probably contributed to the continued growth of shrimp imports in the first half of 1984: (1) the strength of the U.S. dollar, (2) more cautious purchasing in the Japanese market and (3) sustained production of Latin American aquaculture shrimp. The result was a decline in domestic exvessel prices and a build up of a cold storage holdings in the first half of 1984. The relatively low exvessel prices combined with below average South Carolina catches increased vessel income losses in 1984 (Rhodes, 1984).

In the 1980-83 period, South Carolina annual exvessel prices generally increased compared to the previous year (Fig. 9). In 1984, this pattern changed. Monthly exvessel prices during 1984 were lower than the same month in the previous year during

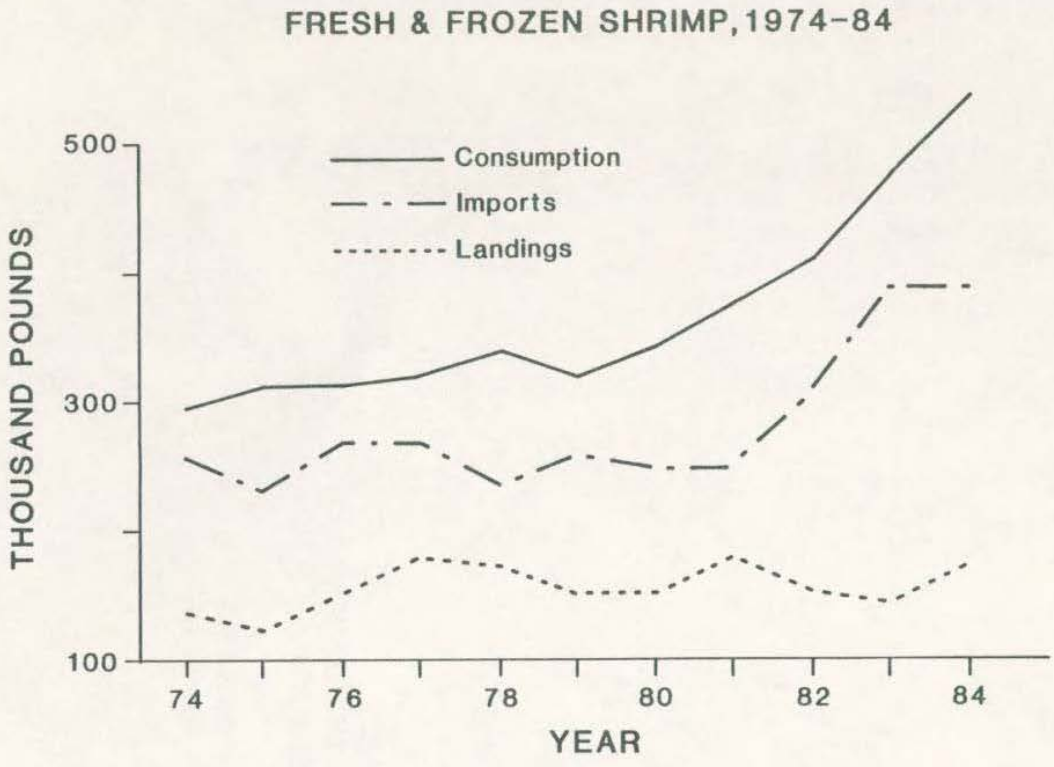

Figure 7. Fresh and frozen shrimp imports, domestic landings, and apparent consumption in the United States, 1974-84.

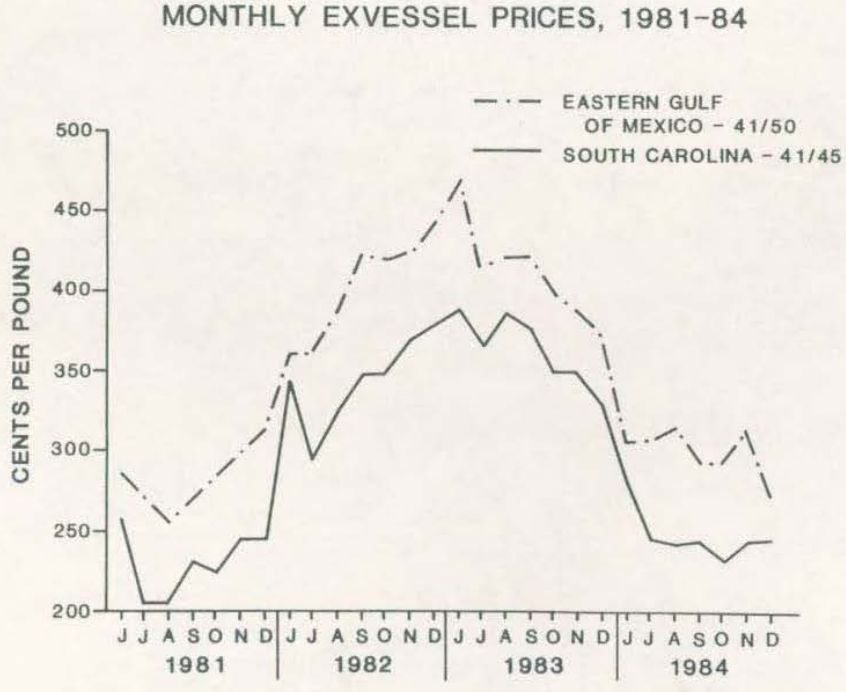

Figure 8. Average weighted monthly exvessel prices for the Eastern Gulf of Mexico (41/50 counts) and South Carolina (41/45 counts), 1981-84.

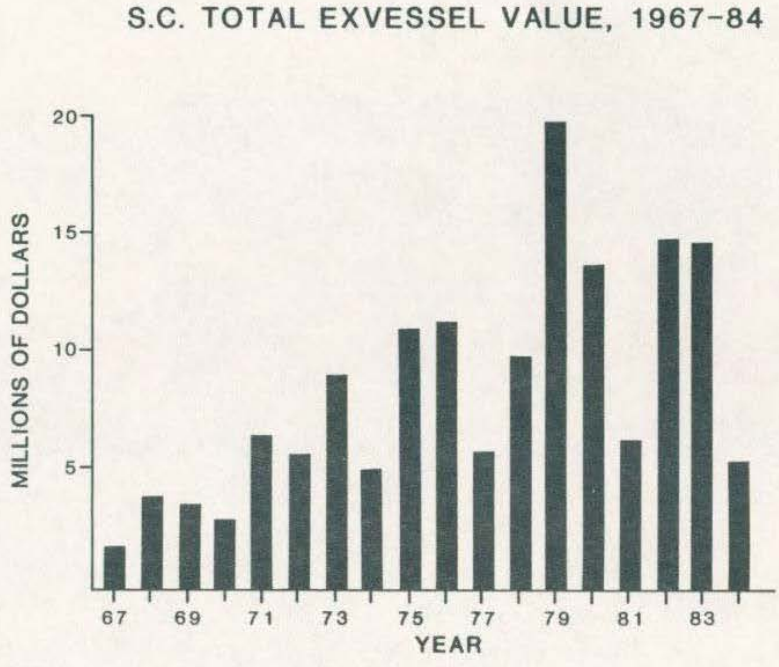

Figure 9. Annual aggregate average exvessel price for commercial shrimp landings (excluding rock shrimp) in South Carolina, 1967-84.

June through September (Table 3) due to the previously described decline in 1984 Gulf exvessel prices. Since about 76% of the 1984 below average landings occurred in the June-September period, a major decline occurred in the fisheries aggregate exvessel value (revenues) (Fig. 10).

Although South Carolina exvessel prices are generally unresponsive to South Carolina production and are strongly influenced by Gulf of Mexico prices, this generalization should be qualified due to the premium rating that South Carolina white shrimp receive from major buyers compared to brown shrimp (J. Roy Duggan, King Shrimp Company, personal communication). Consequently, it is possible that the opening of South Carolina sounds might influence prices for white shrimp on the Atlantic coast. In addition, when South Carolina landings are extremely low, local demand may have more affect on prices than during periods of normal production.

Part-time shrimpers with possibly lower costs (e.g. smaller boats) and smaller quantities of shrimp to sell may obtain prices significantly different from those reported. Consequently, the use of exvessel reported prices might under-estimate net income losses, particularly for operators of smaller boats, if the sounds were closed.

Exvessel Prices by Shrimp Size (Count)

Exvessel unit prices vary directly with size. Chui's (1980) study indicated that the demand structure by size can significantly influence the aggregate exvessel value of domestic landings in the Gulf. It showed that the total monthly value could be maximized when total monthly regional supplies were allocated to "large" and "medium" categories. The life history of wild stocks precludes such allocation and moreover the influx of medium shrimp (26-40 counts in this study) from Latin American aquaculture may have altered this situation.

A recent study (Prochaska and Adams 1985) indicates that the 31-40 count shrimp market appears to be much more sensitive to changes in imports than the 21-25 count market. Since expanding Latin America aquaculture production has been targeting shrimp in the 26-40 count sizes (part of the medium shrimp market), the medium shrimp market segment will most likely be affected by aquaculture shrimp imports. Consequently, management efforts like the Texas closure which increase the domestic supply of 31-40 count shrimp may need to be reconsidered.

Overcapitalization

Overcapitalization, as defined by Blomo (1981) is the "... use of too many factors of production, or fishing effort, than is optimally profitable for the industry or economically efficient for society." As in the Gulf (Blomo 1981), the South Atlantic shrimp fishery exhibits symptoms of overcapitalization in an open access fishery (Liao and Rhodes 1981). These symptoms include a large influx of fishing crafts during 1967-77 (Fig. 11), a significant increase in the average size of documented vessels during the same period (Fig. 12), and the decline of real (deflated) income per vessel between 1967 and 1983 (Fig. 13). Furthermore, past studies (Rhodes 1980; Jones et al. 1979) indicated that the average South Carolina shrimp vessel over 55 ft probably experienced income losses in five of the 10 seasons in the 1971-80 period.

Overcapitalization in the southeastern shrimp fishery is attributed to the rapid entry of new, expensive vessels as partially induced by relatively high shrimp prices in the 1970's (Blomo 1981) and the slow exit of vessels during "poor" seasons. Unlike in fisheries where fishing craft may be relatively unspecialized and start-up costs (e.g. gear, boat, etc.) are relatively low (e.g. the blue crab fishery), the exit of double-rigged trawlers has been retarded by the decline in vessel selling prices. Trawler owners are reluctant to sell vessels at a loss and also expect improved seasons to increase the value of their vessel. Also, the high cost and low availability of hull insurance have recently become significant disincentives for potential buyers. In 1984, the overcapitalization of South Carolina's shrimp fishery was further amplified by the combined decline in exvessel shrimp prices and harvestable white shrimp.

Although the number of vessels and boats involved in the fishery did not increase markedly between 1982 and 1983 (Fig. 11), the South Carolina double-rigged trawler fishery still displays the symptoms of overcapitalization in an open access fishery that historically enjoyed high product prices. Moreover, overcapitalization has exacerbated the problems of competition among commercial shrimpers and between them and the other user groups.

Socioeconomic Variables and Fishery Management in South Carolina

Objective determination of benefits and costs is complicated when the fishery is composed of many different user groups with a wide range of motivations. Lack of socioeconomic information regarding these groups precludes development of a model to quantify benefits and costs associated with various management policies. Because South Carolina does not have a homogeneous fleet, it is reasonable to assume that motivational characteristics differ even among operators who derive most of their income from commercial shrimping. Additionally, there are part-time fishermen who seek

Table 3. Monthly average exvessel prices for South Carolina's commercial shrimp landings, 1979-84*.

Month	1979	1980	YEAR 1981	1982	1983	1984	1981-83** Averages	1984 % of 1983
January	$3.41	$2.30	$2.56	$3.39	$3.47	$3.38	$3.14	97%
February	3.00	4.37	NA	4.50	3.92	NA	NA	NA
March	NA	NA	4.45	NA	3.70	NA	NA	NA
April	4.79	3.82	NA	NA	NA	NA	NA	NA
May	4.95	3.51	NA	5.66	5.67	NA	NA	NA
June	3.34	2.72	2.85	3.76	5.17	2.91	3.93	56%
July	4.14	2.72	3.18	3.75	3.91	3.12	3.61	80%
August	4.37	3.14	3.11	4.18	4.50	3.64	3.93	81%
September	4.11	2.95	3.16	4.67	4.22	4.00	4.02	95%
October	4.64	3.23	3.67	5.02	4.57	4.49	4.42	98%
November	3.76	2.98	3.41	5.57	4.01	4.47	4.33	111%
December	2.90	2.51	3.62	3.99	2.94	4.40	3.52	150%

* These data do not include rock shrimp landings.

** These are unweighted averages.

(Data Source: Fisheries Statistics Section)

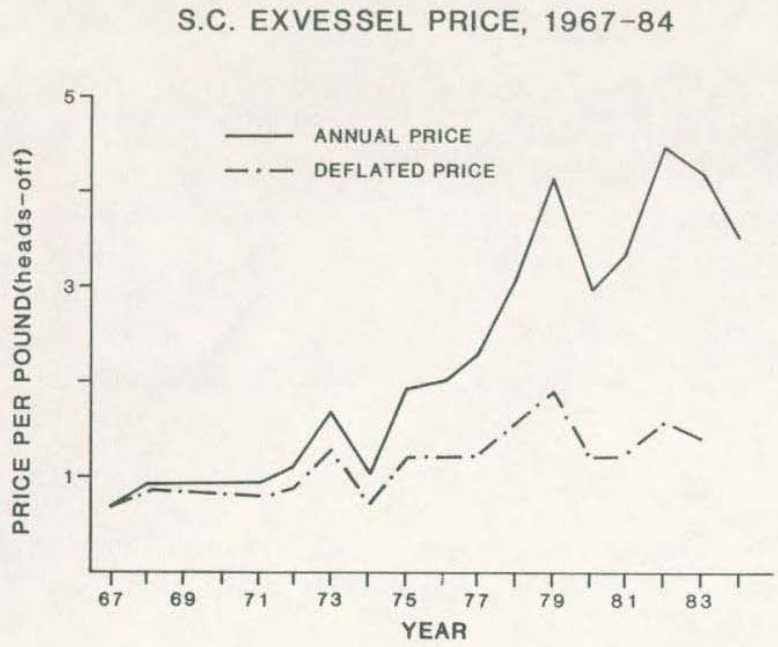

Figure 10. Aggregate value of South Carolina commercial shrimp landings, 1967-84.

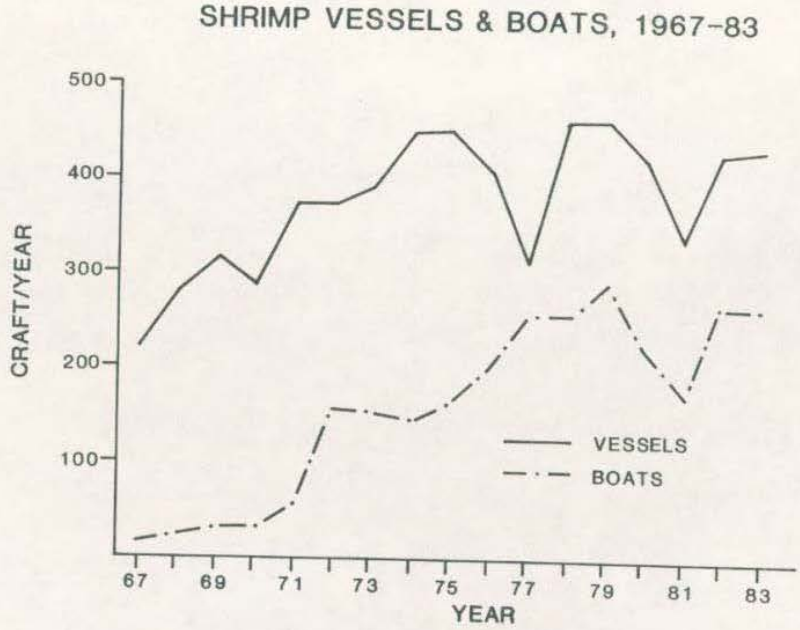

Figure 11. Annual number of vessels (i.e. gross tons > 5) and boats participating in South Carolina's commercial shrimp fishery (Source: National Marine Fisheries Service).

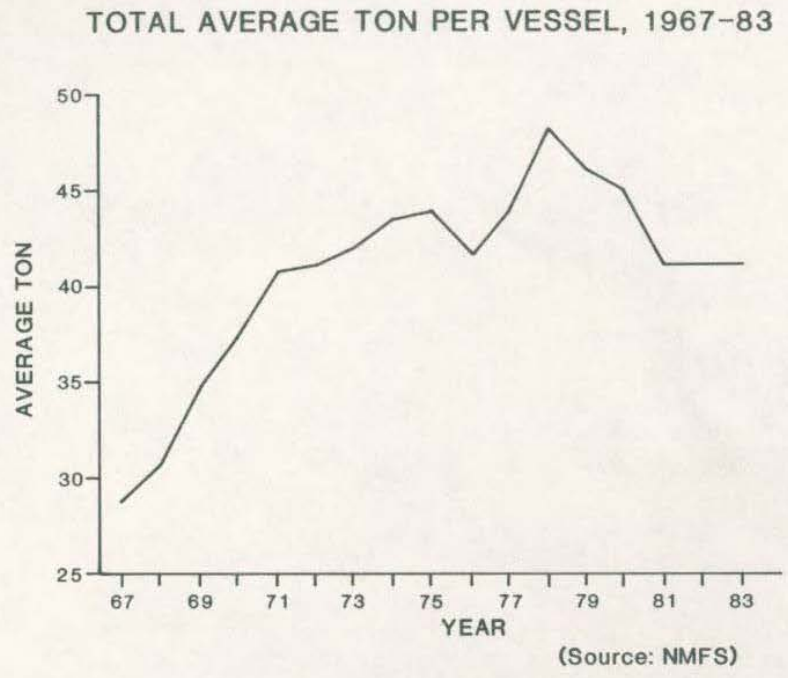

Figure 12. Annual average gross tonnage of trawlers participating in South Carolina's commercial shrimp fishery (Source: National Marine Fisheries Service).

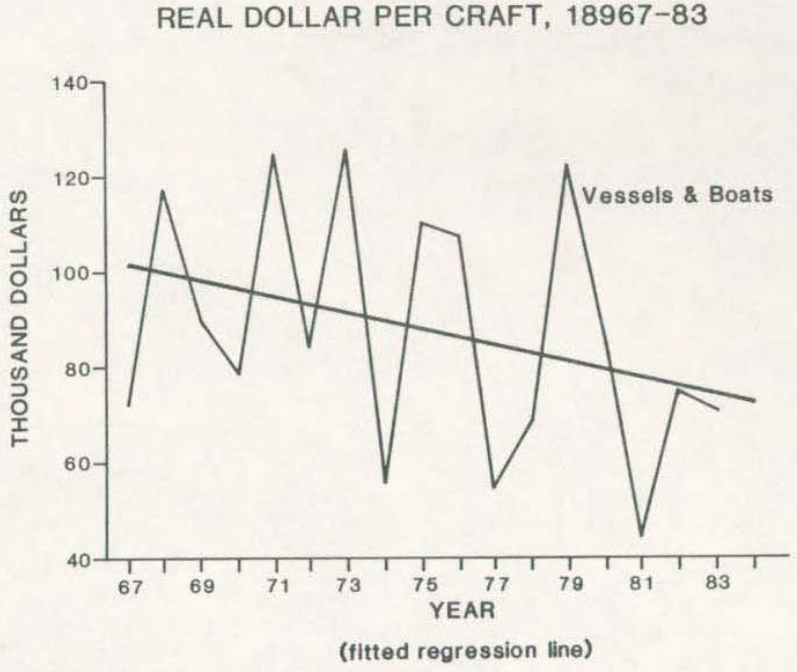

Figure 13. Aggregate average real (deflated) dollars per fishing craft participating in South Carolina commercial shrimp fishery (Data Source: National Marine Fisheries Service).

recreational and other noncommercial benefits (e.g. group recognition) from the resource. While the size of the boat may be a proxy for the amount of financial investment in and income derived from commercial shrimping, it may not be a good indicator of the license holder's objective or of the intensity (e.g. willingness-to-pay) of those objectives. Consequently, policies which optimize conditions for one group may create "losers" in others because the motivations and harvest methods of the participants vary.

In addition to the paucity of information, especially regarding sociocultural variables influencing various user groups, there has not been any explicit management policies regarding expected net benefits to accrue to different user groups other than resource preservation for future use. Historically, past decisions by the S.C. Wildlife and Marine Resources Commission have generally implied that all user groups that obtain a license have a right to harvest shrimp in the sounds and bays. A related example includes an incident in 1977 when the Commission was asked to exclude channel net fishermen from temporarily harvesting shrimp for the benefit of trawler owners. The Commission denied the exclusion. Rules and regulations regarding trawling locations, seasons and gear use might then be viewed only as local modifications and exceptions of this implicit policy.

The fundamental problem that decision makers must confront when managing a common property resource is: WHO gets WHAT? The concept that everyone who buys a license is entitled to an equal opportunity to compete for the resource does not guarantee that the share they actually realize will be an equitable one. Traditionally, the equitability issue as it applies to other public sector goods has been resolved by the legal system or political process. The issue of income distribution due to fishery management policies has not been explicitly addressed in South Carolina.

Aggregate Monetary Benefits and Costs

In the absence of integrated information on the biology, economics and sociology of South Carolina's shrimp fishery, quantitative observations can only be made on apparent aggregate monetary impacts of various management policies. In addition, these observations will only superficially touch on the allocation of aggregate monetary benefits and costs in the restricted context of a major user group, commercial fishermen, and not recrational fishermen.

When evaluating the impact of various management policies, the use of aggregate gross revenues for the fishery may not be a good proxy for changes in the fisheries aggregate net revenues (aggregate gross revenues less aggregate nominal costs for the fishery) if the fishery has a heterogenous fleet of vessels. For example, assume the smaller vessels (boats) in the South Carolina commercial fleet collectively generate higher net revenues per unit of standardized effort than larger vessels. If the smaller vessels were directly or indirectly forced from the fleet by fishery management action and gradually replaced by larger vessels, it then becomes possible that the aggregate gross revenues generated by the fishery might increase but the aggregate net revenues the in fishery could actually decline because the fleet's aggregate costs have increased more than revenues due to the addition of "larger" vessel effort and the exit of smaller more efficient vessels. A corollary of this situation is that the fleet's nominal return on investment, one proxy for economic efficiency, might decline despite an increase in aggregate gross revenues.

A recent economic analysis of costs and benefits due to a proposed closure of inshore waters (e.g. bays) was performed by Texas A&M University on the brown shrimp fishery of Texas (Griffin, et al. 1979). At the time of this analysis, Texas shrimpers were allowed to harvest 300 pounds of shrimp per day per fisherman in the bays during the open season from May 15 to July 15. These laws allowed the commercial harvest in the state's bays where the brown shrimp mature and eventually emigrate to deeper offshore waters. Two different groups of shrimpers were harvesting the brown shrimp, the "bay shrimpers" which generally used vessels less than 50 feet in length and "offshore shrimpers" with larger vessels. Their results indicated that landings of shrimp from inshore areas were inversely associated with offshore landings during the latter part of the season (Griffin et al., 1979). They concluded that the proposal to close the spring open season in the Texas brown shrimp fishery would result in a short-term aggregate gain to the fishery as high as $10.3 million. They also estimated that the benefits and costs would be allocated in a manner that offshore vessels could gain up to $10.38 million while "bay shrimpers" could lose as much as $1.16 million. Consequently, the offshore vessels would benefit at the expense of the bay shrimpers.

The above analysis has probably been altered by the Texas Closure and recent changes in the shrimp market. In addition, with this open access fishery, the forecasted increase in net revenues would have attracted additional vessels. Consequently, the long-term effect could be no increase in net revenues for individual vessels due to the added effort of new vessels.

GEAR AND USER GROUP CONFLICTS

Spatial Competition Between Trawlers and Crabbers

Some concern has been expressed that the continued opening of bays and sounds for trawling may conflict with the crab (pot) fishery operating in those areas. Unfortunately, no strong data exist to evaluate the effects of inshore trawling on the crab fishery because landings are recorded by county at monthly intervals and the statistics combine all collecting gears so that pot- versus trawl-collected catches can not be identified. Finally, the market price often dictates how crabs are sold, making it difficult to compare county landings for graded (basket) or ungraded (picking) crabs. For example, the total crab landings in Beaufort County were lower in October 1983 (the month following the opening of sounds) than in September 1983 (the month before sounds were open) whereas the opposite trend was observed during those two months in Charleston County, where more inshore waters are closed to trawling. The same trends were not observed, however, when comparisons were limited to either graded or ungraded landings.

The commercial blue crab pot fishery in Georgia was reduced during periods when the sounds and bays were open (Shipman, 1983). Georgia DNR, however, felt that this socio-economic impact could be partially countered by the entry of part-time crabbers into the shrimp fishery when the sounds are opened. Additionally, it should be realized that the loss of crabs to the pot fishery may be countered by the sale of crab bycatch obtained from trawling. Thus, the more pertinent issue may be one of catch distribution among the fisheries rather than a loss of the resource due to biological effects.

The closure of sounds minimizes spatial competition between trawlers and crabbers in limited areas and reduces potential interference with sportfishermen. Although the extent of competition for fishing grounds in South Carolina's bays and sounds is unknown, competition for space among crabbers and shrimpers is probably minimal since most crabbers have their pots located in creeks and other non-trawled areas in order to increase their catch of male crabs (or to avoid gear loss). Information supporting or refuting this opinion is lacking.

No evidence currently exists to support the idea that opening bays and sounds to shrimp trawling has a serious negative impact on the crab fishery in this state; however, more data are needed before this issue can be resolved.

Competition between shrimp trawlers and recreational anglers

Closure of inside waters to trawling reduces the possibility of interference with recreational fishermen. Little direct competition apparently exists between the two groups for game fish, based on the observed incidental catches of sound and bay shrimp trawlers and the composition of the fish bycatches that they land for sale. Most of the species preferred by sport fishermen, e.g. spotted seatrout, red drum (spottail bass), and sheepshead, are not abundant over the open, soft bottom trawled by shrimpers, so the problem of physical competition for fishing space appears to be overstated.

Distribution of shrimp among competing user groups

The principal issue is that of distribution of a limited resource. There are six major user groups that compete for shrimp:

1. Recreational fishermen. These individuals harvest shrimp by a variety of methods in the sounds and bays, in addition to tidal creeks and marsh areas that are permanently closed to commercial shrimp trawlers. Recreational fishermen use seines, drop nets, and cast nets, primarily in areas that are closed to trawling. A few sport fishermen also purchase commercial trawl licenses ($75.00) in order to fish with small trawls (usually commercial trynets) in those areas that are open to commercial trawling. No license is required to harvest shrimp for personal consumption (food, bait) using other gears.

2. Small-boat resident commercial shrimpers. These fishermen typically operate boats less than 31 ft long and weighing less than five net tons. Many are part-time fishermen and have other jobs outside of fishing. Often they will take leave from their regular jobs to fish the first few days of the sound and bay opening. Others derive most or all of their income from fishing, but move from fishery to fishery (crab, oyster and clam, or finfish) depending on the season and relative financial attractiveness of the available fishing opportunities. Few small-boat shrimpers rely exclusively on shrimping for their income. Among owners of boats less than 25 ft long, 47 percent reported that less than 30 percent of their income was from shrimping (Farmer and Whitaker 1980). Shrimping in the sounds and bays is important, however, to many fishermen, the majority of whom are small-boat operators. Of the survey respondents, 41 percent reported that more than 50 percent of their income

came from the sound and bay fishery.

Although the gear fished by small-boat operators varies considerably, a single rig is typical, with the net being about 40 ft in width at the mouth. Many small-boat operators have independent local outlets for their catch and market it directly. Of the major commercial users, small-boat owners have the least financial investment in the shrimp resource, in terms of captial outlay and the percentage of income derived. Small-boat fishermen generally are owner-operators.

3. Small-boat nonresident commercial shrimpers. Most of these individuals come from North Carolina or Georgia to fish for the first few days of the sound and bay opening. Of the 428 nonresident licenses issued in FY 1983-1984, 26 percent were for boats of 31 ft or less. These fishermen also are owner-operators for the most part.

4. Large-boat resident commercial shrimpers. This user group accounts for the major portion of the shrimp catch. Owners of large boats also have the greatest direct financial investment in the resource and the most dependency on it. Operators of large boats in South Carolina are usually owners, although an individual may have an interest in more than one vessel. There are no fleet operations comparable in scale to those in the Gulf. Virtually all large boats fish with at least two nets and are referred to as double-rigged boats.

   Many large-boat operators in Beaufort County will participate in the sound and bay fishery for the first few days and then move offshore for most of the balance of the season. Some fish in and out of the inside areas for most of the season, depending on the relative availability of shrimp. Some double-riggers prefer not to fish in the sounds and bays due to feelings about conservation and problems associated with crowding, but claim to do so only because their competitors use these areas. There is substantial division of opinion among double-riggers regarding the advisability of fishing in inside waters, with the polarization of views tending toward a south (pro)- north (con) orientation.

5. Large-boat nonresident commercial shrimpers. Nonresident double-riggers crowd the sounds and bays on opening day. Most boats from Georgia leave after the first few days. Operators of North Carolina boats fish the opening day, after which some move south and a few remain in South Carolina for most of the season. Purchase of South Carolina licenses by large-boat nonresidents tends to reflect the impressions regarding the upcoming season, with license sales being lower when poor seasons are anticipated.

6. Non-trawl commercial fishermen. Some fishermen, including nonresidents, use seines and cast nets, primarily in estuarine areas closed to trawling, to catch shrimp for sale. In 1984, 60 licensed commercial channel-netters fished in North Santee and Winyah Bays.

It is generally perceived that the permanent closure of the sounds and bays would confer an economic benefit to the operators of large boats by enabling them to harvest most of the available shrimp. Of course, such an advantage would be at the expense of the small boat fishermen. This view assumes that the recreational fishery (or its catch) is not large, the level of natural mortality in the sounds and bays is not unusally high, and the emigration of shrimp into coastal waters follows a normal pattern. A large estuarine recreational fishery could remove a substantial portion of the population before it became accessible to commercial fishermen. A sound closure would have no positive benefit and could entail a weight loss if the aggregate weight of the shrimp lost to natural causes exceeded the gain from growth of the survivors. Drought conditions might delay the emigration of large shrimp for prolonged periods, during which they would remain vulnerable to natural mortality. If a fishery was permitted, some of the shrimp that would otherwise be lost to natural causes would instead be caught by fishermen. An inflexible permanent closure would prove detrimental to all components of the commercial sector, including the operators of large boats, if such factors were in effect.

Two of the major points of dissatisfaction raised by commercial shrimpers, particularly the operators of large boats, are the recreational fishery regulations (or lack thereof) and the number of nonresident commercial shrimpers. Present policy permits recreational fishermen to have access to the resource at a time and in places off limits to the commercial trawlers. Recreational fishermen pay no license fee to harvest shrimp (unless trawling for themselves) and do not derive direct monetary benefits from the resource <u>other</u> than the market value of the shrimp caught. There are non-monetary benefits derived by recreational fishermen as reflected by their expenditures on boats, lodging, food, etc.

It is not the catch of shrimp for these purposes that disturbs most commercial fishermen. It is the sale of shrimp caught in closed (to licensed commercial trawlers) areas by unlicensed "recreational"

fishermen, even if these individuals are using legal gear. Commercial fishermen view this as unfair competition.

The competition between resident and nonresident fishermen is particularly important with respect to the sound and bay controversy. In recent years, many nonresident commercial shrimpers have fished the sounds and bays during the first few days of the openings, causing moderate to severe crowding in some areas (especially Calibogue Sound).

Georgia DNR estimated that about 50 percent (49,784 lbs.) of the 99,553 lbs. of shrimp landed in Georgia during the first week of October 1983 came from one day of shrimping in South Carolina's sounds (S. Shipman, Memorandum, 1983). From 1979 to 1983, shrimp caught in South Carolina but landed in Georgia or North Carolina averaged about 7 percent of the total South Carolina catch from September through December (Table 4). Most out-of-state landed shrimp were landed during September and October and probably came from the opening of the sounds and bays (Table 5).

Shrimp licenses from 1974 to 1983 averaged 1,152 per year (Range: 789-1,502). Non-resident licenses accounted for an average of 30.7 percent over the same period (Range: 25-35 percent). In FY 1984, Georgia accounted for 37 percent (159) of the nonresident license sales and North Carolina accounted for 60 percent (255). Of the Georgia licenses, 35 percent went to vessels less than 31 feet in length with the remainder going to vessels larger than 30 feet. Small boats comprised 21 percent of the licenses purchased by North Carolina residents. It is probable that all small vessels and most large vessels from North Carolina and Georgia came to South Carolina to participate in the sound and bay fishery.

This problem is most apparent in years when relatively good shrimping is anticipated in South Carolina sounds, since both nonresidents and part-time resident fishermen (primarily small-boat operators) are more likely to purchase licenses. Although landings statistics do not precisely identify the percentage of shrimp taken during these openings by nonresidents, the figures suggest that nonresidents may take close to half of the catch. It is not practical (nor legal) to totally exclude nonresidents from state territorial waters because South Carolina fishermen do shrimp in the waters of other states, both on the eastern seaboard and in the Gulf, and their reciprocal fishing rights must be maintained. In recent years characterized by declining per-vessel income and average to poor local harvests, operators of large boats have found it increasingly necessary to extend their season by fishing in waters off Florida and the Gulf states. Locally available alternative fishing employment, e.g. offshore finfish trawling, dragging for rock shrimp, or offshore bottom hook-and-line fishing, has not proved to be a satisfactory off-season opportunity for most large South Carolina shrimp vessels.

MANAGEMENT CONSIDERATIONS

The major issue underlying the sound and bay controversy is the distribution of the shrimp resource. A socially efficient distribution system must address the following concerns:

1) Acceptability. The various users of the resource must be satisfied with the system to the point where they accept its basic concepts and comply with its regulations in reasonably good faith.

2) Flexibility. The system must be able to respond promptly and effectively to changes in the status of the resource and the levels of participation by its users.

3) Reduction of transaction costs. The expenses of administering the system, monetary and labor costs to the management agency, must be minimized.

4) System evaluation. Some means of gauging the performance of the system must be available.

A brief discussion of how each aspect relates to the South Carolina sound and bay shrimp situation follows.

Acceptability - "There are no objective and rational criteria for determing who gets what from a common property resource. The real question is whether or not the distribution is acceptable to all parties that might have an influence on the scheme...." (Christy 1973). Any sound and bay closure policy must have some measure of approval from each major user group and be acceptable to management agencies if it is to succeed. Criteria for consideration include: 1) proximity of the user groups to the resource, 2) manageability of the users through regulations and enforcement thereof, 3) the relative need for and dependency on the resource by each user group, and 4) equitability of distribution, both in tangible and perceived terms.

The proximity criterion implies that small-boat commercial fishermen should be permitted access to the resource. If the sounds and bays are closed permanently, this access would be denied unless special exemptions were granted.

The manageability criterion applies mainly to law enforcement. The regulations should be nondiscriminatory, simple, easily understood, and uniformly enforced.

Table 4. Percentage of SC shrimp landed out of state by month.*

	1979	1980	1981	1982	1983	Average
Sept.	11	9	14	6	3	8.6
Oct.	12	3	9	2	12	7.6
Nov.	10	4	6	0	2	4.4
Dec.	20	13	1	0.2	0.4	6.9
Sept.-Dec.	12	6	10	3	5	7.2
Total lbs.	3,416,912	2,365,490	1,034,110	2,111,033	1,961,128	

*Information provided by South Atlantic Cooperative Statistics Program through Fisheries Statistics Section, SCWMRD.

Table 5. N.C. and GA Landings from South Carolina by month.*

	Sept.	Oct.	Nov.	Dec.	Total
1979	120,534	159,246	69,922	70,911	420,613
%	29	38	17	17	100
1980	88,206	25,109	14,346	25,577	153,238
%	58	16	9	17	100
1981	49,082	36,249	12,850	896	99,077
%	50	37	13	1	100
1982	51,318	11,701	0	430	63,449
%	81	18	0	1	100
1983	26,039	60,637	5,114	1,500	93,290
%	28	65	5	2	100

*Information provided by South Atlantic Cooperative Statistics Program through Fisheries Statistics Section, SCWMRD.

The need criterion implies that small-boat fishermen should have an opportunity to harvest shrimp in the sounds and bays, since these users can not compete on the offshore grounds. Although they have a larger financial commitment and, consequently, a greater economic dependency on the resource, large-boat operators have the option of fishing inside waters or elsewhere.

The equitability criterion is the most difficult to apply, since it has so many intangibles. The perceived economic consequences of closure exacerbate the problem. Optimal economic distribution exists when nothing more can be done to make one group better off without making another worse off, but demonstrating that factually is nearly impossible in this situation. Then, the perception of economic fairness becomes the key point.

Flexibility - Recruitment of shrimp is a function of both emigration from the creeks and growth in the sounds and bays, both of which are subject to highly variable, short-term environmental conditions. "Inasmuch as climate is not predictable or controllable, it is only through the flexibility currently provided by statute that the state (Georgia) can manage our marine resources in a responsible manner" (Georgia DNR annual report 1983). Sound and bay openings characteristically produce high catch rates for a few days, then catch-per-unit-of-effort (CPUE) declines dramatically until a new wave of recruitment becomes available. An efficient distribution system needs flexibility to adjust to these changes.

Reduction of administrative costs - The costs of administering the management (distribution) system need to be minimized in terms of both money and time. The major expenses currently associated with sound and bay policy are pre-opening sampling and the costs of notification of the industry.

System evaluation - Improvements in the data base are necessary before the Marine Resources Division can conduct a meaningful analysis of the effects and effectiveness of management policies.

A realistic distribution system should incorporate: 1) reasonable security for the resource, 2) sufficient flexibility to deal with changes in recruitment, 3) sufficient time intervals to allow adjustments to be made, 4) recognition of multiple objectives, and 5) no significant number of uncompensated "losers". The following observations are relevant to the sound and bay situation:

1. The options of complete closure, partial closure, or any combination thereof on short notice if environmental conditions warrant are adequate to protect the sound and bay shrimp population.

2. If a mechanism for short-notice, short-term, staggered openings is in place, there would be sufficient flexibility for adjusting to changes in the character of emigration from the creeks.

3. Staggered openings would allow enough time in between them to analyze CPUE data and evaluate environmental conditions. A short-notice system for declaring openings would contribute greatly to this.

4. Giving recreational fishermen the opportunity to catch shrimp in tidal creeks and rivers (i.e., areas closed to trawling), subject to restrictions to prevent excessive harvesting of small shrimp, satisfies the objective of permitting harvest for personal noncommercial use. Allowing small-boat commercial fishermen to fish sounds and bays subject to gear and catch restrictions grants this group an opportunity to harvest the resource that might not be otherwise feasible. A system of short-term, short-notice openings would reduce nonresident competition among the large-boat fishermen, maximizing harvest opportunities for resident operators. Through the license mechanism, nonresidents would still have an opportunity to fish state waters, guaranteeing the reciprocal rights of South Carolina fishermen in waters of other states.

5. A flexible closure system based on recruitment levels would contribute to improving physical and economic yield from the resource while giving all user groups the opportunity to participate. If all groups are afforded this opportunity, then there is no uncompensated party. While the perception that economic loss has been incurred may persist with one or more groups, the actual distribution of income from the resource in reality is then a function of the efforts of each user group within a system of equal opportunity to participate in the fishery.

The legal authority for management of the shrimp resource is stated in Section 50-17-1590 of the South Carolina Code of Laws:

"The Wildlife and Marine Resources Commission, after consulting with the Marine Resources Division, may either prohibit trawling or any other commercial fishing

activity in any of the fishing zones or specific areas therein, in or out of season, if it feels such action should be taken in the best interest of the State."

In the absence of established standards of what constitutes the "best interest of the State," the management objectives of the Marine Resources Division are:

1. Maintenance of the maximum productive potential of the shrimp resource through protection of key elements of the habitat, particularly nursery areas.

2. Continuance of maximum access to the resource for recreational and noncommercial subsistence purposes, consistent with the levels of opportunity afforded to other user groups and the status of the shrimp stocks.

3. Assurance of equal opportunities of utilization for all resident commercial user groups.

4. Continuance of granting equal access to nonresident fishermen in order to guarantee the reciprocal rights of South Carolina fishermen in the waters of other states.

5. Maximization of the economic yield of the commercial harvest. It is recognized that policies intended to achieve this objective may result in a lower physical (weight) yield than might otherwise be obtainable.

SUMMARY OF FINDINGS

The net conclusion of analyses of closures in similar fisheries is that the benefits (in physical yield and economic value) tend to increase with recruitment, with above-average recruitment being required to realize any appreciable gains. Available data do not allow a quantitative evaluation of possible benefits resulting from past closures in the South Carolina fishery, since too many speculative assumptions would have to be made. Given recent levels of recruitment, it is probable that past policy has neither increased nor decreased the overall physical and economic yield potential of the resource significantly (Appendix 1).

Studies of size composition in South Carolina have shown that opening of the sounds and bays does not significantly impact the individual size of shrimp that become available to the offshore fishery (Appendix 1).

U.S. shrimp markets are undergoing a transition partially in response to increasing supplies of imported shrimp. Thus, the potential economic benefits accruing from the harvest of fewer medium shrimp vs. more smaller ones are diminishing. The past economic justification for maximizing the harvest of medium shrimp (i.e. 26-40 count) is therefore becoming less clear.

The impact of trawling in sounds and bays on the habitat, crabs, and fish appears to be negligible. Interference with other users of the sounds and bays, primarily crabbers and recreational anglers, does not seem to be a significant problem. The principal issue is the efficient distribution of the shrimp resource among: 1) recreational fishermen, 2) small-boat, primarily part-time commercial fishermen, 3) large-boat, full-time resident commercial fishermen, and 4) large-boat nonresident commercial fishermen. What we are confronted with is not a biological, resource-oriented problem. The fundamental issue is distribution of the resource among competing user groups.

RECOMMENDATIONS

The question as to whether the sounds and bays should be closed to trawling is mainly a socioeconomic rather than a biological one. Competition for a limited resource has increased tremendously in recent years. A major issue in the shrimp fishery is whether maximum employment or maximum return on investment is more desirable. It is generally believed that permanent closure of the sounds and bays would benefit the owners and operators of larger boats at the expense of the owners and operators of small boats. This action would reduce competition from smaller boats because they can not fish consistently in offshore waters and it would lessen the influx of non-resident shrimpers. Consideration should be given, however, to the loss of income and employment by those who depend on the sounds and bays for at least part of their livelihood. By definition, a permanent closure would also preclude the flexibility considered necessary to effectively manage the resource.

There are numerous problems related to shrimping in the sounds and bays. To a great extent, these are a result of greatly increased fishing effort in recent years, both by resident and non-resident shrimpers as well as recreational fishermen. Of the three alternative courses of action available, which are: 1) continuation of the present system, 2) introduction of permanent closures for some or all areas, and 3) opening of sounds and bays in a more limited, controlled, and flexible system, the Marine Resources Division considers the third to be most appropriate. Within that framework, we feel that the following recommendations would be helpful in maintaining the resource and equitably distributing it among the various user groups.

1) Protection of nursery area. Nursery habitats should be identified more precisely and protected from adverse impacts due to alteration. Research in this area should be emphasized.

2) Open sounds on firmly established criteria. Criteria should include the abundance of shrimp, their individual size, market outlook, and environmental conditions such as rainfall, spring tides, and water temperature. The decision criteria should be established as soon as possible, clearly defined, and communicated to all user groups.

3) Educate user groups on the facts that determine policies. Undertake educational programs for recreational shrimpers and the commercial industry. The survey of commercial shrimpers by Farmer and Whitaker (1980) revealed that many of them have misconceptions about the sound and bay fishery which contribute to their lack of acceptance of certain policy aspects.

4) Flexibility should be maintained in management. This will be even more important as economic considerations play a larger role in future evaluations of sound and bay management. Environmental conditions in the last few years have produced unique situations where management required more flexibility to deal adequately with the situation.

5) Have authority conferred to a single source. Confer authority for in-season management, such as short-term openings and closings of the sounds and bays, on a centralized easily accessed source, preferably a single office or individual.

6) Management should be season-long. If the available shrimp are too small or catch rates become too low (reflecting low abundance), the sounds and bays should be closed until the average size reaches an acceptable standard and abundance increases.

7) Improve the data collection system. Require dealers and dock operators to submit shrimp catch data by count and total poundage per vessel per trip to the Marine Resources Division. This could be done by requiring all fishermen to participate in the present shrimp ticket system. In order to make use of a flexible, season-long management program, data must be available on a real-time basis requiring full cooperation of Law Enforcement personnel in prompting dealers to get information in quickly. Crab catches should be reported by gear to allow evaluations of potential interactions between the shrimp and crab fisheries.

OPTIONS

There are several options that should receive consideration relative to the revision of the sound and bay management policy.

1) Open for short periods. This would involve opening the sounds and bays for 2-3 days and not opening again until conditions warrant.

2) Open on neap tides. Opening during neap tide minimizes the mortality of undersized shrimp that are flushed from the creeks on spring tides. Opening on neap tide, however, means that low water would occur near sunrise when the vessel density is highest, thus increasing the chance of groundings. On the other hand, low water would not be as low as that of spring tide low water when accidents may be more common, especially with nonresident fishermen who are unfamiliar with the sounds and bays.

3) Opening day should be Monday, Tuesday, Wednesday, or Thursday. Some shrimpers ask that opening day be early in the week so that in case of mechanical failure during the most productive shrimping days, parts-supply houses would be open. By opening on a Friday, a fisherman could miss several days if he had mechanical problems.

4) Have a 24-hour or less notice for openings. Opening on short notice minimizes non-resident participation and hazardous overcrowding during the first few days of the season. It should be clear to all that no fisherman would be privy to advance information regarding the opening date.

5) Establish a quick notification system that places more responsibility on the shrimper. Use a toll-free telephone number (with recorded message) and news media broadcast to notify the industry of openings. Telephone calls to key individuals such as dock owners, fleet owners, and officers of the shrimper's associations could also be made.

6) Opening day shrimping should start a few hours after sunrise. Some fishermen believe that shrimp caught at sunrise are generally of poorer quality than those caught later in the day. In the past, some processors have apparently made deductions from their payments to shrimpers, claiming that many opening-day shrimp were soft and damaged. Opening later in the day on days when shrimp are very abundant could remedy this problem; however, studies should be done to examine the extent of this problem before such a regulation is made since the sunrise tow is usually the best of the day. Observers aboard shrimp trawlers on sound and bay opening days when trawling was to begin at sunrise have reported that many fishermen invariably begin towing well before daylight. This is done to get a head-start on competitors, but it makes for hazardous trawling.

7) Experiment with intermittent or pulse openings of the sounds and bays. This may determine an optimal time period between openings which could improve catch rates and contribute to greater economic efficiency.

8) Experiment with test closures of certain areas. Permanent closures of specified areas where small shrimp are characteristically abundant may be warranted. The Bottleneck area in the Coosaw River portion of St. Helena Sound is one potential area.

9) Close the sounds and bays to commercial crab trawling during the winter and early spring. Closure of the winter trawl fishery for crabs would not have a significant impact on resident trawlers or processors (if legal outside areas remained open). Such action would allay the concerns over exploitation or injury of mature pre-spawning crabs, ovigerous crabs, and overwintering white shrimp.

10) Gear restrictions. It may be necessary to restrict shrimpers to using small gear (e.g. 40-ft. nets) if the number of shrimpers becomes too large. This alternative might be used in lieu of limiting participation.

11) Reduce participation through various means if usage is considered excessive relative to the resource's productive capacity. A moratorium on the number of licenses issued for the sound and bay fishery, based on the average number of licenses sold in recent years, could be considered. Issuance of a specified number of sound and bay licenses or permits through a modified lottery or auction system is another option.

12) Pre-determine the options for the management authority. If the sounds and bays are to be opened to commercial trawling, the criteria which will determine if and when to open and close these areas would have been discussed and accepted well beforehand. These criteria may include average shrimp size, abundance, market conditions (price), etc. By using this approach, the MRD would select one of several management options. Selection of a particular option would be dictated by the previously selected criteria. All debate over management strategy would have occurred previously, allowing the MRD to simply follow procedure and by-pass the controversy that has occurred prior to the season opening date in recent years. This facilitates comprehension of what is happening (or will happen) by the public, avoids unnecessary debate and delays through public hearings, board meetings, etc., and minimizes unwarranted external intervention.

13) Set an early (August) opening to minimize opening day crowding. Previous opening days with several days of notification have attracted numerous nonresident shrimpers. By opening before shrimp accumulate, nonresidents would possibly leave the state because of low catch rates. However, Savannah shrimpers could return to Calibogue Sound on very short notice once shrimp appear.

    A potential disadvantage of this option is that fishing early in the season could result in small shrimp being taken before growing to a more economically attractive size. Fishery managers have noted that when a shrimping area is open, at least a few boats will be trawling, especially if shrimp are present, regardless of size. By opening before shrimp accumulate in the sounds and bays, local shrimpers could harvest a larger percentage of the shrimp stock.

14) Have sounds and bays closed on weekends to reduce interference with recreational users.

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Appendix 1. SUMMARY OF DATA RELATIVE TO FINDINGS

Analysis of catch and catch-per-unit-of-effort (CPUE)

Initial analysis indicates commercial CPUE in outside areas before the opening of the sounds or during the first few days they are open is the best statistical predictor of both the outside and overall (inside and outside combined) catch. The biological basis for this apparently strong statistical relationship is suspect. It assumes that the percentage of the total recruitment represented by the early outmigrants (those available offshore prior to the sound openings) is either relatively constant or at least proportional to the total recruitment.

Simple linear regressions were calculated for the following categories:

1. Cumulative monthly commercial catch (Y) against pre-opening (-7 days) and early season (0-3 days) commercial CPUE (X)

2. Cumulative commercial catch (Y) against September commercial catch (X)

Calibogue Sound - The highest correlation for commercial catch during September-December was against the commercial catch in September ($r = 0.78$). This is not surprising because the September catch averaged 41% of the season catch during 1976-1983.

Port Royal Area - The cumulative commercial catch off Hilton Head was highly correlated with commercial CPUE there 7 days prior to the sound opening. The cumulative commercial catch, combined for Port Royal Sound and Hilton Head coastal waters, was also strongly associated with the CPUE off Hilton Head 7 days prior to the sound opening. The cumulative combined catch (for inside and outside waters) was also highly correlated with September commercial catches, particularly in Port Royal Sound. Figure 14 illustrates the regression between the combined inside-outside commercial catch during September-December and commercial CPUE off Hilton Head 7 days prior to the sound opening.

St. Helena Area - The season (September-December) commercial catch in St. Helena Sound was best correlated with the commercial sound catch in September ($r = 0.98$), but this was expected because the September catch averaged 38% of the season catch during the years considered. There were no uniformly good correlations between the commercial catch in the sound and pre-season or early season CPUE.

The season coastal catch in the Bay-Edisto area was highly correlated with the commercial CPUE in the Bay-Fripp area for 7 days before the sound opening ($r = 0.97$) (Figure 15).

Southern State - Both the cumulative monthly and season coastal commercial catches were highly correlated with pre-opening commercial CPUE in outside waters, as well as with September outside catches in the same areas. The cumulative and season total commercial catches (for sounds and coastal areas combined) were also strongly associated with commercial CPUE in coastal waters 7 days prior to the opening (Figure 16). For the regression illustrated, the average percentage error in predicted vs. actual total catch in the southern state area during September - December was $\pm$ 3.9.

Several commercial shrimpers have stated that shrimp catch rates drop dramatically immediately following the opening of the sounds to commercial trawling. They claim that catches are poor for the remainder of the season both in the sounds and on the beaches. Although effort and total catch drops significantly following the first few days of the sound and bay season, available shrimp ticket system data indicate that boats that continue to fish in the sounds and adjacent areas maintain catch rates of over a box (box = 100 lbs) or more per day (Tables 6 and 7). In fact, daily catches well into the season are often over one box and occasionally more than one and one half boxes. Using average values for all three sounds, CPUE's in the sounds were 178 to 521 lbs. for the first three days and gradually decreased to about 175-200 lbs. after the first week. Catch rates recorded two months into the season were typically 100 to 125 lbs per day.

Offshore catch rates seem to improve following the opening of the sounds. This phenomenon may be explained by incorrect reporting of shrimp that were actually caught in the sounds. However, shrimpers have observed that offshore catches late in the day of opening day and the following days actually improve because the activity in the sounds "moves the shrimp offshore".

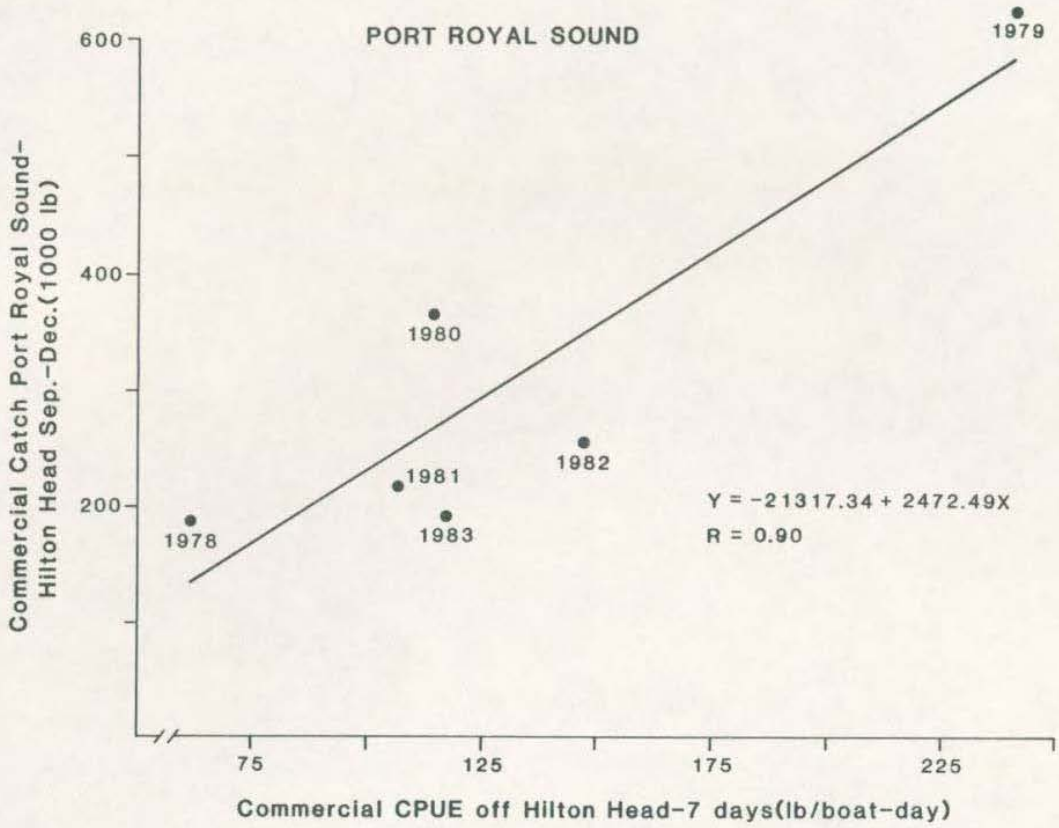


Figure 14. Regression of commercial catch for Port Royal Sound and Hilton Head area in September and December against commercial catch per unit of effort off Hilton Head seven days prior to the sound opening.

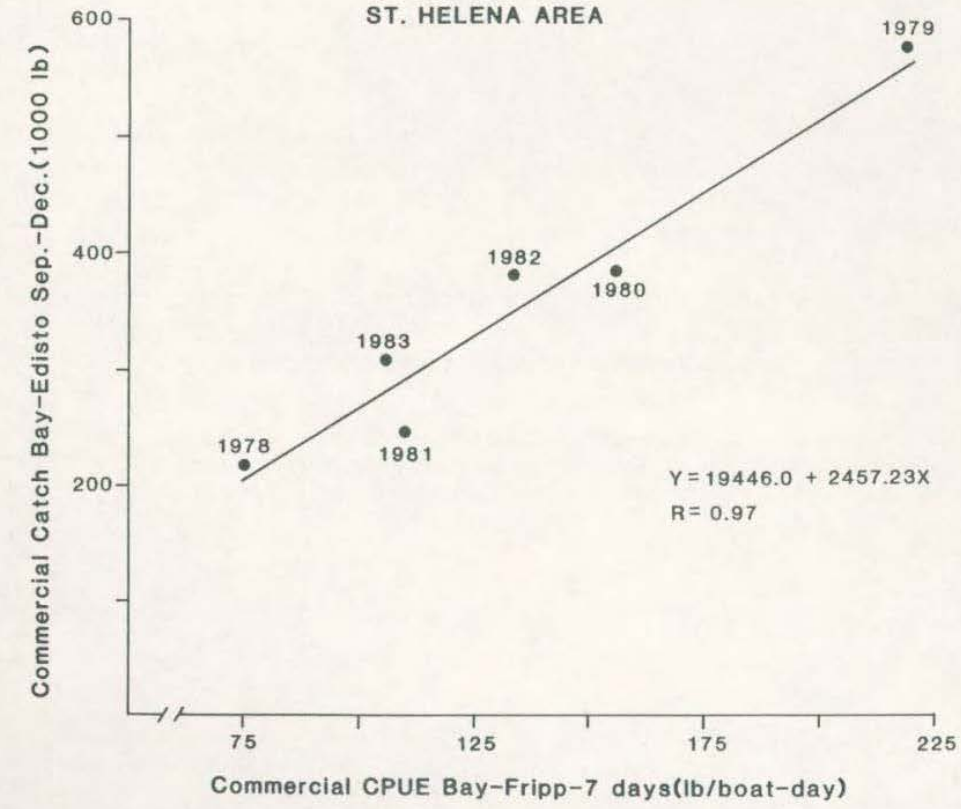


Figure 15. Regression of commercial catch in the Bay-Edisto area for September through December against commercial catch per unit of effort in the Bay-Fripp for seven days before the sound opening.

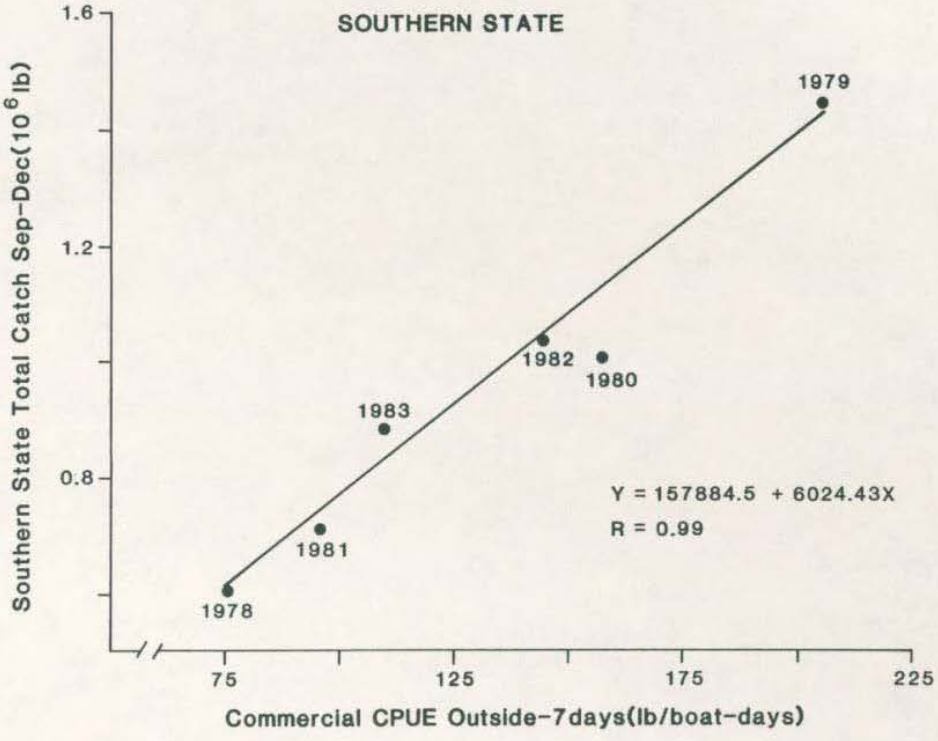


Figure 16. Regression of cumulative and season total commercial catches for sounds and coastal areas combined against commercial catch per unit of effort in coastal waters seven days prior to the opening.

Table 6. Average commercial CPUE (lbs/boat/day) for St. Helena, Port Royal and Calibogue Sounds (1978-1983) for periods after opening day.

	DAYS AFTER OPENING					
YEAR	0-3	4-6	7-9	11-20	21-30	51-60
1978	245	160	160	143	184	168
1979	463	278	218	136	145	135
1980	310	176	173	123	137	104
1981	178	120	120	118	107	151
1982	521	330	227	139	122	94
1983	436	269	154	193	91	110

Table 7. Average commercial CPUE (lbs/boat/day) for offshore areas adjacent to South Carolina's three sounds (Hilton Head, Bay Point to Fripp Island, Hunting Island to Edisto Beach) for periods before and after the opening date of the sounds.

	7 DAYS BEFORE OPENING	DAYS AFTER OPENING					
YEAR		0-3	4-6	7-9	11-20	21-30	51-60
1978	76	188	144	130	147	166	176
1979	211	252	227	281	213	169	183
1980	165	140	194	144	150	195	104
1981	97	129	137	135	105	106	132
1982	144	159	219	108	126	131	114
1983	NR	110	72	66	120	100	132

NR = No Report

Analysis of Size Composition of Shrimp

Examination of size (count for headless shrimp) for the seven days subsequent to opening of S.C. sounds and bays indicated similarity in modes for shrimp caught within sounds and adjacent areas offshore (Fig. 17). The modal size (31-35 count) of shrimp from within sounds exactly coincided with that of shrimp caught in adjacent offshore areas for 1978, 1981 and 1982. For 1979, 1980 and 1983, the difference in modal size of shrimp between these two areas was slight. These data indicate that there is no major size discrepancy between shrimp in legal trawling areas of the sounds and those found outside during the first week of the sound and bay season.

Comparisons in size composition for the entire sound and bay season between the southern sounds, areas adjacent, and the northern "control" area off Morris Island and Charleston Harbor indicate few major differences in modal size (count) (Fig. 18). For 1978, 1979 and 1981, modal size was $\leq$ 31-35 count and was consistent between the three major areas. In 1980, 1982 and 1983, the modal size was fairly consistent between the southern sounds and the areas adjacent. Modal size of shrimp off Morris Island, however, was considerably less than the other two areas during these years. The comparisons between modal sizes are important in view of the argument voiced by some shrimpers in the southern region that by closing the sounds, shrimp in the sounds would grow and move offshore to the beaches, resulting in catches consisting of larger shrimp. These data indicate this is not the case, since similar size or smaller size shrimp were caught off Morris Island, which is designated by law as a beach area. It is likely that the hydrography of a particular area is important in determining when and at what size shrimp move offshore. The imminent reduction in river discharge into Charleston Harbor may result in larger shrimp being taken at Morris Island.

Among the three southern sounds, overall shrimp size appears smallest in St. Helena Sound. In 1980, for instance, 53 percent of the catch was comprised of shrimp smaller than 50 count (heads-off), while Calibogue's was 18 percent and Port Royal's was 14 percent. In other years, however, shrimp size was very comparable in all areas. One such year was 1978 where 36/40 count or larger accounted for 91 percent of St. Helena's catch, 98 percent of Port Royal's and 94 percent of Calibogue's. The variability in shrimp size in St. Helena is most likely caused by the variability in salinity as influenced by river discharge. Calibogue and Port Royal sounds show relatively little fluctuation with salinity remaining relatively high.

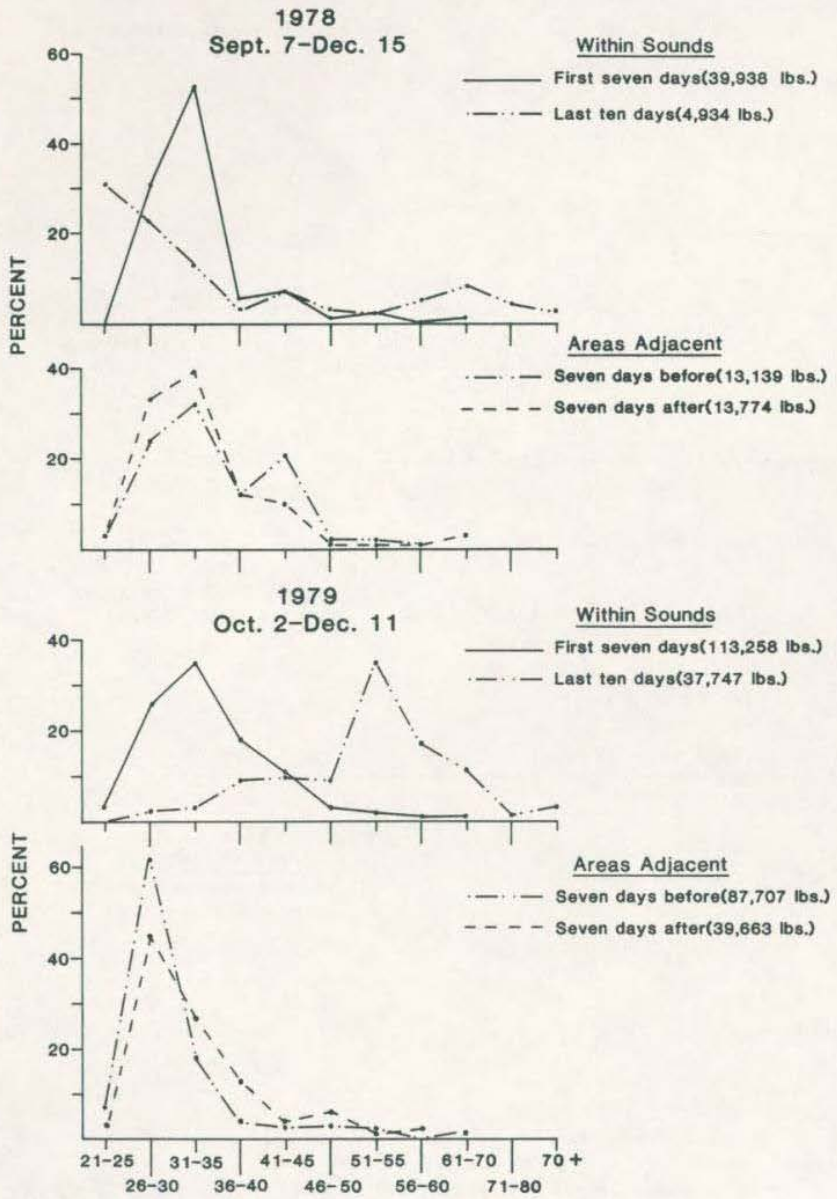
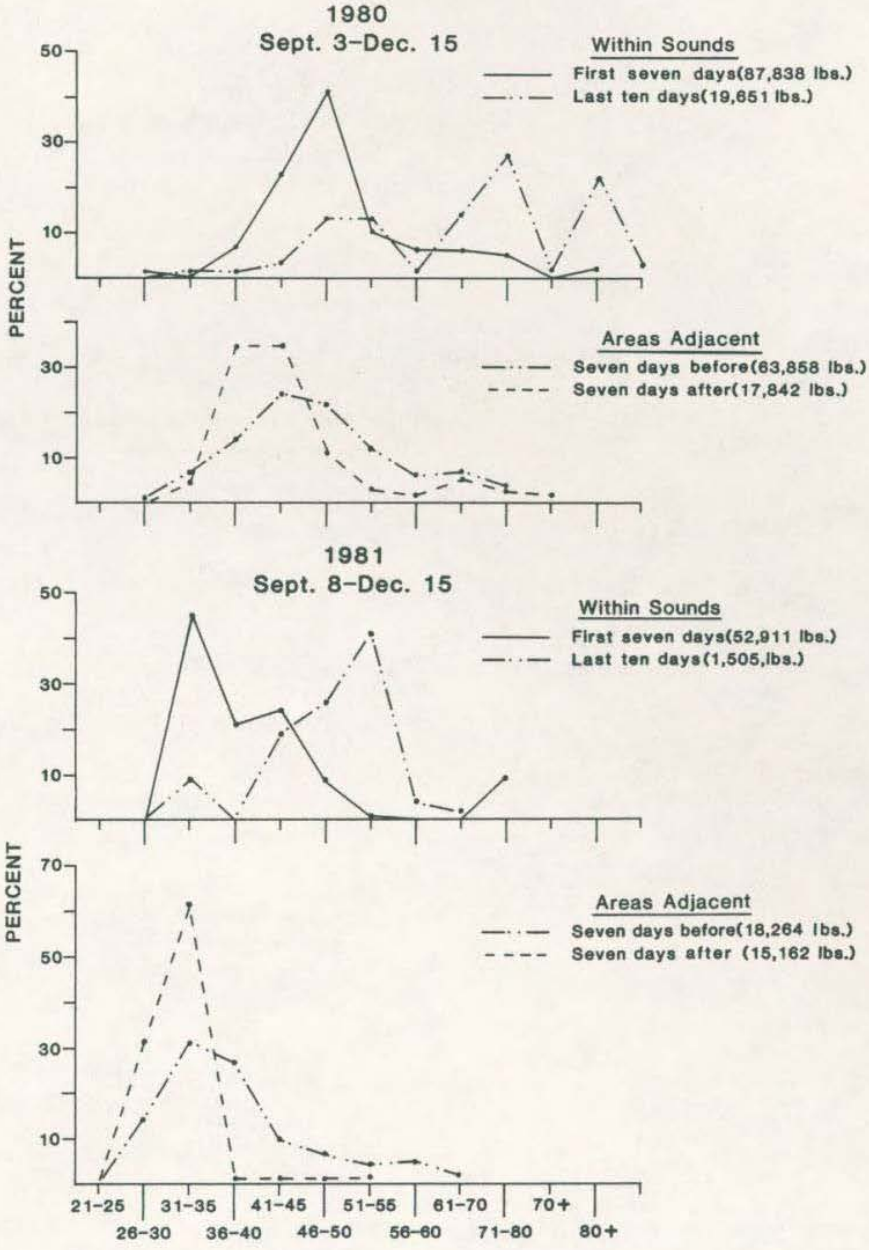
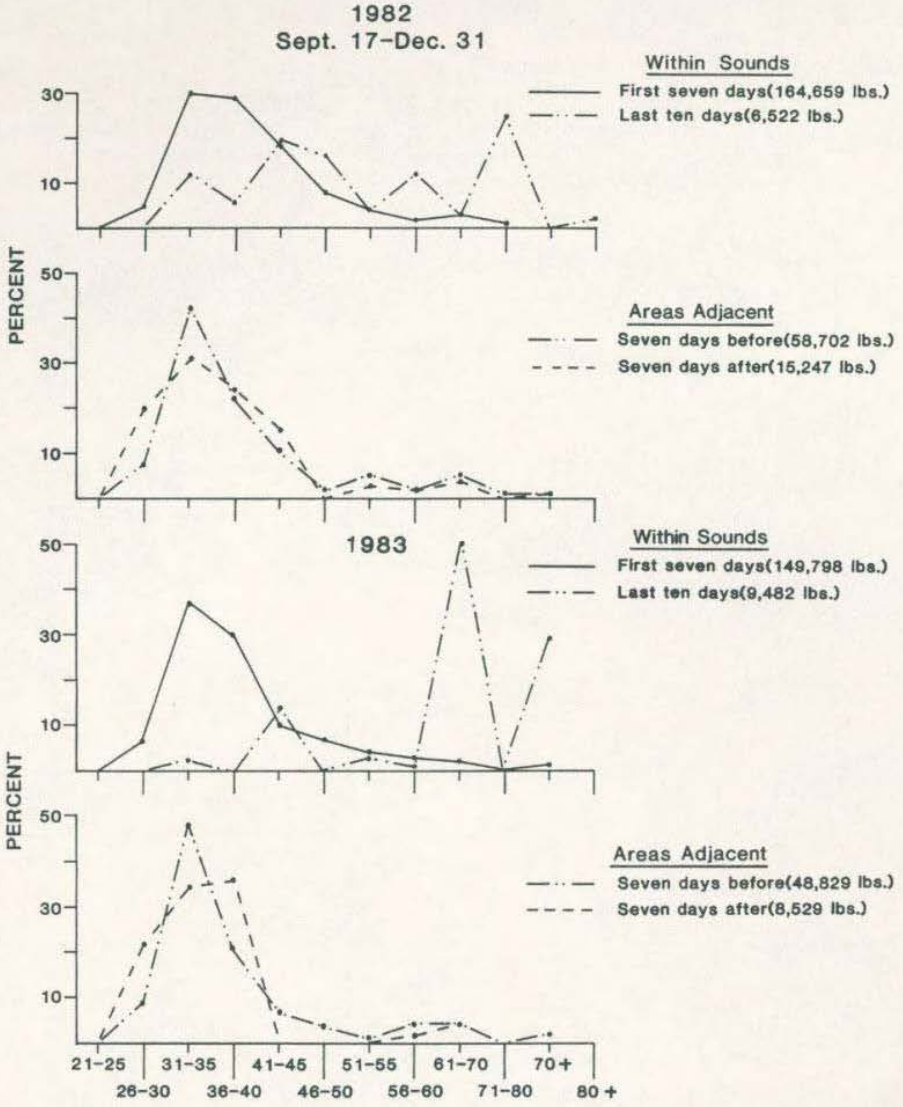


Figure 17. Comparisons of percent size composition (headless count) for shrimp caught within sounds during the first seven days and the last ten days of the sound and bay season with those caught in adjacent areas seven days before and seven days after for the years 1978-1983. Numbers in parentheses are sample size and do not reflect total catch.


1980
Sept. 3–Dec. 15
Within Sounds
First seven days(87,838 lbs.)
Last ten days(19,651 lbs.)
Areas Adjacent
Seven days before(63,858 lbs.)
Seven days after(17,842 lbs.)
1981
Sept. 8–Dec. 15
Within Sounds
First seven days(52,911 lbs.)
Last ten days(1,505,lbs.)
Areas Adjacent
Seven days before(18,264 lbs.)
Seven days after (15,162 lbs.)
PERCENT
50
30
10
70
21–25
26–30
31–35
36–40
41–45
46–50
51–55
56–60
61–70
71–80
70+
80+


1982
Sept. 17-Dec. 31
Within Sounds
First seven days(164,659 lbs.)
Last ten days(6,522 lbs.)
Areas Adjacent
Seven days before(58,702 lbs.)
Seven days after(15,247 lbs.)
1983
Within Sounds
First seven days(149,798 lbs.)
Last ten days(9,482 lbs.)
Areas Adjacent
Seven days before(48,829 lbs.)
Seven days after(8,529 lbs.)
PERCENT
PERCENT
30
10
50
30
10
50
30
10
50
30
10
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-70
71-80
70+
80+

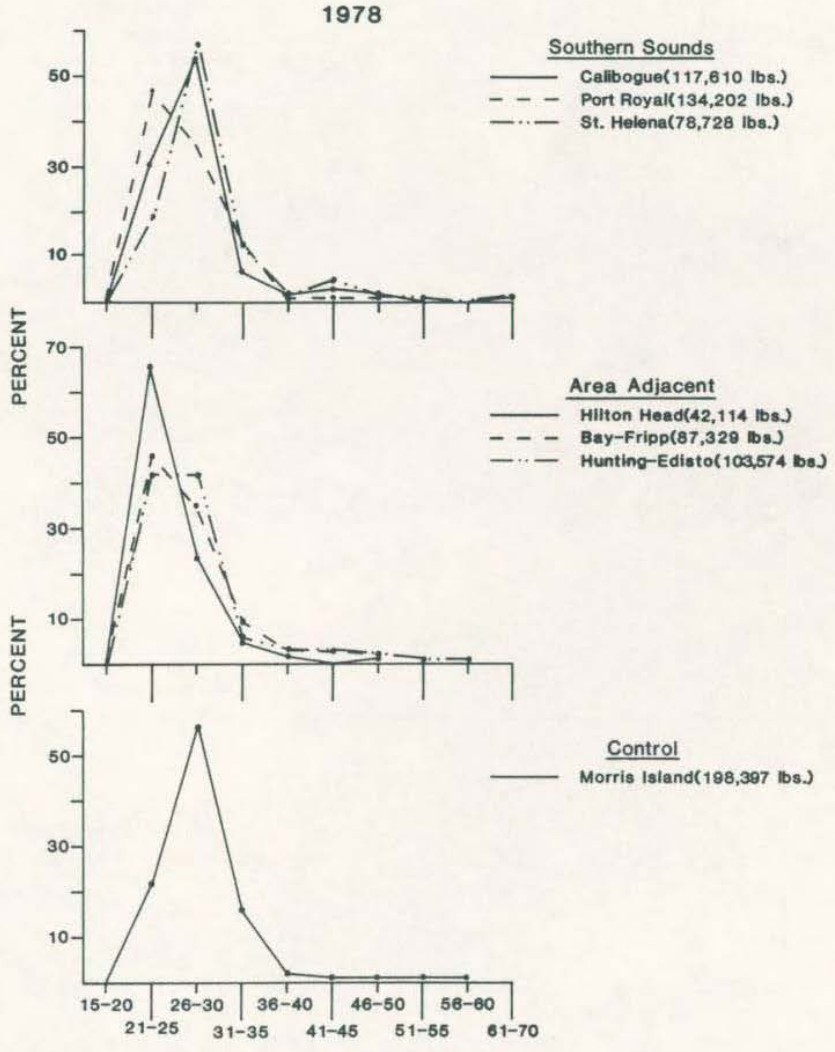
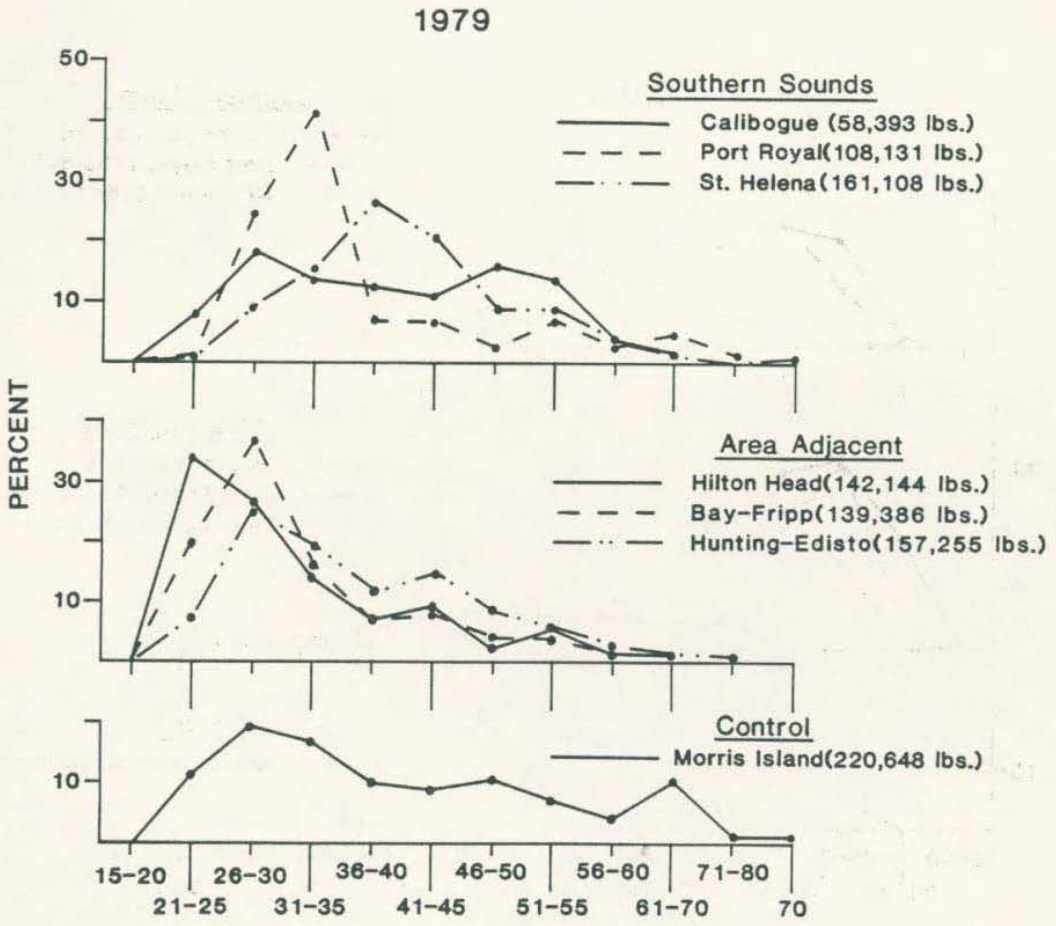
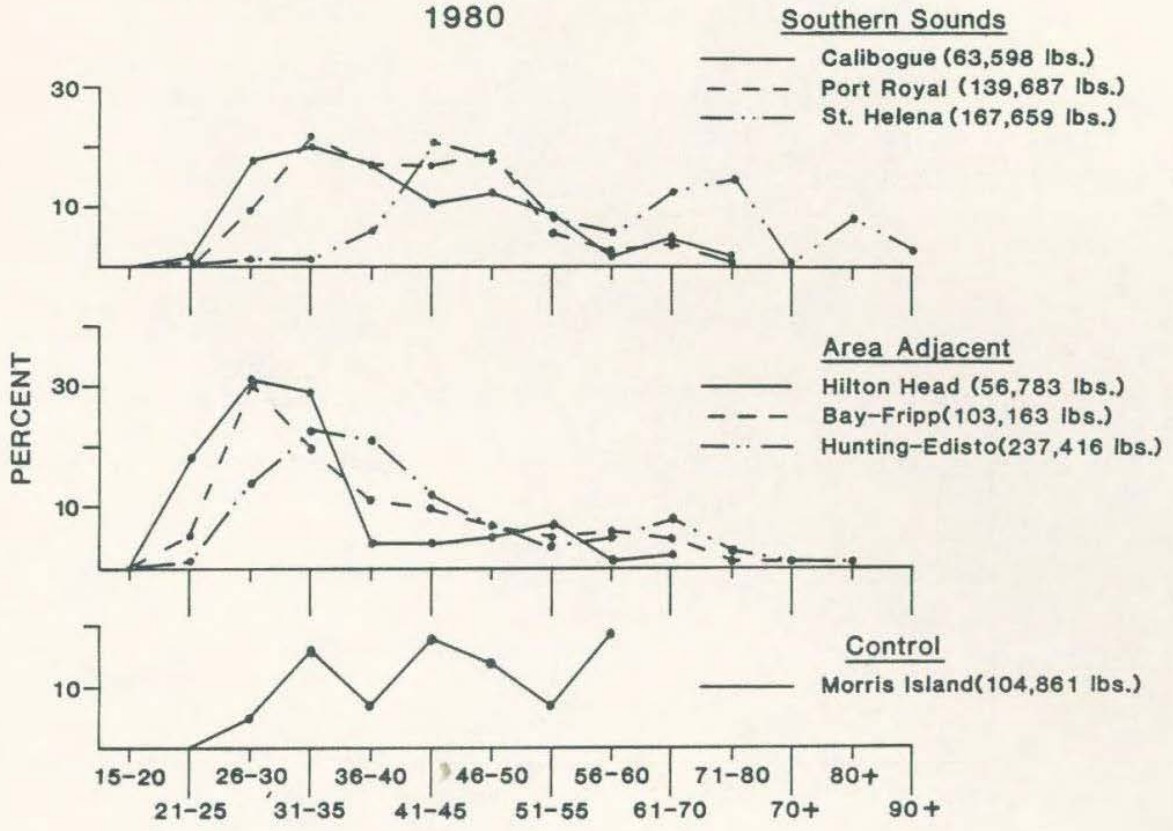
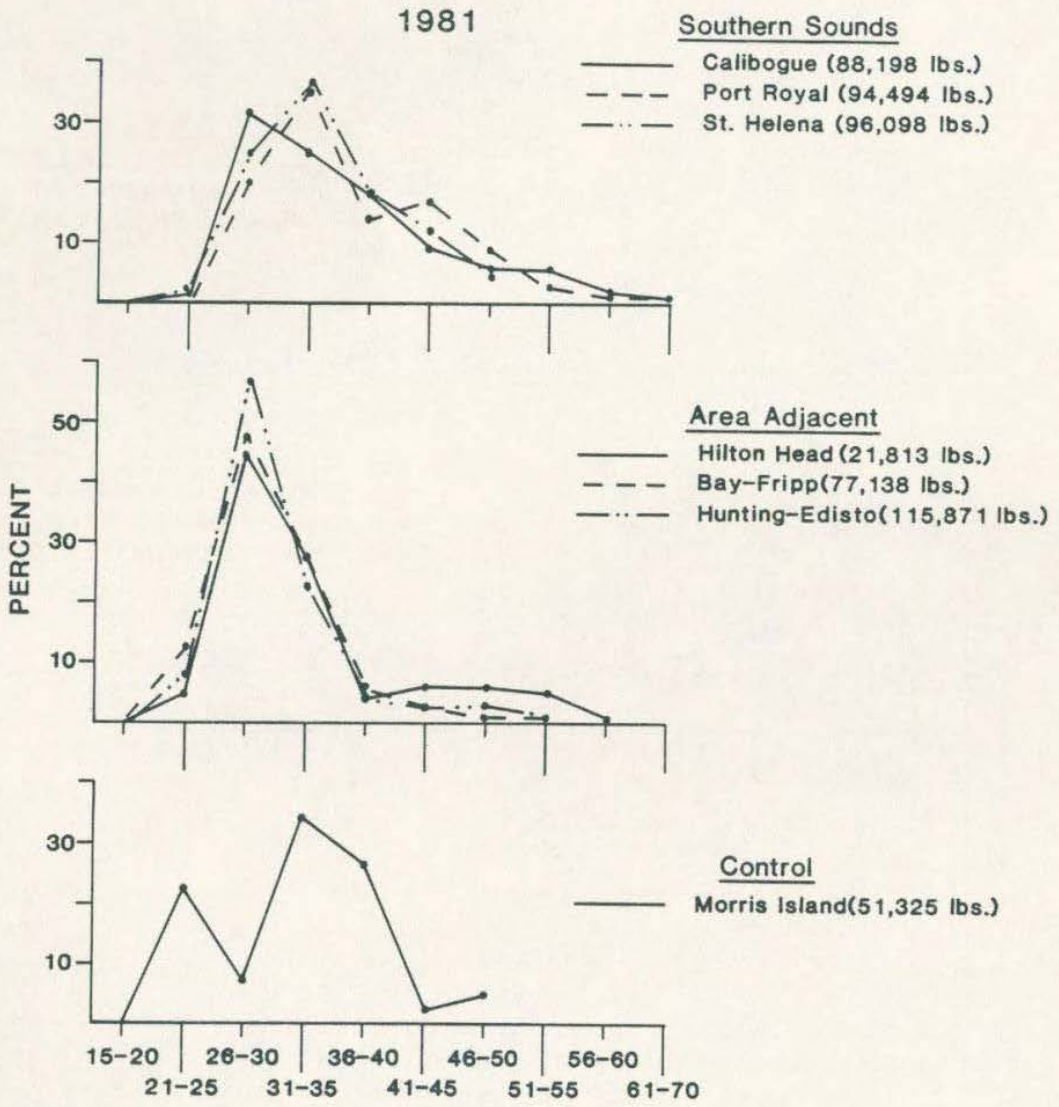
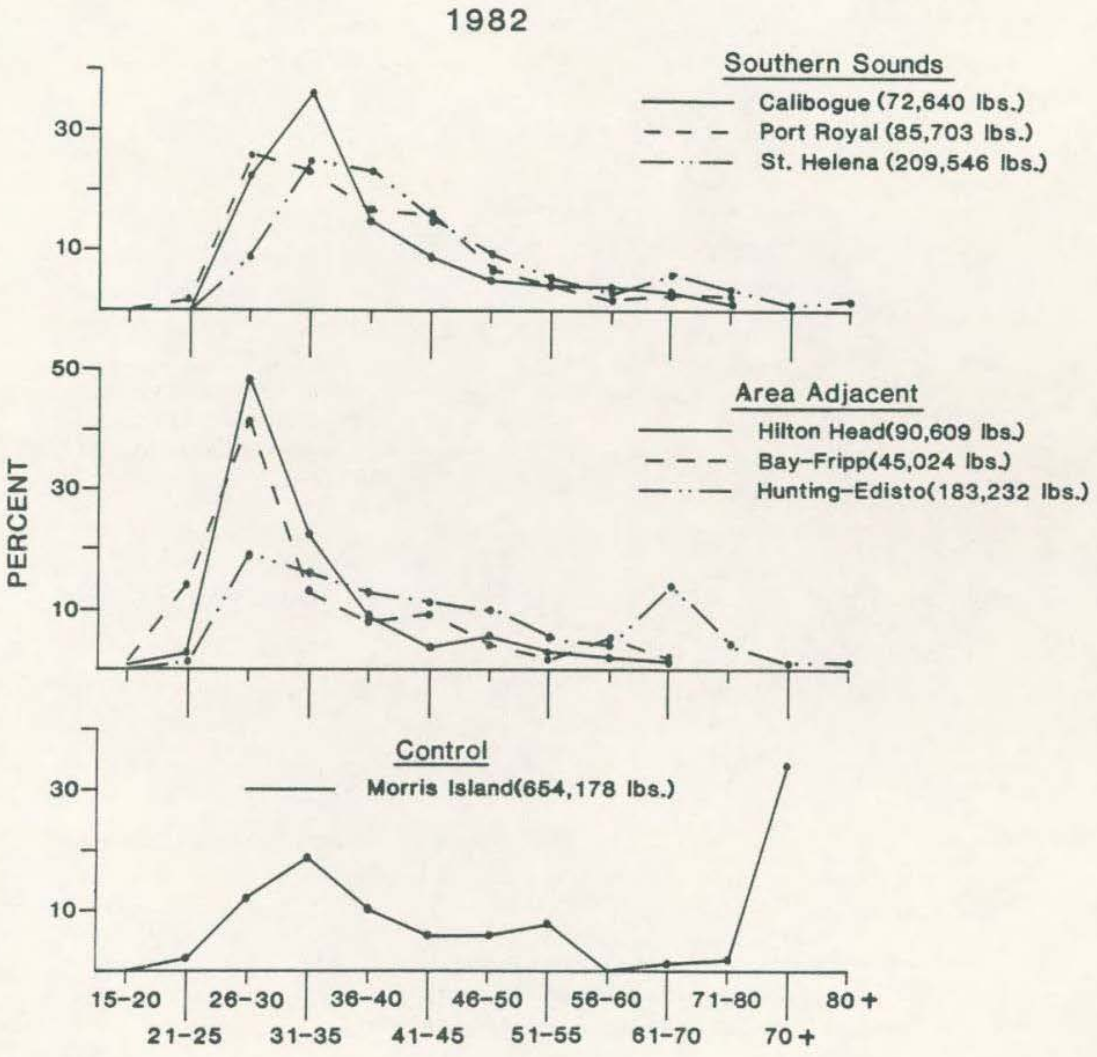


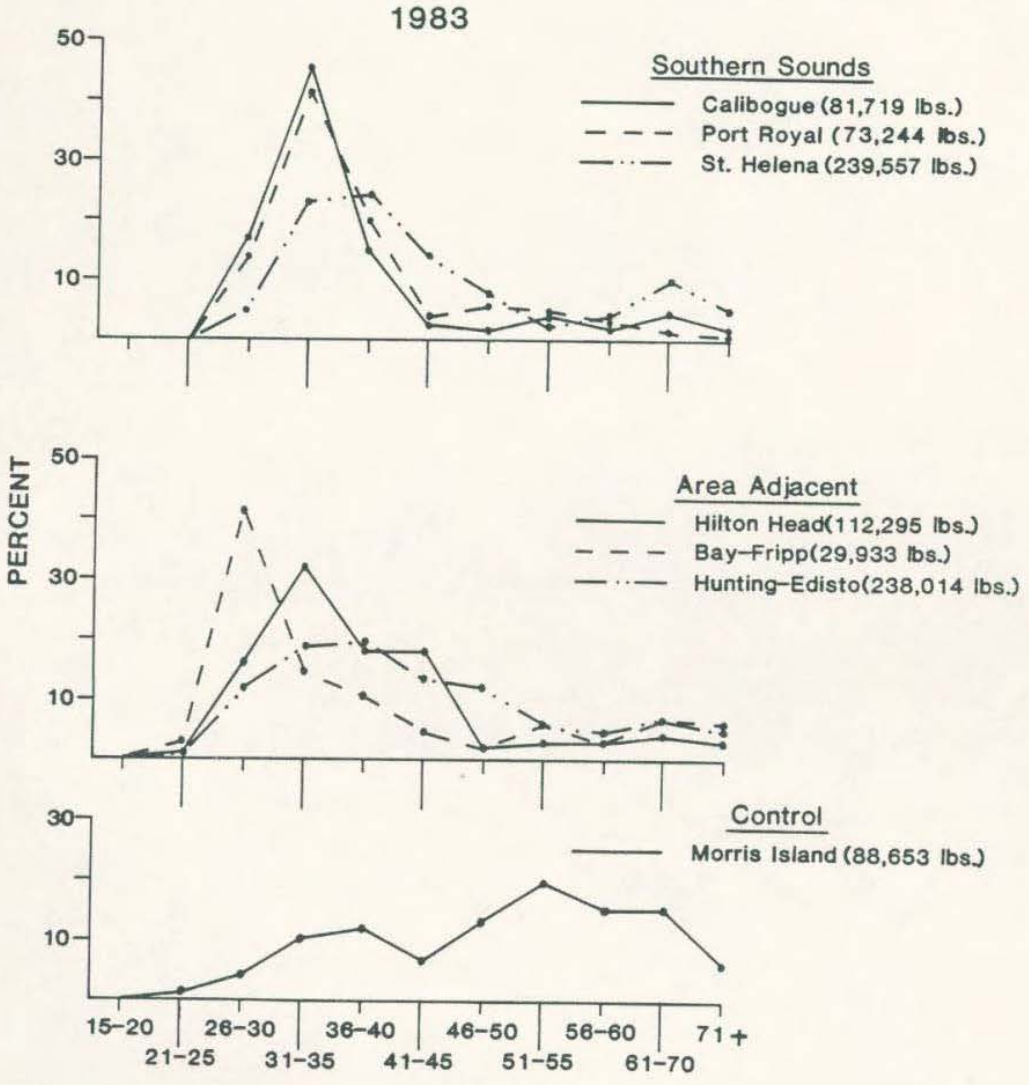
Figure 18. Comparisons of percent size composition (headless count) between the southern sounds, areas adjacent, and a northern "control" area off Morris Island.


1979
Southern Sounds
Calibogue (58,393 lbs.)
Port Royal(108,131 lbs.)
St. Helena(161,108 lbs.)
Area Adjacent
Hilton Head(142,144 lbs.)
Bay-Fripp(139,386 lbs.)
Hunting-Edisto(157,255 lbs.)
Control
Morris Island(220,648 lbs.)
PERCENT
50
30
10
30
10
10
15-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-70
71-80
70


1980
Southern Sounds
Calibogue (63,598 lbs.)
Port Royal (139,687 lbs.)
St. Helena (167,659 lbs.)
Area Adjacent
Hilton Head (56,783 lbs.)
Bay-Fripp(103,163 lbs.)
Hunting-Edisto(237,416 lbs.)
Control
Morris Island(104,861 lbs.)
PERCENT
30
10
30
10
10
15-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-70
71-80
70+
80+
90+


1981
Southern Sounds
Calibogue (88,198 lbs.)
Port Royal (94,494 lbs.)
St. Helena (96,098 lbs.)
Area Adjacent
Hilton Head (21,813 lbs.)
Bay-Fripp (77,138 lbs.)
Hunting-Edisto (115,871 lbs.)
Control
Morris Island (51,325 lbs.)
PERCENT
30
10
50
30
10
30
10
15-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-70


1982
Southern Sounds
Calibogue (72,640 lbs.)
Port Royal (85,703 lbs.)
St. Helena (209,546 lbs.)
Area Adjacent
Hilton Head(90,609 lbs.)
Bay-Fripp(45,024 lbs.)
Hunting-Edisto(183,232 lbs.)
Control
Morris Island(654,178 lbs.)
PERCENT
30
10
50
30
10
30
10
15-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-70
71-80
70+
80+


1983
Southern Sounds
Calibogue (81,719 lbs.)
Port Royal (73,244 lbs.)
St. Helena (239,557 lbs.)
Area Adjacent
Hilton Head(112,295 lbs.)
Bay–Fripp(29,933 lbs.)
Hunting–Edisto(238,014 lbs.)
Control
Morris Island (88,653 lbs.)
PERCENT
50
30
10
15–20
21–25
26–30
31–35
36–40
41–45
46–50
51–55
56–60
61–70
71+