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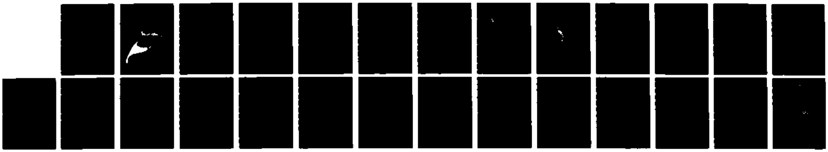

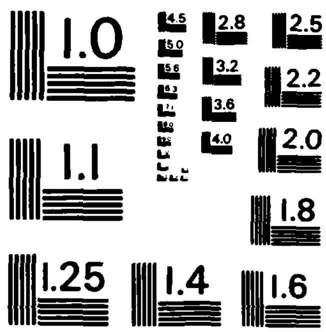

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September 1984

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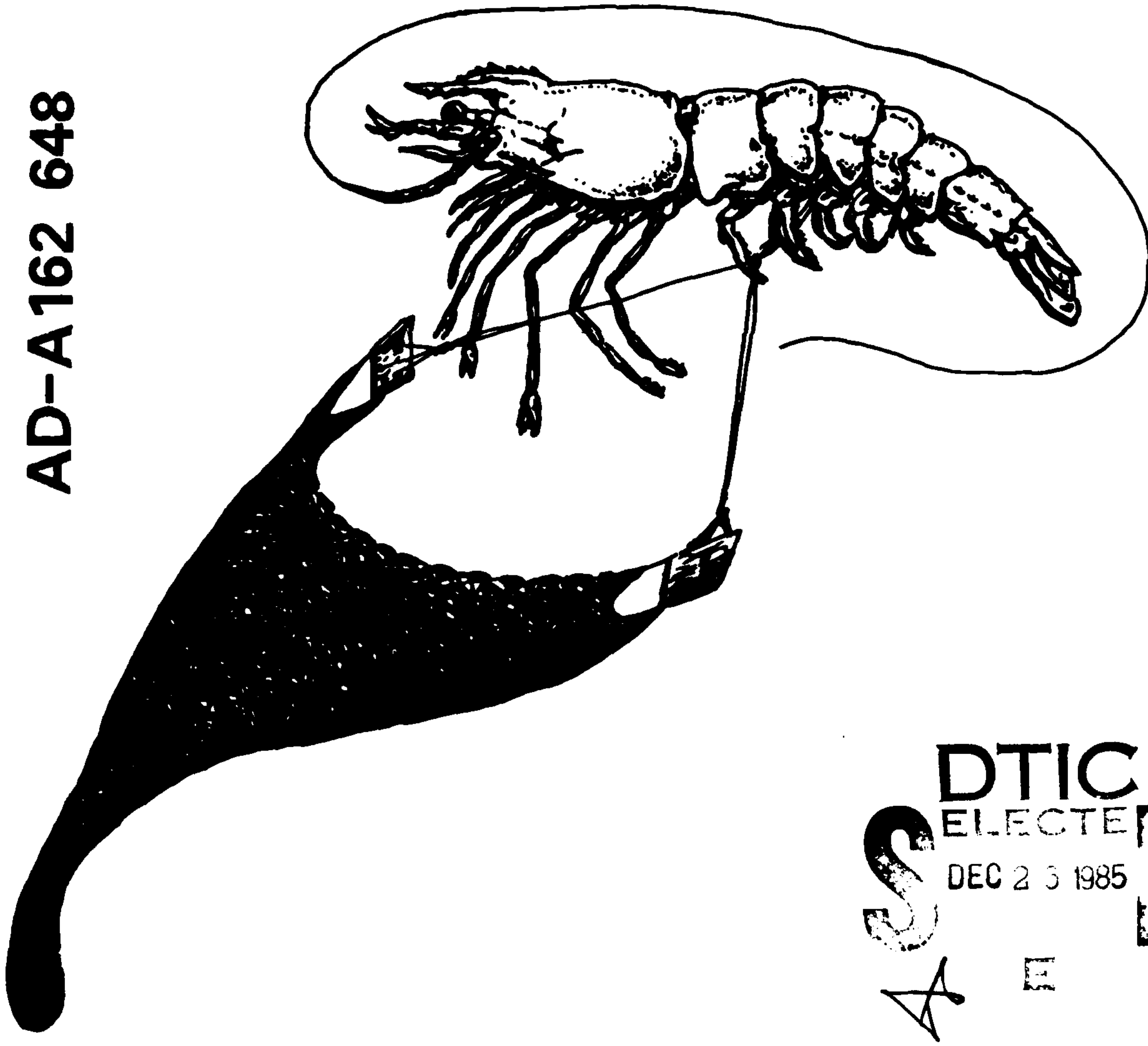
Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Gulf of Mexico)

WHITE SHRIMP



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 (Gulf of Mexico)

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 (1)	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

CONTENTS

ACKNOWLEDGMENTS

I am grateful for the reviews and suggestions of Tom VanDevender, Mississippi Bureau of Marine Resources, Long Beach, Mississippi; Steve Heath, Alabama Marine Resources Department, Dauphin Island, Alabama; and Jack Pullen, U.S. Army Corps of Engineers, Vicksburg, Mississippi.

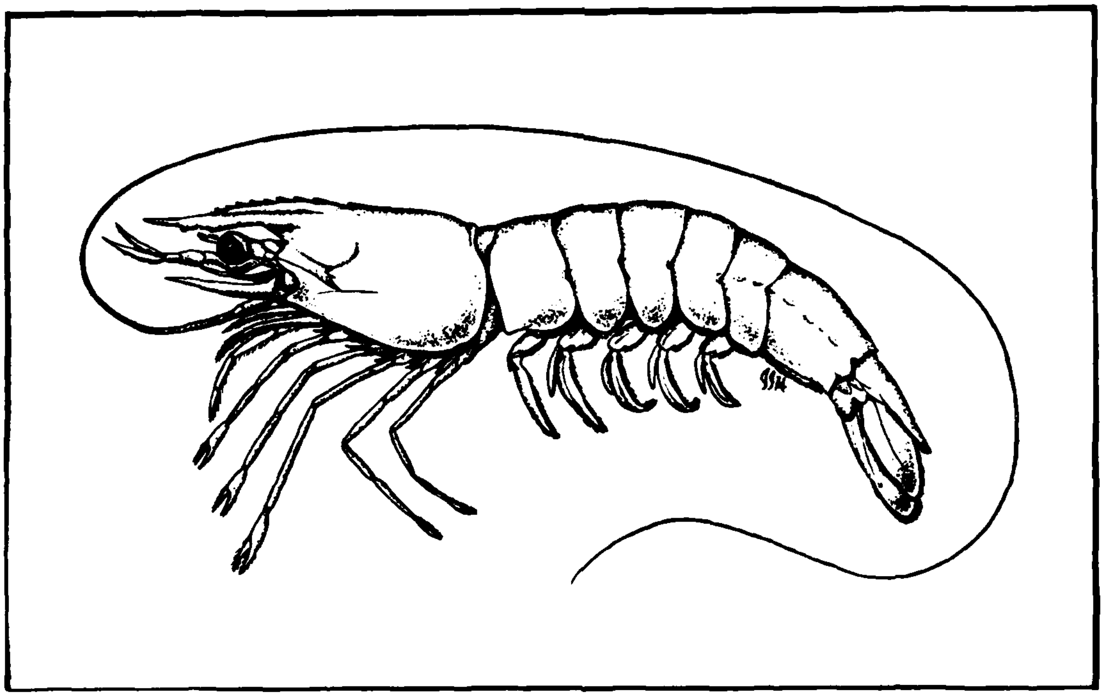

Figure 1. White Shrimp.

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; Mexico: camarón blanco (Pérez-Farfante 1969).

Class .... Crustacea
Order .... Decapoda
Family .... Penaeidae

Geographic range: White shrimp inhabit waters along the Atlantic coast from Fire Island, New York, to Saint Lucie Inlet, Florida, and along the Gulf of Mexico coast from Apalachee Bay, Florida, to Ciudad, Mexico (Pérez-Farfante 1969). They are scarce or absent along the lower east and west coasts of Florida. Centers of abundance are the coastal waters of Georgia, northeast Florida, Louisiana, and northeast Tabasco and the adjacent waters of Campeche, Mexico. Distribution in the northern Gulf of Mexico is illustrated in Figure 2. Highest densities of white shrimp in gulf waters are off the coast of

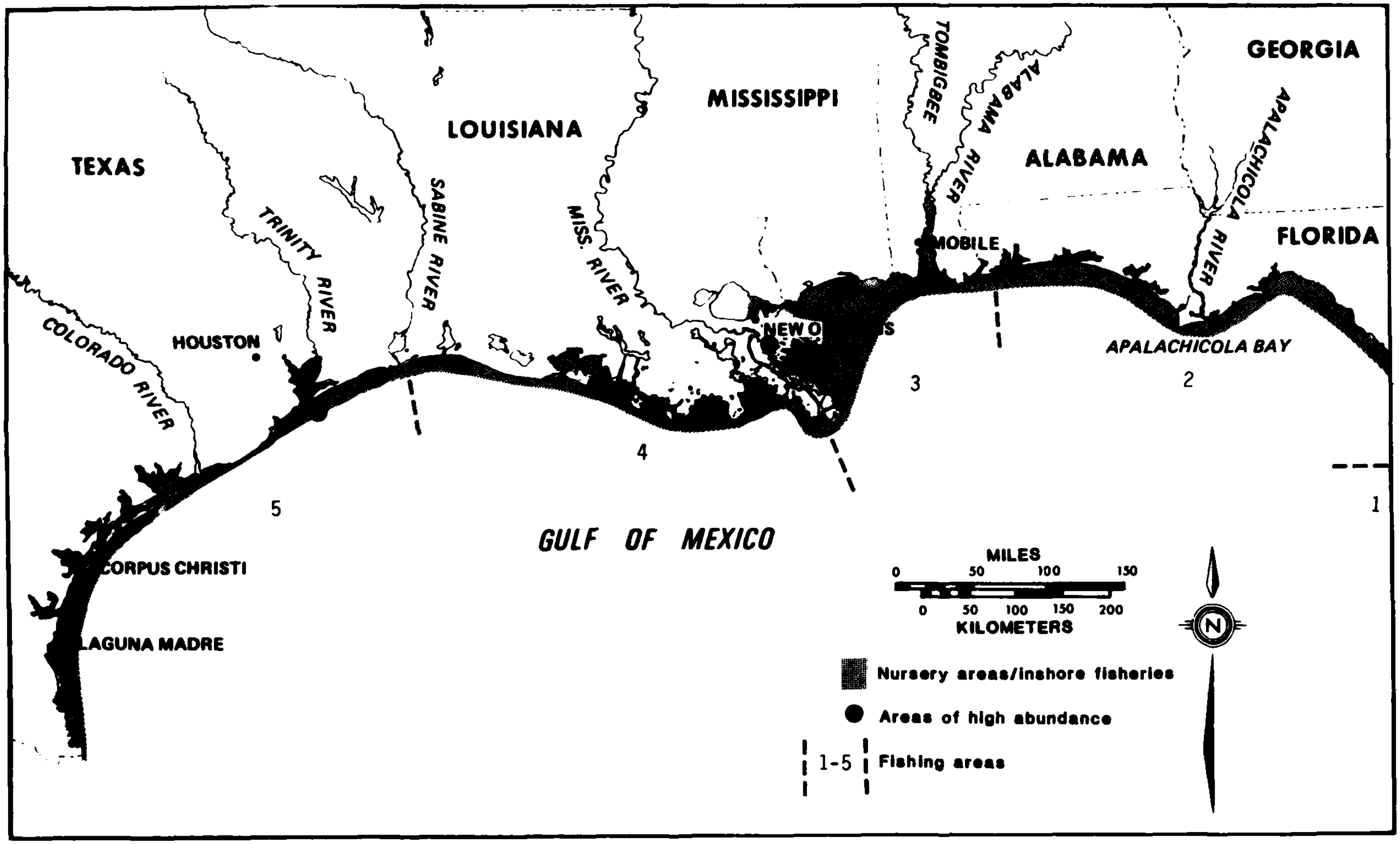

Figure 2. Nearshore distribution of white shrimp along the Gulf of Mexico.

Louisiana in water less than 9 m deep (Klima et al. 1982).

MORPHOLOGY/IDENTIFICATION AIDS

Lateral rostral grooves do not extend beyond the base of rostrum in adults nor to the posterior margin of the carapace in juveniles (Williams 1965); adrostal sulcus is short, extending to epigastric (back) tooth of rostrum; gastrofrontal carina is absent; petasma has distal portion of lateral lobe-bearing diagonal ridge on inner surface, and distal ventromedial corner is rounded. Thelycum is open type; has anterolateral ridges turned mesially and pair of fleshy protuberances on sternite XIV. Antennal flagella are 2.5 to 3 times the body length (Pérez-Farfante 1969). Zamora and Trent (1968) reported that the keel on the sixth abdominal somite of postlarvae is smooth in white shrimp but bears spines in brown shrimp (P. aztecus) and pink shrimp (P. duorarum).

Lengths given in the following sections refer (unless otherwise indicated) to total length.

REASONS FOR INCLUSION IN SERIES

The Gulf of Mexico shrimp fishery is the most valuable fishery in the continental United States. The white shrimp was the major commercial shrimp in the gulf up to the mid-1930's. Brown and pink shrimp often were shunned because the flesh was brownish and presumably inferior. After World War II, the stigma was overcome and brown and pink shrimp production increased sharply. However, the mean annual white shrimp landings of 31.5 million lb in 1956-74 still made up 27% of the total U.S. gulf shrimp production.

The white shrimp is not only highly valued for human food, but is also a popular bait for hook and line fishermen and a major prey of predatory fishes. In 1976 in the United States, more than 90,000 commercial and sport fishermen used about 60,000 boats and vessels to fish for seven species of shrimp (Christmas and Etzold 1977).

The major problem of the fishing industry is getting maximum yield from each year's shrimp stock, which consists largely of shrimp that are less than 1 year old. In Louisiana, for example, excessive fishing for small young white shrimp is controlled by banning commercial fishing for shrimp each spring until the shrimp reach a certain size (based on average numbers per pound).

The annual level of recruitment appears to depend largely on environmental conditions, rather than on the abundance of spawning stocks. Shrimp management will succeed only if appropriate measures are taken to maintain suitable estuarine nursery grounds (Christmas and Etzold 1977).

LIFE HISTORY

Spawning and Larvae

Various localities and times for spawning of white shrimp have been reported: in oceanic waters 3 to 31 m deep in the northern Gulf of Mexico (Pérez-Farfante 1969); in similarly oceanic waters of the Gulf of Mexico with depths of 9.1 to 55 m, from late spring to early fall (St. Amant and Lindner 1966); from late March or early April until November, but mainly from April to September in Louisiana (Lindner and Anderson 1956); from April to August in shallow water (14 m) near Galveston, Texas (Temple and Fischer 1967). Although spawning usually peaks in June or July, length-frequency distribution of shrimp in commercial catches suggested two main broods developed in some locations and three in others (Pérez-Farfante 1969).

Spawning begins when water temperatures increase in the spring and ends with rapid temperature declines in fall (Lindner and Anderson 1956). On the basis of low percentages of spent females in the populations in June, July, and August, Lindner and Anderson (1956) suggested that white shrimp spawn more than once--and possibly up to four times--during their life span.

Preferred salinities for spawning of at least 27 parts per thousand (ppt) were reported by Cook and Murphy (1969).

Sexes are easily distinguished by the modified endopod of the first pair of pleopods in males and the open-type thelycum between the third, fourth, and fifth pereiopods in females (Lindner and Cook 1970). Two partly fused ovaries extend most of the length of the body and, when ripe, occupy nearly all space not filled by other organs. Copulation takes place while the shrimp are in the hard-shelled form, when the male attaches a spermatophore to the thelycum of the female. Spermatozoa are believed to be released from the spermatophore simultaneously with the expulsion of the eggs. However, in a study by Pérez-Farfante (1969), females without a spermatophore spawned eggs that hatched and yielded larvae that were reared to subadults; from 0.5 to 1.0 million eggs were discharged per spawn. Ripe eggs are 0.192 to 0.3 mm in diameter, are spherical and opaque, and have a purplish-blue chorion. Eggs are discharged directly into the water and sink to the bottom (Anderson 1966). Spawning in laboratory aquaria occurred only at night (Lindner and Cook 1970).

Eggs hatch into planktonic nauplii 0.3 mm long within 10 to 12 hr after fertilization (Klima et al. 1982). The nonfeeding nauplii are carried by prevailing currents while they undergo five molts over 24 to 36 hr to become free-feeding protozoea, 1 mm long (Anderson 1966). Five nauplial, three protozoeal, and three mysis stages, followed by the first mastigopus or first postlarval stage, were reported by Pérez-Farfante (1969). Johnson and Fielding (1956) wrote that the metamorphic period exceeded 10 to 12 days, depending on food and habitat conditions. Subrahmayam (1971) reported that white shrimp larvae live throughout the water column.

<u>Postlarvae and Juveniles</u>

Early planktonic postlarvae develop offshore, but some move toward inshore waters. Anderson (1966) wrote that shrimp are still planktonic at the end of two postlarval stages, about 15 to 20 days after hatching when they are about 5 mm long; however, Williams (1965) reported that white shrimp enter estuaries during the second postlarval stage, at about 7 mm, and then begin a benthic existence. The time between hatching and movement to estuaries is about 2 to 3 weeks.

Favorable currents transport larvae and early postlarvae toward inshore waters (Pérez-Farfante 1969), where they enter the estuaries on flood tides through tidal passes (Benson 1932). Recruitment of postlarvae in Louisiana coincided with the influx of water of higher salinity (White and Boudreaux 1977). In Texas, white shrimp postlarvae entered estuarine nursery areas from May until November, the peak being in June and September (Klima et al. 1982). St. Amant and Lindner (1966) indicated that white shrimp postlarvae enter inshore nursery areas from mid-April to mid-November; peak abundance is in May to July and again in September and October. Baxter and Renfro (1967) found two peak movements of postlarvae into Galveston Bay, Texas, during summer.

Duronslet et al. (1972) reported that postlarval white shrimp were more abundant at night at the surface than at the bottom of a tidal pass. They found no significant depth differences during daylight sampling, although abundance was lowest near the surface (0.8 m deep).

Christmas et al. (1976) classified shrimp 25 to 75 mm as juveniles, but Pérez-Farfante (1969) considered white shrimp to be juveniles after they had developed according to the ultimate rostral tooth formula: 4 to 10 upper and 0 to 3 lower (mode: 8 upper and 2 lower). Freshly caught white shrimp often have widely spaced body chromatophores; thus, they are lighter colored than pink or brown shrimp. When the shrimp are 28 mm long, sexes can be distinguished by differences in the endopods of the first pleopods and in sternite XIV.

Peak abundance of juvenile white shrimp occurs in shallow marshes of Louisiana 1 to 2 months after maximum catches of postlarvae (Gaidry and White 1973). On the nursery grounds, juvenile white shrimp move farther up the estuary than do juvenile brown or pink shrimp--as far as 160 km in Louisiana and 210 km in northeast Florida (Pérez-Farfante 1969). Williams (1958), who evaluated the use of experimental substrates by juveniles of three shrimp species, found white shrimp predominately over or in muddy substrates of loose peat and sandy mud; white shrimp laid their long antennae above the surface substrate when burrowing, in contrast to brown and pink shrimp, which often buried their shorter antennae. Williams (1958) speculated that respiratory requirements of white shrimp while they burrowed and sought cover and food influenced their preference for muddy or peaty substrate. Juvenile white and brown shrimp tended to avoid coarse substrate and sought food rather than cover in softer bottoms (Williams 1958). Shrimp about 8 mm long were found in shallow, muddy bottom waters with low to moderate salinity (Anderson 1966). Rulifson (1981) found that juvenile white shrimp aggregated in sandy-muddy substrate but that brown shrimp sometimes displaced them in this habitat. Giles and Zamora (1973) reported that brown shrimp displaced juvenile white shrimp from grass cover in experimental aquaria.

White shrimp are usually more active than brown or pink shrimp. Clark and Caillouet (1975) observed significantly higher trawl catches of juvenile white shrimp (35 to 97 mm long) during the day than at night in Galveston Bay, Texas. Wickham and Minkler (1975) did not observe white shrimp burrowing, but found they were quiescent on the substrate or in shallow depressions for several hours during the day.

The growth of juvenile white shrimp varies by size, sex, location, season of the year, and year (Pérez-Farfante 1969). Usually growth is slow at water temperatures below 20°C (Etzold and Christmas 1977).

Postlarvae and juveniles use estuaries during summer and fall until they reach market sizes of 120 to 160 mm long (Klima et al. 1982). Juvenile white shrimp occupied the extreme shoreward waters in Mobile Bay, Alabama (Loesch 1976). Open coastal lakes and bays may serve as staging areas for juveniles before they move offshore (White and Boudreaux 1977). Anderson reported that as juveniles grew, they moved from shallow marshes into deeper creeks, rivers, and bays when they were about 51 mm long in June or July (Anderson 1966). White shrimp become abundant on the inshore fishing grounds by mid-June in Louisiana, Mississippi, and Alabama, and by mid-July in Texas and west Florida (Collier et al. 1959). Sampling in Alabama in 1977-82 indicated peak abundance in July (Steve Heath, Marine Biologist, Alabama Marine Resources; pers. commu., May 16, 1983). Anderson

(1966) noted that white shrimp began to appear on nearshore shrimping grounds by July or August; the largest shrimp were nearest the open gulf.

Emigration

White shrimp emigration from estuaries appears to be governed by the size of the shrimp and the environmental conditions within the estuarine system (Klima et al. 1982).

When white shrimp reach 120 to 140 mm (St. Amant and Lindner 1966) or 100 to 120 mm (Etzold and Christmas 1977), they leave Gulf of Mexico estuaries as waters cool from September to December. However, small white shrimp may emigrate to offshore waters temporarily in winter and return to estuaries when water temperatures rise. Emigration in Texas estuaries usually extends from late August and September to December--the period during which the offshore commercial fishery exploits white shrimp (Klima et al. 1982). Peaks of white shrimp emigration from Galveston Bay, Texas, were correlated closely with decreases in water temperature of 3° to 6°C and in salinity of 3 to 10 ppt (Pullen and Trent 1969). Benson (1982) reported that white shrimp moving near the surface at night tended to school during ebbing tides. Offshore movements of white shrimp seem to consist of random feeding movements of 160 km or more, as well as some inshore-offshore movements in response to temperature changes (Etzold and Christmas 1977). Cold fronts increase movement from inshore staging areas to offshore waters (White and Boudreaux 1977). White shrimp along most of the Gulf of Mexico coast exhibit little alongshore movement except in lower Texas, where they may move into Mexican waters in fall and winter, and back toward Texas waters in summer (Etzold and Christmas 1977). White shrimp, 100 mm long, overwintering offshore between Ship Shoal and Trinity Shoal, Louisiana, return in spring to form a valuable spring inshore fishery (Gaidry 1974).

Adults

Male white shrimp have been found at progressive stages of maturity at different lengths: with joined petasmal endopods at 105-127 mm; with ripe sperm at 118 mm; and with fully developed spermatophores at 155 mm (Pérez-Farfante 1969). The shortest ripe female recorded by Burkenroad (1939) measured 135 mm; St. Amant and Lindner (1966) listed 140 mm as the minimum length of females spawning in the northern Gulf of Mexico.

In the northeastern Gulf of Mexico, white shrimp moved during fall and winter into deeper water and toward the mouth of the Mississippi River (Pérez-Farfante 1969). Anderson (1966) concluded from tagging studies that the Mississippi River outflow may be a natural barrier to east-west movements of white shrimp.

GROWTH

Growth rates of white shrimp vary with size, sex, and time of year (Pérez-Farfante 1969). Kutkuhn (1962) reported that growth rates were slower in coastal waters east of the Mississippi River than off the northwestern coast of the Gulf of Mexico. The difference in growth rates delayed the peak offshore harvest about a month (from October to November). Rate of growth in weight, as contrasted to growth in length, was low in small shrimp, highest in mid-size shrimp, and intermediate in large shrimp. Population growth was dynamic and difficult to predict from year to year.

White shrimp nauplii undergo five molts to become free-feeding planktonic protozoea. Protozoea grow to a length of 2.5 mm through three protozoeal stages before reaching the first mysis stage (Dobkin 1961). After three mysis stages and two postlarval stages, young white shrimp about 7 mm long enter estuaries, where their growth rate is about 1.2 mm per day (Williams 1965). Johnson and Fielding (1956) estimated growth in captivity after hatching to be 80 mm in 2 months. Early spring growth is nearly identical to the previous summer's growth rate of 18 to 30 mm per month. Winter growth of shrimp offshore probably averages less than 0.5 mm per day (Christmas and Etzold 1977). In Mobile Bay, Alabama, Loesch (1965) found that shrimp length increased 18 to 31 mm during the summer compared with 12 to 27 mm in winter.

White shrimp in Louisiana may reach a length of 150 mm, growing about 100 mm in 60 days (1.6 mm per day) during summer before moving offshore (White and Boudreaux 1977). Marked white shrimp in Galveston Bay, Texas, grew from a length of 9.8 mm in mid-August to 146 mm in late September (6 weeks), or about 30% faster than reported in lower temperature waters along the Louisiana coast (Klima 1974). In the Gulf of Mexico, lengths attained by white shrimp at different intervals after hatching were 80 mm in 2 months, 110 mm in 3 months, 130 mm in 4 months, 145 mm in 5 months, and 155 mm in 6 months (November). Growth was slow from November through March, but resumed in spring; white shrimp were 173 mm long in May and ready to spawn (Anderson 1966).

The length-weight formula $W = aL^b$, where W is weight (g), L is total length (mm), and a and b are constants, for white shrimp differed little between sexes: male, $\text{Log } W = -5.694 + 3.261 \text{ Log } L$; female, $\text{Log } W = -5.635 + 3.234 \text{ Log } L$; and combined sexes, $\text{Log } W = -5.665 + 3.247 \text{ Log } L$ (Fontaine and Neal 1971). The slope ("b") was not significantly different in the three formulas. Christmas et al. (1976) calculated length-weight relations for white shrimp 30 to 104 mm long as $Y = -4.8049 + 2.8180 X_{TL}$ and for shrimp 105 to 199 mm long as $Y = -5.73 + 3.283 X_{TL}$; where Y was weight (g) and X was total length.

Female white shrimp grow more rapidly and reach larger sizes than males (Etzold and Christmas 1977). Anderson (1966) listed a large male at 182 mm and a female at 197 mm in the Carolinas, and Holthuis (1980) listed 175 and 200 mm as maximum total lengths for males and females respectively. On the basis of the growth of marked and recaptured shrimp, Klima (1974) estimated average maximum length for white shrimp as 214 mm in Galveston Bay, Texas, and 224 mm in nearshore Louisiana.

Mortality

The yearly abundance of white shrimp varies widely (Anderson 1966; Christmas and Etzold 1977). Gunter (1956) considered 40% mortality per week or up to 60% mortality a month to be a reasonable estimate for juveniles in estuaries. Offshore mortality of eggs and larvae is probably higher. Christmas and Etzold (1977) stated that information on mortality is inadequate to determine optimal harvest outside the nursery grounds. They reported that weekly fishing mortality was 6% to 17%, natural mortality was 8% to 24%, and total weekly mortality ranged from 14% to 24%.

Mortality rates of white shrimp probably decrease with an increase in size (Christmas and Etzold 1977). A problem in Louisiana has been the high catch of relatively small white shrimp in inshore and estuarine waters (White and Boudreaux 1977). Recommended is a closure of the inshore nursery grounds (largely estuaries) to trawling to decrease the mortality of the smaller white shrimp before they migrate offshore. Estimated catches offshore are closely related to the inshore abundance of juveniles (St. Amant and Linder 1966; Loesch 1976).

Because recruitment of shrimp into the fishery in any one year is independent of the abundance of parent stocks the year before (environmental conditions are the major factor), management should be aimed at maximizing recruitment into the fishery (Christmas and Etzold 1977). Because few shrimp live longer than 1 year (Anderson 1956; Klima et al. 1982), the bulk of the shrimp in the commercial catch is less than 1 year old (Etzold and Christmas 1977).

Hurricanes have been implicated in major summer losses of white shrimp. Kutkuhn (1962) showed that hurricanes striking the Louisiana coast in summer 1957 caused unexpectedly high mortalities because of higher salinities, destruction of habitat and food supplies, dispersal and stranding, and excessive turbulence. Barrett and Gillespie (1973) reported a 61% drop in the Louisiana white shrimp catch in 1961 after Hurricane Carla and an 88% drop in the August 1969 production in Mississippi after Hurricane Camille. Sudden cold fronts also have caused high mortality of white shrimp in shallow estuaries and coastal waters.

Disease and Parasites

The extent of mortality from disease and pollution is not well known (Barrett and Gillespie 1973). A 99% loss of eggs to a microsporidian parasite infection of the gonads was reported by Gunter (1956). Middleditch et al. (1980) reported that a *Vibrio* infection of male white shrimp prevented fertilization under laboratory conditions. Extensive reviews of diseases and parasites of penaeid shrimp have shown that viruses, bacteria, fungi, protozoa, helminths, and nematodes cause diseases (Lindner and Cook 1970; Couch 1978; Overstreet 1978). Couch (1978) ranked disease after predation and periodic physical catastrophes as a limiting factor in nature and after the meeting of nutritional and reproduction requirements in mariculture. Overstreet (1978) suggested that shrimp mortality attributed to low oxygen may be caused by biosymbionts in shrimp.

The cestode *Prochistanella penaei*, which infects the hepatopancreas of adult shrimp, is of concern in the Mississippi Sound (Christmas et al. 1976), but microsporidian protozoans probably have more economic impact because they cause the musculature of the shrimp to appear cottony.

THE FISHERY

The Gulf of Mexico shrimp fishery is the most valuable commercial fishery in the United States. In 1980, the catch of 129 million pounds was valued at over $302 million (National Marine Fisheries Service 1981). Blomo et al. (1978) reported that Gulf of Mexico shrimp landings in 1976 composed 83% of the total value of the U.S. shrimp landings and 20.3% of the total value of all U.S. commercial fisheries.

Commercial production of white shrimp has increased greatly over the years. Before 1902, less than 12 million lb of shrimp were landed annually in the northern Gulf of Mexico (Barrett and Gillespie 1975). From 1880 through 1918, the annual white shrimp catch averaged 172,000 lb along the Texas coast and 5.9 million lb off the Louisiana coast (Klima et al. 1982). Cast nets and haul seines were the principal gears until the otter trawl was introduced in 1917 (Gunter and Edwards 1969). In 1927, the catch was 7.4 million lb in Texas and 26 million lb in Louisiana. From 1927 to 1945, annual landings (primarily white shrimp) averaged 7.8 million lb in Texas and 40.5 million lb in Louisiana. Brown and pink shrimp were not marketed before about 1945 because the public objected to their dark coloration, but the stigma did not last long.

In the late 1940's, large concentrations of brown and pink shrimp were discovered in the gulf off the Texas and Florida coasts. With public acceptance of these species in the markets, intensive fishing began in the 1950's. When the U.S. Bureau of Commercial Fisheries began to record catch statistics for the entire Gulf of Mexico in 1956 (Klima et al. 1982), the pink and brown shrimp catch made up only 8% of the total shrimp landings in Texas and 2% of the landings on the western Florida gulf coast. From 1965 to 1975, brown and pink shrimp made up 71% of the Gulf of Mexico's average annual shrimp catch of 127 million lb, but white shrimp made up only 27% of the landings (Barrett and Ralph 1977).

To facilitate the recording of commercial shrimp landings, Barrett and Gillespie (1975) divided the Gulf of Mexico coastline into five areas (Figure 2): (1) Key West to Sanibel, Florida; (2) Sanibel to Pensacola, Florida; (3) Pensacola to Mississippi River; (4) Mississippi River to Texas, and (5) Texas coast. They reported that the average annual catch of white shrimp in 1958-72 was less than 1 million lb in area 1, over 1 million lb in area 2, over 3 million lb in area 3, over 19 million lb in area 4, and over 7 million lb in area 5.

In 1965-76, white shrimp landings as a percentage of total shrimp catches varied in five areas along the gulf coast as follows: Apalachicola, Florida, 0.7%; Pensacola to Mississippi Sound, 1.6%; Louisiana, 23%; Texas, 9.5%; and western Mexico, 0.1% (Barrett and Ralph 1977). Matthews (1982) reported that 18% of the white shrimp catch for 1981 in Texas was in offshore waters. The Louisiana fishery consisted primarily (81%) of small white shrimp (68 or more per pound); the highest catch (26%) came from inshore waters of Terrebonne and Timbalier Bays. Catches of small white shrimp were highest (13.4% of gulf total) offshore from Vermilion Bay, Louisiana. White shrimp caught in this area may be migrants from inshore water in the Golden Meadow area of Louisiana (Barrett and Ralph 1977). From 1965 to 1975, the average percentages of total white shrimp catches in the Gulf of Mexico that were contributed by different areas were as follows: inshore near Golden Meadow waters, 10.6%; offshore waters near Vermilion Bay, 14.3%; the offshore waters south of Pecan Island, Louisiana, 9.5%; and offshore waters off Cameron, Louisiana, 8.7% (Barrett and Ralph 1977).

Inshore and offshore white shrimp landings for Louisiana show good direct correlation (White and Boudreaux 1977). Barrett and Gillespie (1975) reported a high positive correlation between catch and rainfall in Texas but a negative correlation in Louisiana. The differences were related to differing characteristics of freshwater inflow into estuarine nursery grounds in the two regions.

Production of white shrimp exceeds that of brown shrimp in Louisiana's estuaries near the Pearl, Mississippi, Atchafalaya, Calcasieu, and Sabine Rivers (Barrett and Gillespie 1973). If one uses the 91-m depth as Louisiana's offshore shrimping boundary (Barrett and Gillespie 1973), there are 15.27 million surface acres offshore and 3.43 million surface acres inshore. As judged by 1967-72 shrimp landings, Louisiana's estuaries annually produced at least 20.2 lb of shrimp per acre, of which 7.3 lb (36%) were white shrimp. Estimates of white shrimp catch varied from 14.8 lb per acre south of Golden Meadow, Louisiana, to 0.04 lb per acre in Lake Pontchartrain, Louisiana.

The management of shrimp fisheries in the Gulf of Mexico Fishery Conservation Zone was described in the Shrimp/Fishery Management Plan implemented by the U.S. Secretary of Commerce (Jones et al. 1982). The five Gulf States establish regulations governing the white shrimp fishery within their territorial waters. The goal is to protect the resource and yet maximize catches by the various user groups (Etzold and Christmas

1977). Shrimp seasons are established on the basis of inshore shrimp surveys that indicate the expected sizes, locations, and abundances of shrimp species using nurseries and moving between inshore and offshore shrimping grounds. Minimum sizes have been established in some states to decrease fishing pressure on juveniles. Bottom trawls are the basic gear used by commercial, noncommercial or sport, and bait shrimp fisheries (Christmas and Etzold 1977). Juneau and Pollard (1981) found that sport shrimpers exerted 55% of the total fishing effort and landed 44% of the white shrimp harvested from Vermilion Bay, Louisiana, from October 1977 through September 1979.

The bait shrimp fishery for penaeid shrimp on the inshore nursery grounds is an important industry (Christmas et al. 1976): 22,200 lb were sold in Alabama in 1968; 60,317 lb were taken in 7 months in Mississippi in 1971; and 676,000 lb were taken per year in Galveston Bay, Texas. Live and dead shrimp were the major bait used by anglers at a warm-water discharge in Galveston Bay, Texas (Landry and Strawn 1973). The market value of the bait shrimp taken in Mississippi was 3 times the value it would have had if sold for human food. In 1955, an estimated 59 million bait shrimp were taken by the bait shrimp fishery along northeast Florida (Christmas et al. 1976).

ECOLOGICAL ROLE

Larval penaeid shrimp feed on zooplankton and phytoplankton. Dobkin (1961) reported that <u>Penaeus</u> protozoea fed on green algae, diatoms, and copepods. Cook and Murphy (1969) used cultured algae to feed protozoea and newly hatched brine shrimp to feed the mysis stages. Christmas and Etzold (1977) reported that early stages of <u>Penaeus</u> larvae fed on plankton and suspended detritus. Brown shrimp feed at the vegetation-water interface, ingesting the top layer of sediment containing detritus, algae, and microorganisms (Lassuy 1983). Fecal pellets can be an important food of juvenile shrimp.

Both juvenile and adult white shrimp are omnivorous, and the primary differences in food selection are the nature and location of the food selected. Lindner and Cook (1970) concluded that white shrimp were selective and particulate feeders. In summarizing three studies of gut contents, Christmas and Etzold (1977) reported that major food items included detritus, chitin, parts of annelids and gastropods, fish parts, bryozoans, sponges, corals, filaments of algae, and vascular plant stems and roots; lipids supplied by annelids are believed to be important for ovarian maturation (Middleditch et al. 1980); cannibalism is common among juveniles and adults (Pérez-Farfante 1969); and shrimp body fatty acids are influenced by diet in the seasonal food chains (Bottino et al. 1980). Although Brown (1977) reported food conversion ratios of 1.3 and 1.9 for white shrimp fed in two marine ponds at Marifarms, Inc., Panama City, Florida, Bardach et al. (1972) cited production of only 1 kg of cultured Japanese (Kuruma) shrimp per 10 to 15 kg of feed at optimum 25°C temperature--leading to the suggestion that the carnivorous nature of shrimp and great energy loss in molting guarantee inefficient food conversions. In a 204-day energy budget calculated for brown shrimp grown from 12.5 to 127 mm, Erahim (1973) showed that about 26.4% of the energy was used for egestion, 34.5% for respiration, 20.5% for growth, and only 3.9% for shedding exoskeleton. Brown shrimp were capable of using 44% of the organic carbon in test foods.

White shrimp are an important food for many marine and estuarine fish (Gunter 1956; Pérez-Farfante 1969; Lindner and Cook 1970; Benson 1982). Carr and Adams (1973) reported larval and juvenile shrimp to be important food for 13 of 21 juvenile fishes occupying seagrass beds in the Florida estuaries of the Gulf of Mexico.

White shrimp recycle basic nutrients by feeding on organic matter and microorganisms in sediments (Odum 1971; Carr and Adams 1973). When water temperatures and salinities were favorable along the Louisiana coast, shrimp abundances were greatest in waters where substrates had the highest organic content (Barrett and Gillespie 1973; Gaidry 1974). Investigators have suggested that juveniles, which tolerate relatively low salinity, migrate up estuaries to reduce the effects of competition and predation, besides gaining access to an abundant food supply (Hedgpeth 1963; Gunter 1967).

ENVIRONMENTAL REQUIREMENTS

Temperature

Water temperature helps regulate the times and locations of white shrimp spawning, as well as rate of growth, habitat selection, osmoregulation, movement, and mortality. Sudden water temperature increases in spring trigger spawning, and rapid temperature declines in the fall are associated with the end of spawning (Lindner and Anderson 1956). The growth rate is highest in summer and becomes slow or negligible in winter. Increased temperature may increase the rate of molting, but not necessarily the size at molting (Pérez-Farfante 1969). Turner (1977) showed good correlation between heating-degree-days and catch/effort ratio for penaeid shrimp, which was similar to correlations between yield-per-hectare and latitude of penaeids. St. Amant and Lindner (1966) reported that water temperatures below 20°C greatly inhibited growth, which became practically nil at 16°C. Growth rates increased rapidly at temperatures above 20°C. Zein-Eldin (1964) stated that temperature and food supply limited growth of white shrimp postlarvae more than did salinities between 2 and 35 ppt.

White shrimp have been reported to be more tolerant of high temperatures and less tolerant of low temperatures than either brown or pink shrimp (Etzold and Christmas 1977). Mortality of white shrimp was reported at water temperatures above 42°C and below 8°C and was complete at 3°C or less, regardless of salinities; survival at low temperatures seemingly depended on rate of temperature decline, the duration of low temperature, and salinity, as well as on the actual temperature (Joyce 1965). Wiesepape (1975) found 24-hr 50% mortality to be 36°C and 37°C for white shrimp acclimated at 29°C and 34°C, respectively. Postlarval and 30-mm juvenile white shrimp had somewhat higher resistance times than did 50-mm juveniles. Temperature tolerated by postlarvae were higher in brown shrimp than white shrimp.

Salinity

Adult white shrimp spawn offshore where salinities are at least 27 ppt. Larval shrimp are carried shoreward by currents until they enter estuaries on flood tides--usually when they are in the second postlarval stage. Juvenile white shrimp move as far as 160 km up tidal streams in Louisiana and up to 210 km into fresh water (0.26 ppt) in northeast Florida (Pérez-Farfante 1969). Juvenile shrimp were found 160 km upstream from 1.0-ppt salinity waters in St. Johns River, Florida, from July through November in 1962 and 1963 (Joyce 1965). Joyce suggested that high calcium ion concentrations in this river may explain the relative ease with which marine species enter and remain in low salinity waters. Pérez-Farfante (1969) reported 0.42 ppt as the lowest salinity in which white shrimp were recorded in the northern Gulf of Mexico. Although field studies have shown that juvenile white shrimp seem to prefer relatively low salinities, laboratory studies reveal that they appear indifferent to varying salinities since they have been reared successfully at 18 to 34 ppt salinities (Pérez-Farfante 1969).

Salinity is a contributory limiting factor to the distribution of juvenile white shrimp. Postlarval white shrimp were most abundant at 1 to 5-ppt salinities in Mobile Bay, Alabama, and at 5 to 10-ppt salinities in Texas (Gunter 1967). Small shrimp (15 - 66 mm long) did not fair well in 41-ppt salinity in the Laguna Madre, Texas (Gunter 1961).

Juvenile white shrimp in Louisiana overwinter in low salinity waters influenced by the Atchafalaya River (Gaidry 1974). White and Boudreaux (1977) concluded that high freshwater discharges during 1954 to 1974 significantly ($P<0.01$) reduced white shrimp production because larger juvenile populations developed in nursery habitats with salinities of 1 to 2-ppt.

In Texas coastal waters, a positive relationship between white shrimp production and increased rainfall has been attributed to a sharp increase in low salinity nursery areas. Annual white shrimp catches in waters off Texas from 1927 to 1964 showed a strong statistical correlation ($r = 0.656$) with rainfall of the one and two preceding years (Gunter and Edwards 1969). A high significant correlation ($r = 0.85$) between May-June freshwater inflow and white shrimp catches and commercial landings was demonstrated by Williamson (1977) in 1959 to 1975 in San Antonio Bay, Texas.

Temperature - Salinity Interactions

Temperature-salinity ranges for white shrimp vary at different life stages, but the interactions are more pronounced at the extremes of the tolerance ranges. Couch (1978) reported that a broken-back syndrome appears when sudden drops in salinity (from 15-18 ppt to 3 ppt) combine with cold water (8° C). Laney (1973) found critical thermal maxima for white shrimp to be influenced largely by acclimation temperatures, by the size or life stage of the test animal, and to a lesser extent by salinity. Freshwater inflow may reduce coastal water temperatures, which in turn affect growth rates of white shrimp (White and Boudreaux 1977). Barrett and Gillespie (1975) stated that higher rainfall and lower air temperature in late spring and summer affect distribution and reduce the size of white shrimp harvest, although the relation between white shrimp and water temperature is not well understood.

Substrate

As previously mentioned, white shrimp prefer shallow, muddy-bottom substrate. Production and catches along the Louisiana coast were highest in areas with substrate containing high organic matter (Barrett and Gillespie 1973; Gaidry 1974). Turner (1977) found good linear correlation ($R^2 = 0.69$) between intertidal land area and average annual shrimp catch along Louisiana's inshore waters. Correlation between brown shrimp catches and percentage of saline vegetation in Louisiana was highly significant ($R^2 = 0.92$). Inshore catches and numbers of hectares of vegetated estuaries in the northeastern Gulf of Mexico (Tampa Bay, Florida to Mobile Bay and Perdido Bay, Alabama) showed strong correlation ($R^2 = 0.64$). Lassuy (1983) suggested that temporal and spatial shifts by brown, white, and pink shrimp reduced direct competition for preferred substrate. White shrimp were reported to burrow less deeply than brown or pink shrimp into muddy substrates, and to be more active in daylight. Rulifson (1981) and Giles and Zamora (1973) found that brown shrimp displaced white shrimp from sandy-muddy substrate and grass cover. Benson (1982) indicated that postlarval juveniles and adults tolerate relatively high turbidities in estuaries. Kutkuhn (1966) reported higher concentrations of young shrimp in bays with more detritus in suspension. He suggested (Kutkuhn 1962) that excessive turbulence and related factors resulting from hurricane-induced high tides caused excessive inshore losses of white shrimp in Louisiana in summer 1957.

Other Environmental Requirements

The loss of nursery grounds has been considered the major threat to the Gulf of Mexico white shrimp fishery (Gunter 1956). Christmas and Etzold (1977) cited coastal studies in Florida, Louisiana, and Texas where major alterations or losses of estuarine shrimp nursery habitat resulted from dredging and spoil disposal, or impoundments. Biglane and LaFleur (1968) reported that man-made canals in Louisiana estuaries caused increased salinities and adversely affected white shrimp nursery waters. Christmas and Etzold (1977) suggested that the increases in salinities have caused shifts in dominance from white shrimp to brown shrimp along the central-northern gulf.

The effects of pesticides and pollution on shrimp populations along the gulf coast are also of concern (Biglane and LaFleur 1968; Christmas and Etzold 1977). Couch (1978) reviewed toxicity and biological effects on shrimp for large numbers of pesticides, heavy metals, petroleum products, and chemotherapeutic chemicals. Organochloride, organophosphate, and carbamate pesticides, as well as naphthalenes in petroleum, were toxic to shrimp. Cadmium killed gill cells, and accumulated mercury interfered with osmoregulation. Trent et al. (1976) found that mean experimental trawl catches of white shrimp dropped below seasonal averages when dissolved oxygen was below 3.0 ml/l in altered, eutrophic, upland canals associated with housing developments near West Bay, Texas. The maintenance or loss of nursery habitat will ultimately determine the future of gulf coast shrimp resources (Christmas and Etzold 1977).

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15. Supplementary Notes

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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 coastal aquatic species. They are prepared to assist in environmental impact assessment. The white shrimp, Penaeus setiferus, is the second most abundant species in the Gulf of Mexico shrimp fishery, the most valuable fishery in the United States. It serves as food for many fishes and is sold in the bait industry. Spawning occurs in at least 27 ppt salinity at water depths of 8 to 31 m, from April through September. Postlarvae move on flood tides into inshore estuarine nursery areas; peak abundances are in June and September. Juvenile white shrimp move farther inland than do brown shrimp and prefer shallow water with soft substrate. Growth of 1.6 mm per day occurs at water temperatures above 20°C before the shrimp move offshore when inshore waters begin to cool in fall. Juveniles and adults return inshore when water temperatures increase in fall or the following spring. Survival at 8° to 30°C was related to temperature and salinities. Juvenile and adult white shrimp are omnivorous, selective-particulate, benthic feeders. Population abundance has been correlated with coastal marshes and freshwater inflows. Maintaining suitable nursery grounds will decide the future of Gulf Coast white shrimp resources.

17. Document Analysis a. Descriptors

Estuaries Fishes

Growth Feeding

b. Identifiers/Open-Ended Terms

White Shrimp Life history

Penaeus setiferus Spawning

Temperature requirements Habitat requirements

c. COSATI Field/Group

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