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September 1984

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic)

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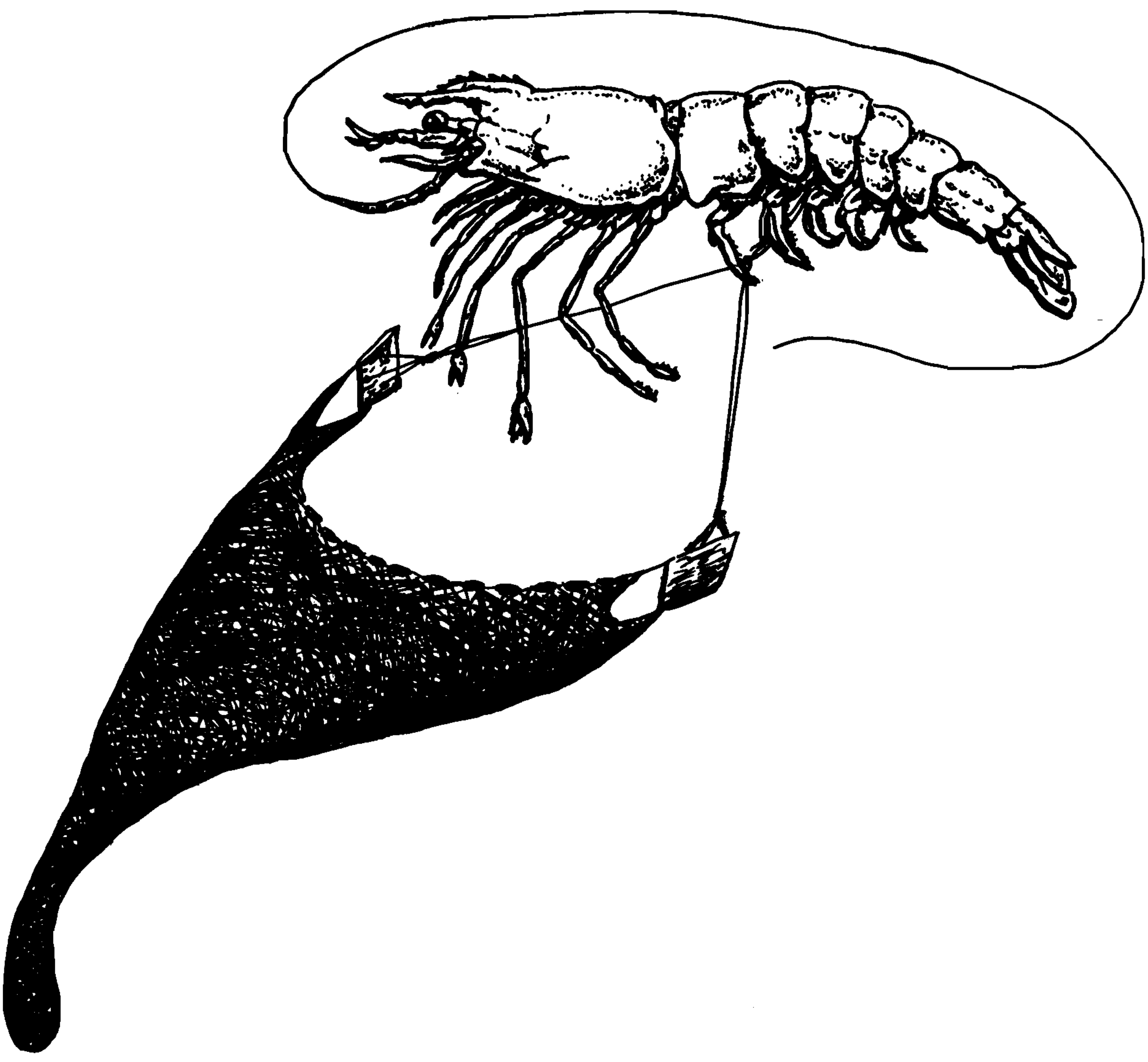

Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic)

WHITE SHRIMP

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees	1.8(C°) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees	0.5556(F° - 32)	Celsius degrees

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For their helpful reviews and suggestions, I thank Susan Shipman, Coastal Fisheries Section, Georgia Department of Natural Resources; Edwin A. Joyce, Jr., Division of Marine Resources, Florida Department of Natural Resources; and David Whitaker, Division of Marine Resources, South Carolina Wildlife and Marine Resources Department.

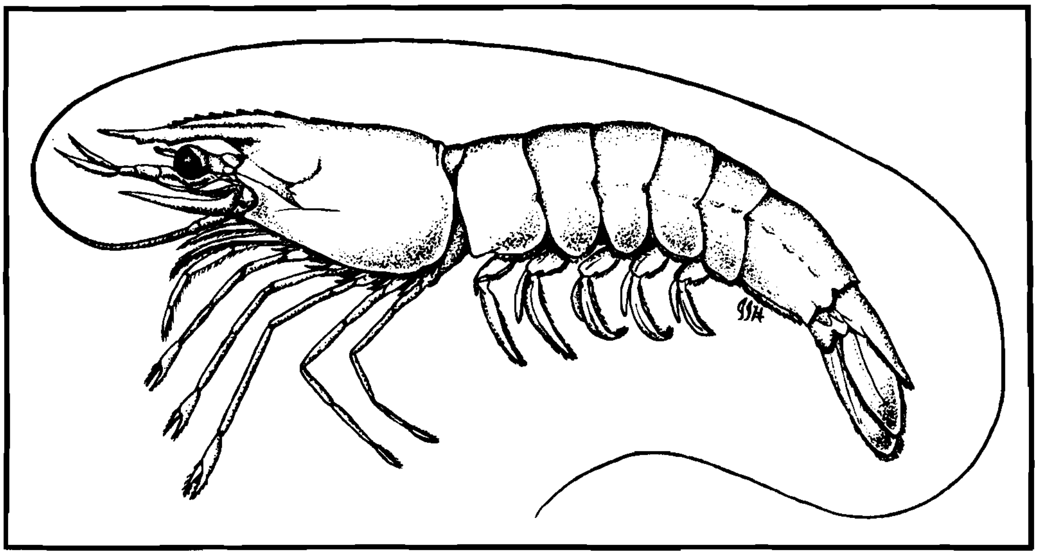

Figure 1. White shrimp.

WHITE SHRIMP

NOMENCLATURE/TAXONOMY/RANGE

Scientific name........Penaeus setiferus (Linnaeus)
Common name......White shrimp (Figure 1)
Other names.................Gray shrimp, lake shrimp, green shrimp, green-tailed shrimp, blue-tailed shrimp, rainbow shrimp, Daytona shrimp, common shrimp, southern shrimp; in Mexico: camaron blanco (Pérez-Farfante 1969).
Class..........................Crustacea
Order..........................Decapoda
Family.........................Penaeidae

Geographic range: White shrimp are distributed along the Atlantic coast from Fire Island, New York, to Saint Lucie Inlet, Florida (Pérez-Farfante 1969), usually in water less than 27 m deep (McKenzie 1981). White shrimp inhabit coastal waters of the Gulf of Mexico from Ochlockonee River of Apalachee Bay, Florida, to Ciudad Campeche, Mexico. Centers of abundance in North and South Carolina, Georgia, and northeast Florida are shown in Figure 2 (Whitaker 1981).

MORPHOLOGY/IDENTIFICATION

Freshly caught white shrimp often have widely spaced body chromatophores; consequently they are lighter colored than pink or brown shrimp (Pérez-Farfante 1969).

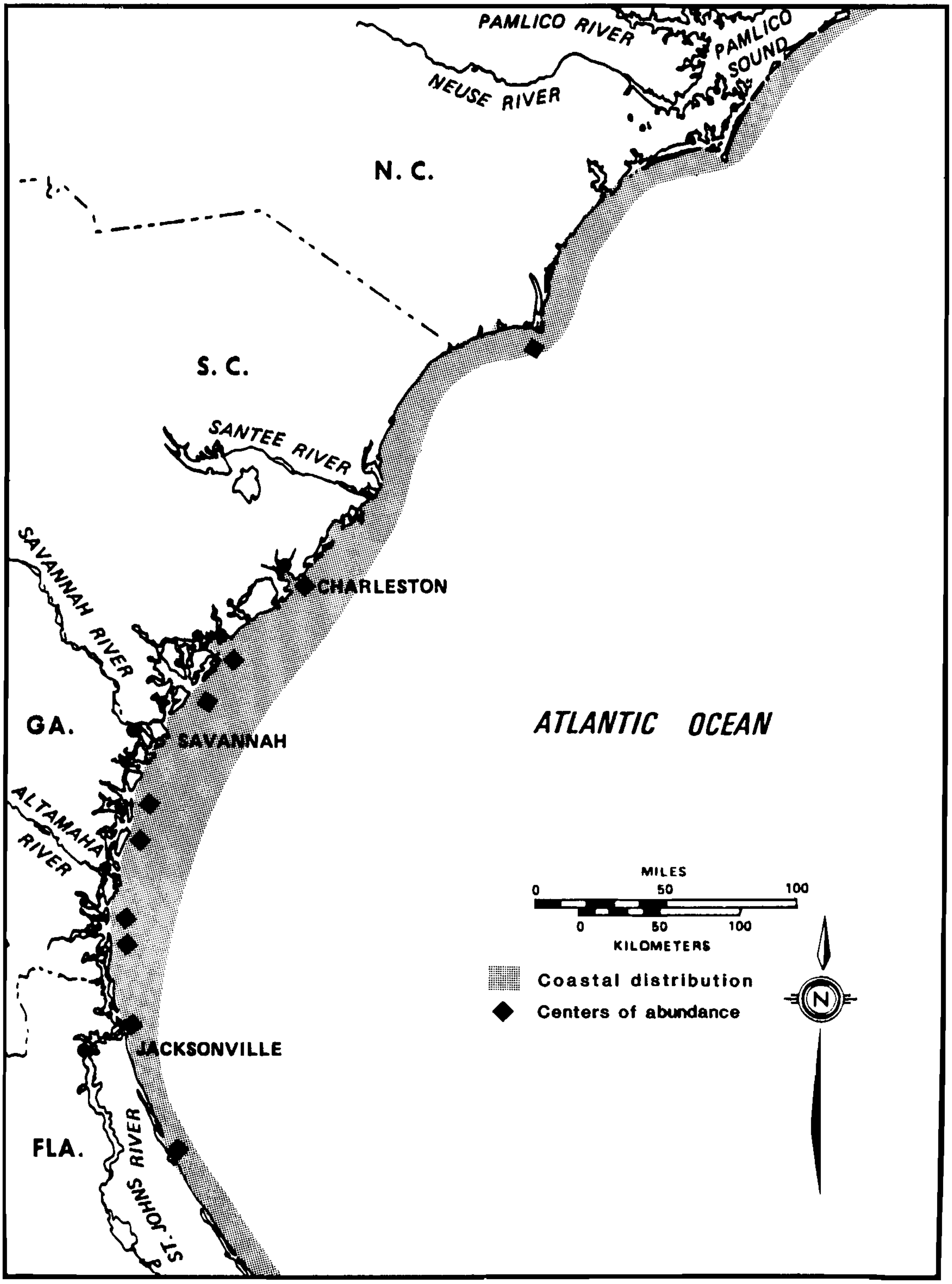

Figure 2. Distribution of white shrimp along the coasts of North and South Carolina, Georgia, and northeast Florida.

The white shrimp is sometimes called the non-grooved shrimp (Whitaker 1981) because its adrostral carina does not extend behind the middle of the carapace in adults (Lindner and Cook 1970) nor to the posterior margin of the carapace in juveniles (Williams 1965). In contrast, the brown shrimp (P. aztecus) and pink shrimp (P. duorarum), co-existing along the southeast and gulf coasts of the United States, each has a deep groove (adrostral sulcus) extending almost to the posterior margin of the carapace. In the white shrimp, the adrostral sulcus is short, extending to the epigastric back tooth of the rostrum. Gastrofrontal carina is absent. Thelycum is open, with anterolateral ridges; mesially turned pair of fleshy protuberances on sternite XIV (Pérez-Farfante 1969). Antennal flagella 2.5 to 3 times the body length in Penaeus setiferus as in P. schmitt, a species found in Cuba, the Virgin Islands, and along eastern Central and South American Atlantic coast south to Laguna, Brazil (Pérez-Farfante 1969). Zamora and Trent (1968) noted that the keel was smooth on the sixth abdominal somite of postlarvae white shrimp but bore spines on brown shrimp and pink shrimp.

Sexes are easily distinguishable by the modified endopod of the first pair of pleopods on the males and the open-type thelycum between third, fourth, and fifth pereopods on the females (Lindner and Cook 1970). At lengths of 28 mm, males can be distinguished from females by the shorter and narrower endopods of the first pleopods and by two protuberances on sternite XIV (Pérez-Farfante 1969).

REASONS FOR INCLUSION IN SERIES

The white shrimp was the first American shrimp to be extensively marketed for food. Commercial shrimping in the United States began as early as 1709 (McKenzie 1981); catches reached 8,181 metric tons (t) in 1917 (when trawls replaced haul seines), and peaked in the late 1920's. By the 1930's, there was concern that the intensive fishery along the southeastern Atlantic coast (North Carolina, South Carolina, Georgia, and northeast Florida) was depleting the resource (Williams 1965). White shrimp contributed an estimated 95% of shrimp catches in 1931 (McKenzie 1981). The annual white shrimp landings for 1976-80 averaged 3,480 t (13% below the 1957-80 average). The decrease was attributed to recent severe winters and cold waters during that period (McKenzie 1981). The harvest of 2,685 t of white shrimp from the Southeastern States in 1982 was valued at $29.4 million (computerized data from National Marine Fisheries Service, Miami, Florida).

In 1957-80, the mean yearly catch of 3,991 t of white shrimp contributed 58% of the total catch of penaeid shrimp in the United States (McKenzie 1981). Shrimp (80% white) accounted for 82% of the ex-vessel 1971-77 values of marine products landed in Georgia (Music 1979).

Catches by sport shrimpers are rarely estimated but they must be considerable. Despite difficulties in estimating recreational shrimp fishing, McKenzie (1981) reported that in 1973, 43% of coastal boat owners in South Carolina fished for shrimp with non-licensed gear and in 1978, 46% of shrimp craft owners in North Carolina reported "sport shrimping" (Theiling 1981). The white shrimp is an important food of many marine and estuarine fishes and invertebrates and is heavily used for bait in South Carolina, Georgia, and Florida. In Georgia, 1,479 noncommercial recreational bait shrimpers were licensed in 1982-83 (Susan Shipman, Ga. Dep. Nat. Resour.; pers. comm.). In 1980, the estimated commercial wholesale bait shrimp catch in northeast Florida was 19.6 million live shrimp valued at $0.77 million and 413.6 t of dead shrimp valued at $1.32 million (McKenzie 1981).

LIFE HISTORY

Spawning

Along the south Atlantic coast of the United States, white shrimp spawn from March to November, but mostly from April (May in South Carolina) to October (Joyce 1965; Lindner and Anderson 1956; Music 1979; McKenzie 1981; Shipman 1983a). According to McKenzie (1981) spawning conditions extended into September in South Carolina, Georgia, and northeast Florida, and into October in central Florida. Shrimp spawn as late as November in Georgia, activity decreasing from south to north (Shipman 1983a). Spawning peaks in May and June along the offshore waters of northeast Florida (Joyce 1965). In general, the increase of bottom water temperatures in spring triggers spawning, and rapid decreases in water temperature in the fall coincide with the end of spawning (Lindner and Anderson 1956; Whitaker 1981). As judged by the low percentages of spent females in June to August, white shrimp may spawn as many as four times during their life span (Lindner and Anderson 1956); however, there is some evidence that they spawn only once in Carolina waters (Williams 1965).

White shrimp spawn along the South Atlantic coast of the United States in water more than 9 m deep (Whitaker 1983a), and within 9 km from the shore (Lindner and Cook 1970; Whitaker 1983b). Spawning shrimp seemingly prefer salinities of 27 ppt or more (Cook and Murphy 1969). In the Gulf of Mexico most white shrimp spawn at depths of 8 to 31 m (Pérez-Farfante 1969). Sexually mature and spent female white shrimp were captured along the northeast Florida coast only in offshore waters at depths over 11 m (Joyce 1965). Little is known about the spawning location offshore from North and South Carolina (Williams 1965), but adult shrimp tagged in North Edisto River estuary in South Carolina in May 1983 were recaptured within 9 km from the coast (Whitaker 1983b).

White shrimp were first spawned in captivity in 1980. The general requirements for maturation and reproduction usually fall in the range of 20% to 60% light intensity, 10 to 14 h photoperiod, 20° to 28°C water temperature, and 26 to 34 ppt salinities. In some laboratory experiments, white shrimp spawned only at night (Lindner and Cook 1970) but in others some spawned during daylight (Lawrence et al. 1980). The food source required was fresh marine invertebrates and fish supplied at 3% to 5% dry weight of the weight of the shrimp (Lawrence et al. 1983).

Eggs

In copulation (limited to hard-shelled individuals), the male attaches a spermatophore onto the thelycum of the female. Spermatozoa are believed to be released from the spermatophore simultaneously with expulsion of the ova. About 0.5 to 1 million eggs are discharged per spawn from each female (Pérez-Farfante 1969).

The eggs of white shrimp are discharged directly into the water and sink to the bottom (Anderson 1966; Lindner and Cook 1970). The spherical and opaque ripe eggs, which are 0.192 to 0.3 mm in diameter, have a purplish-blue chorion.

Larvae

White shrimp are in the larval form for about 10 days or more, depending on food and habitat conditions (Johnson and Fielding 1956). Eggs hatch into 0.3 mm long planktonic nauplii within 10 to 12 h after fertilization (Klima et al. 1982). The nonfeeding nauplii are carried by prevailing currents while they undergo five molts over a 24- to 36-h period to become free-feeding protozoea, 1 mm total length (TL) (Anderson 1966). Protozoea grow to a length of 2.5 mm through three protozoeal stages before attaining the first stage mysis (Dobkin 1961). Postembryonic stages of white shrimp were first described by Pearson (1939). Pérez-Farfante (1969) reported five nauplial, three protozoeal, and three mysis stages, followed by the first mastigopus or first postlarval stage.

Postlarvae and Juveniles

Planktonic postlarvae live offshore, and then move inshore with tidal currents toward estuaries (Whitaker 1983a). At the end of two postlarval stages, about 15 to 20 days after hatching, the shrimp are still planktonic (Anderson 1966). They enter estuaries during the second postlarval stage (7 mm long; 2 to 3 weeks after hatching) and then become benthic (Williams 1965).

Favorable currents transport larvae and early postlarvae shoreward (Pérez-Farfante 1969). Duronslet et al. (1972) sampled postlarval white shrimp in greater numbers at night at the surface than at the bottom of a tidal pass, but found no depth differences during daylight sampling, although abundance was lowest near the surface (0.8 m). No significant differences were detected in plankton net sampling of postlarval shrimp in Georgia waters at different depths, times of day, tidal stages, or lunar pulses. High turbidities may have influenced distribution (Baisden 1983). Water temperature had little effect on the movement of postlarvae into the estuaries (McKenzie 1981).

Postlarval white shrimp enter estuaries in South Carolina and North Carolina from June through September (Anderson 1965). In Georgia, nearshore and northerly bottom currents carry white shrimp postlarvae into estuaries and sounds (McKenzie 1981). The larvae enter estuaries in April and early May in the south Atlantic, and in June and July in North Carolina (McKenzie 1981). In northeastern Florida estuaries juveniles were first taken in June (Joyce 1965). White shrimp 25 to 75 mm long were classified as juveniles by Christmas et al. (1976), whereas Pérez-Farfante (1969) considered white shrimp to be juveniles after they attained an ultimate of rostral teeth: 4 to 10 on the upper rostrum and 0 to 3 on the lower rostrum with modes of 8 upper and 2 lower.

The abundance of white shrimp peaks in June through August in Georgia estuaries (Shipman 1983a). While in estuaries, juvenile white shrimp tend to move farther upstream than do juvenile pink or brown shrimp -- as far as 160 km in Louisiana and 210 km in northeast Florida (Pérez-Farfante 1969).

Juvenile white, brown, and pink shrimp tend to inhabit different substrates (Williams 1958). White shrimp prefer muddy substrates with loose peat and sandy mud. They lay their long antennae above the surface of the substrate when burrowing -- in contrast to brown and pink shrimp, which often bury their shorter antennae. Respiratory requirements during burrowing or cover-seeking, as well as food, influence white shrimp preference for a muddy or peaty substrate. Williams (1958) reported that juvenile white shrimp and brown shrimp avoid coarse substrate and inhabit softer bottoms because food (rather than cover) is more readily available there. Shallow, muddy bottoms in waters of low to moderate salinity (Anderson 1966) serve as optimum nursery grounds for juvenile white shrimp (Whitaker 1983a). In the south Atlantic states, estuarine nursery areas of white shrimp are predominately associated with Spartina alterniflora wetlands (McKenzie 1981). Juvenile white shrimp congregate in sandy-muddy substrate but juvenile brown shrimp sometimes forcefully displace white shrimp from this habitat (Rulifson 1981). Juvenile brown shrimp displaced juvenile white shrimp from grass cover in aquaria (Giles and Zamora 1973). Staggered recruitment of white and brown shrimp probably reduces competition for habitat (Shipman 1983a). Increasing water temperatures reduced the preference of white shrimp affinity for sandy-mud substrates rather than shell substrates.

In 1971-81, white shrimp were largest in South Carolina landings when densities were lowest, suggesting that intraspecific competition was reduced or time spent in the nursery areas was longer (McKenzie 1981). In Georgia, large shrimp predominated the harvest after winter freezes, lending support to the suggestion that the abundance of white shrimp in south Atlantic estuaries determines the size of the shrimp in the fishery or during emigration in the fall (Shipman 1983a). As the season progresses to June or July and juveniles reach lengths of about 51 mm, they move from shallow marshes into deeper creeks, rivers, and bays (Anderson 1966). Along the northeast Florida coast, white shrimp were 70 to 80 mm long in June and July (Joyce 1965). A sharp decrease in the mean length along northeast Florida's offshore waters in August corresponded closely with the arrival of smaller shrimp 120 to 140 mm long) from estuaries (Joyce 1965). Similarly, an increased count (an increase in numbers per pound) of shrimp trawled in Georgia's offshore waters during August signalled the emigration of the summer's first recruits (Shipman 1983a).

Among juveniles, white shrimp are usually more active than are brown or pink shrimp during daylight. In Galveston Bay, Texas, trawl catches of juvenile shrimp 35 to 97 mm long were significantly larger in daytime than at night (Clark and Caillouet 1975). In Florida, the percentage of white shrimp taken during daytime was 83% of all shrimp in inshore waters but only 57% in deep water (Joyce 1965). Small white shrimp may be more active during the day than larger ones (Joyce 1965). In the laboratory, white shrimp did not burrow, but they were quiescent on the bottom or in shallow depressions for several hours during the day (Wickham and Minkler 1975).

Adults

White shrimp usually mature sexually at age I during the calendar year after they hatch. Mature males have joined petosmal endopods at 105 to 127 mm, produce ripe sperm at 118 mm TL, and have fully developed spermatophores at 155 mm TL (Pérez-Farfante 1969). The smallest ripe female recorded by Burkenroad (1939) was 135 mm long, and the minimum length of ripe females in the northern Gulf of Mexico was 140 mm (St. Amant and Lindner 1966). In Florida, the ovaries of white shrimp begin to develop at 110 mm in fall and complete development when growth resumes in the spring (Joyce 1965). Adult white shrimp are powerful swimmers capable of migrating great distances (with currents) and living in euphotic littoral zones at relatively high light intensities (Young 1959). White shrimp catches in bottom trawls may also be low during the midday quiescent period on the substrate surface (Wickham and Minkler 1975). In contrast Veal et al. (1983) reported that since white shrimp generally burrow into the bottom at night, they may become more difficult to catch. Bottom trawl catches at night also might be lower when white shrimp are actively swimming in the water column. Longshore currents influence movement patterns along the southeast Atlantic coast (Shipman 1983b). Numerous reports from shrimpers indicated that white shrimp sometimes school on the surface, particularly in late fall and early winter during their southerly offshore migrations (Susan Shipman, pers. comm.).

Migration

White shrimp along the southeast Atlantic coast migrate southward during autumn and early winter and then northward in late winter and early spring (Lindner and Cook 1970; McKenzie 1981; Whitaker 1982; Shipman 1983b). More specific migrations reported by Joyce (1965) showed a major southerly migration from North Carolina to Cape

Canaveral, Florida, in fall and a northerly migration from the Cape in spring. In Georgia, a mark and recapture study revealed that 96% of the shrimp recovered in the winter came from more southerly waters (Shipman 1983b). A white shrimp tagged in October off North Carolina was recaptured 576 km southward off Florida's east coast and one white shrimp tagged in January off central Florida was recaptured 416 km to the north off South Carolina (Anderson 1966). Whitaker (1981) suggested a correlation between shrimp migration and latitude with activity being greatest in the more southern areas. In northeast Florida, white shrimp 120 to 140 mm TL moved offshore from August through April (Joyce 1965). Detailed analyses of white shrimp sampling from June 1962 - June 1963 by Joyce (1965) revealed that white shrimp caught off Cape Canaveral, Florida had migrated from more northern nursery areas in December and January, suggesting that Cape Canaveral is the southern limit of commercial white shrimping along Florida's east coast. Southward movements of 10 to 20 km per day during fall were suggested by Joyce (1965) for schooling white shrimp along the northeast Florida coast. Movements of individual shrimp tagged in Georgia waters and recaptured off Florida ranged from 1.8 to 6.9 nautical miles per day (Shipman 1983b). Offshore migrants make up the valuable spring fishery for adult females in Georgia, South Carolina, and North Carolina in years following relatively mild winters (McKenzie 1981).

White shrimp emigration from estuaries is governed largely by body size, age, and environmental conditions (Klima et al. 1982; Shipman 1983b). Low water temperatures (<18°C) and spring tides at full moon stimulated mass movements from South Carolina estuaries (Whitaker 1982). During ebb tides, white shrimp tend to school and migrate near the surface at night (Benson 1982). Williams (1958) suggested that muddy substrate is not strongly preferred during emigration from estuaries to the sea. Emigration was delayed in South Carolina and Georgia when unusually low freshwater inflow caused high salinities (Shipman 1983b). In South Carolina, shrimp congregated in the deeper channels (staging areas) as water temperatures declined to about 9°C (McKenzie 1981). Recent studies showed that white shrimp movements offshore in fall and winter are triggered by water temperature declines in estuaries in the south Atlantic (Shipman 1983b), and Louisiana (White and Boudreaux 1977). Precipitation, spring tides, and strong tidal exchanges associated with northeasterly storms also influence the timing and magnitude of emigration from inshore waters (Shipman 1983b).

GROWTH

Juvenile white shrimp grow during summer and fall, grow slowly over winter, and then resume growth as water temperatures rise in the estuaries during April and May. Spring growth is about equal to the summer growth of 18 to 30 mm per month. Similar growth rates were calculated from mark-recapture studies in Georgia from 1978 to 1981 (Shipman 1983b). The rate of increase in weight is relatively low among the small white shrimp, highest in mid-sizes, and decreasing among the larger ones (Kutkuhn 1962).

Following two mysis stages and two postlarval stages, young white shrimp 7 mm long enter the estuaries where their growth rate is about 1.2 mm per day (Williams 1965). Juvenile shrimp in the south Atlantic grow 1.0 to 2.3 mm per day or 28 to 64 mm per month (McKenzie 1981).

Young white shrimp 13 to 68 mm long (mode 33 mm) first appear in Georgia's upper creek and marsh areas in June; by July the mode increases to 43 mm and the range from 13 to 103 mm (Harris 1974). White shrimp in Georgia rivers and sounds are about 78 mm long in July, 108 mm in August, 130 mm in September, and 146 mm in October. During winter the length-frequency mode declines when growth stops and the larger shrimp migrate southward offshore. White shrimp that overwintered in inshore waters grew from a modal length of 118 mm to 162 mm in June, 176 mm in August, and 180 mm in September. Modal lengths in the offshore population were 143 mm in March, 172 mm in June, and 181 mm in August. The growth of tagged adult white shrimp of both sexes up to 15 days after release was greatest in summer at 0.41 mm per day compared with 0.14, 0.10, and 0.13 mm per day in fall, winter, and spring, respectively (Shipman 1983b). Anderson (1966) reported that white shrimp were 80 mm long within 2 months after hatching in May, 110 mm by 3 months, 130 mm by 4 months, 145 mm by 5 months, and 155 mm by 6 months (November). They grew slowly from November through March, but resumed growth in spring; 1-year-old spawners were 173 mm long in May.

Female shrimp grow faster and reach larger sizes than males (Etzold and Christmas 1977). In northeast Florida the largest female sampled by Joyce (1965) was 192 mm long and the largest male was 175 mm long; most shrimp longer than 115 mm were females. Anderson (1966) reported females as long as 197 mm in the Carolinas and males as long as 182 mm.

Mortality

Few white shrimp live as long as one year (Anderson 1966); however, mark and recapture studies showed that a few lived as long as 27 months in Mississippi (Etzold and Christmas 1977), more than 17 months in Georgia (Shipman 1983b), and as long as 4 years (average 18 months) in Texas (Klima et al. 1982). Because of the usually short life span, the abundance of white shrimp would be expected to fluctuate widely from year to year but apparently compensating factors are at work; e.g., in 1977 after a massive winter kill in Georgia coastal waters, when the numbers of spawning white shrimp were reduced to 7% of normal, subsequent recruitment into the fishery was only 40% below normal (Music 1979). For white shrimp in the south Atlantic fishery, instantaneous mortality rates (McKenzie 1981) were 0.02 to 0.25 (fishing), 0.21 to 0.56 (natural), and 0.24 to 0.80 (total). Weekly mortalities ranged from 13 to 51%; the lower rates were nearer to reality for both juveniles and adults (McKenzie 1981).

Hurricanes cause major losses of white shrimp in the Gulf of Mexico. A hurricane striking the Louisiana coast in summer 1957 destroyed large numbers of white shrimp when salinities increased, cover and food supplies were destroyed, dispersal and stranding were excessive, and turbulence in estuaries was high (Kutkuhn 1962). Hurricane Carla caused a 61% drop in the 1961 Louisiana catch of white shrimp and Hurricane Camille caused an 88% drop in production in Mississippi in August 1969 (Barrett and Gillespie 1973). Sudden cold fronts and subsequent declines in water temperatures have caused mortality and reduced recruitment of white shrimp in south Atlantic shallow inshore waters; two consecutive mild winters may be required to support spring harvests in South Carolina (Whitaker 1983a).

Diseases and Parasites

The effect of diseases and parasites on white shrimp mortality is not well known (Barrett and Gillespie 1973). A 99% loss of egg production was attributed to a microsporidian parasite infection of white shrimp gonads (Gunter 1956), yet the next year's production was as high as that of the preceeding year. *Vibrio* infection of male white shrimp prevented egg fertilization under laboratory conditions (Middleditch et al. 1980). Literature reviews of diseases and parasites of penaeid shrimp show that viruses, bacteria, fungi, protozoa, helminths, and nematodes often infect shrimp (Lindner and Cook 1970; Couch 1978; Overstreet 1978). Diseases and parasites ranked after predation and periodic physical catastrophes as limiting factors in nature and after nutrition and reproduction requirements in mariculture (Couch 1978). Symbionts may be related to shrimp kills during low oxygen conditions (Overstreet 1978). A parasitic cestode, Prochristanella penaei, infecting the hepatopancreas of adult shrimp is of some concern in the Mississippi Sound; however, from an economic standpoint, microsporidian protozoans that cause a "cotton" appearance in the musculature of shrimp are the most threatening (Christmas et al. 1976). In Georgia in 1978-81, microsporidian parasites were observed in 3.9% of 33,350 white shrimp captured for tagging. Lower recovery rates of tags from infected than from uninfected shrimp suggested higher mortality among the infected shrimp (Shipman 1983b). Hutton et al. (1959) suggested that infected shrimp may be more susceptible to predation and disease.

THE FISHERY

The characteristics of the white shrimp fishery in the south Atlantic -- including processing, marketing, economics, and sociological aspects -- were reported by McKenzie (1981). The shrimp industries along the Atlantic coast of North Carolina, South Carolina, Georgia, and Florida are based mainly on white, brown, and pink shrimp. Florida's fishery includes the rock shrimp (Sicyonia brevirostris). White shrimp contributed 58% of the total 1957-80 catch in the four States. The low was 31%, following the severe winter of 1976-77, and the high was 76% in 1973. White shrimp contributed an average of 81% to the catch along the east coast of Florida, and 78% of the total catch in Georgia, 58% in South Carolina, and 6% in North Carolina. The average annual white shrimp landings in 1976-1980 (millions of pounds, heads off) were 0.16 for North Carolina, 2.47 for South Carolina, 3.41 for Georgia, and 1.63 along the east coast of Florida (McKenzie 1981).

The average annual white shrimp landings in 1976-80 were 13% below the average of the 1957-80 landings. The decrease was attributed to the severe winters of 1976-77 and 1977-78. The Georgia Department of Natural Resources (1983) reported a 34% drop in 1981 from the 1971-80 white shrimp landings. The drop was caused by unusually low winter water temperatures in 1980-81. Annual catches in Georgia and Florida have been relatively steady, averaging near 18% and 29%, respectively, about the coefficient of variation for the 1957-80 (24-year) average; this average varied 54% in South Carolina and 114% in North Carolina (McKenzie 1981). In the South Atlantic, white shrimp landings (heads-off) in 1957-80 ranged from a low of 3.2 million lb in 1977 to a high of 12.2 million lb in 1971. Although fluctuations in abundance are natural and are expected even when environmental factors appear favorable (McKenzie 1981), alteration of habitats by pollution or physical causes in numerous estuaries are becoming serious factors influencing shrimp production (Etzold et al. 1983).

White shrimp enter the commercial fishery when the gravid shrimp congregate off the central and southward coast of South Carolina in April or May and remain in the South Carolina fishery through June or early July. In Georgia, the white shrimp fishery season opens in June in territorial offshore waters. Juveniles enter the coastal fishery in August in South Carolina, Georgia, and northeast Florida. In North Carolina, they are caught mainly in the fall in the area from Southport to Cape Fear. The fishery continues through mid-December in South Carolina and to the end of December in Georgia and northern Florida (McKenzie 1981). Catches in nearshore waters of Georgia are lowest in June and peak in August and September (Music 1979). Catch per unit of effort was highest in northern Georgia's offshore waters in late summer and fall and landings peaked in September and October (Ga. Dep. Nat. Resour. Coastal Resources Div., Data Manage. Section, pers. comm.). As water temperatures drop, white shrimp move southward and are caught in coastal waters of extreme southern Georgia in January (Music 1979); however, some may be caught as late as February depending on the date of closure of territorial waters (Susan Shipman, pers. comm.). Joyce (1965) reported that abundance peaked in December and January in northern Florida from St. Augustine to Cape Canaveral.

Most commercial shrimp catch is made within 9 km of the coast (Etzold et al. 1983) on trawlable bottoms within the 11-m depth contour. The breadth of the Continental Shelf within the 11-m (6-fathom) contour is greatest along the northern and central Georgia shelf, but is narrower along the coast of northeast Florida, South Carolina, and North Carolina. About 99% of North Carolina's white shrimp catch was taken in its territorial waters. For the other states, the percentages were 90% for South Carolina, 85% for Florida, and 59% for Georgia. In Georgia, two 3-year studies (1974-77, 1978-81) of monthly shrimp distribution and abundance were made by using 30-min trawl samples to evaluate shrimp at 36 stations in estuaries and nearshore waters out to 4.8 km (Music 1979; Shipman 1983a). The catch of white shrimp per hour averaged 50 lb and 32 lb in sounds (52% and 44% of total), 44 lb and 34 lb in creeks (46% and 48% of the total), and 1.5 lb and 5 lb in outside waters (2% and 7% of the total).

Freshwater inflow is the dominant factor influencing abundance, distribution, and growth of white shrimp (McKenzie 1981). During the drought and low freshwater inflow in 1980, the shrimp moved further up estuaries, which lengthened their residency there and increased mortality. The lower landings in 1980-81 were caused by low freshwater inflow and low winter water temperatures.

Since juvenile white shrimp live in coastal wetlands, the areas of such wetlands are useful measures of potential abundance (Turner 1977). The areas of coastal wetland are 79,826 ha in North Carolina, 204,146 ha in South Carolina, 192,508 ha in Georgia, and 47,631 ha in northeast Florida (McKenzie 1981). None of the four states permit commercial trawling in designated nursery areas. A positive relation between the 1962 and 1963 fall white shrimp commercial landings in Florida with relative abundance of July inshore samples was reported by Joyce (1965). Production estimates of offshore harvests in Alabama and Mississippi also have shown a strong relation to inshore abundance of juveniles (St. Amant and Lindner 1966; Loesch 1976). Christmas and Etzold (1977) concluded that subsequent year recruitment is not a major consideration in management because it is largely independent of the abundance of parent stock; therefore, management would be aimed toward maximimum sustained yield from the current year's recruitment. In Georgia, there was little relation between the size of the fall white shrimp landings and salinity, abundance of juveniles in August, and abundance of gravid shrimp in the preceding spring (Shipman 1983a).

Sport and noncommercial bait shrimp fisheries are difficult to evaluate because not all are licensed (McKenzie 1981). Recreational catch has been estimated to equal 10% of the south Atlantic commercial catch (Etzold et al. 1983). The most important data are from boat registrations. In 1973, 44% of the 16,780 registered recreational boat owners in 11 eastern South Carolina counties caught an estimated total of 371 mt of shrimp. Of the 15,888 shrimping craft owners licensed in North Carolina in 1978, 46% were sport fishermen who caught as much as 3% of the commercial catch. In Georgia in 1982-83, there were 1,479 bait shrimping licenses, 76 commercial bait licenses, and 1,959 commercial food shrimping licenses. In 1980-81, 127 non-commercial licenses were issued for the St. Johns River, Florida allowing sport fishermen to take up to 50 lb per day of shrimp by trawling in inshore waters only on weekends and holidays.

Although shrimp are important bait for sport fishing in North and South Carolina, the live-bait industry is relatively small (McKenzie 1981). In Florida the commercial bait fishery landed and sold 22.3 million live shrimp annually in 1972-80 (McKenzie 1981).

ECOLOGICAL ROLE

White shrimp convert detritus, plant material, microorganisms, macroinvertebrates, and fish parts into useful protein for carnivores (e.g. other invertebrates, fish, and man). Nauplii subsist on yolk granules until they reach the protozoea I stage (McKenzie 1981). White shrimp larvae feed on zooplankton and phytoplankton; white shrimp protozoea feed on green algae, diatoms, or copepods (Dobkin 1961). In a laboratory test, cultured algae were fed to protozoea and newly hatched brine shrimp up to the mysis stage (Cook and Murphy 1969). Early stages of white shrimp larvae feed on plankton and suspended detritus (Christmas and Etzold 1977).

Juvenile and adult white shrimp are benthic omnivores; the major differences in food selection are the kinds and availability of materials selected. Juvenile and adult penaeids are benthic omnivores that feed largely at night, except in turbid waters (McKenzie 1981). Fecal pellets of fish and invertebrates can be an important food item of juvenile shrimp. Lindner and Cook (1970) noted that white shrimp were selective particulate feeders. Major food reported in three studies were detritus, chitin, parts of annelids and gastropods, fish parts, bryozoans, sponges, corals, filaments of algae, and vascular plant stems and roots (Christmas and Etzold 1977). Lipids supplied by annelids in the diet were important for ovarian maturation (Middleditch et al. 1980).

Cannibalism is common among juvenile and adult white shrimp (Pérez-Farfante 1969), but McKenzie (1981) suggested that the cannibalism reported in the literature was related to crowding in aquaria. Bottino et al. (1980) found that body fatty acids in shrimp were influenced by diet. Food conversion ratios of 1.8 and 1.9 (i.e., 1.8 or 1.9 lb of food yield 1 lb of shrimp) were reported for white shrimp fed in two marine ponds at Marifarms, Inc., Panama City, Florida (Brown 1977). Assimilation efficiency in juvenile white shrimp may reach 80% to 85% for a variety of plant and animal materials (McKenzie 1981). White shrimp were an important food for many marine and estuarine fish (Gunter 1956; Pérez-Farfante 1969; Lindner and Cook 1970; McKenzie 1981; Benson 1982). Larval and juvenile shrimp were important food items for 13 of 21 juvenile fish species captured from seagrass beds in Florida estuaries of the Gulf of Mexico (Carr and Adams 1973).

White shrimp are invaluable in the food chains of coastal waters. They recycle basic nutrients by feeding on organic matter and microorganisms in sediments (Odum 1971; Carr and Adams 1973). Concentrations along the Louisiana coast are greatest where substrates are high in organic content and where water temperatures and salinities are favorable (Barrett and Gillespie 1973; Gaidry 1974). Kutkuhn (1966) illustrated the dependence of white shrimp on the estuarine environment. Juveniles tolerate lower salinities than do many other fish and shellfish; this salinity tolerance reduces competition between shrimp and fish and may be as important as food supply for the growth and survival of these seasonal migrants (Hedgpeth 1963; Gunter 1967).

ENVIRONMENTAL REQUIREMENTS

Temperature

Water temperature directly or indirectly influences white shrimp spawning, growth, habitat selection, osmoregulation, movement, migration, and mortality. Spring water temperature increases trigger spawning, and rapid water temperature declines in fall portend the end of spawning (Lindner and Anderson 1956). Growth is fastest in summer and slow or negligible in winter. Water temperatures below 20°C inhibit growth of juvenile shrimp (Etzold and Christmas 1977) and growth is virtually nil at 16°C (St. Amant and Lindner 1966). Growth rates increase rapidly as temperatures increase above 20°C. Increased water temperature affects molting rate (Pérez-Farfante 1969). Good correlation between heating-degree-days and catch/effort ratio for penaeid shrimp was similar to correlations of yield-per-hectare versus latitude (Turner 1977). Temperature and food supply limited the growth of white shrimp postlarvae more than did salinity differences between 2 and 35 ppt (Zein-Eldin 1964).

Severe winters in 1939-40, 1966, 1976-77, and 1977-78 caused mass mortality and reduced catches in the South Atlantic white shrimp fishery (McKenzie 1981; Shipman 1983a; Whitaker 1983a). The Georgia Department of Natural Resources (1983) reported a 34% drop in white shrimp landings in 1981 and a 99% drop in 1981 spring catch of roe shrimp after the unusually cold 1980-81 winter. White shrimp are more tolerant of high temperatures and less tolerant of low temperatures than either brown or pink shrimp (Etzold and Christmas 1977). Among postlarvae, brown shrimp were more resistant than white shrimp to higher temperatures.

White shrimp mortality was reported at water temperatures of 8°C and lower (Joyce 1965). Mortality of white shrimp is total at 3°C or lower, regardless of salinity. White shrimp survival at low temperatures depends on ambient temperature, the rate of temperature decline, the duration of low temperatures and salinity (Joyce 1965). The impact of low water temperature and low salinity on white shrimp was discussed by Music (1979) and Shipman (1983a). Adult white shrimp (> 90 mm long) may be more susceptible than juveniles to cold temperatures (Whitaker 1983a). Wiesepape (1975) found the 24-h LC_{50} (temperature causing 50% mortality in 24 h) to be 36° and 37°C for white shrimp acclimated at 29° and 34°C, respectively. Postlarvae and 30-mm long juveniles have similar but higher resistance times than 50-mm juveniles.

Salinity

Adult white shrimp spawn offshore where salinities are at least 27 ppt. The larvae move shoreward and become second-stage postlarvae as they enter estuaries on flood tides. Juvenile white shrimp moved 160 km upstream into water of less than 1.0-ppt salinity waters in the St. Johns River, Florida (Joyce 1965). Juvenile white shrimp have even been recovered from Lake Monroe Power Station filter screens located 270 km from the mouth of the St. Johns River -- especially when low rainfall and low river stages caused reverse tidal flow (Edwin Joyce, pers. comm., February 1984). The high calcium ion concentrations in the St. Johns River may explain the relative ease with which marine species enter and remain in low salinity waters (Joyce 1965). The lowest salinity in which white shrimp were recorded in the northern Gulf of Mexico was 0.42 ppt (Pérez-Farfante 1969). Although field studies indicate that juvenile white shrimp prefer low salinities, laboratory studies have revealed that white shrimp appear to tolerate a wide range of salinities; they have been successfully reared at salinities of 18 to 34 ppt (Pérez-Farfante 1969). McKenzie (1981) cited several studies in which fast growth was reported for white shrimp at salinities of 7 to 15 ppt.

White shrimp in Georgia move toward higher salinity waters as sexual development progresses, and most spawn offshore in the sea (Harris 1974).

Temperature - Salinity Interactions

Temperature-salinity tolerance ranges for white shrimp vary at different life stages, but the interactions are more pronounced at the extremes of tolerance. For example, Couch (1978) reported that broken-back syndrome (dorsal separation of third and fourth pleural plates on abdominal) appears after sudden drops in salinity (from 15 ppt to 3 ppt) in cold water (8°C). The critical thermal maxima for white shrimp are influenced largely by acclimation temperatures, and to a lesser extent by salinity and size of test animal (Laney 1973). Freshwater inflow may affect coastal water temperatures, which in turn affect the growth rates (White and Boudreaux 1977) and migration of white shrimp (Shipman 1983b). Spring spawning of white shrimp coincides with a rapid rise in bottom water temperatures in high salinity offshore waters (McKenzie 1981).

Substrate

White shrimp prefer shallow, muddy-bottom substrate. Landings of shrimp along the Louisiana coast were highest in areas where substrates were highly organic (Barrett and Gillespie 1973; Gaidry 1974). A relative higher linear correlation ($R^2 = 0.69$) between intertidal land area and average annual shrimp catch along Louisiana's inshore regions was reported by Turner (1977). The relation between inshore catches and hectares of vegetated estuarine habitat in the northeastern Gulf of Mexico (Tampa Bay, Florida, to Mobile Bay and Perdido Bay, Alabama) also showed a strong correlation ($R^2 = 0.64$). A direct relationship between commercial shrimp landings and intertidal vegetated areas and degrees latitude was reported by Turner (1977). The annual landings (kg/ha) in 1955-64 were 19.7 in North Carolina, 7.9 in South Carolina, 13 in Georgia, and 22.4 in east Florida. White shrimp undoubtedly composed most of the landings except in North Carolina. Southward fall migration probably account for the high landings from Florida waters. The area of nearshore soft sediments correlate well with white and brown shrimp distribution from Pamlico Sound, North Carolina to northern Florida (McKenzie 1981).

Temporal and spatial shifts by brown, white, and pink shrimp help reduce direct interspecific competition especially for certain substrate (Lassuy 1983). White shrimp burrow less deeply into muddy substrates and are more active in daylight than are brown or pink shrimp. Staggered seasonal recruitment of brown and white shrimp into south Atlantic estuaries would reduce competition (Baisden 1983).

Other Environmental Considerations

The loss of nursery grounds has been considered the major threat to the white shrimp fishery in the Gulf of Mexico because that is where shrimp are most vulnerable to habitat disturbance (Gunter 1956). Studies in Florida, Louisiana, and Texas identified landfill, dredging, and impoundments as major detriments to shrimp production (Christmas and Etzold 1977; Etzold et al. 1983). Because of the loss of rich organic material along bulkheads, shrimp abundance there was reduced to about 1/8 that of nearby unaltered shorelines (Mock 1967). About 18,171 ha of wetlands, 3.5% of the total, were lost from the South Atlantic coast between 1954 and 1968 (McKenzie 1981). Manmade canals in Louisiana estuaries have increased salinity and adversely affected white shrimp survival and growth (Biglane and LaFleur 1968). Increased salinities have favored brown shrimp over white shrimp in the central-northern Gulf of Mexico (Christmas and Etzold 1977). The effects of pesticides and pollution on shrimp habitat along the gulf coast are also of concern (Biglane and LaFleur 1968; Christmas and Etzold 1977). Several examples of white shrimp losses to pesticides along the South Carolina coast were given by McKenzie (1981) and the toxicities and biological effects of pesticides, heavy metals, petroleum products, and chemotherapeutic chemicals were given by Couch (1978). Trawl catches of white shrimp dropped below seasonal averages when dissolved oxygen was below 3.0 mg/l in altered, eutrophic canals associated with housing developments in West Bay, Texas (Trent et al. 1976). Maintaining suitable nursery grounds ultimately may decide the future of the shrimp resources of the gulf coast (Christmas and Etzold 1977) and south Atlantic (McKenzie 1981; Etzold et al. 1983).

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16. Abstract (Limit: 200 words)
Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of aquatic species. They are prepared to assist in environmental impact assessment. The white shrimp, Penaeus setiferus, is the most important commercial species in the Southeastern United States. It serves an important ecological role as food for other large invertebrates and fishes. Major bait industry is in northeast Florida and Georgia. Spawning occurs offshore within 9-m depth contour where salinities are at least 27 ppt. In spring, postlarval shrimp move with tidal currents into inshore estuarine waters. Juvenile white shrimp prefer shallow organic-rich substrate with low salinities (1-10 ppt). Nearshore soft sediment areas correlated well with white and brown shrimp distributions. Water temperature influences spawning, growth, habitat selection, emigration, and mortality. Low winter temperatures have greatly affected survival, recruitment, and harvest in the South Atlantic fishery. Maintaining suitable nursery grounds is a major concern for the future of the fishery.

17. Document Analysis a. Descriptors
Estuaries
Fishes
Growth
Feeding

b. Identifiers/Open-Ended Terms
White shrimp
Penaeus setiferus
Salinity requirements
Temperature requirements
Habitat requirements
Life history
Spawning

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	Unclassified	19
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	Unclassified	

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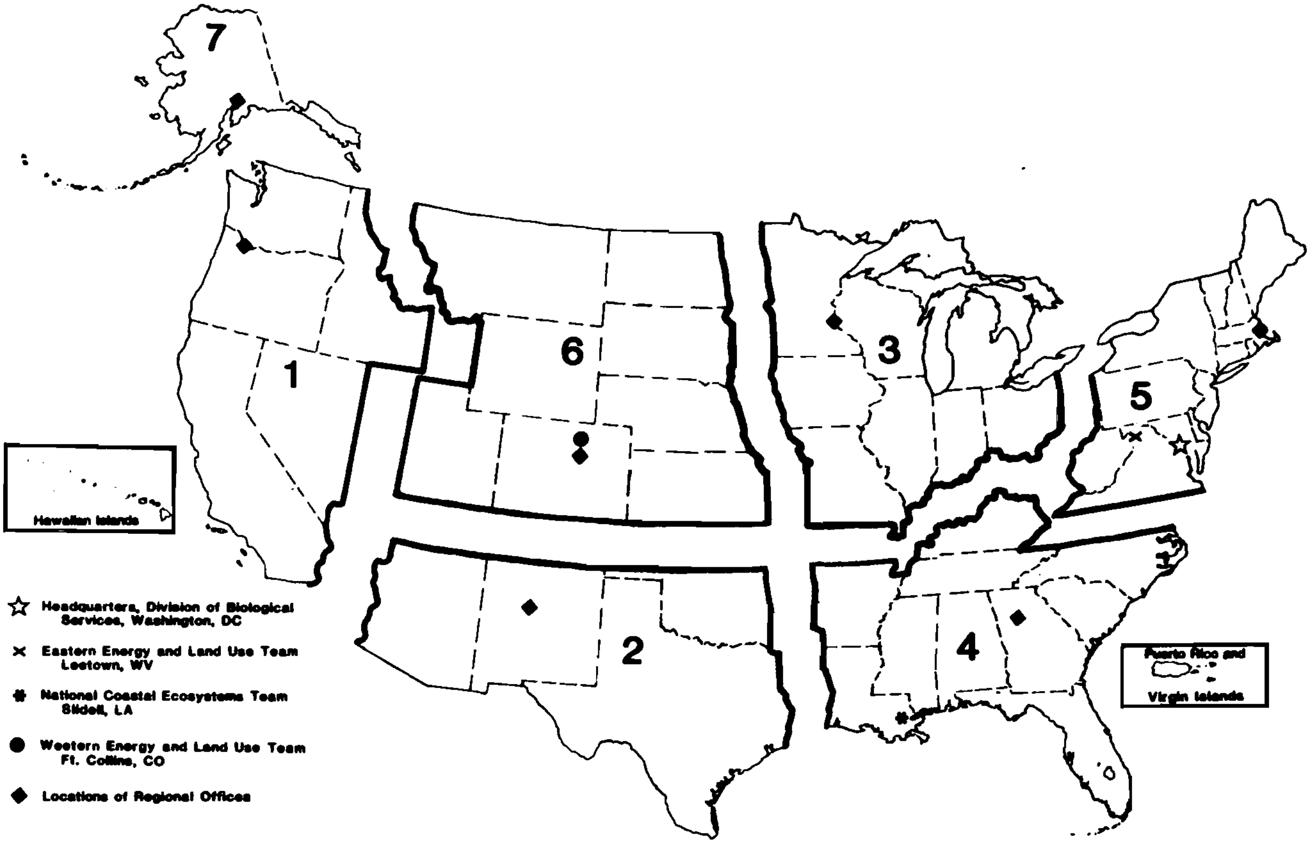

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