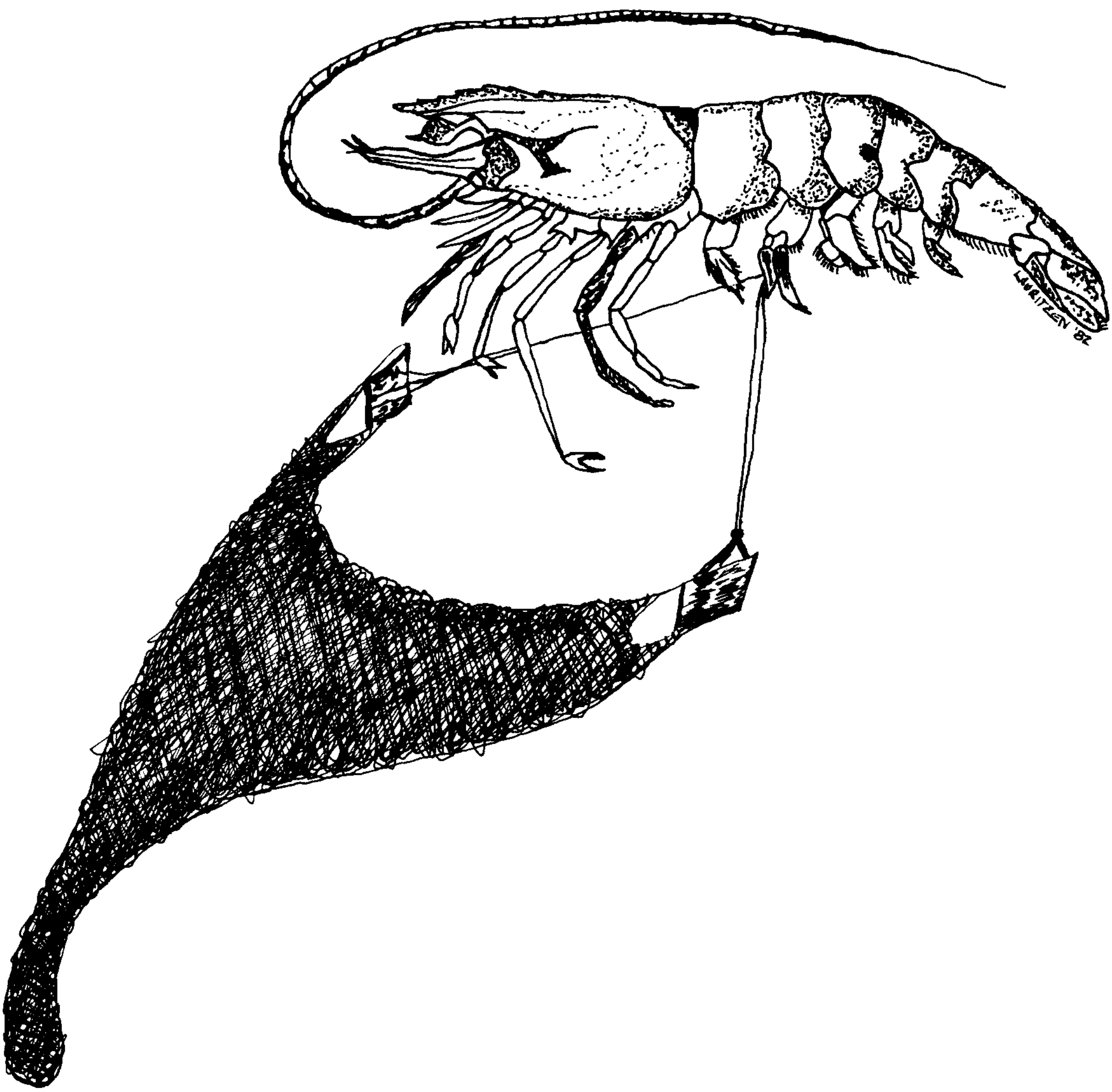
FWS/OBS-82/11.17
October 1983

TR EL-82-4

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

PINK 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 (South Florida)

PINK SHRIMP

by

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Vicksburg, MS 39180

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Research and Development
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This series should be referenced as follows:

U.S. Fish and Wildlife Service. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. U.S. Fish Wildl. Serv. FWS/OBS-82/11. U.S. Army Corps of Engineers, TR EL-82-4.

This profile should be cited as follows:

Bielsa, L. M., W. H. Murdich, and R. F. Labisky. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (south Florida) -- pink shrimp. U.S. Fish Wildl. Serv. FWS/OBS-82/11.17. U.S. Army Corps of Engineers, TR EL-82-4. 21 pp.

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.

A Habitat Suitability Index (HSI) model is being prepared by the U.S. Fish and Wildlife Service for the pink shrimp. HSI models are designed to provide a numerical index of the relative value of a given site as fish or wildlife habitat.

Suggestions or questions regarding this report should be directed to:

Information Transfer Specialist
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1010 Gause Boulevard
Slidell, LA 70458

or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER
Post Office Box 631
Vicksburg, MS 39180

CONTENTS

CONVERSION FACTORS

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 (mt)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	BTU
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
BTU	0.2520	kilocalories
Fahrenheit degrees	0.5556(F° - 32)	Celsius degrees

ACKNOWLEDGMENTS

We are grateful for the reviews by Dr. Edward Klima, National Marine Fisheries Service, Galveston, Texas, and by Mr. Thomas Costello, National Marine Fisheries Service, Miami, Florida.

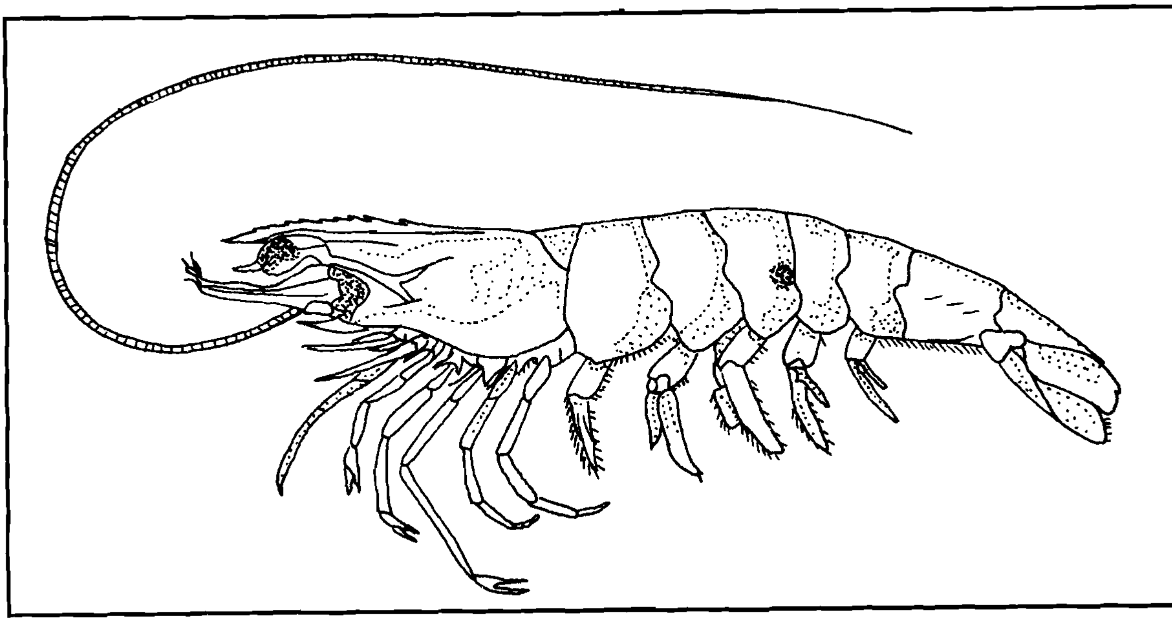

Figure 1. Pink shrimp.

PINK SHRIMP

NOMENCLATURE/TAXONOMY/RANGE

Scientific name. . . . Penaeus duorarum duorarum Burkenroad, 1939

Preferred common name. . . .Pink shrimp (Figure 1)

Other common names. . . Spotted shrimp, pink-spotted shrimp, brown-spotted shrimp, grooved shrimp, green shrimp, pink-night shrimp, red shrimp, hopper, skipper, pushed shrimp (Perez Farfante 1969)

Class. . . . . .Crustacea

Order. . . . . Decapoda

Family . . . . .Penaeidae

Geographic range: range extends from lower Chesapeake Bay to south Florida (including Bermuda) in the Atlantic Ocean, and into the Gulf of Mexico, terminating south of Cabo Catoche at Isla Mujeres, Mexico (Perez Farfante 1969). It is especially abundant in broad, shallow continental shelf areas, and in shallow bays and estuaries. Maximum densities are found in the eastern and southwestern Gulf of Mexico, along the Florida and Yucatan coasts, respectively (Costello and Allen 1970) (Figure 2).

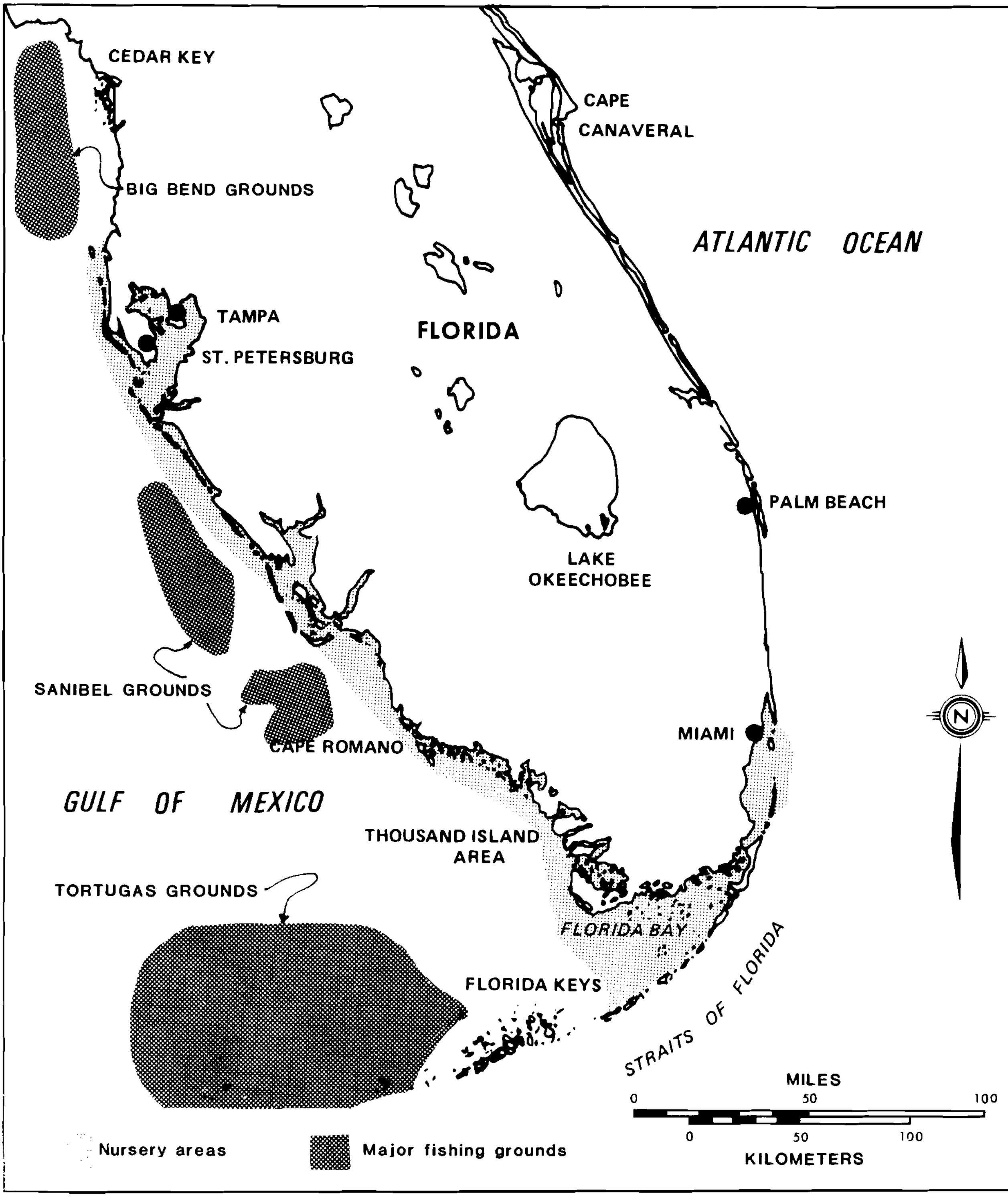

Figure 2. Geographic distribution of pink shrimp in south Florida.

MORPHOLOGY/IDENTIFICATION AIDS

Morphological Characteristics

Williams (1965) provided the following description: "Integument thin, polished, translucent. Carapace with a median carina continuous anteriorly with rostrum and extending nearly to posterior border of carapace, flanked on each side by a broad, rounded groove; posterior half of carina with a median longitudinal groove; anterior half arcuate, highest above orbit and with 9 or 10 sharp teeth; posterior tooth remote from others, anterior 6 or 7 on rostrum proper. Lower margin of rostrum [with] two to three teeth (occasionally one); tip slender, horizontal or directed slightly downward, unarmed. Anterior margin of carapace with strong antennal spine on carina extending backward nearly to well-developed hepatic spine. Cervical groove extending halfway from hepatic spine to dorsal carina. A subhorizontal suture below hepatic spine, and a groove extending from near hepatic spine to near base of ocular peduncle. An orbital ridge behind eye.

"Female with thelycum composed of two broad lateral plates, and a median plate. Posteromedian part of median plate of adult with a well-developed, short, longitudinal carina extending anteriorly toward roughly semicircular, concave anterior portion. Lateral plates produced medially to meet in midline, except variably divergent at anteromedian corners, thus exposing carina of median plates.

"Abdomen with segments four to six carinate, carina of sixth ending posteriorly in a spine and flanked on each side by a narrow groove. Telson with deep median groove and an acuminate tip. Petasma of male with distal ends of distoventral lobes curved medially, not projecting free of distolateral lobes; external edge of distoventral lobes with a series of 2 to 12, usually 4 to 7, small spinules; median or attached edge of distoventral lobes with a compact group of 5 to 16 large, long, sharp, curved spines; fold of distolateral lobe rather small and armed inconspicuously if at all."

Burkenroad (1939) divided the species into two forms: A and B. Williams (1965) and Perez Farfante (1969) equated form A with the subspecies _P. duorarum duorarum_ from the Atlantic and Gulf of Mexico, and the form B with _P. duorarum notialis_ from the Caribbean Sea, Atlantic Coast of South America and Africa. In form A, the dorsolateral grooves of the sixth abdominal segment are almost or entirely closed; in form B, the dorsolateral grooves of the sixth abdominal segments are broadly open (Williams 1965).

Color and Pigmentation

Color and pigmentation varies mainly with locality and age (Williams 1965). In coastal Florida and on the Tortugas grounds, shrimp colors range from deep pink and reddish to gray and brown (Perez Farfante 1969). Juveniles and young adults near coastal areas and estuaries are gray or reddish-brown. Adults from offshore waters range in color from red to pink to nearly white (Williams 1965). An abdominal spot (gray, blue, purple, red, or brown) is usually present at pleural juncture of third and fourth abdominal segments (Williams 1965; Perez Farfante 1969).

Size (Length)

Large males commonly reach about 170 mm total length (TL), and large females 210 mm TL (Williams 1965). Specimens have been reported as large as 230 mm TL (Iversen et al. 1960).

Morphological Differences Among Related Species

Morphological differences among the three related species of shrimp, pink, brown (*Penaeus aztecus*), and white (*P. setiferus*), were cited by Lassuy (1983):

Pink: Dorso-lateral grooves on last abdominal segment prominent and narrow; spot on juncture of third and fourth abdominal segments usually present.

Brown: Adrostral and postrostral crests long, extending almost to the posterior margin of carapace; gastro-frontal crests present; dorso-lateral grooves on last abdominal segment well-defined and broad; spot on juncture of third and fourth abdominal segment usually absent.

White: Length of adrostral grooves less than length of anterior half of carapace; postrostral crests poorly defined posteriorly and gastro-frontal crests absent.

Although all three species are found in Florida waters, the pink shrimp is by far the most prevalent species. The principal populations of brown and white shrimp are found off the Louisiana and Texas coasts, respectively (Gunter et al. 1964).

REASON FOR INCLUSION IN SERIES

The pink shrimp fishery is the most economically important of all fisheries in Florida. More than 17 million pounds of pink shrimp (heads off) were landed at Florida ports in 1981, providing a total exvessel value of over $45 million (Table 1). The total value of Florida's commercial fisheries in 1981 was approximately $172 million (National Marine Fisheries Service 1982); thus, the pink shrimp catch constituted 26% of the total dollar value derived from the State's commercial fisheries. Additional monetary value can be credited to pink shrimp taken in the extensive bait-fishing operations along both coasts.

Pink shrimp is also an important link in marine food chains. Its life cycle, distribution, and large biomass render the species vulnerable to diverse predators, many of them commercially or recreationally important species themselves. The over-harvest of pink shrimp would precipitate a decline in the abundance of the species. Hypothetically, such a decrease in biomass could, in turn, negatively affect the predatory species, thus altering the balance of the whole ecosystem (May et al. 1979).

Estuaries and other shallow coastal seagrass communities, which are at risk of development, are important nursery grounds for the species. Preservation of these habitats is essential for the development of shrimp through the early stages of their life cycle, and, consequently, for the continuation of harvestable shrimp populations.

LIFE HISTORY

Sexual Maturity

Females and males attain sexual maturity at 85 and 74 mm TL,

Table 1. Commercial landings (heads-off) in pounds and exvessel monetary values for pink shrimp from the east and west coasts of Florida, 1970-1981 (A. C. Jones, National Marine Fisheries Service, Miami, FL; pers. comm.).

	East coast		West coast	
Year	Pounds (1,000s)	Dollars (1,000s)	Pounds (1,000s)	Dollars (1,000s)
1970	2.9	2.9	14,527.7	11,411.4
1971	-- [a]	--	11,361.0	10,660.6
1972	--	--	12,155.4	14,988.3
1973	4.4	7.6	14,860.0	20,712.8
1974	3.8	9.4	14,865.8	18,928.7
1975	29.4	63.6	14,779.4	24,324.9
1976	8.8	28.6	13,593.8	31,367.2
1977	96.8	313.0	15,923.8	32,251.1
1978	52.2	164.6	14,738.4	30,580.4
1979	127.8	553.6	13,101.8	42,256.8
1980	109.2	488.8	12,110.9	32,541.3
1981	81.6	257.6	17,024.3	45,421.5

[a] Landings unavailable.

respectively (Eldred et al. 1961). Ripe females exhibit turgid and enlarged ovaries, with peripheral rod-like bodies in the ova; females may spawn more than once during their life (Cummings 1961). Mature males exhibit joined endopods, and spermatophores with spermatozoa (Eldred et al. 1961).

Spawning

Pink shrimp emigrate from shallow, coastal nursery grounds to deeper offshore waters in the late juvenile or early adult stage (Williams 1955a). Spawning occurs in oceanic waters at depths of 4 to 48 m (12 to 156 ft), and probably in deeper waters also (Perez Farfante 1969).

The species spawns throughout the year on the Tortugas Shelf at water depths between 15 and 48 m (49 and 157 ft). In late fall and winter, spawning activity shifts from shallow to deep water (within those depths where spawning takes place); this shift may be due to the movement of adult shrimp to deep waters when temperatures of shallow waters decrease (Munro et al. 1968). Larvae are more abundant during spring, summer and fall than during winter (Jones et al. 1970), indicating some seasonality of reproduction. Spawning on the Tortugas fishing grounds occurs mainly during the last phase of the lunar month (Munro et al. 1968). Eldred et al. (1965) found that rising temperatures were an important factor in triggering spawning, which occurs principally at water temperatures between 19.6° and 30.6°C (67.3° and 87.1°F) (Jones et al. 1970). The peak in spawning activity generally coincides with maximum bottom-water temperatures (Munro et al. 1968).

The eggs, approximately 0.23 to 0.33 mm in diameter (Eldred et al. 1965), are demersal (Ewald 1965). Coloration is generally an opaque yellow-brown, but the chorion may appear bluish under certain light reflections (Dobkin 1961). Ewald (1965) reported that eggs of pink shrimp spawned in the laboratory "...were visible to the naked eye and appeared like fine, white powder." The number of eggs produced per spawn is unknown, but a 172-mm TL white shrimp contained 860,000 (Anderson et al. 1949).

Larvae

Ewald (1965) found that laboratory-reared larvae exhibited five naupliar stages, three protozoeal stages, and two to five mysis stages. Under laboratory conditions, the duration of the larval development was 15 days in 26°C (79°F) water and 21 days in 21°C (70°F) water; shrimp underwent fewer mysis stages in the 26°C water than in the 21°C water (Ewald 1965). Approximately 870 x 10^{10} protozoeal larvae are produced yearly on the Tortugas grounds; survival rates averaged 80.4% per day (Munro et al. 1968). Peak abundance of larvae was found at water temperatures of 19°C (66°F) or greater (Eldred et al. 1965; Jones et al. 1970; Allen et al. 1980; Kennedy and Barber 1981).

The pelagic larvae are carried into the Florida Current from the Tortugas grounds by westerly and southwesterly currents; the Florida Current, in turn, transports the larvae to the nursery grounds in Everglades National Park (Munro et al. 1968). Jones et al. (1970) and Kennedy and Barber (1981) reported that larvae may use tidal currents to enter the estuarine nursery grounds.

Postlarvae

Postlarvae enter estuarine and coastal bay nursery areas at 8 mm TL (Copeland and Truitt 1966). Peaks of abundance occur in spring and late fall. The abundance of immigrating postlarvae increases with increasing velocity of flood tides (Tabb et al. 1962). Postlarvae become benthic at about 10 mm TL, and concentrate where habitat offering shelter is adequate (Costello and Allen 1970).

Juveniles and Adults

Pink shrimp spend from 2 to 6 months in nursery areas (Costello and Allen 1966). Activity patterns that may take place while shrimp remain in nursery areas have been observed under laboratory conditions by Wickham (1967), who reported that (1) a bimodal pattern of diurnal burrowing and nocturnal activity in juvenile pink shrimp was observed at full and new moons, and (2) the timing of nocturnal activity peaks corresponded with the normal tide progression in the area where the shrimp were captured. Wickham (1967) believed a circadian rhythm was responsible for the nocturnal activity because it repeated itself under constant light conditions. Costello and Allen (1970) indicated that burrowing was influenced also by type of substrate and lunar phase. Thus, activity patterns of pink shrimp in nurseries are probably a product of circadian rhythms and rhythmically-occurring environmental stimuli.

Joyce (1965) reported that pink shrimp attain a size of 95 to 100 mm TL prior to emigration from the nursery areas to offshore waters. However, most authors agree that this size is season- and area-dependent (Iversen and Idyll 1960; Eldred et al. 1961; Tabb et al. 1962). Emigration occurs year-round with a principal peak during fall and a lesser one during spring (Eldred et al. 1961; Huff and Cobb 1979; Kennedy and Barber 1981).

The greatest concentrations of adult shrimp are found between 9 and 44 m (29 and 144 ft) (Kutkuhn 1962), although some specimens have been found in Florida waters at depths of 110 m (360 ft) (Bureau of Commerical Fisheries 1962).

GROWTH AND MORTALITY

The growth rate of pink shrimp differs among the different stages of its life cycle; it is influenced also by sex and by water temperature (Iversen and Jones 1961). Dobkin (1961) and Ewald (1965) observed growth from 0.38 mm TL (nauplii) to 4.1 mm TL (postlarvae) in 2 to 3 weeks. Monthly growth rates for juveniles have been reported ranging from 7 to 52 mm (Williams 1955b; Eldred et al. 1961; Tabb et al. 1962). Monthly growth rates for sub-adult and adult shrimp are considerably less, ranging from 0 to 22 mm TL (Costello and Allen 1960; Iversen and Idyll 1960; Iversen and Jones 1961; Costello 1963; Knight 1966; Kutkuhn 1966).

Phares (*in* Nichols 1982), using von Bertalanffy procedures, developed growth parameters for pink shrimp in the eastern Gulf of Mexico: males, L_∞ = 173.3 mm and K = 0.2217, and females L_∞ = 182.2 mm and K = 0.2726 where L_∞ is the theoretical maximum length, and K is the monthly growth coefficient. The same study also provided the following total weight (W)/total length (TL) conversions:

$$W = 6.504 \times 10^{-6} \; TL^{3.0612}$$
for males and,

$$W = 6.247 \times 10^{-6} \; TL^{3.2896}$$
for females, where

W is expressed in g, and TL is expressed in mm.

The sex ratio of juvenile pink shrimp has been reported as 1:1 (Idyll 1964; Saloman 1965). However, Eldred et al. (1961) reported that differences in size of shrimp, geographic area and season often shifted the sex ratio from 1:1. In Tampa Bay, for example, females were slightly more common than males among shrimp less than 55 mm TL, males were more prevalent among shrimp between 55 mm and 85 mm TL, and females were again more numerous than males at sizes greater than 85 mm TL. In the Tortugas, males outnumbered females at all sizes below 100 mm TL; the sex ratio was about equal at 100 mm TL, but females were more prevalent than males at 105 mm TL and larger.

Seasonally, in the Tortugas, females were predominant from March to June and from September to December, but males were more abundant than females the rest of the year. In Tampa Bay, females were clearly more numerous than males from April to July and from September to December, whereas males were predominant only in January; the sex ratio was basically even for all remaining months (Eldred et al. 1961).

Pink shrimp become available to the bait fishery at about 6 weeks of age or 47 mm TL (Saloman 1965). Sexual maturity is attained at 9 or 10 weeks of age. Pink shrimp were first recruited into the Tortugas commercial fishery at 15 weeks, providing a fishable life span of 68 weeks (Kutkuhn 1966). Although average maximum age has been indicated as 83 weeks (Kutkuhn 1966), absolute maximum age may reach or exceed 2 years (Eldred et al. 1961).

The size composition of landed pink shrimp varies with habitat, season and time of day (Costello and Allen 1970). Small and immature shrimp inhabit shallow-water estuarine areas, whereas mature shrimp emigrate to deep offshore waters (Costello and Allen 1970). Shrimp harvested on the Tortugas grounds ranged from 49 to 230 mm TL (Iversen et al. 1960).

Mortality rates of harvestable shrimp from Florida waters varied substantially; total mortality (Z) coefficients ranged from about 0.10 to 0.36 (Table 2). The relative proportion of total mortality attributable to fishing mortality (F) varied similarly, ranging broadly between about 30% and 80%. Bi-weekly rates of fishing mortality were estimated at 6.8% and 13.1% on the Sanibel and Tortugas grounds, respectively, during the early 1960's (Costello and Allen 1968). Males seemingly exhibit higher mortality rates than females (Berry 1970).

THE FISHERY

The fishery for pink shrimp in the United States is concentrated along the central and southern coastal regions of the Gulf of Mexico. In Florida, gulf waters yield 99% and Atlantic waters 1% of the total annual landings of pink shrimp, which, in 1981, exceeded 17 million pounds (Table 1). Florida's two principal shrimping grounds in the gulf are located at the Tortugas and Sanibel (McPherson 1982; Figure 2).

Table 2. Instantaneous mortality coefficients for pink shrimp in Florida.

Area	F (Fishing)	M (Other)	Z (Total)	Source
Tortugas	0.16-0.23	0.02-0.06	0.22-0.27	Berry 1967
Sanibel	0.07	0.16	0.23	Costello and Allen 1968
Tortugas	0.14	0.22	0.36	Costello and Allen 1968
Tortugas	0.09	--	0.07-0.12 (♀) 0.10-0.16 (♂)	Berry 1970

The Tortugas grounds (approximately 10,000 km^2) contributed nearly half (48%) of the total state-wide catch of pink shrimp annually during the late 1970's and early 1980's. The high yield of shrimp from the Tortugas grounds is attributable to the proximity of the extensive Florida Bay nursery area. A most striking observation is that the Tortugas shrimping grounds were not discovered until 1949. The Sanibel grounds (approximately 2,000 km^2), which receive stock from the Charlotte Harbor-Pine Island Sound and Tampa Bay nurseries, yielded about 28% of the State's annual catch of pink shrimp.

The Big Bend fishery, which extends from Pasco County along the central-west coast to Franklin County in the Panhandle, produces about 20% of the annual landings of pink shrimp. This fishery is supported by Apalachicola Bay and nearby estuarine areas.

The size distribution of pink shrimp landed from the Tortugas grounds in the 1950's and early 1960's indicates that pink shrimp are fully recruited into the fishery at 120 mm TL (Figure 3). Recruitment of pink shrimp in the eastern Gulf of Mexico occurs year-round; the peak of recruitment, however, takes place in fall, with a secondary peak occurring in spring (Nichols 1982). Nichols also reported that whereas prerecruitment stocks in fall have increased during the past two decades, prerecruitment stocks in spring have remained relatively stable. Adequate stock recruitment of pink shrimp on Florida's fishing grounds, however, may be at risk in future years if the critically important estuarine-nursery areas are degraded by the developmental processes associated with the State's rapidly expanding human population.

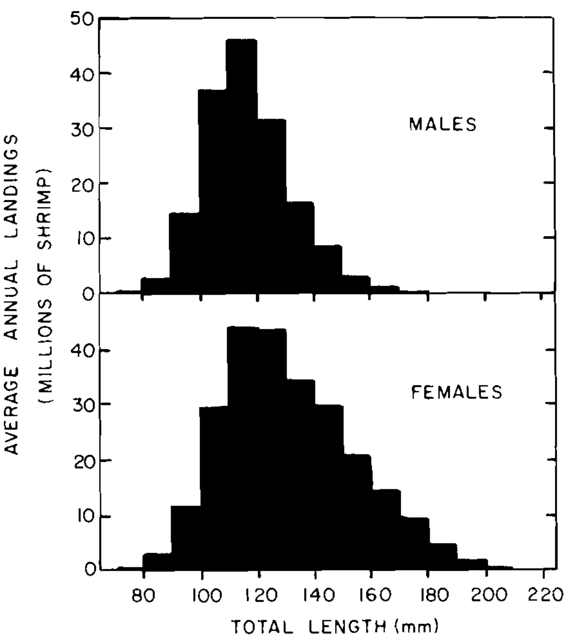

Figure 3. Calculated mean annual length distributions for male and female Penaeus duorarum, Tortugas grounds, Florida, 1956-65 (from Berry 1970).

Commercial shrimpers use basically the same fishing gear and methods, with local modifications, throughout the Gulf of Mexico. Vessels range in size from about 15 to 26 m (50 to 85 ft). The newer boats have either steel or fiberglass hulls and are usually diesel powered. Although some fishermen still prefer to pack their catch in ice, most now utilize freezers because of the increased length of fishing trips and ever-rising ice prices.

The standard commercial shrimp net is the otter trawl. These funnel-shaped nets are weighted along the bottom and have a row of floats along the top to keep the mouth of the net open. A large, metal-rimmed wooden "otter" board or trawl "door" is attached to each side or "wing" of the net to help spread the net (Dumont and Sundstrom 1961). Standard shrimp otter trawls have a spread of about 13.7 m (45 ft), and have a mesh size of 45 mm (1.75 inches). Most of the trawling for pink shrimp in Florida waters is conducted at water depths between 7 and 37 m (30 and 120 ft).

Otter trawls are commonly "double rigged," with one net towed from an outrigger on each side of the vessel. Often, "twin rigs" are used, wherein two trawls are towed from each side. These rigs are usually fished for 2 to 3 hours at a time. A much smaller "try" net of the same mesh size is fished concurrently. This net is brought on board much more frequently, and its contents are used as an estimate of the catch in the larger nets (D. A. Emiliani, National Marine Fisheries Service, Galveston, TX; pers. comm.).

ECOLOGICAL ROLE

Pink shrimp function as omnivorous consumers (predators) in estuarine and marine ecosystems, preferring benthic prey. Juveniles and young adults in estuarine habitats forage along the bottom in shallow-water grass beds. Foraging occurs mainly at night, although some takes place during the day, particularly in turbid water. Seasonally, feeding activity peaks during the summer (Costello and Allen 1970).

The food habits of the predatory pink shrimp change as it progresses through the various stages of its life cycle. Laboratory-reared larvae feed on microplankton; advanced larvae and postlarvae feed on nauplii as well as microplankton cultures (Ewald 1965). In Tampa Bay, the diet of juvenile pink shrimp included dinoflagellates, foraminiferans, nematodes, polychaetes, ostracods, copepods, mysids, isopods, amphipods, caridean shrimps, caridean eggs, and mollusks; sand, debris, algae, diatoms, seagrass, and fish scales have also been found in shrimp digestive tracts (Eldred et al. 1961). Although food habits of adult pink shrimp are not known in detail, Williams (1955a) reported that stomachs of young adult and adult pink shrimp in North Carolina estuaries contained foraminiferans, gastropod shells, squid, annelids, crustaceans, small fishes, plant material, and debris.

Pink shrimp are a major prey species to a wide variety of fish. Inshore species, such as snook (*Centropomus undecimalis*) (Marshall 1958), spotted seatrout (*Cynoscion nebulosus*) (Tabb 1961), and mangrove or gray snapper (*Lutjanus griseus*), feed heavily on pink shrimp. Pearson (1929) found that 61% of the spotted seatrout in coastal waters of Texas had eaten shrimp exclusively. Shrimp were the second most abundant food item taken by snook in southwestern Florida (Marshall 1958). Forty-two percent of the mangrove snapper stomachs from Everglades Park contained pink shrimp (Croker 1960).

Reef species, such as mutton snapper (*Lutjanus analis*), red grouper (*Epinephelus morio*), black grouper (*Mycteroperca bonaci*), and even pelagic king mackerel (*Scomberomorus cavalla*), are all predators of pink shrimp (Costello and Allen 1962, 1970). Pink shrimp have also been found in the stomachs of bottle-nosed dolphins (*Tursiops truncatus*) (Gunter 1951) and striped dolphins (*Stenella coeruleoalba*) (Miyazaki et al. 1973).

A variety of birds also utilize shrimp as a food resource to some extent. Wading birds are opportunistic feeders, and take shrimp in coastal areas (Bent 1926). Seabirds commonly forage in mixed-species flocks to feed on concentrations of prey (Hoffman et al. 1981). Shrimp, which often congregate when moving through channels (Tabb et al. 1962) and into and out of estuaries, are probably easy prey for diving seabirds at these times. Reptiles and aquatic mammals in estuarine habitats also may prey on shrimp (Costello and Allen 1970).

As competitors, pink shrimp share habitats with both white and brown shrimp. The three species exhibit different preferences for salinity, temperature, substrate, and cover. The above-mentioned preferences, in turn, determine maximum densities of each shrimp species at different times of the year within the same estuary (Williams 1955a).

Williams and Deubler (1968) found postlarvae of pink shrimp in North Carolina estuaries at salinities ranging between 0.40 and 36.76 parts per thousand (ppt), whereas postlarvae of brown shrimp were found to be more abundant at salinities between 0.10 and 34.88 ppt. Gunter et al. (1964) ranked juveniles of white, brown, and pink shrimp, in terms of salinity tolerance, as "low, intermediate, and high," respectively.

Pink and brown shrimp have been found to exhibit different temperature tolerances. Williams (1955a) found maximum densities of juvenile pink shrimp in estuarine habitats of North Carolina at water temperatures between 23° and 28°C (73° and 82°F).

Substrate preferences explain partially the differential distributions of pink, brown, and white shrimp in nursery areas. In experimental tank studies, pink shrimp preferred coral mud or substrates containing remains of mollusk shells; brown and white shrimp, however, chose silt bottoms (Williams 1958). Williams (1958) conjectured that substrate preferences could be explained by the availability of food and cover in the different kinds of substrates.

Williams (1955a) suggested that pink, brown, and white shrimp avoided direct competition in estuarine areas of North Carolina by occupying the nursery areas at different times of the year. Pink shrimp entered estuarine areas in early summer, at which time juvenile and young adult brown shrimp were emigrating from the nursery grounds. Maximum densities of white shrimp were observed in areas of relatively low salinities where few pink and brown shrimp occurred. Although the exact nature and degree of competition among these three commercial species of *Penaeus* is not known (Williams 1955a), it is reasonable to assume that the three species have developed different physiological requirements, which allow them to occupy different realized niches in Florida nursery grounds as well as in North Carolina estuaries.

Hildebrand (1955) reported that competition between pink and white shrimp in offshore environments was probably mitigated by differences in substrate preference, food and daily-activity cycles.

Because of its role as predator, prey and competitor, pink shrimp constitutes an important link in estuarine and marine food chains. Stable ecosystems are the product of a particular combination of species in relatively fixed proportions; if one of the species is greatly disturbed, those ecosystems become unstable (Hobson and Lenarz 1977). May et al. (1979) stated that for species not at the top of the trophic chain, e.g., the pink shrimp, the level of harvest should be below that which greatly reduces population abundance; consequently, under some circumstances, predation alone may reduce shrimp populations to unharvestable levels. Degradation of estuarine habitats may significantly decrease numbers of pink shrimp. This decrease could affect directly all the commercial species of fish that rely on the pink shrimp as a major food resource.

ENVIRONMENTAL REQUIREMENTS

Temperature

Tolerance of pink shrimp to water temperature varies with latitude (Costello and Allen 1970). Pink shrimp have been collected from Florida waters at temperatures ranging from 10° to 35.5°C (50° to 95.9°F); they become narcotized at 13.3°C (56°F) (Eldred et al. 1961). However, Williams (1955a) collected juvenile pink shrimp in water temperatures between 4° and 34°C (39° and 93°F) in estuarine areas of North Carolina.

Mortalities due to low water temperatures have not been reported in the warmest part of the species range (Costello and Allen 1970). Juvenile pink shrimp are sensitive to low water temperatures in shallow-water environments, and, consequently, move to deeper (warmer) water at the onset of the cold weather. When shallow waters warm, the shrimp return to this habitat, unless they have attained the size for emigration to offshore grounds (Tabb et al. 1962). In the coldest part of their range, i.e., estuarine areas of North Carolina, extremely cold winters may cause many pink shrimp to die (Williams 1965). Total mortality in a live bait tank was observed at a water temperature of 12°C (54°F) (Eldred et al. 1961). There are no records of death due to high water temperatures (Costello and Allen 1970).

Salinity

Pink shrimp exhibit different degrees of preference to salinity at different stages of their life cycle. Hughes (1969a) indicated that tidal transport of postlarvae may be initiated by increases in salinities of flood tides. Hildebrand (1955) reported that juveniles exhibited a preference for salinities of 20 ppt or more. As they grow, they move into deeper, saltier water, until finally they leave the bays and enter the open sea (Williams 1955a). Gunter et al. (1964) reported the greatest biomass of pink shrimp along the gulf coast was distributed "around the South Florida islands, where the salinities are oceanic." Tabb et al. (1962) found postlarvae at salinities from 12 to 43 ppt, juveniles from 5 to 47 ppt, and adults from 25 to 45 ppt in Florida Bay. Adult pink shrimp have been found on the Tortugas grounds at salinities from 36.2 to 37.7 ppt (Iversen and Idyll 1960).

Interactions between water temperature and salinity impose strict environmental restraints on shrimp populations. At low temperatures, all shrimp have difficulty adjusting to changes in salinity; survival rates are higher at moderate to high salinities under conditions of low water temperatures (Williams 1960). Williams (1955a) stated that pink shrimp have osmoregulatory capabilities superior to those of brown shrimp at low water temperatures, and thus exhibit a greater capability for overwintering in estuaries in the northern part of their range.

Habitat

Pink shrimp are associated with shell sand, sand, coral-mud, or mud bottoms (Williams 1965). Subadults prefer shell sand and loose peat (Williams 1958); adults prefer calcareous sediments, but are found also on hard sand bottoms, "particularly in non-turbid waters" (Hildebrand 1955). In contrast, Williams (1965) found that both white and brown shrimp preferred soft, muddy bottoms.

Pink shrimp dispersion in nursery areas may be limited by the geographical distribution of seagrasses within estuaries. Inshore fisheries do not occur in areas where seagrasses are rare or absent (Hoese and Jones 1963). Turtle grass (Thalassia testudium) provides not only cover for shrimp but also suitable habitat for shrimp food species (Moore 1963). Williams (1955a) reported high densities of shrimp populations where the seagrasses, Diplanthera wrightii and Zostera marina, were present; he reported also that decomposing forest litter constituted a suitable habitat for shrimp in nursery areas of North Carolina.

Turtle grass was practically eliminated from sections of Apalachee Bay, Florida, because of decreased light penetration resulting from turbidity and coloring of the water by kraft-mill effluents; the most heavily polluted areas were, in fact, totally without rooted macrophytes (Zimmerman and Livingston 1976). Dugan and Livingston (1982) reported that the unpolluted parts of Apalachee Bay had stable invertebrate populations, whereas the polluted parts of the estuary had less than half of the number of invertebrates. They attributed the difference to the reduction in seagrass biomass in the polluted parts of the bay. Similarly, dredge-and-fill operations in Tampa Bay have degraded the seagrass beds that serve as shrimp nursery areas (Saloman 1965).

Van Lopik et al. (1979) have described several shoreline development practices that severely degrade shrimp habitat. The most obvious and highly publicized of these is the flow of polluted waters into estuaries. Other practices that negatively alter shrimp nursery habitats include: (1) direct saltwater intrusion (or diversion of natural freshwater discharge), which causes unfavorable salinity regimes; (2) impounding of natural waterways, which prevents the influx of immigrating shrimp; and (3) bulkheading of shorelines, which removes the critical marsh- or mangrove water interface. Mock's (1967) findings emphasized the consequences of shoreline modification; he found 2.5 times as many brown shrimp and 14 times more white shrimp along a natural shoreline than along a bulkheaded shoreline.

Water Movement

The migration patterns and geographical distribution of shrimp may be controlled to a large extent by currents. Postlarvae rely on inflowing currents to move into estuaries (Hughes 1969b). In experimental tank studies, juvenile pink shrimp showed a positive rheotaxis, which gave way to active downstream swimming when salinity decreased (Hughes 1969a). Juveniles were reported to move offshore on ebbing currents (Burkenroad 1949; Hughes 1969b). In some south Florida bays, juveniles may move on each tidal change (Tabb et al. 1962).

Adult pink shrimp are also positively rheotactic; this orientation to the water current may be a mechanical response, and may also be the result of optic fixation (Fuss and Ogren 1966).

Other Environmental Requirements

Light is an important factor in controlling activity of shrimp. Pink shrimp remain buried during daylight, emerge from the substrate at sunset, and become active at night (Hughes 1968). In laboratory studies, adult pink shrimp tended to burrow in the presence of solar light; they became active when light intensity diminished to less than 0.01076 lumens per m^2 (Fuss and Ogren 1966). Shrimp exhibited nocturnal activity when exposed to constant low-light conditions for several days; this persistent pattern of nocturnal activity evinced a rhythmic control of burrowing and emergence activities (Hughes 1968).

Although oxygen requirements of pink shrimp are not known in detail, Subrahmanyam (1976) indicated that oxygen consumption in pink shrimp followed a rhythmic pattern that coincided with the tidal cycle. Bishop et al. (1980) demonstrated that oxygen consumption of brown shrimp increased with increases in ambient temperatures.

Diseases and Pollutants

Pink shrimp are vulnerable to numerous diseases (Johnson 1978). No disease, however, exerts an appreciable impact on the commercial pink shrimp fishery (K. N. Baxter, National Marine Fisheries Service, Galveston, TX; pers. comm.). The whitish discoloration of body tissue, which is referred to as "milk" or "cotton" shrimp, is more noticeable than other "diseases" of shrimp. The condition is caused by high levels of microsporidian infection (Johnson 1978). Commonly observed blackened areas of the exoskeleton are caused by chitinoverous bacteria, which attack the edges or tips of exoskeletal parts and cause internal damage if they are able to enter the body (Johnson 1978). Detailed information on shrimp diseases and on the responses of shrimp to nonpetrol chemicals and heavy metals is available in Costello and Allen (1970), Johnson (1978), and Couch (1978).

Available evidence indicates that petroleum and other oil products have a negative impact on penaeid shrimp. Refined and crude oil have been reported to be highly toxic to shrimp (Couch 1978). Soto et al. (1981) detected the presence of petroleum hydrocarbons in marine sediments and in the body tissues of pink shrimp and other penaeid species caught on the Campeche Bank of Mexico.

Botello et al. (1981) indicated that pink and brown shrimp were not able to metabolize high molecular weight hydrocarbons (obtained from oil from Kuwait), and stated that these toxic compounds would increase in concentration along the higher levels of the food chain, attaining their maximum concentration in man. Diesel fuel is highly toxic to protozoeal and naupliar stages of the shrimp *Penaeus californiensis* (Botello et al. 1981).

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. FWS/OBS-82-11.17*		3. Recipient's Accession No.
4. Title and Subtitle: Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida) -- Pink Shrimp			5. Report Date: October 1983
			6.
7. Author(s): Lourdes M. Bielsa, William H. Murdich, and Ronald F. Labisky			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: School of Forest Resources and Conservation, University of Florida, 118 Newins-Ziegler Hall, Gainesville, FL 32611			10. Project/Task/Work Unit No.
			11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address: National Coastal Ecosystems Team, Division of Biological Services, Fish and Wildlife Service, USDI, Washington, DC 20240	U.S. Army Corps of Engineers, Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180		13. Type of Report & Period Covered
			14.

15. Supplementary Notes

*U.S. Army Corps of Engineers Report No. TR EL-82-4

16. Abstract (Limit: 200 words)

The pink shrimp (Penaeus duorarum) supports the most economically important commercial fishery in Florida. In 1981, exvessel landings, exclusive of the bait-shrimp catch, totalled 17 million pounds (heads-off), valued at $45 million. Nearly half (48%) of the catch is taken from the Tortugas grounds, a fishing area not discovered until 1949; 28% of the catch is from the Sanibel grounds. Florida Bay and Charlotte Harbor/Tampa Bay are the nursery areas providing recruitment stocks for the Tortugas and Sanibel grounds, respectively. Larval pink shrimp immigrate from the offshore spawning grounds to estuarine and coastal bay nursery areas, entering as postlarvae (8 to 10 mm TL). Monthly growth rates during the juvenile stage of development vary from 7 to 52 mm TL. Sexual maturity is attained at 9 to 10 weeks of age, or at sizes of 85 mm TL for females and 74 mm TL for males, after which time they emigrate to offshore waters for spawning. Spawning occurs year-round. Recruitment similarly occurs year-round, with a major peak in spring and a secondary peak in fall. Prerecruitment stocks in fall have increased during the past 2 decades, whereas those in spring have remained stable. Pink shrimp are fully recruited into the fishery at 120 mm TL. The pink shrimp functions in the marine ecosystem as both a predatory and a prey species. Pink shrimp, in estuarine habitats, tolerate a wide range of water temperatures (10°C to 35°C) and salinities (5 to 47 ppt). Pollution by petrol- and non-petrol chemicals poses a potential contamination hazard to both pink shrimp and their estuarine habitats. Maintenance of the integrity of estuarine habitats is the most critical need in the management of pink shrimp for sustained exploitation.

17. Document Analysis a. Descriptors

Economics, habitats, harvest, growth, mortality, populations, recruitment, spawning

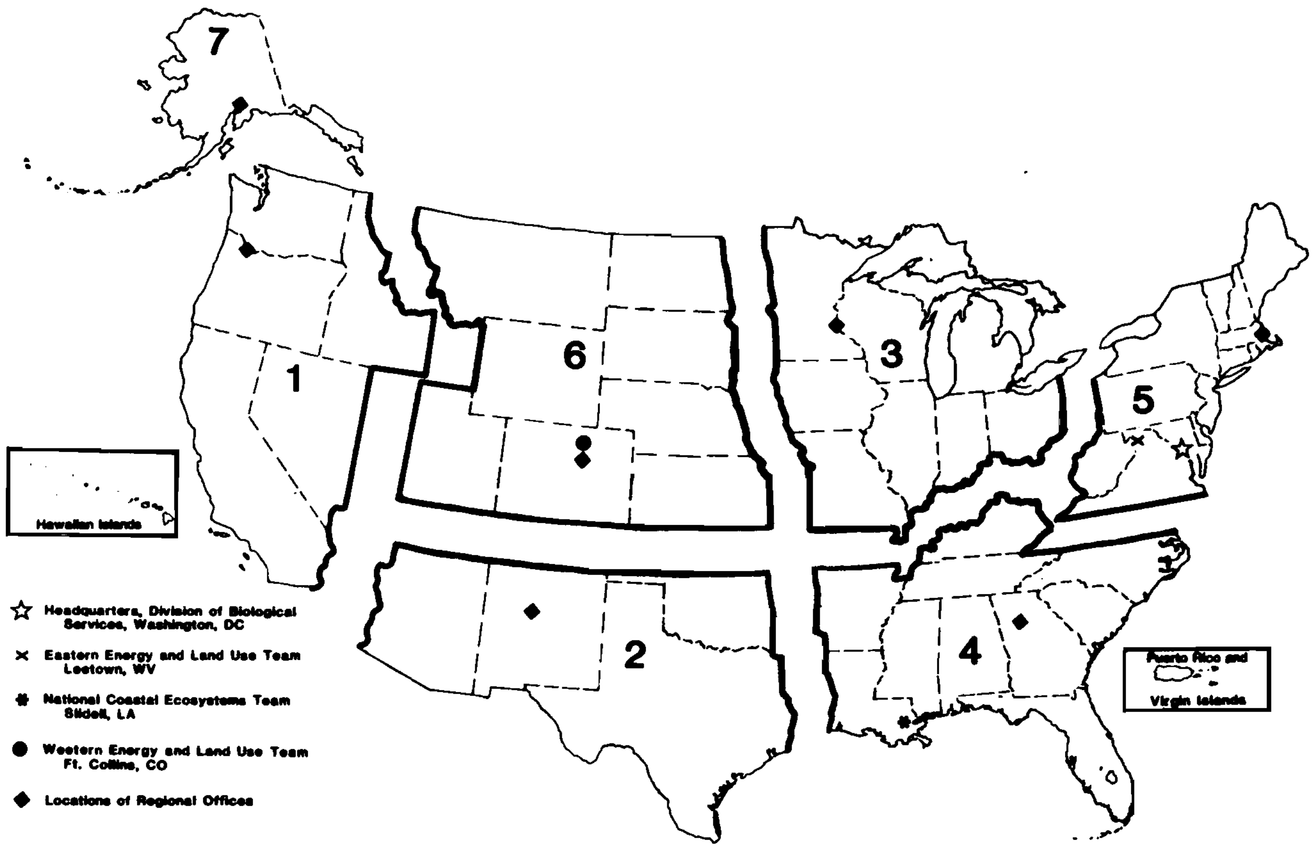
b. Identifiers/Open-Ended Terms

Penaeus duorarum, pink shrimp, south Florida

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	Unclassified	21
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce



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