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March 1984

TR EL-82-4

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

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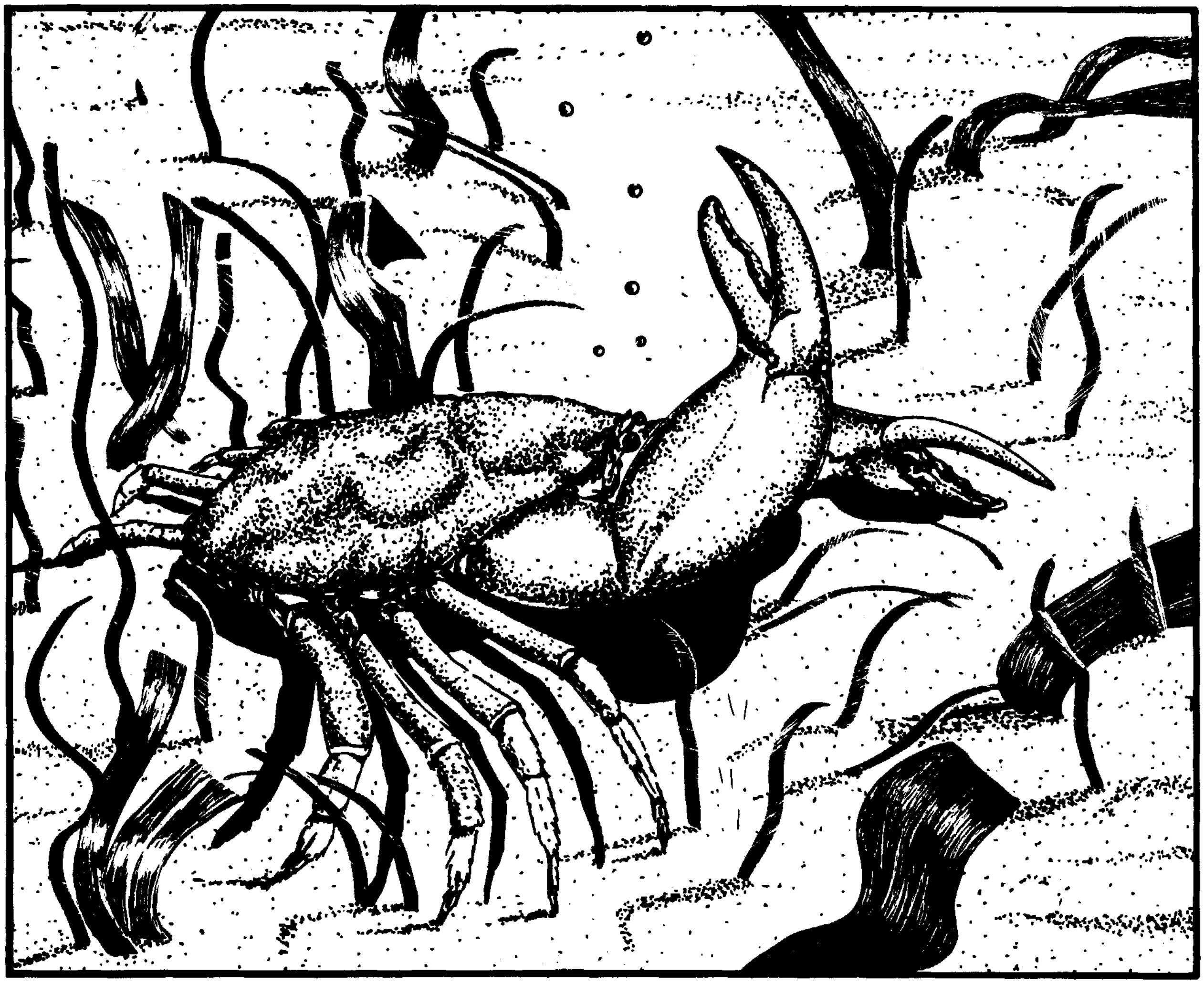

Fish and Wildlife Service
U.S. Department of the Interior

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

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

STONE CRAB

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:

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Attention: WESER
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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 gratefully acknowledge the reviews and comments of Ms. Theresa M. Bert, Yale University, New Haven, Connecticut, and Dr. Robert Gore, Academy of Natural Sciences of Philadelphia, Pennsylvania.

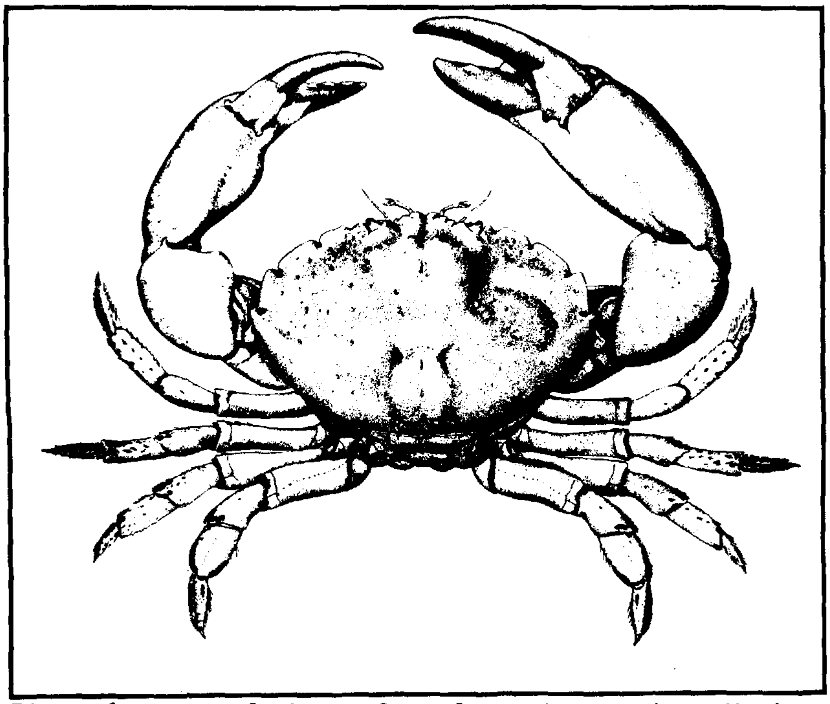

Figure 1. Dorsal view of a male stone crab, Menippe mercenaria (Say), from Williams (1965).

STONE CRAB

NOMENCLATURE/TAXONOMY/RANGE

Scientific name. . . . . Menippe mercenaria (Say)
Common name. . . . . . Stone crab (Figure 1)
Class. . . Malacostraca (from Barnes 1980)
Order. . . . . Decapoda
Family. . . . . Xanthidae

Geographic range: From Cape Lookout, North Carolina, southward and throughout the Gulf of Mexico to Yucatan, Mexico; Bahamas; Cuba; and Jamaica (Williams 1965; Bert et al. 1978). Presently it is suspected from morphological studies that Menippe mercenaria inhabiting the northern Gulf of Mexico should be split into two species with the demarcation between their ranges at Apalachicola Bay, Florida (D. Felder, University of Southwestern Louisiana, Lafayette, Louisiana, and A. B. Williams, Smithsonian Institution, Washington, D.C.; pers. comm.). On the other hand, preliminary electrophoretic studies and field observations of hybridization in the zone of sympatry suggest incipient species (T. Bert, Yale University, New Haven, Connecticut; pers. comm.). In this paper, discussions will focus on M. mercenaria from peninsular Florida (Figure 2), with some references to studies from the Atlantic coast of other Southern States.

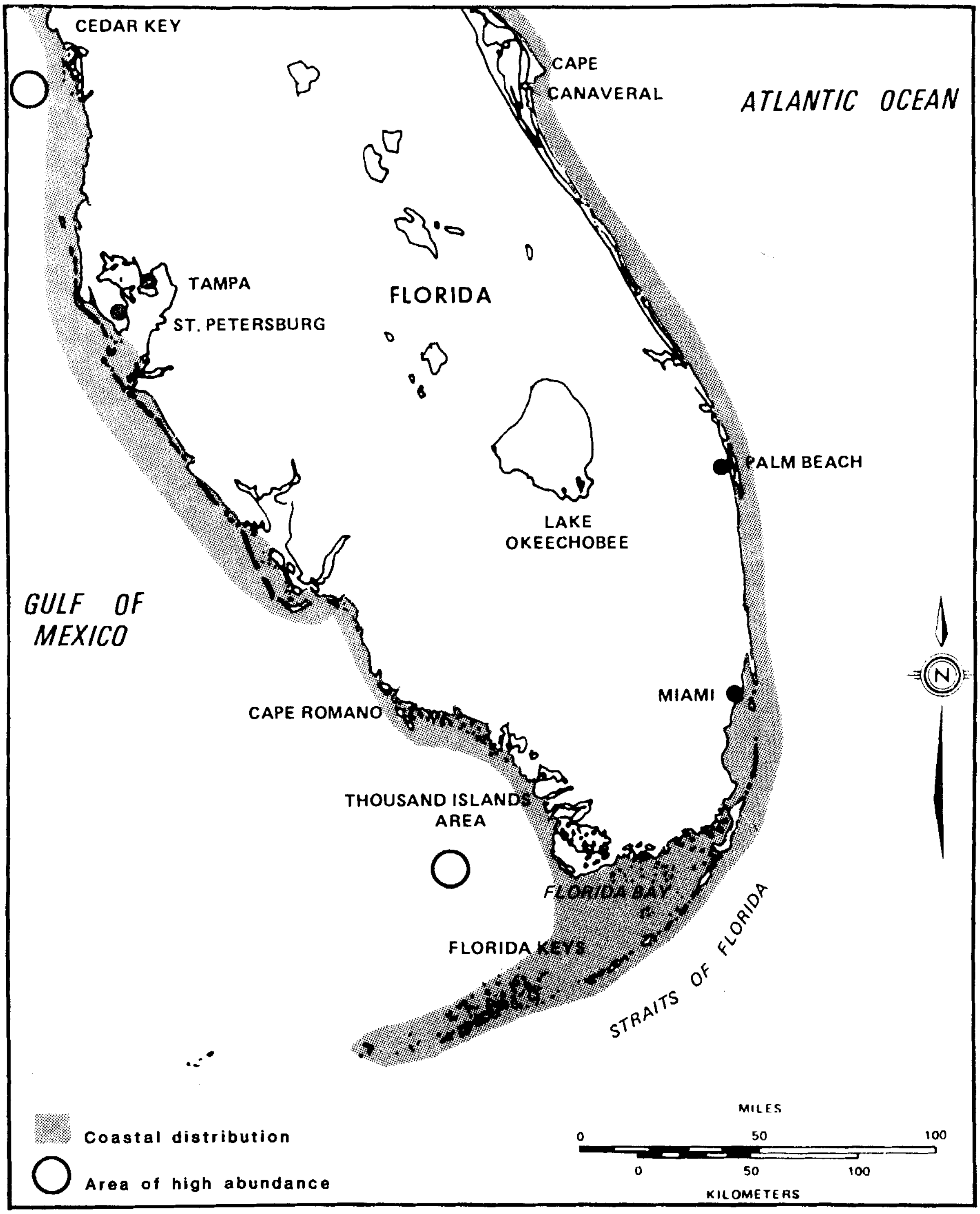

Figure 2. Coastal distribution of stone crab in south Florida.

MORPHOLOGY/IDENTIFICATION AIDS

Carapace transversely oval, approximately two-thirds as long as wide, convex, nearly smooth to unaided eye, minutely granulate and punctate. Anterolateral border divided into four lobes: first two wide, third wide but dentiform, fourth much narrower and dentiform. Front with a median notch and a broad trilobulate lobe on each side. Orbital border thick, fissures indistinct.

Chelipeds large and heavy, unequal in size, nearly smooth; inside surface of hands with a patch of fine oblique parallel striae serving as a stridulating organ and adapted for playing against thick edge of second and third anterolateral teeth and outer suborbital tooth; dactyl of major chela with a large basal tooth, and immovable finger with a large subbasal tooth; fingers of minor chela with numerous small teeth. Walking legs stout and distally hairy (Williams 1965).

Color in life: Northern and western gulf form - small juveniles greenish or bluish gray to gray or dark tan, with small dark spots on dorsal carapace and chelae; adults are deep chocolate brown dorsally, with cream-colored to purplish underneath carapace and chelae. Legs are dark brown and not banded or occasionally faintly banded with yellow or cream color. Florida peninsular gulf coast form - adults are light gray or tan dorsally on carapace and chelae, with dark brown or grayish spots, and cream color to white undersides. Legs are dark brown with distinct yellow to white bands at the junctions of the segments. Juveniles are deep maroon to nearly black, with white tips on the chelae and one to four small white spots on dorsal carapace (T. Bert, pers. comm.).

Larval stages are described by Porter (1960) and Hyman (1925). Manning (1961), Wass (1955), and Hay and Shore (1918) described coloration and morphological changes in juvenile stages of M. mercenaria.

Menippe nodifrons is similar to M. mercenaria but is smaller, more purplish, and posseses tubercles or small bumps on the anterior margin of its carapace (Kaplan 1982).

REASON FOR INCLUSION IN THE SERIES

The stone crab (Menippe mercenaria) is the largest of the xanthid crabs within its range and is the only one to support a fishery. Stone crabs are formidable predators with massive claws well-suited for breaking open the shells of many mollusks. The claws are harvested for their appeal as a delicacy with high market value. In Florida the annual stone crab landings are valued at well over $4 million, placing this species among the State's top 10 commercially important marine species.

LIFE HISTORY

Copulation and Spawning

Copulation takes place within burrows or crevices, making it difficult to observe individual copulations or the timing of the stone crab mating season (Bert et al. 1978). Binford (1913) witnessed matings and males guarding burrows containing females during August in North Carolina. Bender (1971) reported mating to occur from November to March at Cedar Key, Florida.

Copulation between stone crabs was described by Binford (1913), Savage (1971), and Yang (1972). A male first courts a female for up to 12 hr and then, using his walking legs, flips the female ventral side up beneath him (Yang 1972). During mating, males cradle upside-down females within their walking legs. The female telson curves over the rear portion of the male carapace. Chelae of male crabs are held in a defensive posture during mating, yet loss of a chela does not seem to interfere with other aspects of the mating ritual. Copulating females seen by Yang (1972) were freshly molted, with soft shells. Binford (1913) described the male's handling of the soft-shell female as being done "with care" to avoid injury to the female. Matings lasted from 6 to 8 hr (Yang 1972).

During copulation masses of sperm are transferred from male to female within spermatophores, which are stored by the female crab within a chitin-lined seminal receptacle. Sperm are retained in the receptacle until spawning occurs, when only a portion of the sperm is used for fertilization of a single batch of eggs. Binford (1913) reported that fertilization occured within the lumen of the ovary, although many more sperm cells attach to the eggs within the oviducts.

A single female may produce from four (Porter 1960) to six (Binford 1913) egg masses or "sponges" during a single mating season. Cheung (1969) reported an average of 4.5 spawnings per molt. Each egg sponge may contain between 500,000 and 1,000,000 eggs according to Binford, or from 160,000 to 350,000 according to Noe (1967). The number of eggs spawned is positively correlated with size of the female (McRae 1950). After hatching one batch, a female may deposit a new egg mass within a week. Spawnings may occur up to six successive times without an intervening mating (Binford 1913). Porter (1960) reported that a female spawned four times without mating or molting during a single summer, and Cheung (1968) reported transmolt retention of sperm by females.

Binford (1913) described the upright spawning position of the female stone crab. A basket is formed of the female's extended abdomen and the exopods of her abdominal appendages. Fertilized eggs are released into this basket and become attached by a sticky secretion to hairs on the exopods. After hatching occurs and larvae are released, the female scrapes the egg shells and their stalks off these exopod hairs (Binford 1913). Hatching is reported to occur within 9 days to 2 weeks after spawning (Binford 1913; Porter 1960).

Williams (1965) reported spawning to occur from May to July and perhaps August in North Carolina. Further south spawning can occur year-round in Biscayne Bay and Florida Bay (Noe 1967; Cheung 1969; Bender 1971; Bert et al. 1978). In south Florida spawning frequency is very low from November through March (Cheung 1969). Temperature and photoperiod are primary regulators of spawning frequency (Noe 1967; Cheung 1969; Bender 1971). Cheung (1969) reported accelerated ovarian development at 29°C, or during the warmest month in Biscayne Bay, with spawning peaking during August and September. In autumn, as temperatures fall and day length decreases, egg development reportedly slows and spawning frequency decreases. In females, molting increases in frequency in autumn and winter when spawning frequency decreases.

Larval Development

Development of the planktonic larvae to first crab stage usually requires 27 to 30 days in the laboratory (Porter 1960; Mootz and Epifanio 1974), but may be altered considerably by diet (Mootz and Epifanio 1974), temperature, and salinity (Porter 1960; Ong and Costlow 1970; Scotto 1979). Larvae normally pass through five zoeal stages. They may also enter either a prezoeal stage just after hatching or a sixth zoeal stage (Porter 1960). Porter (1960) stated that neither the observed prezoea nor the sixth zoeal stage ever molted to more advanced stages. The prezoeal stage was believed to be caused by the stress of an artificial environment on the developing embryos.

For *M. nodifrons*, Scotto (1979) found that the sixth stage did molt into megalopae, and that it may occur in nature under certain conditions. For *M. mercenaria*, Ong and Costlow (1970) found that only 2 of 11 sixth-stage zoea observed in their study reached the megalops stage but neither became first crabs. The sixth-stage zoea in their study occurred under several different combinations of temperature and salinity, and thus could not be attributed to the effects of these two factors.

During larval life, M. mercenaria presumably feeds on zooplankton. In culture they fare best on a diet of Artemia nauplii (Porter 1960). At the peak of energy demand during larval development individual larvae consume up to 91 brine shrimp nauplii per day (Mootz and Epifanio 1974), which is equivalent to 0.502 calories per day. During their entire larval existence individual stone crabs consume a total of 7.329 calories.

Optimal growth rates and best survival levels in Mootz and Epifanio's culture system were seen at a temperature of 30°C and salinities in the range of 30 to 35 ppt, as was also found by Ong and Costlow (1970). Under these conditions larvae reached the megalopae stage in 14 days and the first crab in 21 days. Survival rates peaked at 60% to 72% under this combination of conditions.

Postlarvae

The ecology of the megalopae of M. mercenaria is unknown owing primarily to difficulties in differentiating larval stages of stone crabs from those of other xanthid crabs (Bert et. al. 1978). In mass culture tanks, under highly artificial conditions, Yang and Krantz (1976) found that megalopae settled upon window-screen panels. They also noted that megalopae were extremely sensitive to poor water quality. Megalopae first appeared in Yang and Krantz's mass cultures on day 9 after hatching and first crabs appeared on day 13.

Juvenile Crabs

Savage and McMahon (1968), Manning (1961) and Bender (1971) defined juveniles to be crabs of less than 3.0 cm in carapace width (CW) (but see Growth Characteristics below). During the juvenile phase M. mercenaria's coloration patterns change from dark purple with three white dots in a triangular pattern on the dorsal surface (juveniles less than 1.0 cm CW) to, depending on habitat, a mottled gray to green background (juveniles greater than 1.0 cm) (Bender 1971). According to Bender (1971), juvenile stone crabs in tanks can change their coloration patterns, after a few days, to blend with their surroundings.

In North Carolina Williams (1965) found the smallest juvenile stone crabs in deep channels where they lived beneath shell fragments. At a size of about 13 mm CW, small crabs move into shallower water and are found wherever crevices are abundant: about rocks, jetties, pilings, and in oyster shell rubble. At Cedar Key, Florida, juveniles less than 1.3 cm are found in deep channels and in seagrass beds (Bender 1971). At a larger size, 3.0 to 5.0 cm, small crabs are found on oyster bars during the summer in the Cedar Key area (McRae 1950; Bender 1971). McRae (1950) reported oyster bars to be a least preferred habitat of stone crabs, although he did find juvenile and adult crabs there. Bender (1971), working in the same area, reported finding many stone crabs on oyster bars. In the Florida Keys and at Cedar Key, sponges, gorgonians, submerged rock, and Sargassum mats are commonly used as refuges by juvenile stone crabs (Bender 1971; Bert et al. 1978). Offshore from Alligator Harbor, Florida, juveniles were commonly found in colonies of the bryozoan Schizoporella pungens (W.J. Lindberg, University of Florida, Gainesville, Florida; unpubl. data). Juvenile stone crabs are believed to be attracted to seagrass beds both by their abundant refugia and by Thalassia-blade epiflora and epifauna (Bert et al. 1978).

Adults

McRae (1950) found egg-bearing females always on grass flats or in channels, never on oyster bars. He also reported that few adult stone crabs were found on shallow flats during the spring and early summer months, a peak period of spawning. Another spawning peak occurs in late summer and early fall (T. Bert, pers. comm.). McRae (1950) and Bender (1971) reported that adults move onto shallow grassflats in autumn. McRae (1950) witnessed finding heterosexual pairs of crabs occupying burrows in shallow flats during fall. Pairings last from the time of courting and mating to the time when the exoskeleton of the newly molted female hardens (Bender 1971). At this point the female can defend herself, and both sexes vacate the burrow.

Migrations involving one sex and/or a single size class have been reported to occur seasonally (Bert et al. 1978)[1]. Females appear to be year-round residents of grassflats, but do move from shallow to deep flats as temperatures increase in the spring (Bender 1971). Male crabs normally live further offshore than do females, but move into shallower grassflat areas to mate with recently molted females at the end of the spawning season (McRae 1950; Bender 1971; Sullivan 1979). Movement patterns and habits of stone crabs found well offshore are not described in the current literature.

Sullivan (1979) described movements of nearshore M. mercenaria along the southwest coast of Florida. Average movement of tagged individuals showed that male movement was directed shoreward (easterly) or longshore (northerly) during fall and winter. This pattern reversed in spring and males moved offshore (westerly). Females moved inshore during fall and winter, and offshore during March. After 1 month of offshore movements females again headed shoreward. The 1-month offshore movement of females would perhaps bring them to deeper grassflats, as described for the Cedar Key population by Bender (1971).

GROWTH CHARACTERISTICS

Growth for M. mercenaria, like other crustaceans, can be characterized by the frequency of molting or intermolt interval, and by the incremental increase in size per molt. Published descriptive data suggest patterns for these parameters which, for the most part, await statistical analyses. Cheliped growth and regeneration, as the basis for management of this fishery, was the primary focus for much of the work related to growth.

Larval growth involves metamorphosis through five, sometimes six, zoeal stages and a megalopa, as discussed above. Figure 3 (from Ong and Costlow 1970) illustrates the slightly faster development at higher salinity and the markedly faster development at higher temperatures within the tolerance ranges for stone crabs. Under culture conditions of 25°C and 30 ppt, Mootz and Epifanio (1974) defined the progression of larval stages as follows: first zoea from day 0 to 4; second zoea from day 5 to 8; third zoea from day 9 to 11; fourth zoea from day 12 to 15; fifth zoea from day 16 to 20; and megalopa from day 21 to 28.5. The relationship of larval dry weight over time was exponential and described by the equation:

$$\log 1000Y = 1.0114 + 0.07687X$$

where: Y = is mg dry weight
X = is age in days.

The average dry weight of the first crab stage reported by Mootz and Epifanio was 0.69 mg, but carapace dimensions were not given. The average size of the first crab stage from natural populations has not been estimated in the literature. The smallest crab from a collection of 80 early juvenile crabs measured 1.40 mm CW (Savage and McMahan 1968).

Various morphometric relationships and apparently growth per se are equivalent among males and females as juveniles, but then the sexes diverge with sexual maturity (Savage and Sullivan 1978). Savage and McMahan (1968) found an approximate intermolt interval of 40 days for juveniles, but also noted a trend for the intermolt period to increase with the increasing size (i.e., CW) of juvenile crabs. They also found an incremental increase in CW per molt of about 15% of the pre-exuvial dimension, with generally smaller increments exhibited by crabs with widths above 10 mm. Salinity and temperature were not controlled in this study, and ranged from

[1]A trap bias may call into question trap data indicating migration (T. Bert, pers. comm.).

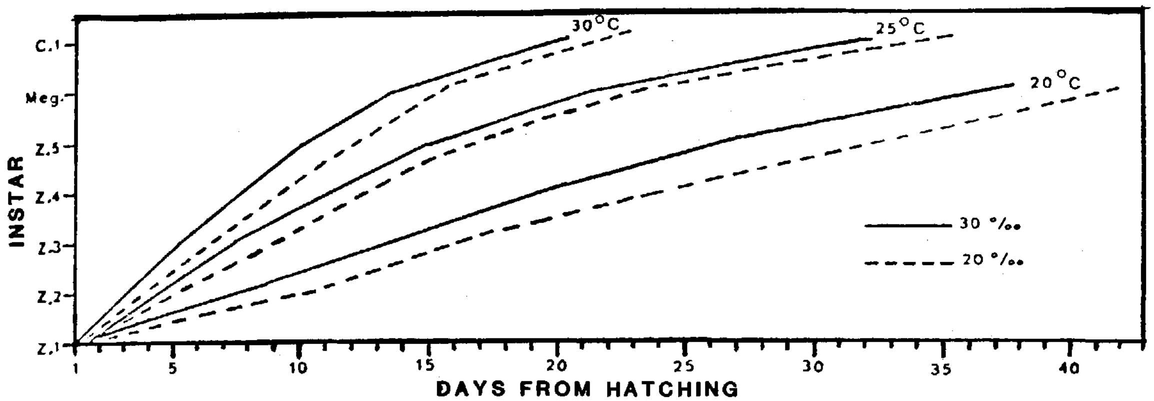

Figure 3. Average rates of development for the larvae of M. mercenaria at 20 and 30 ppt and three different temperatures; Z.1 through Z.5 are zoeal stages, Meg. is the megalopa, and C.1 is the first crab stage (from Ong and Costlow 1970).

23.32 to 35.68 ppt and from 15.5° to 30°C, respectively, so it is not known if systematic changes in conditions contributed to these perceived trends toward slower growth.

The transition from juvenile to adult form apparently occurs at a CW of about 35 mm. As juveniles approach this size, their carapace shape transforms to the adult shape (Manning 1961), and carapace-width versus claw-size relationships begin to diverge between the sexes (Savage and Sullivan 1978). By assuming a first crab stage of 1.40 mm CW, an intermolt interval of 40 days, and an incremental increase of 15% per molt, the juvenile existence is calculated to cover seven molts and 320 days until the transition to an adult form. Add to this the duration of larval existence (see Figure 3), and sexual maturity should not occur until at least 1 year of age. Sullivan (1979) indicated "that large-scale participation in egg production does not occur until approximately 60 mm CW," with the smallest ovigerous females reported from Florida collections being 36.9 mm CW (Savage and Sullivan 1978), 46.0 mm CW (McRae 1950), and 54 mm CW (Sullivan 1979). Therefore, the size and age at sexual maturity are not clearly known, and are no doubt subject to variation.[2]

The reported patterns of growth among intact adults show differences between the sexes and a trend toward slower growth in larger individuals. In general, males are heavier and gain weight faster than females of the same CW (Sullivan 1979). This dimorphism results in part from males' having greater chelae growth increments than females and, consequently, increasingly larger claws for any given CW (Savage and Sullivan 1978; Sullivan 1979). Chelipeds account for approximately 51% of the live weight in adult stone crabs (Davis et al. 1978). Furthermore, Cheung (1969) suggested that summer spawning inhibits molting by females (females molt primarily in winter). This, too, would contribute to an overall size difference between males and females, as found by Bender (1971), assuming the intermolt period of males is not similarly affected.

[2]More detailed data on size at sexual maturity, patterns of growth and population, age structure are forthcoming by Bert et al. (T. Bert, pers. comm.).

Savage and Sullivan (1978) noted that an increase in the intermolt interval and a decrease in the average percentage of growth was associated with larger size (i.e., CW). They reported, from laboratory studies, average intermolt intervals of 107.0 days for crabs 60-69 mm premolt CW, 142.8 days for 70-79 mm CW, 156.8 days for 80-89 mm CW, and 159.0 days for 90-99 mm CW. Comparable size classes from another group of their crabs showed average percentages of growth (i.e., increase in CW) of 14.4%, 12.6%, 10.2% and 10.2%, respectively. These trends were not statistically tested, but suggest slower growth in older crabs. Cheung (1973, cited in Costello et al. 1979) suggested a terminal molt stage at about 112 mm CW (year IV or V); however, considerably larger crabs were reported by Sullivan (1979), and T. Bert (pers. comm.) claims females can reach 130 mm CW and males, 145 mm CW.

Autotomy or loss of a cheliped, either naturally or induced by the fishery practice, alters both the incremental increase in CW and the intermolt interval. Savage and Sullivan (1978) reported average increments of 7.7 mm CW per molt and 6.5 mm CW for singly and doubly autotomized crabs, respectively, almost 2 and 3 mm less than for intact controls. They further observed that the intermolt interval may be shortened by autotomy just after ecdysis or lengthened by autotomy later in the molt cycle. Claw regeneration was nearly complete after two molts (Savage and Sullivan 1978).

Size frequency distributions from field sampling were presented by Sullivan (1979) and interpreted to indicate year I crabs from 45 to 60 mm CW, year II crabs centered around 80 mm CW, and year III and some year IV crabs around 100 mm CW. However, claw length rather than CW legally defines harvestable size for stone crabs. According to Sullivan (1979), males reach harvestable major claw sizes at about 80 mm CW; females, at about 87 mm CW. Harvestable minor claws are produced at about 93 mm CW for males, and 103 mm CW for females.

THE FISHERY

Menippe mercenaria in Florida supports a unique sport and commercial fishery in which, by law, only the claws are harvested and the live crabs are returned to the water. The fishery practices and socioeconomic characteristics are described in detail by Bert et al. (1978) and the stone crab fishery management plan (Costello et al. 1979). The value of Florida landings places stone crabs among the top 10 commercial marine species in the State (Prochaska 1976). Estimates of the recreational catch are not known and are considered negligible, although almost four out of five stone crab permitholders fall into the recreational category (Zuboy and Snell 1982). The legal fishing season runs from 5 October to 15 May. During that period in 1980-81, the commercial catch of stone crab claws had a reported dockside value of $4,873,884 (Zuboy and Snell 1982).

The closed summer season and minimum claw size of 7.0 cm propodus length (2.75 inches) are intended to protect spawning females and ensure at least one reproductive season before entry into the fishery. The requirement to return live crabs to their habitat immediately after declawing is intended to promote survival for regeneration of harvestable claws and added reproduction. From tagging studies, Sullivan (1979) estimated 20%-25% of legal-sized crabs were undergoing claw regeneration. He further noted claw regeneration to a harvestable size within 1 year. Davis et al. (1978) experimentally observed mortality rates of 28% and 46.5% for singly and doubly autotomized crabs, respectively. Despite such significant mortality, allowing crabs the opportunity to survive, regenerate, and reproduce seems preferable to the alternative of harvesting entire crabs for use of just the claws.

Commercial landings have been concentrated along Florida's west coast, as indicated in Table 1 and Figure 4. Recent stock assessments indicate expansion of the fishery further offshore and

Table 1. The percentage of landings in the Florida west coast stone crab fishery, 1967-76, partitioned according to fishing grounds shown in Figure 4 (from Costello et al. 1979).

Year	Everglades Florida Bay	Southwest coast	Tampa Bay	Cedar Key	Panhandle
1967	93.4	1.6	0.5	4.5	-
1968	90.5	4.0	0.3	4.4	-
1969	77.5	4.8	3.4	14.3	-
1970	80.8	3.4	1.9	13.8	-
1971	83.1	2.4	0.0	13.3	1.2
1972	89.0	2.5	0.7	7.4	0.4
1973	72.9	14.1	1.8	10.3	0.9
1974	79.3	10.6	0.9	8.5	0.6
1975	79.7	3.1	2.2	14.2	0.9
1976	68.0	7.9	5.2	18.2	0.7

a decline in the catch per trap haul within the territorial sea (i.e., inside 9 nautical miles) and slightly beyond (Zuboy and Snell 1980, 1982).

Catch and effort statistics are given in Table 2, and were used by Zuboy and Snell (1982) to generate the production models shown in Figure 5. They noted a discontinuity in the data and therefore fitted two alternative curves, one of which will be taken to describe the fishery when sufficient data are available. Their best estimate of maximum sustainable yield (MSY) for the west coast fishery was taken to be the average of the 4 high years, 1.88 million pounds. Zuboy and Snell (1982) further stated that "the stone crab fishery should produce approximately 2 million pounds of claws annually at an effort of 250,000 - 300,000 reported traps, given no detrimental environmental effects and the continuance of current size and season regulations". However, if nearshore stocks are declining and are being offset in the total catch by expansion into relatively unexploited offshore fishing grounds, then one could expect a decline in total catch as those offshore stocks become fully exploited.

ECOLOGICAL ROLE

Feeding Habits

Actively feeding larval stages of stone crabs are generally thought to be almost entirely carnivorous. In laboratory culture they have been sustained through all larval stages on a diet of brine shrimp nauplii (*Artemia* sp.) (Porter 1960; Mootz and Epifanio 1974; Scotto 1979; Sulkin and Van Heukelem 1980). Porter (1960) found low survival levels in cultures of stone crab larvae that were fed only algal cells. Sulkin and Van Heukelem (1980) found reduced survival levels in stone crab larvae maintained on rotifers instead of *Artemia*. Apparently *Menippe* larvae have strict dietary requirements that are met by only certain types of planktonic animals. No dietary studies of zoeae or megalopae have been performed, but planktonic larval stages and permanent zooplankton are probably their preferred prey.

The natural diet of juvenile stone crabs is also unknown. Bender (1971) reported that juvenile stone crabs held in captivity ate polychaetes, small bivalves, oyster drills, and each other. In aquaria, juvenile crabs ate everything from fish

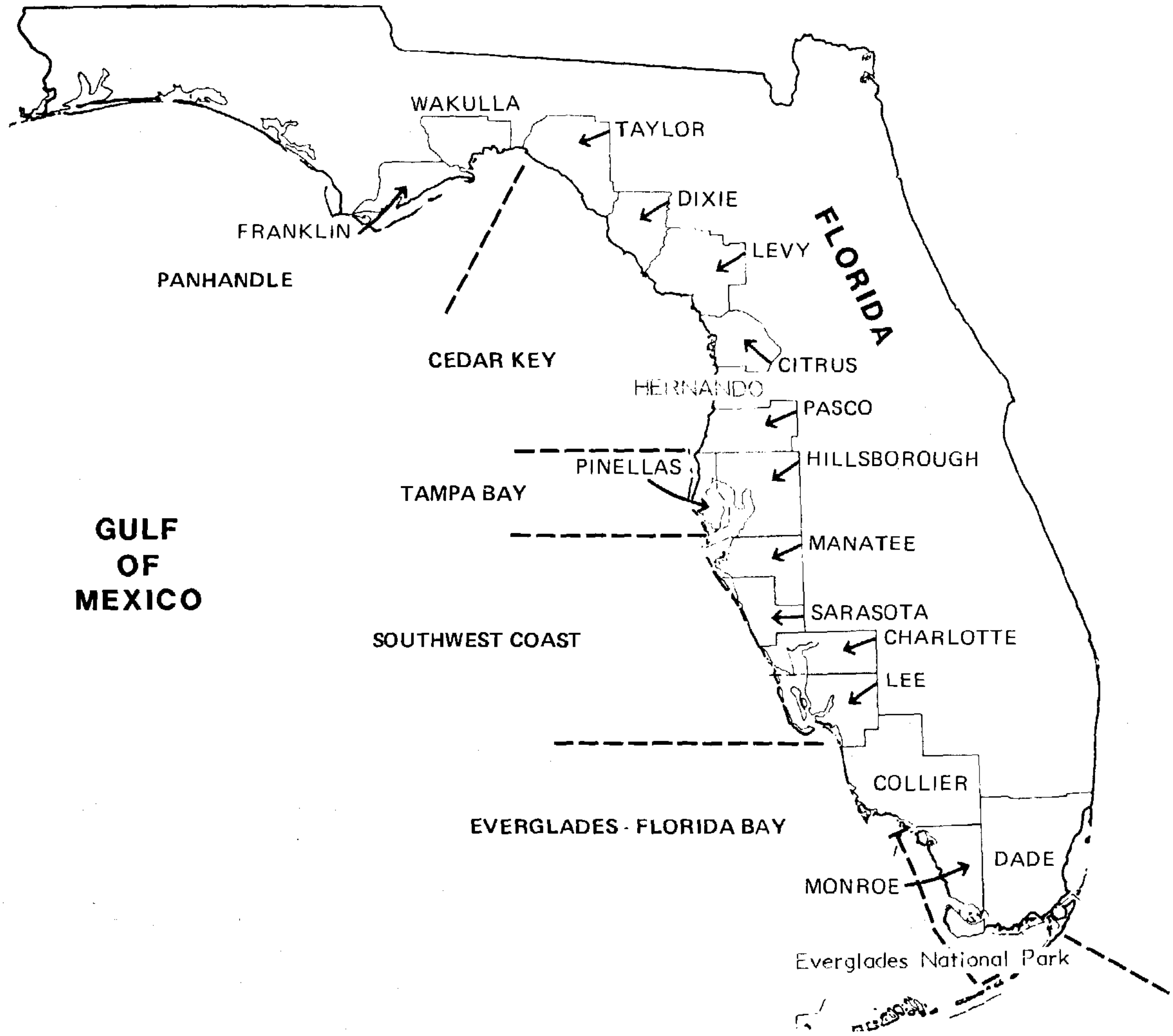

Figure 4. Gulf of Mexico stone crab fishing grounds by region and county (from Costello et al. 1979).

flesh to beef liver and chicken parts (Savage and McMahan 1968).

Adult stone crabs can generate tremendous crushing forces with their smaller chelae or "pincer." Brown et al. (1979) reported that the pincer of M. mercenaria can exert a pressure on its rearmost crushing teeth of up to 19,000 $lb/inch^2$. The pincer also has occluding teeth that are used in cutting shell or tissue. These formidable claws are used to break open shells of numerous types of mollusks (Menzel and Nichy 1958; Bender 1971; Merz 1979). Cheung (1976), however, speculated that the larger, or crusher claw, is the most important claw in feeding because, when the original crusher is removed, the pincer or fast claw develops, through molting, into a more heavily built replacement crusher claw.

Behavior

Larval behavior of M. mercenaria is unknown except for their positive

Table 2. Catch and effort statistics for the west coast of Florida stone crab fishery (from Zuboy and Snell 1982).

Season	Catch[a] (millions of pounds)	Traps (thousands)	Catch per trap (lb)
1962-63	0.30	14.6	20.6
1963-64	0.35	15.0	23.3
1964-65	0.35	21.0	16.7
1965-66	0.45	19.7	22.8
1966-67	0.40	43.2	9.3
1967-68	0.55	39.3	14.0
1968-69	0.60	55.9	10.7
1969-70	0.70	36.0	19.4
1970-71	0.85	60.8	14.0
1971-72	0.95	73.7	12.9
1972-73	0.90	113.3	7.9
1973-74	1.25	143.0	8.7
1974-75	1.00	159.1	6.3
1975-76	1.15	193.2	6.0
1976-77	1.45	213.8	6.8
1977-78	2.10	264.3	8.3
1978-79	1.85	222.0	8.3
1979-80	1.93	297.6	6.5
1980-81	1.64	314.6	5.2

[a]Catch is claw weight. Claw weight is 0.5 whole weight.

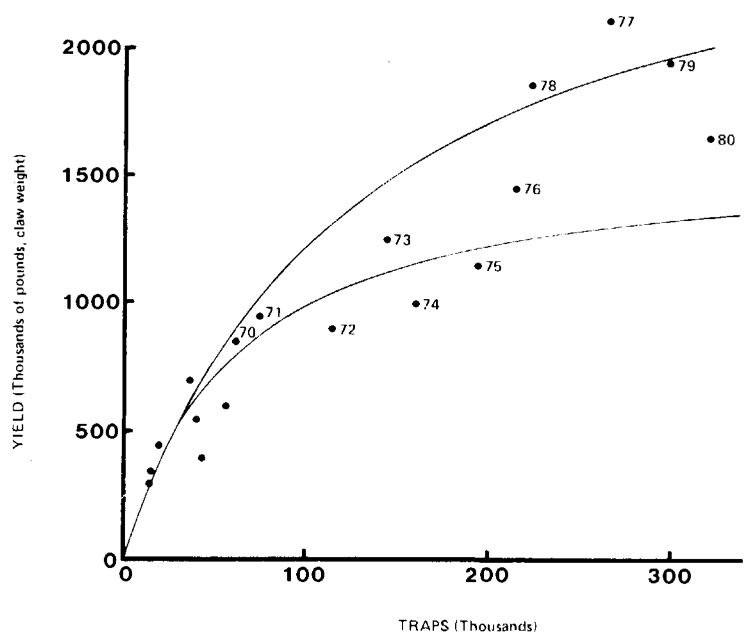

Figure 5. Current alternative production models of the Florida west coast stone crab fishery; points representing annual production, years 1970-80 are indicated (from Zuboy and Snell 1982).

phototaxis and shadow response (Forward 1977). When light levels are suddenly decreased, Menippe larvae stop swimming and sink passively. Forward suggested this as an antipredator tactic and noted that Mnemiopsis leidyi, the comb jelly, is an abundant predator that zoea could avoid by use of the shadow response.

Juvenile stone crabs, from sites along the Texas coast, are reported to feign death upon capture (Powell and Gunter 1967). Bender (1971) reported that juvenile stone crabs captured food with their walking legs and returned to their refuge to eat. They also stridulate or produce a raspy sound by rubbing a patch of fine, oblique, parallel striae, located on the inside surface of each cheliped, against the thick edge of the second and third anterolateral teeth and outer suborbital tooth (Williams 1965). The function of stridulation in both juveniles and adults is unknown (Guinot-Dumortier and Dumortier 1960; Bender 1971).

Adults possess a complex behavioral repertoire. They defend burrows (Sinclair 1977), move offshore and onshore as previously discussed, court before mating (Yang 1972), stridulate (Bender 1971), and employ diverse modes for feeding on several types of gastropods and bivalves (Merz 1979; Vermeij 1978). As one example of behavioral complexity, Merz (1979) described the procedure used by Menippe to open gastropod shells. The attacking stone crab first manipulates the prey shell with its two large claws and its walking legs. The minor claw or pincer may be inserted into the snail's aperture with a probing motion that may have a chemosensory function. The crab then positions the shell between the teeth of its crusher and attempts to crush the spire, the siphonal canal, or the columellar region. If crushing these areas fails because the snail is large relative to the crab, the crab may reposition the snail so that the thumb of the crusher can be inserted into the aperture of the shell. This places the lip of the shell between the teeth of the crab's claw. The crab then bends the lip outward, an action which, in juvenile snails, causes the lip to break. This action, when repeated, "peels" the shell so that either the fleshy snail parts are exposed or the size of the snail is reduced and may be grasped for further attempts at crushing.

Predators

Larval stone crabs are undoubtedly subject to a wide range of plankton-feeding predators as are other zooplanktonic animals (Levinton 1982). These predators may include other planktonic animals or small fishes.

Juvenile stone crabs are preyed upon by grouper and black sea bass (Bender 1971). They are presumably also preyed upon by many other species of large fish.

Adult stone crabs possessing both claws can probably defend themselves against a wide range of predators, but are eaten by a few species. According to reports by fishermen, crabs in traps are often eaten by octopods, sea turtles, and horse conchs (Bert et al. 1979). In holding tanks and in traps stone crabs also practice cannibalism.

Disease

Iversen and Beardsley (1976) reported a shell disease caused by several species of chitinoclastic bacteria in several crustaceans, including stone crabs taken from Florida waters. Menippe mercenaria from Florida's west coast apparently are attacked by this disease more often than are crabs from the east coast. The disease produces dark spotted areas on the exoskeleton of its crustacean hosts. It apparently does not kill the crabs, but does reduce the market appeal of claws.

ENVIRONMENTAL REQUIREMENTS

Temperature

Adult stone crabs can be considered eurythermal because they have been found in ambient temperatures of 8°-32°C (Bender

1971). At the lower temperatures, however, they were usually inactive and sealed themselves in burrows, and at the higher temperatures they sought the coolness of deeper water.

Temperature has an apparent effect on the reproduction and development of stone crabs. Noe (1967) found a significant positive correlation between the percentage of sample females carrying eggs and the ambient temperature, across the range of 21°-30°C in Biscayne Bay. Cheung (1969) also reported a correlation between ovarian development and local water temperature, with an optimum at about 28°C. Similarly, Sullivan (1979) noted an increase in spawning during March, when temperatures rose above 22°C, and a decrease in spawning after the temperature dropped in October. Less than 1% of the females collected were carrying eggs when the water temperature was below 20°C (Sullivan 1979).

Molting was also favored by the optimal temperature (28°C), but was inhibited by spawning (Cheung 1969). The intermolt interval for both juveniles (Bender 1971) and adults (Savage and Sullivan 1978) was shorter at elevated temperatures, although an upper tolerance limit was not noted.

Larval stone crabs are not tolerant of wide temperature ranges, particularly with reduced salinities. Porter (1960) suggested the zoea may not survive in 23°-25°C when salinities are 27 ppt or lower. Ong and Costlow (1970) found development at 20°C only to the megalops stage across the salinity range 20-40 ppt. Survival of megalopae at 20°C was less at 20-25 ppt than at 30-40 ppt, and also less than at 25° and 30°C. Survival to the first crab stage at both 25° and 30°C was lower in 20 ppt than in higher salinities. No larvae survived in a salinity of 10 ppt. They suggested an optimal combination of temperature and salinity at about 30°C and 30-35 ppt. Anger et al. (1981) later calculated a Q_{10} (the factor by which a reaction is increased with a rise of 10°C) for the duration of development to be 2.41 for fed larvae, and a Q_{10} for survival time to be 1.15 among starved larvae.

Salinity

As discussed above, stone crab larvae are sensitive to lowered salinities. On the other hand, adults could be considered euryhaline although they are typically found in salinities approaching full seawater. Karandeyeva and Silva (1973) reported tolerance of gradual salinity changes, i.e., over 3-week periods, to a low of 6-7.5 ppt and a high of 40.5 ppt, with no significant change in oxygen consumption at either extreme. Significant numbers of crabs died, however,when suddenly transferred from normal seawater to 6 ppt. Ambient salinities at stone crab study sites have been reported as 16.3-32 ppt (Bender 1971) near Cedar Key, Florida, and 29-38 ppt in Biscayne Bay (Cheung 1969). Noe (1967) found a significant negative correlation between the number of molting females and salinity over the range of 33-37.5 ppt.

Dissolved Oxygen

Adult stone crabs appear to be tolerant of reduced dissolved oxygen, although the prolonged effects on viability and reproduction are unknown. Karandeyeva and Silva (1973) claimed crabs would remain alive for 17 to 21 hr in the complete absence of oxygen, and would recover when replaced in oxygenated water. They reported a positive correlation between the quantity of oxygen available and the extent of its use. In vitro studies by Leffler (1973) indicated relatively constant metabolic rates over the range of oxygen concentration from 0.8 to 5.6 ml O_2/liter of water. Ayers (1938) calculated oxygen consumption of stone crabs to average 0.51 cm^3 O_2/g/hr (at Standard Temperature and Pressure[3]), among the lowest values of seven crab species tested.

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[3]Standard Temperture and Pressure equals 0°C and 1 atmosphere.

Other Environmental Requirements

Stone crab burrows have been reported from nearshore, shallow-water Thalassia grassflats and adjacent deeper channels (McRae 1950; Bender 1971), and Bert et al. (1978) noted the use of sponges, gorgonians, and shell bottom by juveniles. Anecdotal accounts abound for concentrations of adult stone crabs among crevices of bridge pilings and artificial reef rubble. These studies and accounts suggest a fundamental requirement by M. mercenaria for substrate suitable for refuge, met either by burrowing into consolidated sand-shell mix or by using available hard cover.[4] Expansion of the fishery to offshore depths greater than 8 fathoms (Zuboy and Snell 1982) indicates exploitable stocks beyond the nearshore grassbed habitats. The specifics of shelter use by offshore stone crabs have not been explored.

[4]Bert and Stevely (in prep.) found significantly greater densities along limestone outcroppings, where crabs excavated holes beneath rocks, than on adjacent seagrass beds.

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries on the taxonomy, morphology, range, life history, and environmental requirements of coastal species. They are designed to assist in environmental impact assessment. The stone crab, Menippe mercenaria, is among the top 10 commercial marine species in Florida, valued at $4.9 million in 1980-81. It also supports a substantial sport fishery. Mating occurs primarily in late autumn; spawning peaks during early and late summer. Spawning activity is associated with temperatures above 20°-22°C, and inhibits female molting. Larvae are planktonic and sensitive to the combined effects of lower temperature and reduced salinity; optima are suggested at about 30°C and 30-35 ppt. Estuarine dependence is not definitively established for stone crabs, but the greatest concentrations of adults are adjacent to non-barrier, marsh or mangrove coastlines. Juvenile habitat requirements are not well known. Growth is most rapid for juveniles, and slows with sexual maturity in year II. Adult molt frequency, and consequently growth, is favored by temperatures near 28°C and salinities approaching full seawater. Stone crabs are omnivorous and particularly prey on assorted mollusks.

17. Document Analysis a. Descriptors

Crabs
Growth
Feeding
Spawning
Life history

b. Identifiers/Open-Ended Terms

Stone crab
Menippe mercenaria
Salinity requirements
Substrate requirements
Habitat requirements

c. COSATI Field/Group

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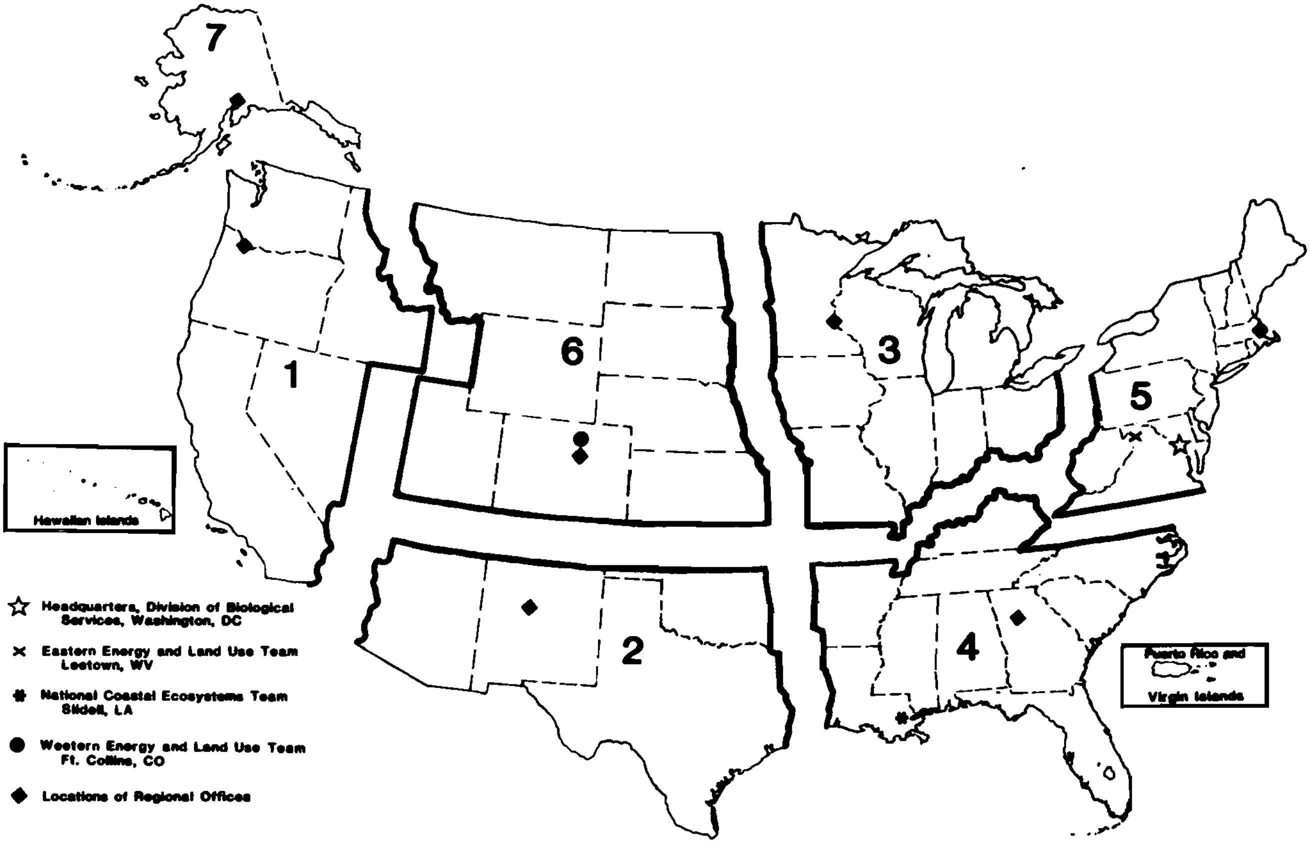

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