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March 1985

TR EL-82-4

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

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GRASS SHRIMP



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

GRASS SHRIMP

by

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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

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
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

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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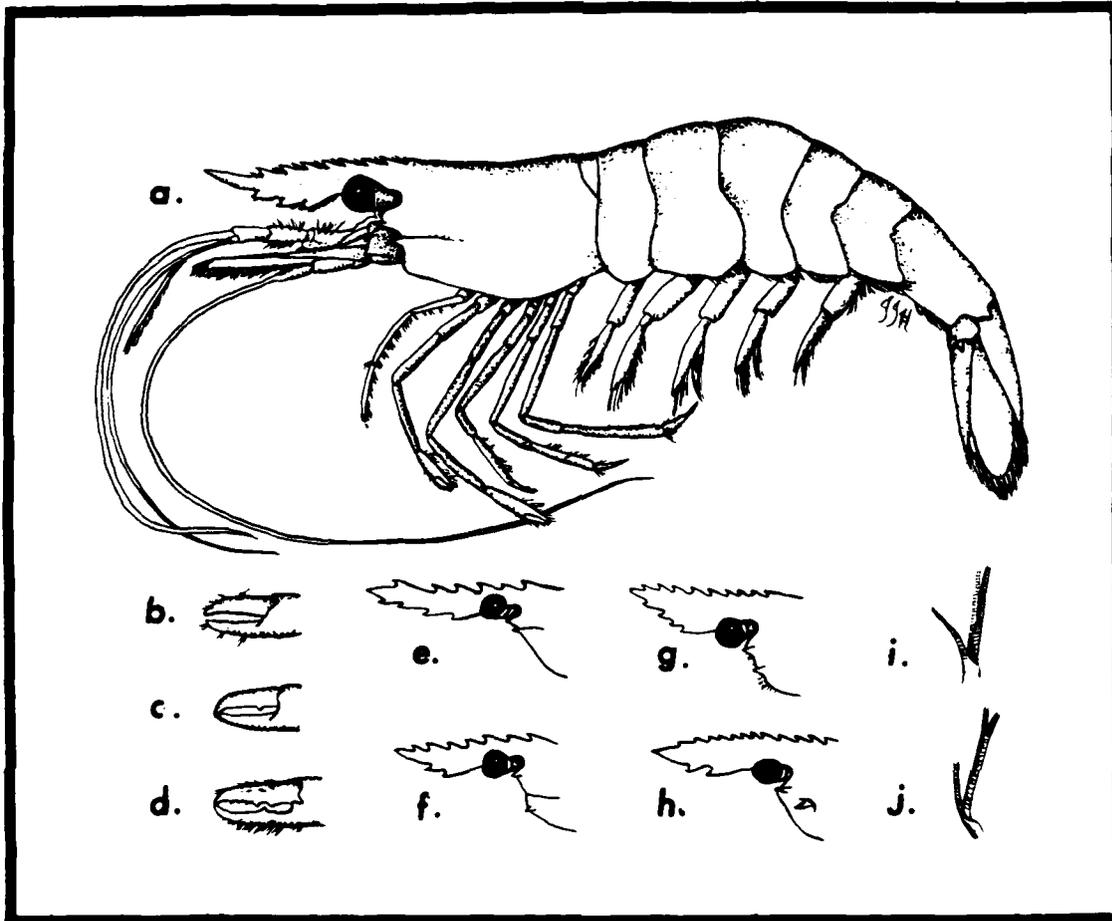


Figure 1. Grass shrimp. a. Palaemonetes pugio; b-d, second chela of P. pugio, P. intermedius and P. vulgaris, respectively; e-h, anterior carapace and rostrum of P. paludosus, P. kadiakensis, P. vulgaris, and Macrobrachium ohione, respectively; i-j, antennule of "brackish water" and "freshwater" grass shrimp, respectively. Scale of drawings to specimens in mm is (a) 7 to 1, (b-d) 16 to 1, (e-g) 4 to 1, (h) 1.6 to 1, and (i-j) 2 to 1.

GRASS SHRIMP

NOMENCLATURE/TAXONOMY/RANGE

Scientific names Palaemonetes pugio; P. vulgaris; P. intermedius; P. paludosus; P. kadiakensis.

Common name Grass shrimp (Figure 1).

Other names Jumpers, glass shrimp, popcorn shrimp, glass prawns, hardbacks.

Subphylum.....Crustacea
 Class.....Malacostraca
 Order.....Decapoda
 Family.....Palaemonidae

Geographic range and speciation: The grass shrimp in the Gulf of Mexico area consist of five species, all relatively similar in morphological characteristics and most with over-

lapping distribution. Because of their similarities, these species are often misidentified or lumped as P. vulgaris.

Although P. paludosus and P. kadiakensis are primarily freshwater species, both are somewhat tolerant of mesohaline conditions (Maguire 1961; Dobkin and Manning 1964; Strenth 1976) and may be encountered in both freshwater and brackish-water tidal marshes (Swingle 1971; Christmas and Langley 1973; Heard 1982).

MORPHOLOGY/IDENTIFICATION AIDS

Most of the information summarized in this section is taken from Holthuis (1952), Williams (1965), Wood (1974), and Heard (1982).

Several diagnostic features distinguish the caridean shrimps, to which the genus Palaemonetes belongs, from the penaeidean shrimps. In the caridean forms, the pleura of the second abdominal somite overlap those of the first, and the third walking legs lack claws or chelae (Figure 1a). Palaemonetes spp. and other members of the family Palaemonidae may be distinguished from members of the families Alpheidae, Processidae, and Hippolytidae by having the second walking leg with an unjointed carpus (the segment just proximal to the chela). The absence of mandibular palps in Palaemonetes distinguishes this genus from the other palaemonid genera Macrobrachium and Palaemon. Furthermore, unlike Palaemonetes, Macrobrachium bears hepatic spines (Figure 1h) and Palaemon floridanus has a prominent striped pattern on the carapace and abdomen.

Other morphological features of Palaemonetes, as well as many other caridean genera and families, include the following: well-developed rostrum bearing both dorsal and ventral teeth, a smooth carapace and abdomen, rounded

abdominal pleura 1-4, well-developed eyes with globular pigmented corneas, well-developed spines on the telson (two pairs dorsally, two pairs posteriorly), and chelate walking legs 1-2 (the second legs are stronger than the first). Grass shrimp are transparent to yellowish brown. Few exceed 50 mm in total length. Males can be separated from females by the presence of the appendix masculina attached to the appendix interna on the endopod of the second pair of pleopods. Also, the endopod of the first pleopod is larger in males than in females of the same age. Additional details were provided by Holthuis (1952) and Williams (1965). Selected morphological features of adults of the five species of Palaemonetes common to waters of the Gulf of Mexico are compared in Figure 1a through 1j and Table 1. However, these features cannot be used to distinguish between juveniles of the brackish-water forms of P. vulgaris, P. intermedius, and P. pugio (Boston and Provenzano 1982). External genitalic details of males may also be used to distinguish between the five species (Fleming 1969).

REASON FOR INCLUSION IN SERIES

Brackish water Palaemonetes are among the most widely distributed, abundant, and conspicuous of the shallow water benthic macroinvertebrates in the estuaries of the Atlantic and Gulf Coasts (Wood 1967; Odum and Heald 1972; Welsh 1975; Sikora 1977). Although grass shrimp have only limited value as fish bait (Huner 1979) or food for cultured fish or humans, their ecological importance is unquestioned. Grass shrimp have been extensively documented as prey of fishes (Gunter 1945; Darnell 1958; Diener et al. 1974; Overstreet and Heard 1982) and other carnivores (Heard 1982) and they are instrumental also in transporting energy and nutrients between various estuarine trophic levels: primary producers, decomposers, carnivores, and detritivores (Johannes and Satomi 1966;

Table 1. Summary of morphological differences between five species of Palaeomonetes (grass shrimp) in the coastal waters of the Gulf of Mexico (Holthius 1952; Williams 1965).

Characters	<u>P. vulgaris</u>	<u>P. intermedius</u>	<u>P. pugio</u>	<u>P. paludosus</u>	<u>P. kadiakensis</u>
Number of teeth on dactylus; fixed finger of second leg	2/1 (Figure 1d)	1/0 (Figure 1c)	0/0 (Figure 1b)	0/0 (Figure 1b)	0/0 (Figure 1b)
Rostral teeth	8-11 on dorsal surface; 1 on tip; 3-5 on ventral surface (Figure 1g)	7-10 on dorsal surface; 1 on tip; 4-5 on ventral surface	7-10 on dorsal surface; tip naked; 2-4 on ventral surface (Figure 1a)	6-8 on dorsal surface; tip naked; 3-4 on ventral surface (Figure 1e)	6-8 on dorsal surface; tip naked; 2-3 on ventral surface (Figure 1f)
Upper antennular flagellum	Fused part of the two rami shorter than free part (Figure 1i)			Fused part of the two rami longer than free part (Figure 1j)	
Position of branchiostegal spine	On anteroventral part of branchiostegal groove				Considerably ventrad to branchiostegal groove (Figure 1f)
Approximate maximum total length (mm)	42	42	50	47	53
Number, size, and color of eggs	Numerous, small, usually grayish brown				Few, large, usually greenish

Adams and Angelovic 1970; Welsh 1975; Morgan 1980).

LIFE HISTORY

Spawning

The spawning season of grass shrimp extends from February through October but may vary with species and geographical location. An exception is *P. paludosus*, which spawns all year in southern Florida (Dobkin 1963). In the prespawning female, the ripening ovaries are discernable as greenish or grayish brown masses of tissue dorsal and posterior to the stomach, and additional setae develop on the ventral surface of the abdomen and thorax. The female's molting condition and subsequent mating and spawning were described for *P. vulgaris* by Burkenroad (1947). He reported that after molting, the female is receptive to the male but that apparently the male recognizes her condition only if physical contact is made with her exoskeleton.

During copulation, which must occur within 7 h after molting, the ventral surfaces of the partners are positioned so that their genital apertures are close together. A spermatophore is quickly extruded by the male onto the genital sternites of the female where it remains until oviposition. Before oviposition, which occurs within 7 h after sperm transfer, part of the spermatophore dissolves (probably due to enzymatic secretions from the female's oviduct) and the spermatozoa are released. Ova are fertilized externally as they are extruded, then manipulated against the pleopods and setae on the ventral surface of the abdomen where they adhere.

The eggs hatch 12 to 60 days after fertilization, depending on species and geographical location. In warmer climates, the incubation period is usually shorter. Osmotic swelling of

the inner membrane, struggling by the larva (protozoa), and ventilatory movements by the female assist in freeing the larva from the egg membrane (Davis 1965). The female molts again within a few days after spawning and may produce an additional brood, depending on the species or time of spawning (Broad and Hubschman 1963; Knowlton and Williams 1970; Beck and Cowell 1976).

Fecundity

The fecundity of *P. pugio* in Rhode Island is greater than that of other shrimp populations that have been studied. For example, in June, the average number of eggs per female was 486 in Rhode Island (Welsh 1975); 372 in Texas (Wood 1967); and up to 247 in South Carolina (Sikora 1977). There was a significant positive correlation between the length (X) of an ovigerous female and the number of eggs (Y). Wood (1967) reported the relation to be $\log Y = 1.19 + 0.0408 X$. Egg counts of *P. paludosus* in Florida ranged from only 8 to 85; $\log Y = 0.6288 + 0.0294 X$ (Beck and Cowell 1976).

Development of Larvae

Larvae are planktonic and feed upon zooplankton, algae, and detritus. Depending on the species and environmental conditions, there may be from 3 to 11 morphologically distinct stages during larval development. Transition from one stage to the next occurs during molting. Intraspecific genotypic variability in the number of larvae and the morphology of different stages may enhance dispersal (Sandifer and Smith 1979).

Larval development has been described for each of the five species: *P. vulgaris* and *P. pugio* by Broad (1957), *P. kadiakensis* by Broad and Hubschman (1963), *P. paludosus* by Dobkin (1963), and *P. intermedius* by Hubschman and Broad (1974). Some additional interspecific differences in life histories, modified from Hubschman

and Broad (1974), are shown in Table 2. The morphology and behavior of larvae and postlarvae differ. Larvae lack long appendages and swim almost continuously with the head down and the dorsal surface oriented toward the direction of horizontal movement. The duration of larval development may range from 11 days to several months for *P. pugio* (Floyd 1977), depending on environmental conditions. The final larval stage metamorphoses to a postlarva, which closely resembles the adult.

Maturation and Life Span

Juvenile *P. pugio* mature when they are 1.5 to 2 months old and about 15 to 18 mm long; their life span is 6 to

13 months (Alon and Stancyk 1982). The older, overwintering shrimp usually spawn early in the year and die by the next winter. Most young-of-the-year spawn late in the year as adults. Postlarvae that survive the fall and winter spawn in the following spring.

ECOLOGICAL ROLE

Food Habits

Grass shrimp eat a wide variety of aquatic foods. Depending on the availability of a particular food they may be detritivores, primary consumers, or secondary consumers (Odum and Heald 1972; Morgan 1980).

Table 2. Spawning season, fecundity, lengths (mm) at hatching and at metamorphosis, and number of larval molts for *Palaemonetes* spp. in the Gulf of Mexico.

Species	Spawning season	Fecundity (maximum observed)	Length (mm) ^a		Number of larval molts ^a
			At hatching	At metamorphosis	
<i>P. vulgaris</i>	April-October ^b	No data	2.3	6.3	7-11
<i>P. pugio</i>	March-October ^c	486 ^d	2.6	6.3	7-11
<i>P. intermedius</i>	May-September ^b	129 ^e	3.5	7.0	6- 8
<i>P. kadiakensis</i>	February-October ^f	160 ^g	4.4	7.5	5- 8
<i>P. paludosus</i>	Year round ^h	85 ^e	3.8	4.5	3

^aData on length at hatching and metamorphosis and number of larval molts are from the following sources: *P. vulgaris* and *P. pugio*, Broad (1957); *P. intermedius*, Hubschman and Broad (1974); *P. kadiakensis*, Broad and Hubschman (1963); and *P. paludosus*, Dobkin (1963).

^bKnowlton and Williams (1970).

^cWood (1967).

^dWelsh (1975).

^eBeck and Cowell (1976).

^fWhite (1949).

^gMeehean (1936).

^hDobkin (1963).

The fundamental role of grass shrimp as detritivores is explained by Odum and Heald (1972), Welsh (1975), and Adams and Angelovic (1970). As detritivores, grass shrimp aid in the mechanical breakdown of refractory organic material such as fibrous plant materials, as well as assimilate the associated microflora, microfauna, and fungi (Adams and Angelovic 1970). The assimilation of dissolved organic matter sorbed to finely divided particulate matter such as clay particles is important in grass shrimp nutrition (Odum and Heald 1972). Although grass shrimp often live among aquatic macrophytes (Adams and Angelovic 1970; Livingston et al. 1976; Heck and Orth 1980; Morgan 1980; Coen et al. 1981; Gore et al. 1981), there is little evidence that the macrophyte structure is actually consumed. More likely, grass shrimp eat and assimilate the epiphytic microalgae that coat the plant structure (Morgan 1980). Grass shrimp also are predators of meiofauna and small infaunal polychaetes, oligochaetes, nematodes (Sikora 1977; Bell and Coull 1978; Chambers 1981), epiphytic fauna (Odum and Heald 1972; Morgan 1980), and even motile prey such as mysids (Morgan 1980). As epibenthic predators and sediment disturbers, grass shrimp alter infaunal community structure (Bell and Coull 1978; Knieb and Stiven 1982). For example, in North Carolina a sharp decline in the abundance of *P. pugio* due to predation by mummichogs (*Fundulus heteroclitus*) brought about significant changes in infaunal composition.

Predation

In estuaries, numerous fish species and other aquatic carnivores, some of which are valuable sport and commercial fishes, eat large quantities of grass shrimp. Grass shrimp are also eaten by forage fishes such as *Fundulus* spp. (Harrington and Harrington 1972; Welsh 1975; Knieb and Stiven 1982), which in turn are preyed upon by larger fishes.

As prey, grass shrimp play an important role in the transfer of energy from the producer and decomposer levels to higher consumer levels.

Grass shrimp frequently inhabit water near underwater structures and are particularly attracted to dense stands of underwater macrophytes. These stands not only support an abundance and diversity of food for shrimp, but also provide a refuge from predators. Grass shrimp are more prone to predation when displaced from preferred substrata such as macrophytes (Coen et al. 1981; Heck and Thoman 1981) and oyster shells (Thorp 1976).

Parasites

Grass shrimp are hosts for numerous species of parasites and ectocommensals. The most abundant are coccidia (Solangi and Overstreet 1980), microsporidians (Overstreet and Weidner 1974), trematodes (Heard and Overstreet 1983), isopods (Anderson 1977), and leeches (Overstreet 1978). The biology of other host-parasite interrelationships involving *Palaemonetes* spp. were summarized by Johnson (1977) and Overstreet (1978). Diseases and parasites do not appear to be major factors in limiting the abundance and growth of grass shrimp in the Gulf of Mexico.

Behavioral Ecology

Field studies have shown that the movement and distributional patterns of grass shrimp may be influenced by both photoperiod and tidal cycles. Swimming of European species, *Palaemonetes* varians, peaked in morning and evening (Antheunisse et al. 1971). The only observation on nocturnal movement of *P. pugio* was documented by Shenker and Dean (1979), who reported that some shrimp are buried in the sediments during daylight. These studies, as well as that of Sikora (1977), indicated that grass shrimp in tidal creeks migrate seaward (downstream) or drift with the current during ebb tides

and migrate upstream into tidal creeks during incoming tides.

During laboratory experiments on agonistic behavior in *P. pugio* and *P. vulgaris*, females were dominant over males and large shrimp were dominant over smaller ones. In interspecific pairings, *P. vulgaris* generally dominated *P. pugio* (Chambers 1981), and *P. vulgaris* is known to displace *P. pugio* from the preferred shell substratum (Thorp 1976). Such displacement may favor coexistence between these two sympatric species by reducing the future potential for agonistic behavior. Distributional differences between two sympatric species are believed to be caused by displacement of *P. vulgaris* by *Palaemon floridanus* from the preferred red algal substratum (Coen et al. 1981).

GROWTH CHARACTERISTICS

Because populations of grass shrimp may produce more than two broods a year, length-frequency distributions may be polymodal and growth rates are difficult to characterize (Sikora 1977). Grass shrimp population growth characteristics have been described for *P. pugio* in Texas (Wood 1967), South Carolina (Sikora 1977; Alon and Stancyk 1982), North Carolina (Knowlton and Williams 1970), and Rhode Island (Welsh 1975); and for *P. paludosus* in Florida (Beck and Cowell 1976). Growth rates vary somewhat between species, sexes, habitats, and times of year. These differences are exemplified in part by the different daily growth rates of *P. pugio* from two populations in South Carolina (Table 3).

According to Beck and Cowell (1976), *P. paludosus* grows 3.25 mm per month in summer and fall. In Rhode Island, the length of *P. pugio* increased rapidly from July through September; females had then reached a total length of about 3 cm and males about 2.6 cm. The growth of grass

Table 3. Mean daily growth increments (mm) of *Palaemonetes pugio* from two habitats in South Carolina (data from Alon and Stancyk 1982).

Locality and sex	Season	
	Summer	Winter
North Inlet		
female	0.143 + 0.111	0.090 + 0.067
male	0.087 ± 0.060	0.086 ± 0.041
Minim Creek		
female	0.133 + 0.109	0.089 + 0.041
male	0.069 ± 0.036	0.068 ± 0.042

shrimp was negligible from September to May in Rhode Island (Welsh 1975). In contrast, one group of *P. pugio* in South Carolina is born and recruited in early spring, grows rapidly during summer, and dies before winter. A second group is recruited in late summer, grows rapidly in autumn and again the following spring, and usually dies by midsummer (Alon and Stancyk 1982). These age and growth characteristics make it difficult to tabulate lengths of grass shrimp of different ages.

In the southern and southeastern coastal waters of the United States, overwintering *P. pugio* spawn in late February through March at water temperatures of 15° to 20°C. Juveniles from the February-March hatch mature and spawn from late summer (July-August) to November. By then the length distribution is highly bimodal. Shrimp of the summer-fall hatch mature from October to February and reproduce during the following spring. Shrimp hatched in spring grow faster than those hatched in summer and fall but have a shorter life span.

In colder coastal waters, growth patterns are different. In Rhode Island, this species spawns only once during May to July in any one year. Length distribution is consequently unimodal throughout the year (Welsh 1975).

Salinity is yet another factor that affects growth. In South Carolina, *P. pugio* matures and spawns at a younger age in habitats with relatively high salinity than in those with relatively low salinity (Alon and Stancyk 1982), but specimens collected in low salinity waters were smaller than those from more saline waters (Wood 1967).

ENVIRONMENTAL REQUIREMENTS

Aquatic Vegetation

Grass shrimp, macrophytes, and algae live in the same communities and are subject to many of the same environmental factors (Beck and Cowell 1976; Thorp 1976; Morgan 1980; Coen et al. 1981; Heck and Thoman 1981). Studies in Florida showed that *P. pugio* was most abundant in habitats characterized by aquatic macrophytes, relatively high turbidities, and low salinities (Livingston et al. 1976).

Because grass shrimp depend on aquatic vegetation in many coastal waters, alterations of estuaries that destroy vegetation could seriously reduce their abundance. In one instance, weirs built in marshes to benefit wildlife produced dense masses of aquatic vegetation that supported an abundance of grass shrimp far higher than that in nearby less densely vegetated waters (Weaver and Holloway 1974). In another study in West Bay, Texas, dredging, bulkheading, and filling of coastal marshes caused a permanent loss of intertidal vegetation. The reduction of detrital input into the adjoining aquatic systems caused a noticeable decrease in abundance of grass shrimp (Trent et al. 1976).

Salinity

The abundance of freshwater and brackish-water grass shrimp in estuaries is clear evidence of their

survival in a wide range of salinities.

Brackish-water shrimp. Field and laboratory studies indicate that *P. pugio* adults tolerate salinities from 0 to 55 ppt but are most common in salinities of 2 ppt to 36 ppt (Wood 1967; Swingle 1971; Bowler and Seidenberg 1971; Christmas and Langley 1973; Kirby and Knowlton 1976; Morgan 1980). The 96 h LD₅₀ values for adults are 0.5 and 44 ppt (Kirby and Knowlton 1976).

Attempts to assess salinity tolerances of larvae on a broad scale have yielded mixed results. McKenney and Neff (1979) were able to rear nearly 50% of the *P. pugio* larvae exposed to a salinity of 3 ppt, whereas, Broad and Hubschman (1962) reported poor survival of larvae at salinities less than 10 ppt. When larvae were exposed to a wide range of arbitrarily selected salinities, the low and high salinities required to kill 50% of the larvae during a 96-h exposure (LD₅₀) were 16 ppt and 46 ppt, respectively (Kirby and Knowlton 1976). Optimum salinity for complete larval development is 20 to 25 ppt (Floyd 1977; McKenney and Neff 1979; Knowlton and Kirby 1984). Possible reasons for the conflicting findings are differences in populations in different geographic locations, and differences in laboratory procedures.

P. vulgaris is more tolerant of high salinity water and less tolerant of low salinity water than is *P. pugio* (Holthuis 1952; Knowlton and Williams 1970; Bowler and Seidenberg 1971; Thorp and Hoss 1975). Although Nagabushanam (1961) reported that salinities as low as 3 ppt were lethal to adult *P. vulgaris*, they have been collected in freshwater (Swingle 1971; Christmas and Langley 1973; Barrett et al. 1978). Schoen and Knowlton (1977) reported 96-h LD₅₀ values of 0.8 and 51 ppt for adults. Larvae of *P. vulgaris* are less tolerant of low salinity than are adults. Larvae thrive at salinities

between 10 ppt and 30 ppt; the optimum is 20 ppt (Sandifer 1973). Larvae do not survive at salinity extremes of 5 and 35 ppt (Knowlton 1965; Schoen and Knowlton 1977). Larvae of both *P. pugio* and *P. vulgaris* survive best, mature early, and often pass through fewer larval stages when salinities are near optimum (Sandifer 1973; Floyd 1977). Interspecific differences in salinity tolerance in estuaries are likely to segregate *P. pugio* and *P. vulgaris* (Bowler and Seidenberg 1971), although biotic interactions such as competition for food and space are probably more important for segregation and coexistence (Thorp 1976).

Although *P. intermedius* is euryhaline, it has been collected from waters with salinities of 5 to 39 ppt (Dobkin and Manning 1964). The larvae thrive at salinities of 20 ppt but survival is low at salinities less than 10 ppt (Broad and Hubschman 1962). The larvae have been reared at salinities near 30 ppt (Hubschman and Broad 1974).

Freshwater shrimp. The two freshwater species, *P. paludosus* and *P. kadiakensis*, often live in brackish waters (Christmas and Langley 1973).

P. paludosus was reported in salinities of 0 ppt to 10 ppt by Tabb and Manning (1961), and one specimen was captured in a salinity of 25 ppt (Swingle 1971). In a laboratory experiment, *P. paludosus* survived for 7 days at a salinity of 30 ppt but died when the salinity was raised to 37 ppt. In another experiment, adult *P. kadiakensis* survived at salinities up to 20 ppt but died at 25 ppt (Maguire 1961; Strenth 1976). Larvae are relatively intolerant of salinities higher than 5 ppt (Hubschman 1975; Strenth 1976) but are more tolerant of higher salinities after they reach stage IV (Hubschman 1975).

The salinity tolerance of grass shrimp is summarized in Table 4.

Water Temperature

Grass shrimp are eurythermal. In coastal waters, *P. pugio* thrives at temperatures of 5° to 38°C (Wood 1967; Christmas and Langley 1973), but survival is greater at 18° to 25°C. Growth is most rapid in waters at temperatures above 30°C but drops rapidly at water temperature below 14°C (Wood 1967). This species breeds at

Table 4. Salinity tolerance limits and optima (ppt) reported by various investigators (see text discussion) for adult and larval Palaemonetes.

Form and species	Adults		Larvae	
	Limits	Optimum	Limits	Optimum
<u>Freshwater forms</u>				
<i>P. kadiakensis</i>	0-25	0	0-10	0
<i>P. paludosus</i>	0-30	0	No data	0
<u>Brackish-water forms</u>				
<i>P. intermedius</i>	5-39	No data	10-30	20
<i>P. pugio</i>	1-55	4-16	3-31	25
<i>P. vulgaris</i>	1-51	No data	5-35	20

temperatures of 22° to 27°C in Rhode Island (Sastry and Vargo 1977) and from 17° to 38°C in Texas (Wood 1967). Preferred water temperatures range from 5° to 35°C for *P. vulgaris* and *P. paludosus* and from 10° to 35°C for *P. paludosus* (Christmas and Langley 1973). Tolerance for warmer waters is greater for *P. pugio* than *P. vulgaris*, but both species are relatively tolerant of the heat stress of effluents from a power plant (Chung 1977). The breeding temperatures for *P. paludosus* range from 18° to 33°C (Beck and Lowell 1976).

Physiological responses of grass shrimp to temperature indicate that *P. vulgaris* adults (McFarland and Pickens 1965) and *P. pugio* larvae (Sastry and Vargo 1977) are metabolically active over a broad range of water temperatures, exhibiting physiological compensation to seasonal temperature changes.

Temperature tolerance data for grass shrimp are summarized in Table 5.

Dissolved Oxygen

Dissolved oxygen is another factor that helps regulate the distribution and abundance of grass shrimp. In Louisiana waters, *P. vulgaris* and *P. pugio* are common in dissolved oxygen

(DO) concentrations of 6 to 11 ppm (Barrett et al. 1978). In Rhode Island, the mortality of *P. vulgaris* was higher than that of *P. pugio*, when both species were caged together in a hypoxic microhabitat (DO = 0.3 ppm) during a tidal cycle. In the laboratory, at oxygen concentrations lower than 1 ppm, survival was higher in *P. pugio* than in *P. vulgaris* at all test temperatures (10° to 30°C). In nature, grass shrimp sometimes climb out of the water during periods of oxygen deficiency, especially during warm summer nights, but such attempts to avoid hypoxia can be effective only for a few hours (Pomeroy and Wiegert 1981). Respiratory studies indicated that *P. pugio* is an oxyconformer; its oxygen uptake decreases as oxygen tension declines from 8 to 2 ppm (Welsh 1975; Dillon 1983).

Physical Factors

Grass shrimp usually inhabit the shallows near the water's edge but have been reported at depths as great as 8 fathoms (Williams 1965). In winter, during temperature lows and in summer, when water temperatures approach seasonal highs, *P. pugio* moves from shallow to relatively deep water (Wood 1967). Thorp (1976) noted that the extent of the movement of grass shrimp among various depths often coincides with the distribution of

Table 5. Temperature tolerance range and optima (°C) reported for adult and larval *Palaemonetes*.

Species	Adults		Larvae	
	Limits	Optimum	Limits	Optimum
<i>P. paludosus</i>	10-35 ^b	18-33 ^c	No data	No data
<i>P. pugio</i>	5-38 ^{a,b}	18-25 ^a	15-35 ^{d,f}	20-30 ^f
<i>P. vulgaris</i>	5-35 ^b	No data	20-30 ^e	20 ^e

Sources:

a - Christmas and Langley 1973; b - Beck and Cowell 1976; c - Wood 1967; d - McKenney and Neff 1979; e - Floyd 1977; f - Sandifer 1973

oyster shell substrates, which, in some waters, are preferred by P. pugio and P. vulgaris. Oyster beds provide food and protection.

Grass shrimp are abundant where turbidity is relatively high. This is particularly true in habitats where water currents tend to keep sediments suspended, such as in shallow tidal creeks or near river mouths. Turbidity may provide some degree of protection from predators in habitats with little vegetation. In less turbid habitats, macrophytes afford protection from predators. Although Livingston et al. (1976) found that grass shrimp abundance was positively correlated with turbidity, turbidity may not be an environmental requirement. In some habitats, grass shrimp have been observed in clear water such as is often associated with dense aquatic vegetation (Weaver and Holloway 1974).

Grass shrimp tend to avoid fast currents and migrate in the direction of tidal currents (Antheunisse et al. 1971; Sikora 1977; Shenker and Dean 1979).

Bioassays

In as much as grass shrimp have been recommended for use as bioassay test organisms (American Public Health Association 1975), much information has been published about mortality and sublethal effects of various toxicants on grass shrimp but only a few are mentioned here. Workers evaluating the effects of kepone and other insecticides (heptachlor, toxaphene, dieldrin, and endosulfan) conclude that P. pugio adults were usually less sensitive and showed a lesser tendency to bioconcentrate these toxicants than did the fish that were tested (Schimmel and Wilson 1977; Schimmel et al. 1977). For example, the 96-h LD₅₀ values for kepone were 121 µg/l and 70 µg/l for P. pugio and for the sheepshead minnow (Cyprinodon variegatus). Bioconcentration factors were 698 for the shrimp and 1,548 for the minnow (Schimmel and

Wilson 1977). On the other hand, grass shrimp are much more sensitive than fish to endrin (Tyler-Schroeder 1979), dithiocarbamates (Rao et al. 1982), various chlorophenols (Rao et al. 1981), and DDT and parathion (Sanders 1972). On the basis of a study of 12 insecticides, Eisler (1969) concluded that grass shrimp are more sensitive to organophosphorous insecticides, and less sensitive to several organochlorine insecticides at high salinity than at low salinity. Low temperatures enhanced the survival of shrimp exposed to both groups of insecticides. Also, for most organophosphorous compounds tested, crustaceans were more sensitive than marine fishes by several orders of magnitude.

Heavy metals such as cadmium are more toxic to grass shrimp than to mummichogs, Fundulus heteroclitus (Eisler 1971). Concentrations of heavy metals (mercury, cadmium, and chromium) are acutely toxic to adult grass shrimp, usually in the order of 100 to 1,000 ppb. Except in areas of sewage or industrial outfalls, such concentrations far exceed those in estuaries. Therefore, grass shrimp are too resistant to be of much value in heavy metal bioassays (Vernberg et al. 1977). Increased temperature or decreased salinity increases the sensitivity of grass shrimp to heavy metals (Fales 1978; Sunda et al. 1978). Sublethal effects of heavy metals on grass shrimp have included loss of a predator avoidance response (Barthalmus 1977), developmental abnormalities in larvae (Shealy and Sandifer 1975), and a reduced tolerance to salinity fluctuations (Middaugh and Floyd 1978).

Attempts have been made by Tatem (1976), Tatem et al. (1978), and Dillon (1982) to evaluate the effects of exposure to petroleum hydrocarbons on survival and various physiological phenomena in grass shrimp. Several conclusions have been drawn from this research: (1) concentrations of petroleum hydrocarbons normally found in saltwater (10 to 20 ppb) and its

sediments are too low to have acutely toxic effects on grass shrimp; (2) when sediments and water are exposed chronically to oil pollution or during a large oil spill, hydrocarbon concentrations could cause acute toxicity; (3) metabolism, reproduction, and growth may be reduced or altered if oil concentrations persist near 1 ppm; (4) grass shrimp rapidly depurate accumulated petroleum hydrocarbons when they are returned to oil-free water; and (5) the toxicity of oil is correlated with the relative proportion of the aromatic fraction present.

Some investigators have evaluated the effects of biocides, such as those used to remove fouling organisms from cooling systems of powerplants (generally chlorine), on grass shrimp. In a review by Hall et al. (1979) it was concluded that the detrimental

effects of chlorination on grass shrimp were negligible under normal powerplant operations.

Additional investigations indicated that *P. pugio* was less sensitive than mysid shrimp to drilling muds but that both were several orders of magnitude more sensitive than fishes (Conklin et al. 1980); grass shrimp were more sensitive than pinfish (*Lagodon rhomboides*) to a simulated refinery effluent containing phenol, sulfide, ammonia, and some other components (Hall et al. 1978); and grass shrimp were more sensitive than other crustaceans to ionizing radiation. Radiation affects metabolic pathways involved in the synthesis of non-essential amino acids used in osmotic regulation (Engel et al. 1974).

LITERATURE CITED

- Adams, S.M., and J.W. Angelovic. 1970. Assimilation of detritus and its associated bacteria by three species of estuarine animals. *Chesapeake Sci.* 11:249-254.
- Alon, N.C., and S.E. Stancyk. 1982. Variation in life-history patterns of the grass shrimp *Palaemonetes pugio* in two South Carolina estuarine systems. *Mar. Biol.* 68:265-276.
- American Public Health Association. 1975. Standard methods for the examination of water and wastewater. 14th ed. Am. Public Health Assoc., Washington, D.C. 1,193 pp.
- Anderson, G. 1977. The effects of parasitism on energy flow through laboratory shrimp populations. *Mar. Biol.* 42:239-251.
- Antheunisse, L.J., J.J. Lammens, and N.P. Van den Hoven. 1971. Diurnal activities and tidal migration of the brackish water prawn *Palaemonetes varians* (Leach) (Decapoda, Caridea). *Crustaceana* 21:203-217.
- Barrett, B.B., J.L. Merrell, T.P. Morrison, M.C. Gillespie, E.J. Ralph, and J.F. Burdon. 1978. A study of Louisiana's major estuaries and offshore waters. La. Dep. Wildl. Fish. Tech. Bull. 27:1-197.
- Barthalmus, G.T. 1977. Behavioral effects of mercury on grass shrimp. *Mar. Pollut. Bull.* 8:87-90.
- Beck, J.T., and B.C. Cowell. 1976. Life history and ecology of the freshwater caridean shrimp, *Palaemonetes paludosus* (Gibbes). *Am. Midl. Nat.* 96:52-65.
- Bell, S.S., and B.C. Coull. 1978. Field evidence that shrimp predation regulates meiofauna. *Oecologia* 35:141-148.
- Boston, M.A., and A.J. Provenzano. 1982. Attempted hybridization of the grass shrimp, *Palaemonetes* (Caridea, Palaemonidae) with an evaluation of taxonomic characters of juveniles. *Estuaries* 5:165-174.
- Bowler, M.W., and A.J. Seidenberg. 1971. Salinity tolerance of the prawns, *Palaemonetes vulgaris* and *P. pugio* and its relationship to the distribution of these species in nature. *Va. J. Sci.* 22:94.
- Broad, A.C. 1957. Larval development of *Palaemonetes pugio* Holthuis. *Biol. Bull.* (Woods Hole) 112:162-170.
- Broad, A.C., and J.H. Hubschman. 1962. A comparison of larvae and larval development of species of Eastern U.S. *Palaemonetes* with special reference to the development of *Palaemonetes intermedius* Holthuis. *Am. Zool.* 2:394-395.
- Broad, A.C., and J.H. Hubschman. 1963. The larval development of *Palaemonetes kadiakensis* M.J. Rathbun in the laboratory. *Trans. Am. Microsc. Soc.* 82:185-197.

- Burkenroad, M.D. 1947. Reproduction activities of decapod Crustacea. *Am. Nat.* 81:392-398.
- Chambers, R. 1981. Seasonal feeding and distribution of Palaemonetes pugio and P. vulgaris in Great Sippewissett salt marsh. *Biol. Bull. (Woods Hole)* 161:324.
- Christmas, J.Y., and W. Langley. 1973. Estuarine invertebrates, Mississippi. Pages 255-319 in J.Y. Christmas, ed. *Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi. Gulf Coast Res. Lab., Ocean Springs, Miss.*
- Chung, K.S. 1977. Heat resistance of crustaceans and fishes of an estuarine power plant and their predicted survival in the discharge canal. Ph.D. Dissertation, Texas A&M University, College Station. 443 pp.
- Coen, L.D., K.L. Heck, and L.G. Abele. 1981. Experiments on competition and predation among shrimps of seagrass meadows. *Ecology* 62:1484-1493.
- Conklin, P.J., D.G. Doughtie, and K.R. Rao. 1980. Effects of barite and used drilling muds on crustaceans, with particular reference to the grass shrimp, Palaemonetes pugio. Pages 812-943 in *Research on environmental fate and effects of drilling fluids and cuttings, Vol. 2.* Courtesy Assoc. Washington, D.C.
- Darnell, R.M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. *Publ. Inst. Mar. Sci. Univ. Tex.* 5:353-416.
- Davis, C.C. 1965. A study of the hatching in Palaemonetes vulgaris (Say). *Crustaceana* 8:233-238.
- Diener, R.A., A. Inglis, and G.B. Adams. 1974. Stomach contents of fishes from Clear Lake and tributary waters, a Texas estuarine area. *Contrib. Mar. Sci.* 18:7-17.
- Dillon, T.M. 1982. Dietary accumulation of dimethylnaphthalene by the grass shrimp Palaemonetes pugio under stable and fluctuating temperatures. *Bull. Environ. Contam. Toxicol.* 28:149-153.
- Dillon, T.M. 1983. Oxygen consumption in the shrimp, Palaemonetes pugio, exposed to fluctuating temperatures and food contaminated with the diaromatic petroleum hydrocarbon, dimethylnaphthalene. *Estuarine Coastal Shelf Sci.* 16:403-413.
- Dobkin, S. 1963. The larval development of Palaemonetes paludosus (Gibbes, 1850) (Decapoda, Palaemonidae), reared in the laboratory. *Crustaceana* 6:41-61.
- Dobkin, S., and R.B. Manning. 1964. Osmoregulation in two species of Palaemonetes (Crustacea: Decapoda) from Florida. *Bull. Mar. Sci. Gulf Caribb.* 14:149-157.
- Eisler, R. 1969. Acute toxicities of insecticides to marine decapod crustaceans. *Crustaceana* 16:302-310.
- Eisler, R. 1971. Cadmium poisoning in Fundulus heteroclitus (Pisces: Cyprinodontidae) and other marine organisms. *J. Fish. Res. Board Can.* 28:1228-1234.
- Engel, D.W., M.G. Shelton, and J.C. White. 1974. Effect of ionizing radiation and salinity on grass shrimp. *Rad. Res.* 59:72.
- Fales, R.R. 1978. Influence of temperature and salinity on toxicity of hexavalent chromium to grass shrimp Palaemonetes pugio (Holthuis). *Bull. Environ. Contam. Toxicol.* 20:447-450.

- Fleming, L.E. 1969. Use of male external genitalic details as taxonomic characters in some species of Palaemonetes (Decapoda, Palaemonidae). Proc. Biol. Soc. Wash. 82:443-452.
- Floyd, W.R. 1977. The effects of temperature and salinity on the larval development of the grass shrimp Palaemonetes pugio reared in the laboratory. Va. J. Sci. 28:92.
- Gore, R.H., E.E. Gallaher, L.E. Scott, and K.A. Wilson. 1981. Studies on decapod Crustacea from the Indian River region of Florida. XI. Community structure, biomass and species - aerial relationships of seagrass and drift algae-associated macrocrustaceans. Estuarine Coastal Shelf Sci. 12:485-508.
- Gunter, G. 1945. Studies on the marine fishes of Texas. Publ. Inst. Mar. Sci. Univ. Tex. 1:1-190.
- Hall, L.W., Jr., A.L. Buikema, Jr., and J. Cairns, Jr. 1978. The effects of a simulated refinery effluent on the grass shrimp, Palaemonetes pugio. Arch. Environ. Contam. Toxicol. 7:23-35.
- Hall, L.W., D.T. Burton, and S.L. Margrey. 1979. Influence of acclimation temperature on the interactions of chlorine, elevated temperature, and exposure duration for grass shrimp, Palaemonetes pugio. Trans. Am. Fish. Soc. 108:626-631.
- Harrington, R.W., Jr., and E.S. Harrington. 1972. Food of female marsh killifish Fundulus confluentus in Florida. Am. Midl. Nat. 87:492-502.
- Heard, R.W. 1982. Guide to common tidal marsh invertebrates of the northeastern Gulf of Mexico. Miss.-Ala. Sea Grant Cons., MASGP-79-004. 82 pp.
- Heard, R.W., and R.M. Overstreet. 1983. Taxonomy and life histories of two North American species of "Carneophallus" (Microphallus) (Digenea: Microphallidae). Proc. Helminthol. Soc. Wash. 50:170-174.
- Heck, K.L., Jr., and R.J. Orth. 1980. Structural components of eelgrass (Zostera marina) meadows in the lower Chesapeake Bay - Decapod Crustacea. Estuaries 3:289-295.
- Heck, K.L., Jr., and T.A. Thoman. 1981. Experiments on predator-prey interactions in vegetated aquatic habitats. J. Exp. Mar. Biol. Ecol. 53:125-134.
- Holthuis, L.B. 1952. A general revision of the Palaemonidae (Crustacea: Decapoda, Natantia) of the Americans. II. The subfamily Palaemoninae. Allan Hancock Found. Publ. Occas. Pap. 12:1-396.
- Hubschman, J.H. 1975. Larval development of the freshwater shrimp Palaemonetes kadiakensis Rathbun under osmotic stress. Physiol. Zool. 48:97-140.
- Hubschman, J.H., and A.C. Broad. 1974. The larval development of Palaemonetes intermedius (Decapoda, Palaemonidae) reared in the laboratory. Crustaceana 26:89-103.
- Huner, J.V. 1979. Grass shrimp. La. Conserv., 2nd Quarter:24-27.
- Johannes, R.E., and M. Satomi. 1966. Composition and nutritive value of fecal pellets of a marine crustacean. Limnol. Oceanogr. 11:191-197.
- Johnson, S.K. 1977. Crawfish and freshwater shrimp diseases. Tex. A&M Univ. Sea Grant Coll. Program TAMU-SG-77-605. 23 pp.

- Kirby, D.F., and R.E. Knowlton. 1976. Salinity tolerance and sodium balance in the prawn Palaemonetes pugio Holthuis. Am. Zool. 16:240.
- Knieb, R.T., and A.E. Stiven. 1982. Benthic invertebrate responses to size and density manipulations of the common mummichog Fundulus heteroclitus in an intertidal saltmarsh. Ecology 63:1518-1532.
- Knowlton, R.E. 1965. Effects of some environmental factors on larval development of Palaemonetes vulgaris (Say). J. Elisha Mitchell Sci. Soc. 81:87.
- Knowlton, R.E., and D.F. Kirby. 1984. Salinity tolerance and sodium balance in the prawn Palaemonetes pugio Holthuis, in relation to other Palaemonetes spp. Comp. Biochem. Physiol. 77A:425-430.
- Knowlton, R.E., and A.B. Williams. 1970. The life history of Palaemonetes vulgaris (Say) and P. pugio Holthuis in coastal North Carolina. J. Elisha Mitchell Sci. Soc. 86:185.
- Livingston, R.J., G.J. Kobylinski, F.G. Lewis III, and P.F. Sheridan. 1976. Long-term fluctuations of epibenthic fish and invertebrate populations in Apalachicola Bay, Florida. U.S. Natl. Mar. Serv. Fish. Bull. 74:311-321.
- Maguire, E.J. 1961. The influence of habitat NaCl concentrations on the distribution of two species of Palaemonetes. La. Acad. Sci. 24:71-75.
- McFarland, W.N., and P.E. Pickens. 1965. The effects of season, temperature and salinity on standard and active oxygen consumption of the grass shrimp, Palaemonetes vulgaris (Say). Can. J. Zool. 43:571-585.
- McKenney, C.L., and J.M. Neff. 1979. Individual effects and interactions of salinity, temperature and zinc on larval development of the grass shrimp Palaemonetes pugio. 1. Survival and developmental duration through metamorphosis. Mar. Biol. 52:177-188.
- Meehan, O.L. 1936. Notes on the freshwater shrimp Palaemonetes paludosa (Gibbes). Trans. Am. Microsc. Soc. 55:433-441.
- Middaugh, D.P., and G. Floyd. 1978. Effect of pre-hatch and post-hatch exposure to cadmium on salinity tolerance of larval grass shrimp, Palaemonetes pugio. Estuaries 1:123-125.
- Morgan, M.D. 1980. Grazing and predation of the grass shrimp Palaemonetes pugio. Limnol. Oceanogr. 25:896-902.
- Nagabushanam, R. 1961. Tolerance of the prawn, Palaemonetes vulgaris (Say), to waters of low salinity. Sci. Cult. 27:43.
- Odum, W.E., and E.J. Heald. 1972. Trophic analysis of an estuarine mangrove community. Bull. Mar. Sci. 22:671-738.
- Overstreet, R.M. 1978. Marine Maladies? Worms, germs, and other symbionts from the northern Gulf of Mexico. Mississippi-Alabama Sea Grant. Cons. MASGP-78-021. 140 pp.
- Overstreet, R.M., and R.W. Heard. 1982. Food contents of six commercial fishes from Mississippi Sound. Gulf Res. Rep. 7:137-149.
- Overstreet, R.M., and E. Weidner. 1974. Differentiation of microsporidia

- spore-tails in *Inodosporus spraguei* Gen. Sp. N. Z. Parasitenk. 44:169-186.
- Pomeroy, L.R., and R.G. Wiegert. 1981. The ecology of a salt marsh. Springer-Verlag, New York. 271 pp.
- Rao, K.R., F.R. Fox, P.J. Conklin, and A.C. Cantelmo. 1981. Comparative toxicology and pharmacology of chlorophenols: studies on the grass shrimp *Palaemonetes pugio*. Pages 37-72 in F. J. Vernberg et al., eds. Biological monitoring of marine pollutants. Academic Press, New York.
- Rao, K.R., D.G. Doughtie, and P.J. Conklin. 1982. Physiological and histopathological evaluation of dithiocarbamate toxicity to the grass shrimp, *Palaemonetes pugio*. Pages 413-445 in W.B. Vernberg et al., eds. Physiological mechanisms of marine pollutant toxicity. Academic Press, New York.
- Sanders, H.O. 1972. Toxicity of some insecticides to four species of malacostracan crustaceans. U.S. Bur. Sport Fish. Wildl. Tech. Pap. 66:1-19.
- Sandifer, P.A. 1973. Effects of temperature and salinity on larval development of grass shrimp *Palaemonetes vulgaris* (Decapoda, Caridea). U.S. Natl. Mar. Fish. Serv. Fish. Bull. 71:115-123.
- Sandifer, P.A., and T.I.J. Smith. 1979. Possible significance of variation in the larval development of palaemonid shrimp. J. Exp. Mar. Biol. Ecol. 39:55-64.
- Sastry, A.N., and S.L. Vargo. 1977. Variations in the physiological responses of crustacean larvae to temperature. Pages 401-423 in F.J. Vernberg et al., eds. Physiological responses of marine biota to pollutants. Academic Press, New York.
- Schimmel, S.C., and A.J. Wilson, Jr. 1977. Acute toxicity of Kepone® to four estuarine animals. Chesapeake Sci. 18:224-227.
- Schimmel, S.C., J.M. Patrick, Jr., and A.J. Wilson, Jr. 1977. Acute toxicity to and bioconcentration of endosulfan by estuarine animals. Pages 241-242 in F.L. Mayer, and J.L. Hamelink, eds. Aquatic toxicology and hazard evaluation. ASTM STP 634. American Society for Testing and Materials, Philadelphia, Penn.
- Schoen, R.H., and R.E. Knowlton. 1977. Salinity lethal limits and sodium balance in prawn *Palaemonetes vulgaris* (Say). Am. Zool. 17:922.
- Shealy, M.H., and P.A. Sandifer. 1975. Effects of mercury on survival and development of larval grass shrimp *Palaemonetes vulgaris*. Mar. Biol. 33:7-16.
- Shenker, J.M., and J.M. Dean. 1979. The utilization of an intertidal salt marsh creek by larval and juvenile fishes: abundance, diversity and temporal variation. Estuaries 2:154-163.
- Sikora, W.B. 1977. The ecology of *Palaemonetes pugio* in a southeastern salt marsh ecosystem, with particular emphasis on production and trophic relationships. Ph.D. Dissertation. University South Carolina, Columbia. 122 pp.
- Solangi, M.A., and R.M. Overstreet. 1980. Biology and pathogenesis of the coccidium *Eimeria funduli* infecting killifishes. J. Parasitol. 66:513-526.
- Strenth, N.E. 1976. A review of the systematics and zoogeography of the freshwater species of *Palaemonetes* Heller of North America (Crustacea: Decapoda). Smithsonian Contrib. Zool. 228.

- Sunda, W.G., D.W. Engle, and R.M. Thuotte. 1978. Effect of chemical speciation on toxicity of cadmium to grass shrimp, Palaemonetes pugio: importance of free cadmium ion. Environ. Sci. Technol. 12:409-413.
- Swingle, H.A. 1971. Biology of Alabama estuarine areas - cooperative Gulf of Mexico estuarine inventory. Ala. Mar. Res. Bull. 5:1-123.
- Tabb, D., and R.B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July 1957 through September 1960. Bull. Mar. Sci. Gulf Caribb. 11:554-649.
- Tatem, H.E. 1976. Accumulation of naphthalenes by grass shrimp: effects on respiration, hatching, and larval growth. Pages 201-209 in D.A. Wolfe, ed. Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms. Pergamon Press, Inc. Elmsford, New York.
- Tatem, H.E., B.A. Cox, and J.W. Anderson. 1978. The toxicity of oils and petroleum hydrocarbons to estuarine crustaceans. Estuarine Coastal Mar. Sci. 6:365-374.
- Thorp, J.H. 1976. Interference competition as a mechanism of coexistence between two sympatric species of the grass shrimp Palaemonetes (Decapoda: Palaemonidae). J. Exp. Mar. Biol. Ecol. 25:19-35.
- Thorp, J.H., and D.E. Hoss. 1975. Effects of salinity and cyclic temperature on survival of two sympatric species of grass shrimp (Palaemonetes), and their relationship to natural distributions. J. Exp. Mar. Biol. Ecol. 18:19-28.
- Trent, L, E.J. Pullen, and R. Proctor. 1976. Abundance of macrocrustaceans in a natural marsh and a marsh altered by dredging, bulkheading, and filling. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 74:195-200.
- Tyler-Schroeder, D.B. 1979. Use of grass shrimp (Palaemonetes pugio) in a life-cycle toxicity test. Pages 159-170 in L.L. Marking and R.A. Kimerle, eds. Aquatic toxicology. ASTM STP 667, American Society for Testing and Materials, Philadelphia, Penn.
- Vernberg, W.B., P.J. DeCoursey, M. Kelly, and D.M. Johns. 1977. Effects of sublethal concentrations of cadmium on adult Palaemonetes pugio under static and flow-through conditions. Bull. Environ. Contam. Toxicol. 17:16-24.
- Weaver, J.E., and L.F. Holloway. 1974. Community structure of fishes and macrocrustaceans in ponds of a Louisiana tidal marsh influenced by weirs. Contrib. Mar. Sci. 18:57-69.
- Welsh, B.L. 1975. The role of grass shrimp, Palaemonetes pugio, in a tidal marsh ecosystem. Ecology 56:513-530.
- White, F.A. 1949. Preliminary notes on the breeding season of Palaemonetes kadiakensis Rathbun in the Baton Rouge area. Proc. La. Acad. Sci. 12:71-74.
- Williams, A.B. 1965. Marine decapod crustaceans of the Carolinas. U.S. Fish. Wildl. Serv. Fish. Bull. 65:1-298.
- Wood, C.E. 1967. Physioecology of the grass shrimp Palaemonetes pugio, in the Galveston Bay estuarine system. Contrib. Mar. Sci. Univ. Tex. 12:54-79.

Wood, C.E. 1974. Key to the Natantia
Crustacea Decapoda of the coastal

waters on the Texas coast.
Contrib. Mar. Sci. 18:35-56.

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15. Supplementary Notes *U.S. Army Corps of Engineers Report No. TR EL-82-4		14.		
16. Abstract (Limit: 200 words) This species profile summarizes much of the literature published about the biology of grass shrimp, <i>Palaemonetes</i> spp. Five species (<i>P. pugio</i> , <i>P. vulgaris</i> , <i>P. intermedius</i> , <i>P. paludosus</i> , and <i>P. kadiakensis</i>) are common in coastal waters of the northern Gulf of Mexico, although the last two are primarily freshwater forms. The brackish-water species are among the most abundant shallow-water benthic decapods in estuaries and play important roles as food for fishes and as transporters of nutrients among various trophic levels. They spawn from spring to autumn and the growth of planktonic larvae is normally completed in 7 to 12 molts. Postlarvae of 7-10 mm are 1.5 to 2 months old. The life span of grass shrimp is 6 to 13 months (maximum size rarely exceeds 50 mm). <i>Palaemonetes</i> spp. are eurythermal, euryhaline, and are relatively tolerant to hypoxia and a variety of pollutants. Grass shrimp feed on detritus, epiphytes, and meiofauna. They tend to concentrate near underwater structures and plants, especially in dense stands of underwater macrophytes.				
17. Document Analysis a. Descriptors Estuaries Growth Fishes Feeding b. Identifiers/Open-Ended Terms Grass shrimp Life history <i>Palaemonetes</i> spp. Habitat requirements Temperature requirements Spawning c. COSATI Field/Group				
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