THE BIOLOGY AND FLORIDA FISHERY OF THE STONE CRAB, *Menippe mercenaria* (Say), WITH EMPHASIS ON SOUTHWEST FLORIDA

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Theresa M. Bert
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and Lorin D. Kessler

TECHNICAL PAPER NO. 9
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Florida Sea Grant

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Innumerable recreational and commercial fishermen and others involved in the stone crab fishery were heavily relied upon for extremely valuable and otherwise unobtainable information. These individuals freely gave their valuable time to council the senior writer on many occasions. The writers offer their sincerest thanks to: Mr. Allan Armitt, Mr. Peter Bartholi, Mr. Charlie Brown, Mr. Tim Daniels, Mr. Steve Daniels, Mr. Gary Graves, Mr. Howell Grimm, Mr. Pete Logan, "Sanchez", Col. Frank Taylor, and their mates and associates, all of Monroe county. These persons spent countless hours discussing stone crabs with the senior writer and provided their opinions of the preliminary draft. The management and personnel of Angelo's Fisheries, Charlie Brown Fisheries, Keys Fisheries, and Marathon Seafood, of Monroe county provided data, hospitality, and bases of operation for the field work involved in this study. The Ernest Hamilton Stone Crab Company, Collier county, supplied the basis for a comparison of the problems of the Collier and Monroe county fisheries, as well as a lifeline to the Collier county stone crab fishery.

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PREFACE

During review and final preparation of this manuscript for publication, the controversy between trappers and shrimp trawling fishermen that was predicted (Section 6.2.1) surfaced during the 1977-78 stone crab season. This triggered immediate action by the Gulf of Mexico Fisheries Management Council to formulate a management plan for the stone crab fishery before the conflict could again occur in the 1978-79 season. At the time this manuscript was sent to press, the stone crab management plan was in first draft form and was in the process of review by various industry and scientific subcommittees of the Gulf of Mexico Fisheries Management Council. Thus some of the recommendations mentioned here in Section 8 were already being implemented as this document was being printed for publication. Much information necessary for formulation of the stone crab management plan was derived from this study.

1. INTRODUCTION

The delicious flavor of stone crab (*Menippe mercenaria*) claws was a well-kept secret of Florida seafood connoisseurs for many years. Recently, however, widespread interest has begun to develop in the delicacy. The result has been the rapid mushrooming of the stone crab fishery into a multi-million dollar industry employing several thousand people only since the late 1960's. By far its most dramatic growth has been in southwest Florida, notably Monroe and Collier counties. Although the overall economic importance of the stone crab fishery statewide is relatively small, compared to the vast shrimp and spiny lobster fisheries, it is a vital part of the fishing industry in these counties.

This report is a synthesis of today's extent of knowledge regarding the natural history of the stone crab, and an evaluation of the stone crab fishing industry, which proved to be a complex and complicated endeavor. Cooperation by fishermen, processors, and scientists currently studying the problem was relied upon for much of the information presented. Where possible, evaluations based on unrecorded accounts were supported by available reported data. In all cases regarding important assessments of the magnitude and economics of the fishery, at least three independent information sources were consulted.

This manuscript contains the only complete summary of the research conducted on the stone crab to date and evaluation of the growth, importance, and input of its fishery. It is hoped that this study will add considerably to the knowledge of the relationship of the organism to its fishery. In addition, baseline data for future use in monitoring a commercially exploited area are provided, as well as a better understanding of the relationship of the southwest Florida stone crab fishery to that of the rest of the state.

Because of the broad audience that this paper is intended to serve, a glossary of scientific terms are included for the layman in an appendix. A listing of the many acronyms used throughout the paper follows the glossary.

2. SYSTEMATICS AND BIOGEOGRAPHY

2.1. Classification

Because of its tremendous size and complexity, classification of the phylum Arthropoda (horseshoe crabs, chelicerates, crustaceans, insects, centipedes, millipedes) has evolved highly subdivided categories. Below is a complete listing of the taxonomy of the stone crab and some characteristics that put it in that category.

Phylum Arthropoda (jointed legs)
  Class Crustacea (having a shell)
    Subclass Malacostraca (eight thoracic and six abdominal plates in the skeleton)

Series Eumalocostracea
  Superorder Eucarida (skeletal plates fused together)
    Order Decapoda (ten legs)
      Suborder Reptantia (crawlers)
        Section Brachyura (greatly reduced tails)
          Subsection Brachygnatha (last pair of legs not modified into swimming paddles)
            Superfamily Brachyrhyncha (short snouts)
              Family Xanthidae (mud crabs)
                Genus *Menippe*
                  Species *mercenaria*

2.2. Species Description

The genus *Menippe* has a broad oval carapace. The eyes are on short, thick stalks and the claws are massive and slightly unequal in size. The fingers, one unmoving and one jointed at the base, are pointed and possess a few large teeth. Four species of the genus are known in the Americas: *Menippe mercenaria*, *M. frontalis*, *M. obtusa*, and *M. nodifrons*. Only *M. mercenaria* and *M. nodifrons* are present on the Atlantic coast. Of the two, only *M. mercenaria* is harvested within the area of primary focus of this study.

2.2.1. Larva

A free-swimming planktonic larva is characteristic of most marine crustaceans, including the stone crab. The larva of the stone crab undergoes many developmental stages before becoming a recognizable crab. Five zoeal stages and one megalopa normally occur (Figure 1). The zoea is easily recognized by the very long rostral spine and a pair of lateral spines from the posterior edge of the carapace. The megalopa is remniscent of the probable macruran (shrimp-like appearance) ancestry of Brachyurans.

2.2.2. Juvenile

The juvenile appears very similar to the adult. It is distinguishable by a dark carapace (Hay and Shore, 1918; Wass, 1955), black or deep maroon, changing to dull red with pale dots as the stone crab increases in size (Manning, 1961). The juvenile stone crab has a light band or spot on the outer surface of the manus, legs that are red-cream color banded, and a greater distance between the eyes than the adult. In small specimens, less than 15 mm (0.59 in) carapace width (CW), the stridulatory or sound producing ridges cannot be easily detected (Manning, 1961) and the lateral teeth are smoother than in adults.

2.2.3. Adult

The adult stone crab has an oval body, two-thirds as long as it is wide (Figure 2). Males can be distinguished from females by their slimmer abdomens (Figure 3). Both males and females possess abnormally large, unequal claws, the major and minor chelae, that bear stridulation ridges. If the major chela has never been lost, its width is equal to 34% of the carapace width (Powell and Gunter, 1968). The major chela, or crusher (Figure 4), has a large basal tooth on the immovable finger (Figure 2); the minor chela, or pincer (Figure 5), has numerous small

Figure 1. Larval Stages Of The Stone Crab. A. First Zoeal Stage. B. Second Zoeal stage. C. Third Zoeal Stage. D. Fourth Zoeal Stage. E. Fifth Zoeal Stage. F. Megalopa Stage. (A-E after Porter, 1960; F after Hymen, 1925).

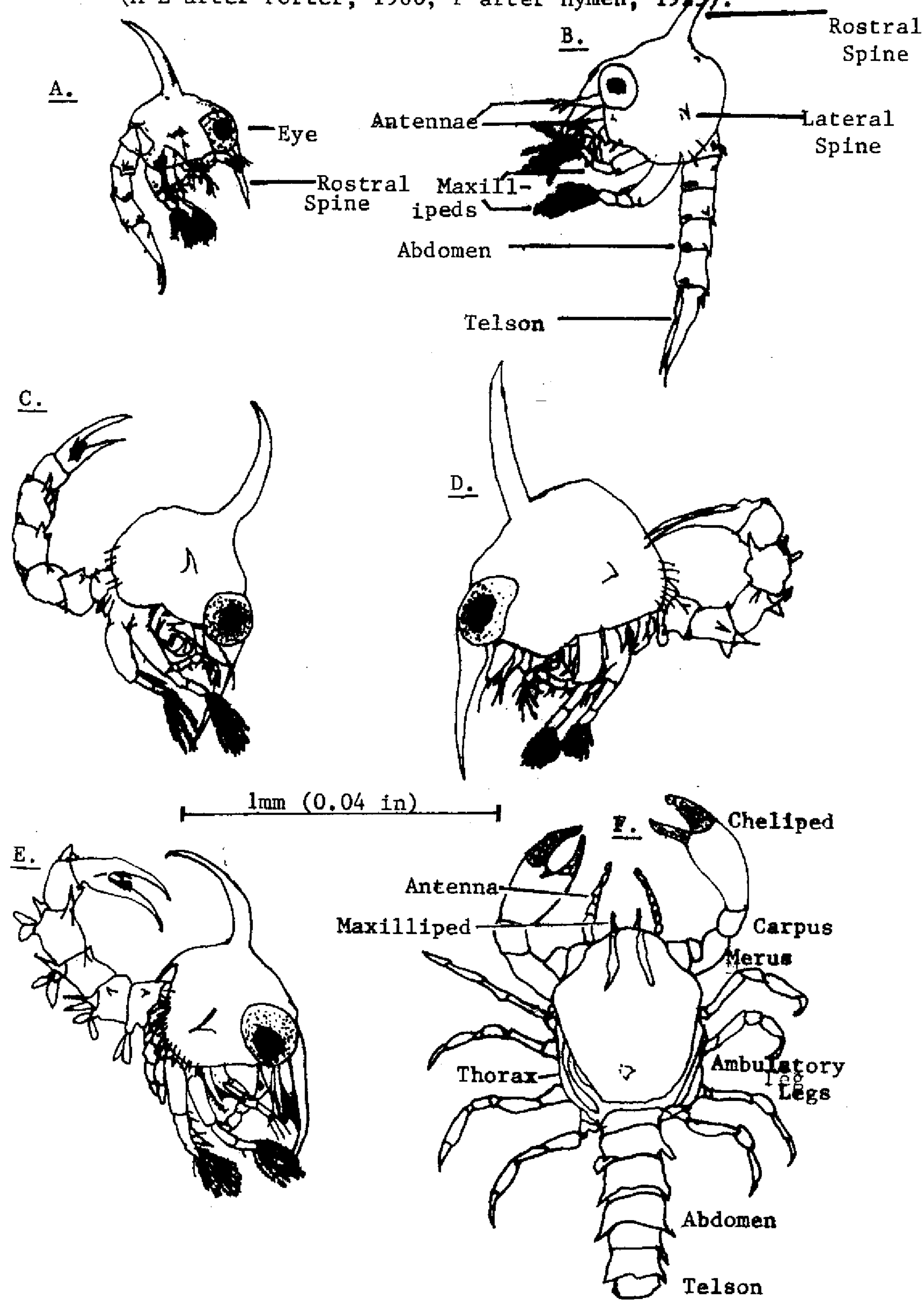
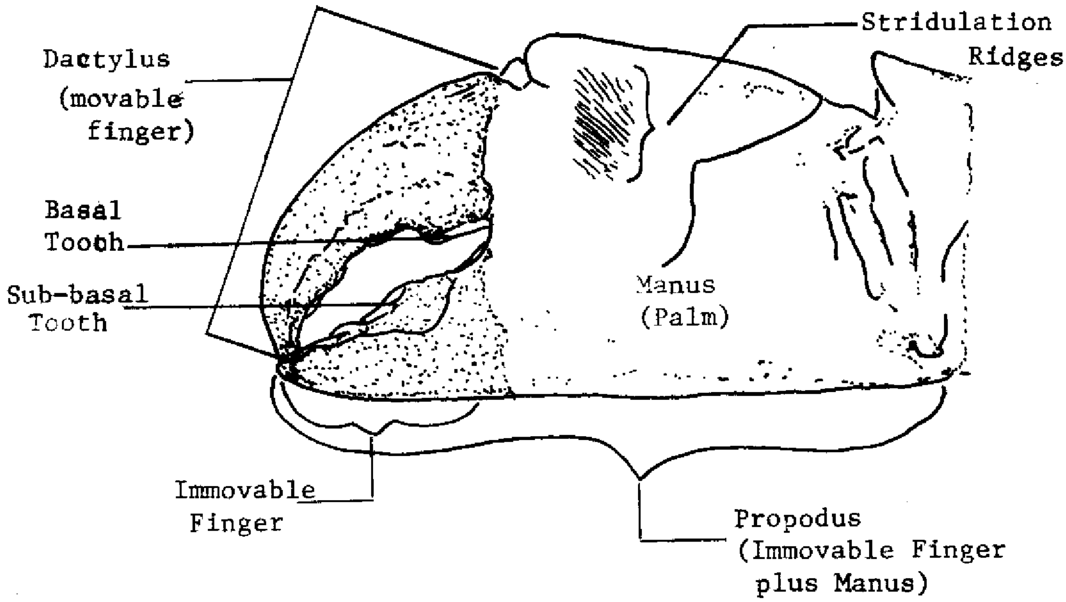


Figure 2. Detail Of Cheliped, And Adult, Dorsal View, Of The Stone Crab (Rathbun, 1930).

Cheliped, Stone Crab



Adult, Stone Crab

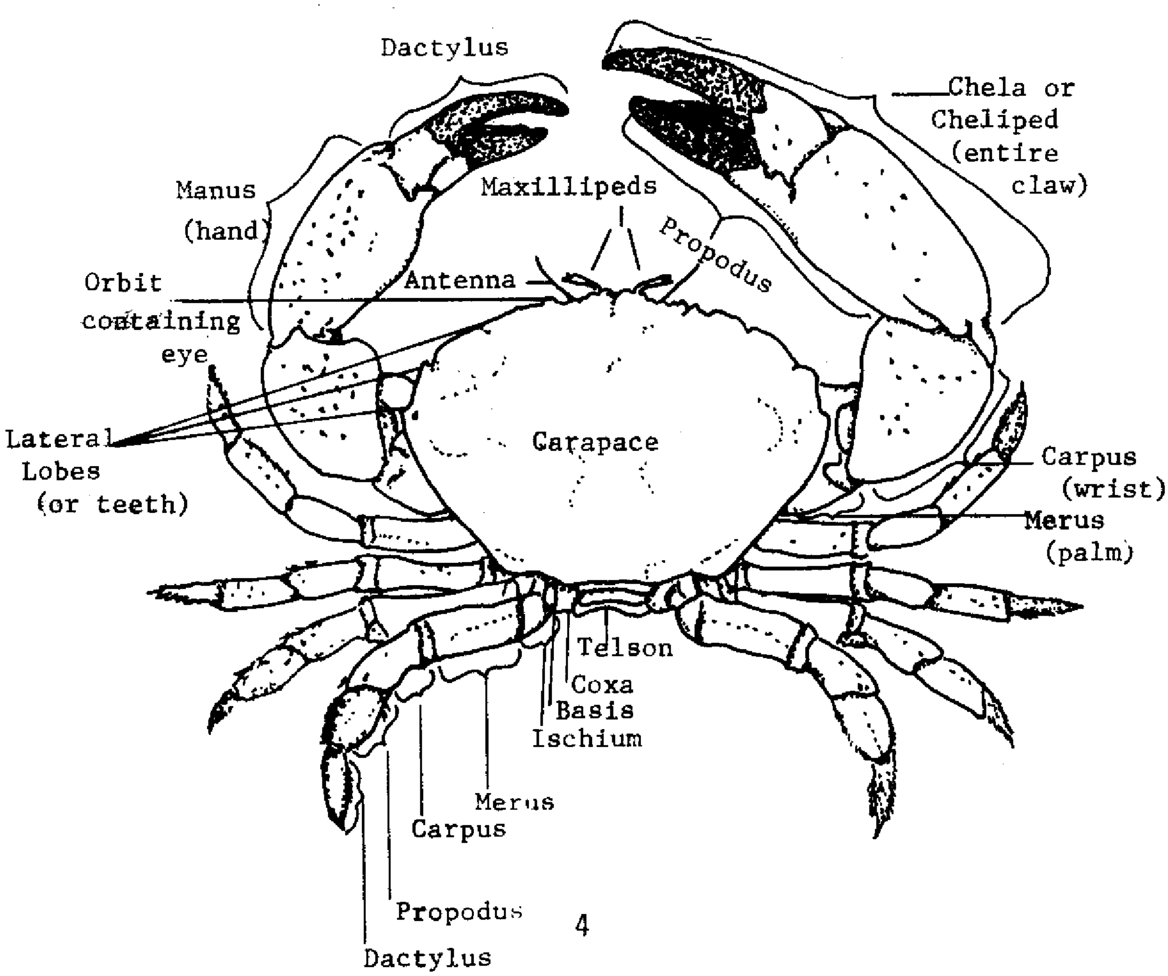
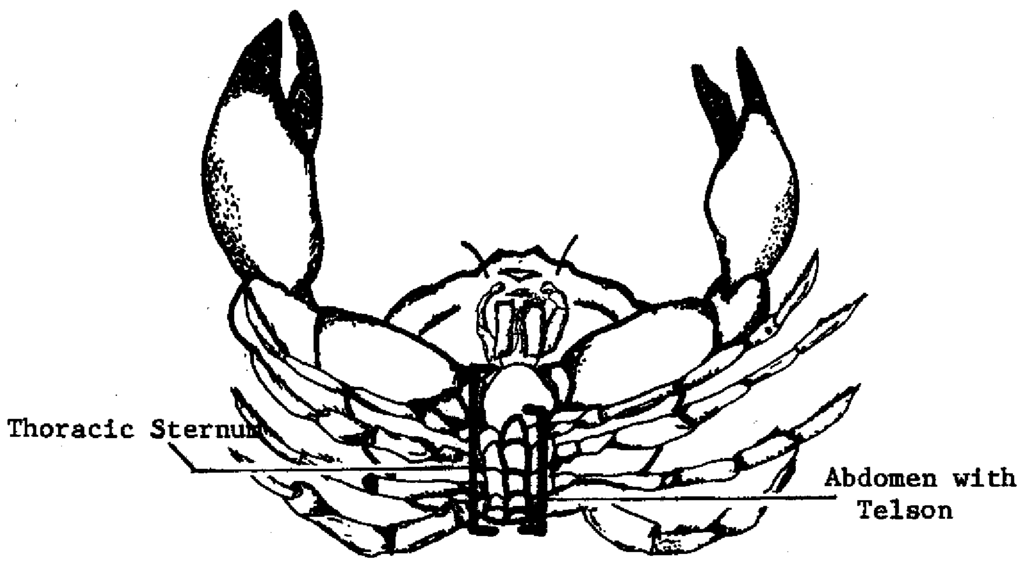
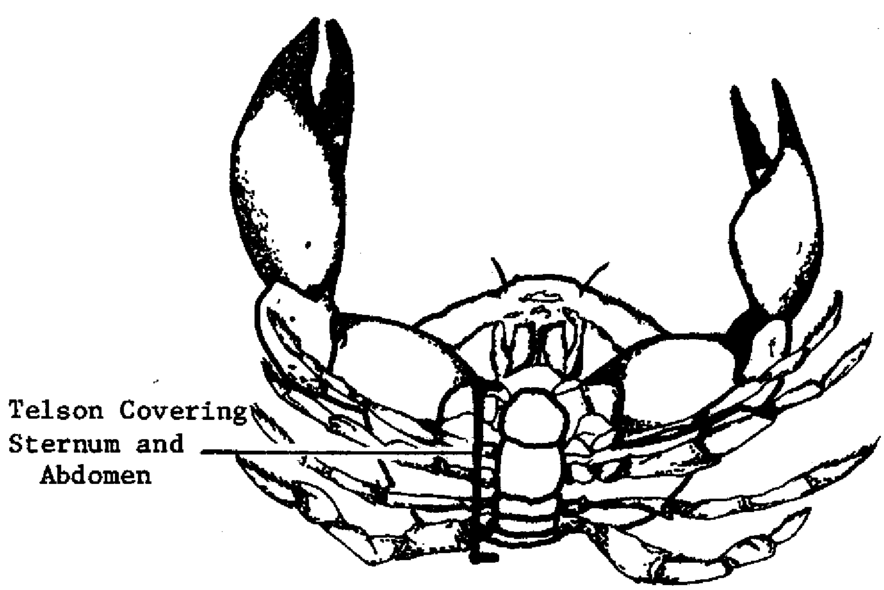


Figure 3. Male And Female Stone Crabs (Redrawn from Futch, 1966).



Male Stone Crab



Female Stone Crab

Figure 4. Major Cheliped, Or Crusher, Of The Stone Crab.

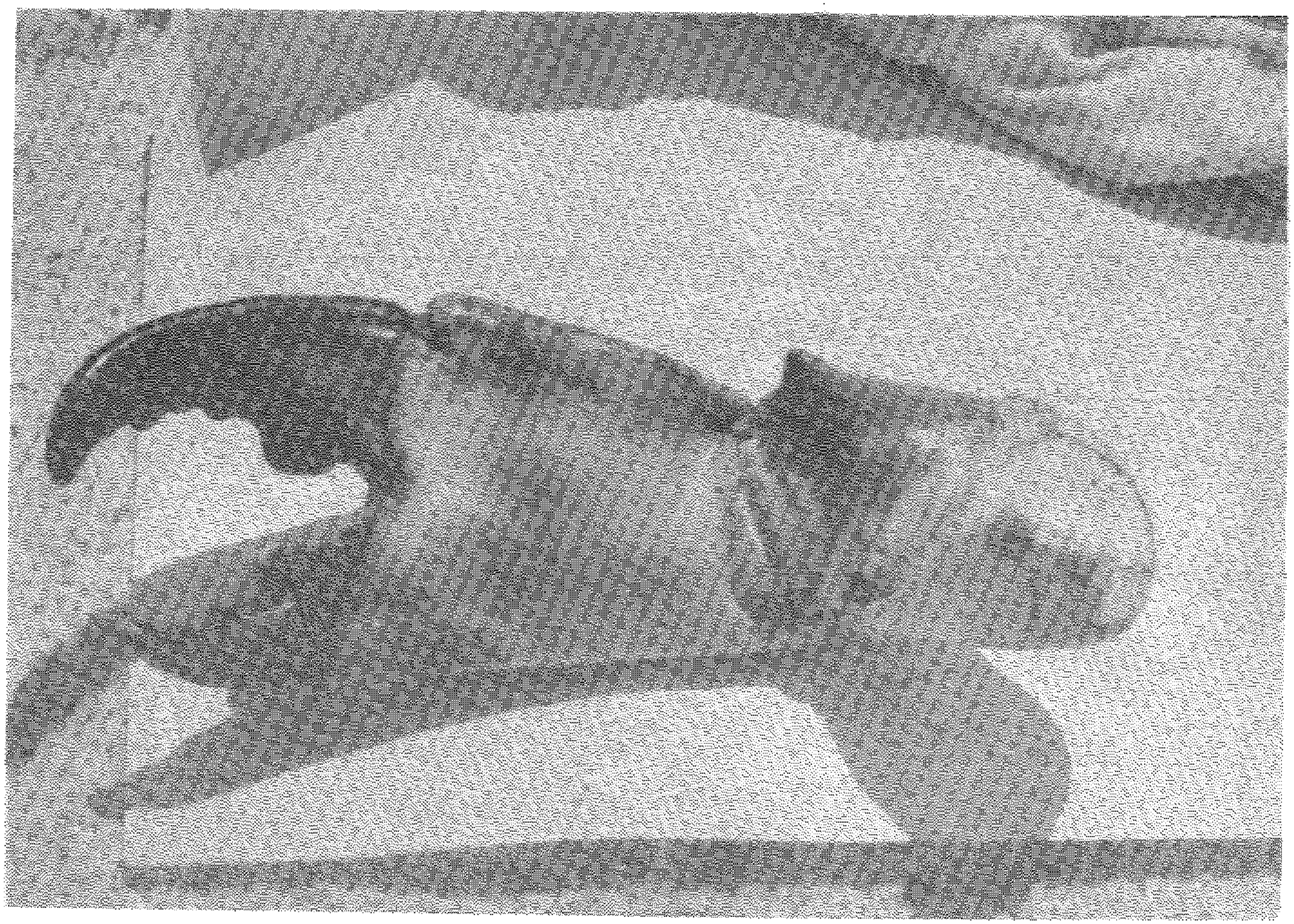
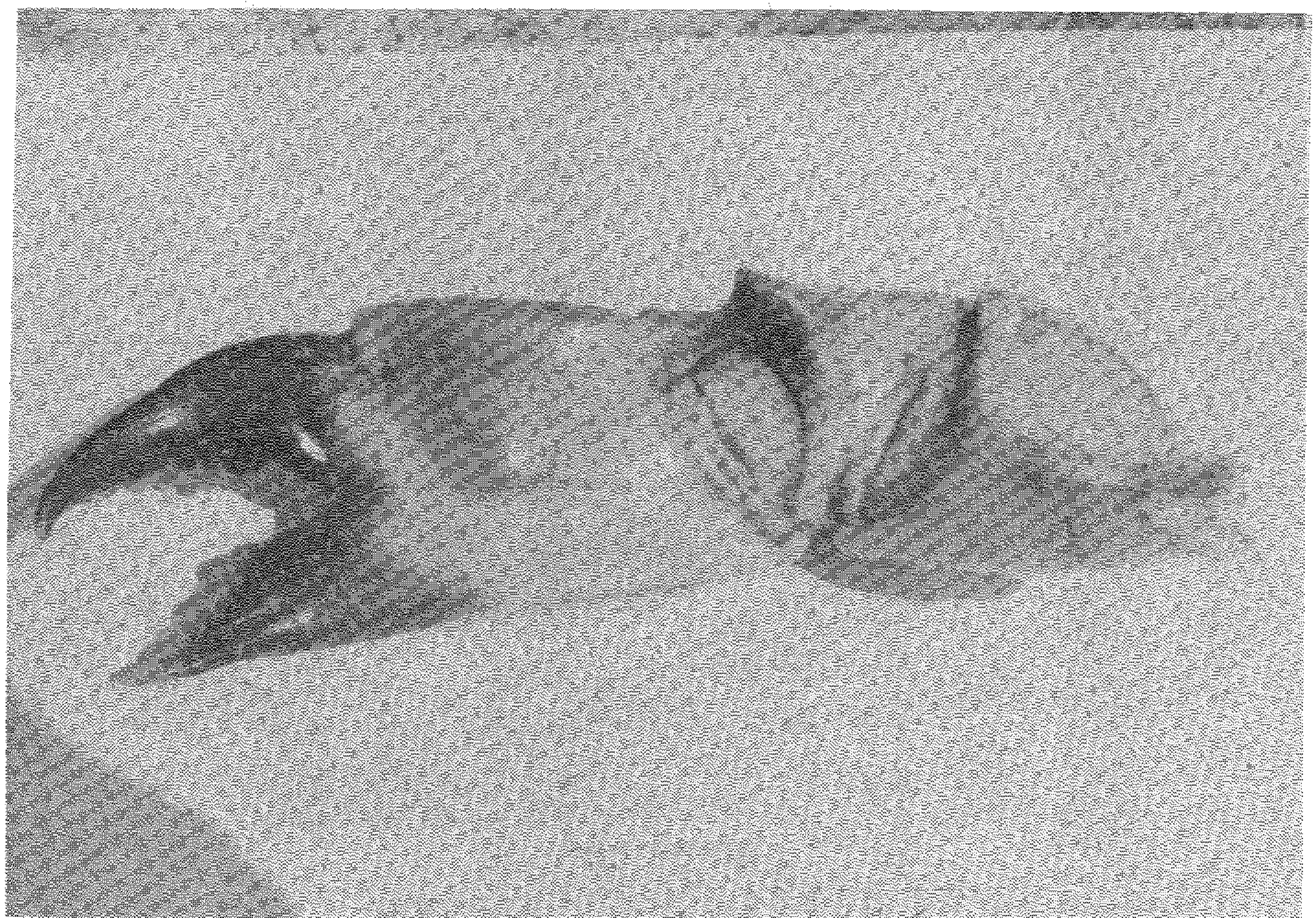


Figure 5. Minor Cheliped, Or Pincer, Of The Stone Crab.



teeth and a slightly larger sub-basal tooth (Savage, et al., 1975). The presence of stridulation ridges, a larger size, less prominent interorbital lobes, and a smooth dorsal carapace mottled with dusky gray are the most easily identifiable features distinguishing *Menippe mercenaria* from *M. nodifrons*.

2.3. Biogeography

The stone crab inhabits warm temperate, subtropical, and tropical waters. It is found along the Atlantic coast from Cape Hatteras, North Carolina, (Hay and Shore, 1918) to Mexico (Rathbun, 1930), in Cuba, Jamaica, the Bahamas (Karandeyva and Silva, 1973), and Yucatan (Williams, 1965). It has also been collected throughout the Gulf of Mexico (Behre, 1950; Gunter, 1950; McRae, 1950; Whitten, et al., 1950; Wass, 1955; Menzel and Hopkins, 1956; Tabb, et al., 1962). The depth at which it has been found ranges from the intertidal zone (McRae, 1950) to 54 m (177 ft) (Bullis and Thompson, 1965).

The stone crab is found in commercially harvestable quantities along certain areas of the continental shelf of Florida: the Cedar Keys region; offshore from Tampa Bay and Boca Grande; and the Everglades-Florida Bay region, including the Ten Thousand Islands (Figure 6). Its greatest concentration apparently extends from the coastal waters adjacent to Collier county and throughout Florida Bay.

The closely related *Menippe nodifrons* is far less common and has a narrower distributional range than *M. mercenaria* (Rathbun, 1930). *M. nodifrons* appears to be a species more common to the Caribbean. Rathbun also noted a specimen obtained from the French Congo in Africa. In the Gulf of Mexico, *M. nodifrons* has been reported only from Cameron, Louisiana (Rabhbun, 1930), and may be absent from Florida Gulf coastal waters (Savage, et al., 1975).

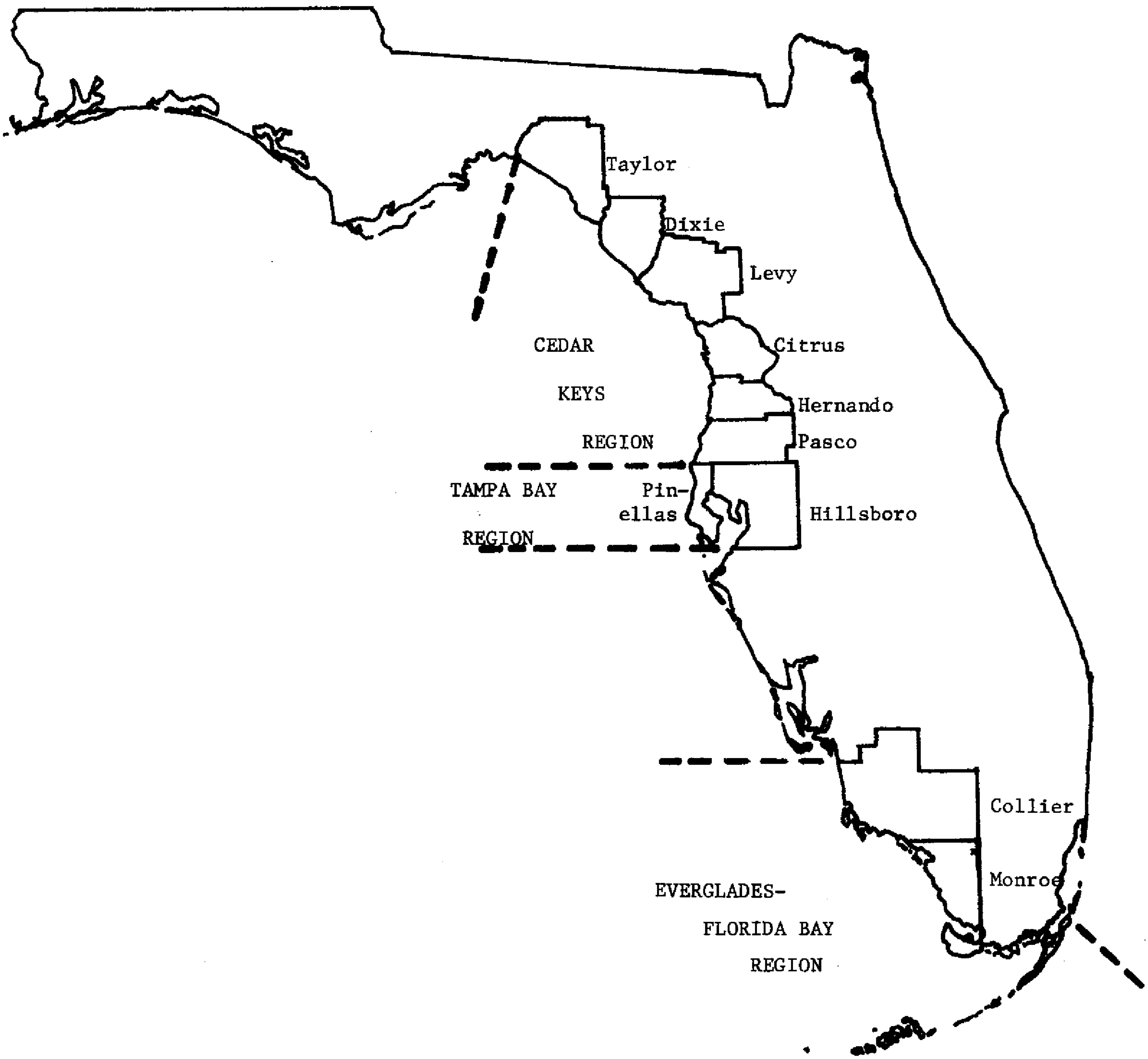
3. LIFE HISTORY

The stone crab undergoes three major phases in development: the larval, juvenile, and adult. Each phase is unique in several aspects of the animal's ecology: growth and development, habitat, migrations, trophic level, and behavior.

3.1. Larval Phase

Of the stages in the life of the stone crab, the least is known about the ecology of the larva. The small size (less than 2 mm, or 0.08 in) and similarity in appearance of Xanthid crab larvae make them at best very difficult to recognize at the species level. When one considers the number of species in the family Xanthidae and the many stages involved in the larval development of each, even a simple task such as habitat establishment becomes nearly insurmountable. Thus much information has yet to be collected on the larval stages of the stone crab.

Figure 6. Principal Florida West Coast Stone Crab Fishing Centers.



3.1.1. Growth, Habitat, Migrations, Behavior

Stone crab eggs hatch at any time of day or night (Hyman, 1925). The prezoea sheds its cuticle within a few minutes after leaving the egg and assumes the first zoeal form. The five zoeal stages are all planktonic. Zoeae are capable of feeble movements in the vertical direction but are essentially at the mercy of water currents. Zoeae live in the water column near the surface until the organism is ready to change into megalopa form. The megalopa too is planktonic but is thought to swim near the bottom, testing the sea floor for a suitable place to settle (Thorsen, 1949).

Each larval stage lasts from three to six days and requires a molt to assume the succeeding stage (Porter, 1960). From hatching to metamorphosis to true crab form takes less than six weeks (Ong and Costlow, 1970). The larvae grow exponentially but the growth rate decreases during the megalopa stage.

Survival rates are unknown except in larvae raised in culture. Larval mortality in nature could be expected to be extremely high, since the larvae spend a long time in the water column (Thorsen, 1949) and require warm water (30°C or 86°F) and oceanic salinities (30-35 parts per thousand, or ppt) for most rapid growth (Ong and Costlow, 1970). Although Bender (1971) reported that females attempt to move to this type of environment to spawn, they are not always able to do so. Thus, in certain broad areas of shallow water where salinity and temperature can fluctuate dramatically, such as Everglades National Park (ENP) waters, larvae hatched from resident crabs may have high mortality rates due to these factors alone. These localities may have a substantial recruitment from larvae developed in adjacent waters that move into the area to settle and metamorphose.

3.1.2. Trophic Level

Stone crab larvae are vigorous carnivores (Mootz and Epifanio, 1974). Food comsumption reaches a maximum at the megalops stage and declines prior to metamorphosis. Stone crab larvae eat smaller planktonic animals. Although their natural diet is not known, several studies have shown that they thrive on *Artemia* (brine shrimp) nauplii (Porter, 1960; Savage and McMahan, 1968; Cheung, 1969; Mootz and Epifanio, 1974).

Planktonic larvae have extremely low survival rates, primarily due to predation (Thorsen, 1949). For example, in the blue crab, whose pelagic larval life span and reproductive capacity is similar to that of the stone crab,only one tenthousandth of one percent (0.000001) of eggs become mature adults (Engel, 1958). The minute size and pelagic habitat of stone crab larvae make them easy prey for a host of fishes and invertebrates, including other zooplankton. The vast number of eggs produced by the stone crab is an adaptive mechanism to offset heavy larval predation.

3.2. Juvenile Phase

3.2.1. Growth

The transition from juvenile to adult coloration and the gradual adoption of adult characters normally occurs when the stone crab measures from about 15 to 30 mm (0.59 to 1.18 in) carapace length (CL) (Manning, 1961). For convenience, animals measuring less than 30 mm carapace width (CW) are usually classified as juveniles. Difference in sex can be readily identified at 9 mm (0.35 in) CW (McRae, 1950; Savage and McMahan, 1968).

Growth rates have not yet been established in natural conditions and vary in the laboratory, apparently increasing with warmer temperatures and more saline water (Bender, 1971). Savage and McMahan (1968) found that juvenile growth averaged 15% with each molt. In their study, crabs of 5 mm (0.20 in) CW molted an average of once every 40 days, with intermolt periods increasing with increasing carapace width. Thus, adulthood may not be reached until the stone crab is at least one year old. Bender believed that sexual maturity is reached in the fall after the first year of growth, presenting a new recruitment of individuals to copulate in the winter.

3.2.2. Habitat and Migration

Existing data on habitat and migrations are incomplete and somewhat conflicting, although some conclusions can be drawn. Hay and Shore (1918) found that young juveniles of 10 to 15 mm (0.39 to 0.59 in) CW migrate inshore to warm bays and estuaries. In the northern Florida Gulf, juveniles have been found in salinities of 24 to 35 ppt (McRae, 1950; Wass, 1955; Menzel and Nichy, 1958). In contrast, Manning (1961) did not record juveniles in water of less than 31 ppt during his three-year study in Florida Bay. Williams (1965) and Bender (1971) have indicated that juveniles occupy areas of slightly deeper water than adults. Some questions arise, however, concerning sampling methods used in these studies. Researchers currently believe that the trawling method used for sampling was biased toward retrieving juveniles. Juveniles have been found in channels in North Carolina (Hay and Shore, 1918), and in deeper seagrass flats (McRae, 1950; Bender, 1971) and along the bottom of tidal channels in Florida Bay (Manning, 1961).

Since they do not dig burrows (Powell and Gunter, 1968), juveniles utilize readily available hiding places that offer close proximity to food items. Crabs that are very small (less than 1.3 cm, or 0.51 in, CW) have a body weight that can be supported by muddy channel bottoms (McRae, 1950; Bender, 1971) and seagrass blades (Bender, 1971). Turtle grass, _Thalassia testudinum_, is preferred (Wass, 1955), probably because its broad blades support a wide variety of epiphytic and epizoic organisms that are utilized as food. In the Florida Keys, sponges, gorgonians, empty shells, shell bottom, and _Sargassum_ mats are also shelters for juveniles. Larger juveniles are very numerous on oyster reefs and rock piles (Menzel and Nichy, 1958).

3.2.3. Trophic Level

The juvenile stone crab is an opportunistic carnivore and has been shown to feed on a wide variety of animal protein sources in captivity, including beef liver and chicken parts (Savage and McMahan, 1968). Although no analysis of the natural diet of the juvenile stone crab has been conducted yet, Bender (1971) reported that they favor polychaetes, seagrass blades, small bivalves, and oyster drills.

The juvenile stone crab is subject to predation by a wider variety of large predators than is the adult. In northern Florida, a serious predator of M. mercenaria less than 10 mm (0.39 in) CL is the mud crab Neopanope taxana Stimpson (Landers, 1954). In addition to being more highly susceptible than adults to traditional stone crab predators, juveniles may fall prey to bottom-feeding and cruising carnivores and omnivores because they do not burrow. Large grouper and black sea bass consume juveniles less than 30 mm (1.18 in) CW (Bender, 1971).

3.2.4. Behavior

The juvenile stone crab commonly adopts passive defense mechanisms when annoyed. It will often feign death (Powell and Gunter, 1968). Vigorous stridulation is frequently initiated (Powell and Gunter, 1968; Bender, 1917), though specifically what this activity accomplishes is as yet unknown. However, the juvenile stone crab can be agressive when provoked (Yang and Krantz, 1976). Crabs less than 20 mm (0.79 in) CW will attack a moving object and hug it with the claws (Powell and Gunter, 1968).

3.3. Adult Phase

3.3.1. Reproduction

Mating. Most information available on reproduction of the stone crab centers on spawning or the maturation of eggs and larvae. Very little data are concerned with the mating season. Bender (1971) believed that mating occurred from November to March at Cedar Key, with a peak of activity in November. Binford (1913) noted a peak of mating activity in August in North Carolina. In the Florida Keys area, reproductive studies have been concerned with the mating, spawning, and rearing of the stone crab in culture only (Cheung, 1968; Yang, 1972;Yang and Krantz, 1976).

It is difficult to hypothesize when molting and mating season may occur in nature, if indeed there is a season. Evidence indicates that the female stone crab molts and mates soon after spawning is terminated (Noe, 1967; Bender, 1971). Spawning season is at least extended through November (Manning, 1961; Sullivan, in press) and appears to extend the year around in Florida Bay (T.M. Bert, pers. obsn.). A peak in copulation occurs late in the year (November or December) in the Everglades-Florida Bay (E-FB) region, soon after most spawning has ended.

Copulation. The copulatory act has been documented by Binford (1913), Savage (1971a), and Yang (1972). Savage confirmed the mating behavior under natural conditions. The male crab will guard a burrow in which there is a recently molted female or one that will soon molt. The male flips the female with his perieopods, opens her abdomen by using his own, and, cradling the female in his walking legs, inserts the first pair of pleopods containing the penes into the female's gonopores. The spermatozoa travel along grooves in the first pleopods driven by a piston-like movement of the second pleopods. The female curls her telson loosely over the male's carapace. The claws of the male are extended in a defensive position while those of the female are held closely to her body. The spermatozoa are transferred into the female where they are stored in a compact mass until spawning, when only a portion are used at a time. A single copulation can provide sperm for fertilization of eggs during an entire spawning season. Up to thirteen spawnings from a single copulation have been recorded (Cheung, 1969). Some credence has been given to the possibility that female stone crabs are polygamous or may store sperm from more than one male from copulations at different molts (Williams, 1965; Cheung, 1968).

Spawning. Spawning season of the stone crab lengthens in duration with movement southward (William, 1965; Noe, 1967; Cheung, 1969; Bender, 1971) until it extends the year around in the Biscayne Bay and Florida Bay areas. All researchers who have investigated environmental factors influencing spawning agree that temperature is the most important regulator of spawning frequency (Noe, 1967; Cheung, 1969; Bender, 1971), with 28°C (85°F) as the temperature of optimum ovarian development (Cheung, 1969). In contrast, new egg formation is inhibited in the fall by decreasing light intensity (Cheung, 1969).

Females reach sexual maturity as small as 33.7 mm (1.31 in) CW (J.R. Sullivan, DNR, pers. comm.) and bear a very large number of eggs with each spawning. The number of eggs per sponge, as the egg mass is called, ranges from 160,000 to 350,000 (Noe, 1967) and is closely related to size (McRae, 1950). Binford (1913) detailed spawning behavior:

> "When a female is ready to lay eggs, she assumes an upright position and holds the abdomen out from her body so that it and the exopods of the abdominal appendages form a basket into which the eggs are run. They there become attached to the hairs of the endopods of the appendages and pass through the embryonic stages of their development, which requires nine to thirteen days. The eggs then hatch and the larvae escape. The female then cleans off the egg shells and their stalks from the hairs of the pleopods and, after one day to three weeks, she spawns again. Eight days is a very common length for the period between the hatching of one batch of eggs and the spawning of the next."

The average number of spawns between molts is 4.5 (Cheung, 1969). Thus, even small female stone crabs have an annual egg production of about 500,000 eggs.

3.2.2. Growth

Growth of the adult stone crab is influenced by a number of external and internal factors, particularly in the female:

1. salinity may effect molting (Noe, 1967);

2. low temperatures cause a reduction in amount of growth attained between molts (Savage, 1971b) and may prevent molting (Passano, 1960b);

3. summer growth is inhibited by initial ovarian development in spawning season, even though warmer temperatures favor growth (Cheung, 1969);

4. ovarian development and egg development and incubation under the abdomen inhibit molting (Cheung, 1969).

As with the larval and juvenile phases, adult growth is enhanced in warmer months. In Florida, the sea water temperature seldom falls below the temperature that is thought to prohibit molting (15°C or 59°F) (Passano, 1960b), so males may molt throughout the year (Bender, 1971). J.R. Sullivan, DNR, (pers. comm.) has evidence that males may increase carapace width by 10 mm (0.39 in) at each molt. Intermolt periods are lengthy in the adult however--six months is the minimum (Cheung, 1969)--and any inhibition can result in a significant decrease in growth and rate of regeneration of missing appendages. Some researchers believe that, unlike many other decapod crustaceans, the stone crab has a terminal molt and will reach a maximum size at a CW between 110 and 120 mm (4.33 and 4.72 in) (Cheung, 1969). However, since molting is inhibited by reproduction, the female is restricted to cooler months of the year to molt. Most females molt from November to spring (Noe, 1967; Bender, 1971) with some shedding occurring throughout the year. Bender attributed the smaller size of the female to this seemingly poorly adapted reproductive-growth strategy.

3.3.3. Habitat

Adult stone crabs characteristically inhabit burrows, 15 to 127 cm (6 to 50 in) deep, in *Thalassia* flats and along the sides and edges of channels (McRae, 1950). Burrows may be as close as 20 to 30 cm (7.9 to 11.8 in) apart in the vicinity of ample food. Mature adult stone crabs construct complex burrows in which four chambers can be identified (Bender, 1971). The burrows of larger stone crabs (CW greater than 75 mm, or 3.0 in) are dug obliquely (Powell and Gunter, 1968) and have openings perpendicular to the direction of prevalent water flow (Bender, 1971). This construction probably functions to minimize sand accumulation in the burrow. Powell and Gunter (1968) observed that younger adults (44 to 73 mm, or 1.7 to 2.9 in, CW) excavated shorter burrows extending straight downward. They found no crabs less than 43.2 mm (1.7 in) CW in burrows.

Adults will also live on rocky or shell bottom, sand, and mud. In Texas and northwestern Florida, they inhabit oyster reefs (McRae, 1950; Powell and Gunter, 1968) and rock jetties (Whitten, *et al.*, 1950). McRae (1950) found the greatest abundance of crabs in the ship channel.

Stone crab burrows also furnish temporary homes to a conglomerate of other marine organisms (McRae, 1950; Bender, 1971). Transient crabs of all kinds (including stone crabs), mollusks and other invertebrates, and even fish make use of the burrows for protection, to seek food, and for survival. Stone crabs themselves use their burrows for a number of reasons:

1. females that molt in winter remain in burrows, probably for protection (Bender, 1971);

2. when caught in shallow water during cold weather, crabs will seal themselves in the burrows for protection (McRae, 1950);

3. mating pairs of stone crabs can often be found in burrows (Bender, 1971);

4. stone crabs commonly stockpile food in their burrows, particularly mollusks (Powell and Gunter, 1968).

Adult stone crabs are hardy and can tolerate most environmental extremes within their distributional range. They live in moderate to high salinity waters. They are able to withstand salinities considerably lower or higher than the normal oceanic concentration (35 ppt), if given the opportunity to accustom themselves to the environment (Karandeyva and Silva, 1973). Thus, they may not be endangered by seasonal salinity fluctuations similar to those occurring in Florida Bay (although Tabb, et al., 1962, found them only in water above 28 ppt).

3.3.4. Migration

Fishermen for many years have followed seasonal migrations during crabbing season. Some stone crabbers in Monroe county say that overall size of the catch for that year depends on the migrating population of crabs, since the resident population is "fished out" early in the season. Early researchers thought that no definite migratory patterns occurred but did acknowledge that some seasonal population shifts may be attributed to reproductive behavior (McRae, 1950; Bender, 1971). Sullivan (in press) has recently obtained information on movements that substantiates this idea. It appears that the onset of these movements may be triggered by several stimuli.

Movements can be divided into two classes: nondirectional and directional. The movements cover distances ranging from a few meters (feet) to several kilometers (miles).

Nondirectional movements seem to show no consistent yearly pattern, but are related to environmental factors that vary from year to year. An increase in food abundance on seagrass flats during summer may stimulate an increase in the general population (Bender, 1971), or in spawning females (Noe, 1967). Water turbulence associated with storms will often provoke localized "walking" in stone crabs. Fishermen agree that highest catch rates are immediately following a "Norther". Stone crabs may move, particularly to deeper water, to seek shelter in burrows and plug the openings in cold weather (Bender, 1971). Tidal currents and contour of the sea floor also exercise an influence on the direction of local crab movements (Bender, 1971).

Directional movements do not appear to be random. They are usually seasonal mass movements of primarily one sex and/or size class. Male stone crabs in Florida seem to live farther offshore than do females, who are year-around residents of shallow seagrass flats. Notable increases in the male population on the flats following spawning season have been noted throughout the Florida Gulf coast (McRae, 1950; Bender, 1971; Sullivan, in press) and at Biscayne Bay (Noe, 1967). Evidently a large population of males moves shoreward, via channels in the area, to mate with the molting females. An influx of females (5 to 7 cm, 2.0 to 2.8 in, CW) reaching sexual maturity also occurs in nearshore areas during early summer (Powell and Gunter, 1968; Bender, 1971) to mate in the fall.

3.3.5. Trophic Level

Shellfish of all kinds are the staple food of the adult stone crab (Powell and Gunter, 1968; Bender, 1971). It has also been observed to eat other crustaceans, including its own species. The stone crab can exist for up to two weeks without additional eating, after consuming a maximum of food (Sushchenya and Claro, 1973).

The stone crab's large powerful claws forestall many would-be predators. However, it is vulnerable to Octopus species. Fishermen frequently find octopi in their traps, and usually where there are octopi, there are few or no remaining live crabs. Fishermen state that, before the advent of today's sturdy traps, the Florida horse conch (*Pleuroploca gigantea*) and sea turtles would destroy the traps by breaking the fragile lathes, devouring the crabs inside.

3.3.6. Behavior

Like the juvenile, the adult stone crab initially adopts a defensive behavior pattern when threatened (Powell and Gunter, 1968). However, when continually annoyed, the stone crab will grasp the offensive object with its cheliped and pinch, exerting considerable force. If the cheliped is grasped while the crab is holding an object, the crab may autotomize, or voluntarily amputate, the cheliped.

Stridulation, once thought to be absent in adults (Guinot-Dumortier and Dumortier, 1960), is reported to be occasional and erratic (Powell and Gunter, 1968; Bender, 1971). Its function has not been determined. Bender mentioned that crabs frequently stridulated when held aloft. Some fishermen believe that crabs "talk" (stridulate) during mating season.

There is a difference of opinion regarding the time of day that the stone crab reaches a peak of activity. Evidence also suggests that the stone crab may follow monthly cycles in degree of mobility. Monroe County fishermen generally agree that the highest yield per trap occurs during the new moon phase and that crabs are more mobile at this time of the month.

Many instances involving habitat and migration have been documented in which a distinct sex and size class has been almost exclusively involved. Adaptations of this type are common and function to avoid niche competition within a species, thus insuring a greater probability of species survival. Additional intraspecific pressure inherent to the stone crab that may accentuate the need for sex and size class separation include the cannibalistic nature of the animal, territoriality, or competition between and within sexes.

4. HISTORY AND DEVELOPMENT OF THE STONE CRAB FISHERY

4.1. Introduction

This paper now turns from a synthesis of known biological data on the stone crab to focus on the fishery that the resource supports. Special attention will be given to the Everglades-Florida Bay (E-FB) fishing grounds. The information is presented, and a number of viable conclusions and recommendations are offered dealing with possible research needs and fishery management options that could provide a sustained yield and insure adequate population levels.

4.2. Development Of The Industry

4.2.1. Southwest Florida

Commercial. The meat of the stone crab, Florida's answer to the American lobster, has been enjoyed by native Floridians since the days of the Glades Indians. Stone crabs provided food to settlers for local consumption throughout Monroe county. The people of Flamingo, Florida (Figure 7) were frequently cut off from external food sources and relied heavily upon readily available seafood items, such as the stone crab, to keep their families from starving (Tebeau, 1968).

The stone crab fishery did not begin growing perceptibly until the early 1960's. Prior to that time, stone crabs were caught as an accessory product of the spiny lobster (*Panulirus argus*) industry (Schroeder, 1925). The market for crabs was restricted to restaurants and consumers in the immediate area of the fishery (Powell and Gunter, 1968). In many instances, whole crabs had to be taken to Miami to be sold. Only the very best were accepted. Fishermen say that, as recently as 1962, supply exceeded demand and sometimes whole stone crabs were sold for only $.30 per dozen, if a market could be found for them at all. Upon establishment of a broader market, composed chiefly of restaurants in large cities, the stone crab industry began steadily and rapidly rising in volume and value of product sold. With only minor setbacks, the industry has grown to its present day status.

Recreational. Noncommercially, stone crabs have been caught by trappers and divers. Diving for stone crab claws has developed into a popular sport in the Tampa Bay region. However, its present importance to the overall catch in the E-FB region is probably negligible. Stone crabs are taken by recreational divers who are usually seeking tropical reef fish or spiny lobsters. Crabs are caught by either teasing the crab up into the water column and grasping the claws when it is suspended, or by pulling the crab out of its burrow with a hooked pole. (Technically, this method of hooking stone crabs is illegal (370.13 Fl. Stat.).)

4.2.2. Monroe County

Early Development. Little information has been documented regarding the earliest days of the Florida Keys stone crab industry. Schroeder (1924) provides the most extensive information. He said:

> "These crustaceans are caught throughout the year, but the most favorable fishing obtains during February, March, and April. They are found rather near the shore and generally not farther than one mile from land."

In those days, the stone crab was a delicacy and demand occasionally exceeded supply, contradictory to the 1950's and early 1960's.

> "...the Key West catch varies from about 10 to 50 dozens a day during the winter and spring season...Small crabs, measuring about 3 inches in width across the carapace, sell at retail for about $1 a dozen, while those 4 or more inches in width bring from $1.50 to $2."

Although the fishery steadily grew (Table I), by 1922 it represented only 0.6% of the total seafood landings in Monroe county.

Table I. Some Early Recorded Stone Crab Landings In Monroe County (Schroeder, 1925).

Year	Volume Landed	
	Pounds	Kilograms
1895	4,680	2,123
1902	8,610	3,905
1918	18,400	8,346
1919	22,000	9,979

Recent Development. The E-FB stone crab fishing region has grown over five-fold in the past ten years (Figure 7) and currently spans an area of approximately 9,850 sq km (3,800 sq mi). Monroe county fishermen have expanded their fishing range from localities among the Keys and shallow water regions close to their homes to encompass the entire area from the Harbor Keys to the vicinity of Highland Point above the Shark River basin (Figure 8). From its original area, estimated at about 900 sq km (350 sq mi), the Monroe county fishery has expanded to include about 5.050 sq km (1,950 sq mi) (Figure 8).

Three centers of activity have developed for stone crab fishing in the Keys. Upper Keys fishermen operate small one-man boats for easy maneuverability in the shallow water of Florida Bay to Cape Sable. Fishing effort is concentrated in the areas of Sandy Key and the center of ENP waters. Fishermen working out of Marathon may travel as far as the Harbor Keys, or above the Shark River basin and eastward to Sandy Key. After the onset of net fishing season (November 15), they move their traps from net fishing grounds and fish an area north of a line drawn from the Harbor Keys to Cape Sable light and less than about 45 to 50 ft (14 to 16 m) deep. (This arrangement was set up by the Monroe county fishermen to allow for just apportionment of the available grounds and resources.) Marathon fishermen generally set their traps in deeper water and need boats that are operable in heavier seas and can accomodate a three-man crew. A third small center for stone crab fishing exists in the Lower Keys. With the exception of a few boats, crabbers in that area are single-man operators and stay essentially in shallow water in the "Back Country", or Gulf of Mexico waters among the Keys.

Relatively few Monroe county fishermen rely on crabbing exclusively as their source of income. Large boat fishermen combine crabbing with crawfishing (fishing for spiny lobster). The stone crab and spiny lobster fishing season overlap. Since the differences between crabbing and crawfishing are very slight, it is a simple matter for the fishermen to combine the two. The effort devoted to fishing for either species depends upon "how well it is catching" during the course of the season. Most large boat fishermen do not normally utilize any auxilliary fishery other than crawfishing, since their boats would have to be rigged in an entirely

Figure 7. Early (Late 1800's To Early 1960's) And Present Fishing Boundaries For The Everglades-Florida Bay Stone Crab Fishery.

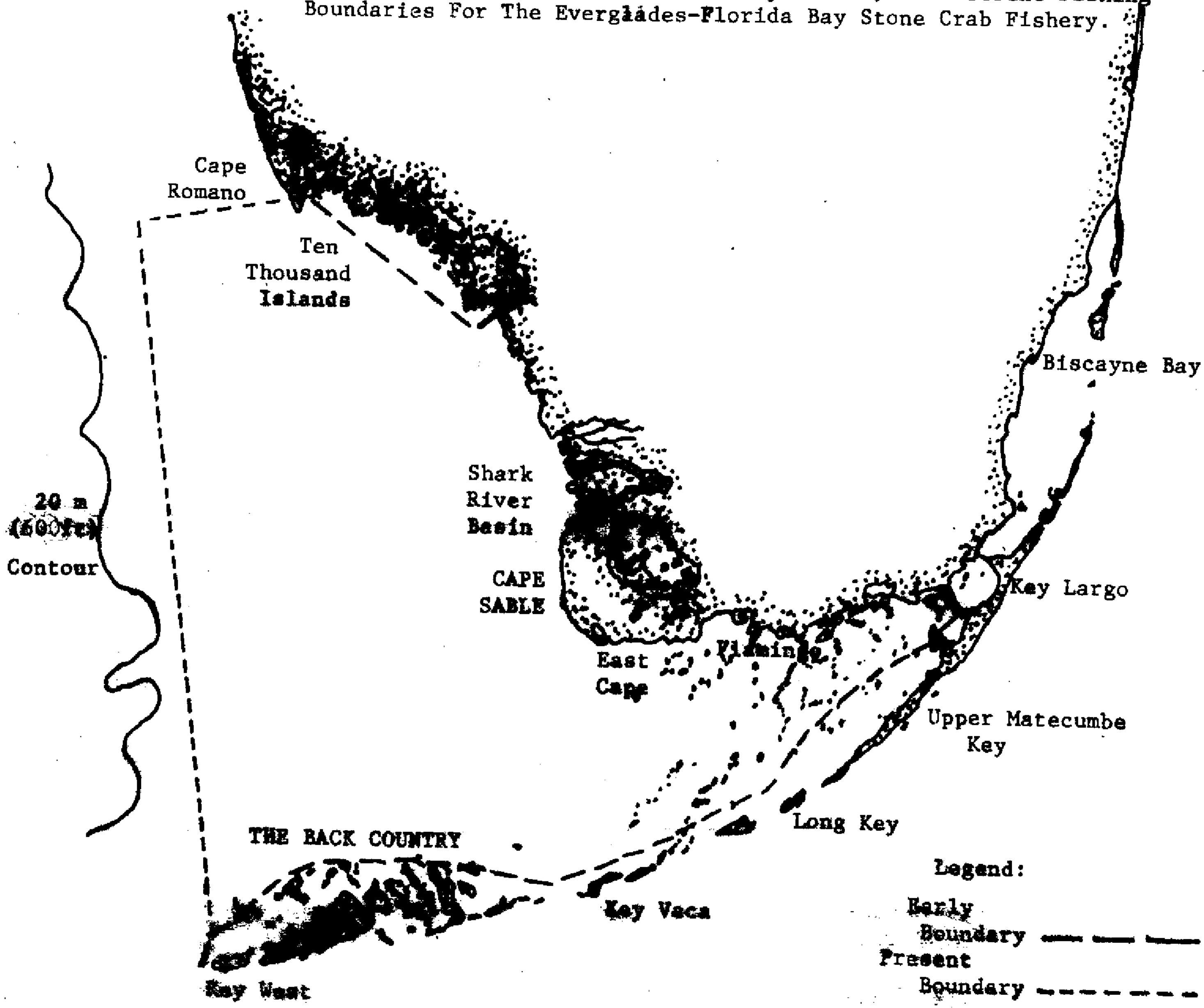
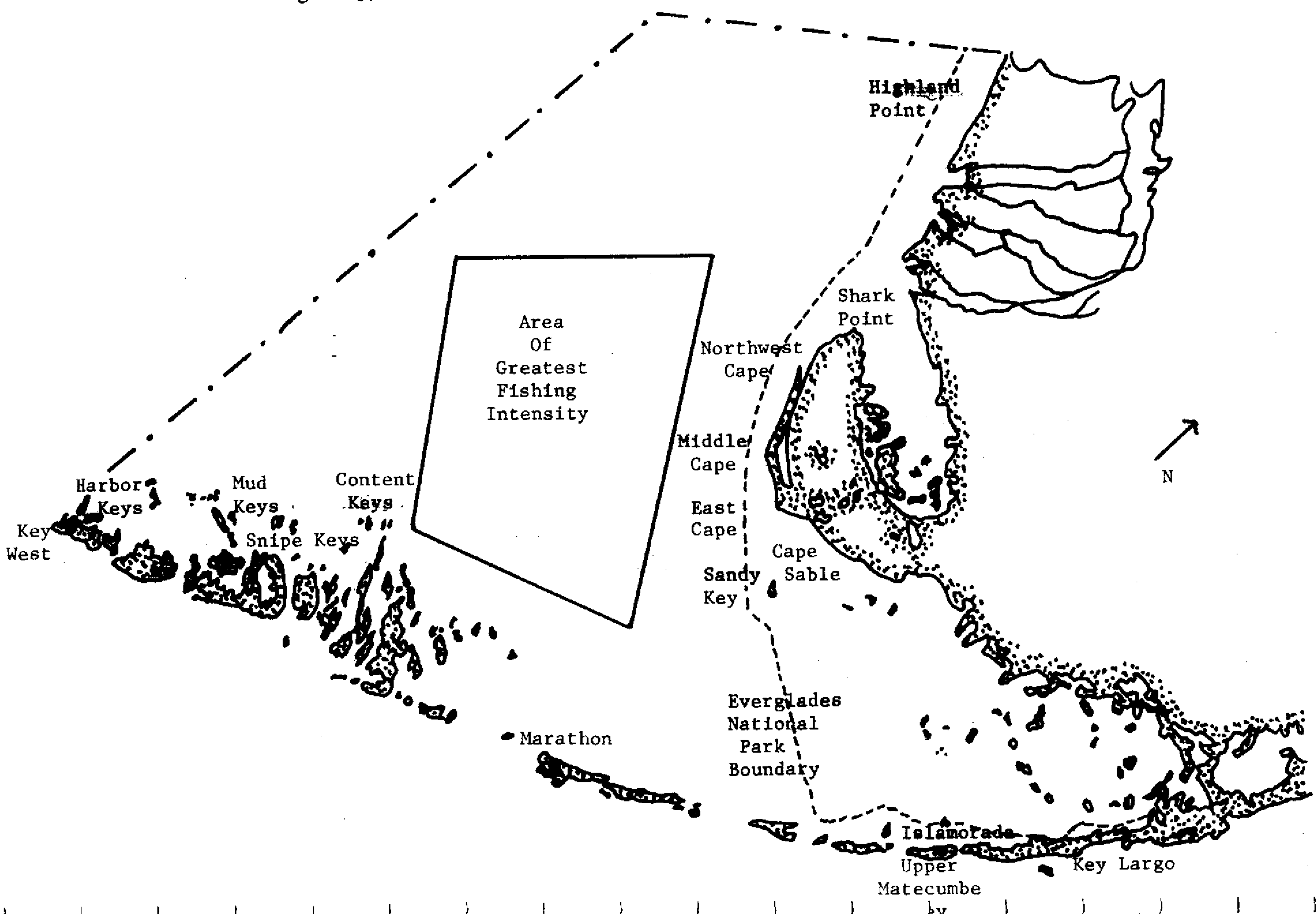


Figure 8. Present Extent Of Monroe County Stone Crab Fishing Grounds.



different manner. Small boat fishermen, particularly those fishing the grounds near the Key West vicinity, support themselves by crawfishing and crabbing from late summer through spring and sponging, bottom fishing, or collecting tropical fish during the early and mid-summer months.

4.3. Development Of Techniques

4.3.1. Early Methods

Small open boats powered by oars, sails, or small gasoline engines, perforated containers to catch crabs in, strong arms, and shallow water were the early stone crabber's tools. Aside from spiny lobster traps, just about anything from old lettuce boxes to cans with holes punched in them were used. Bait came from scrap and trash fish discarded by other fishermen. Stingrays were frequently used by fishermen working near Key West. E-FB fishermen set out their traps in Florida Bay, the Ten Thousand Islands, and channels between the Keys.

4.3.2. Today's Methods

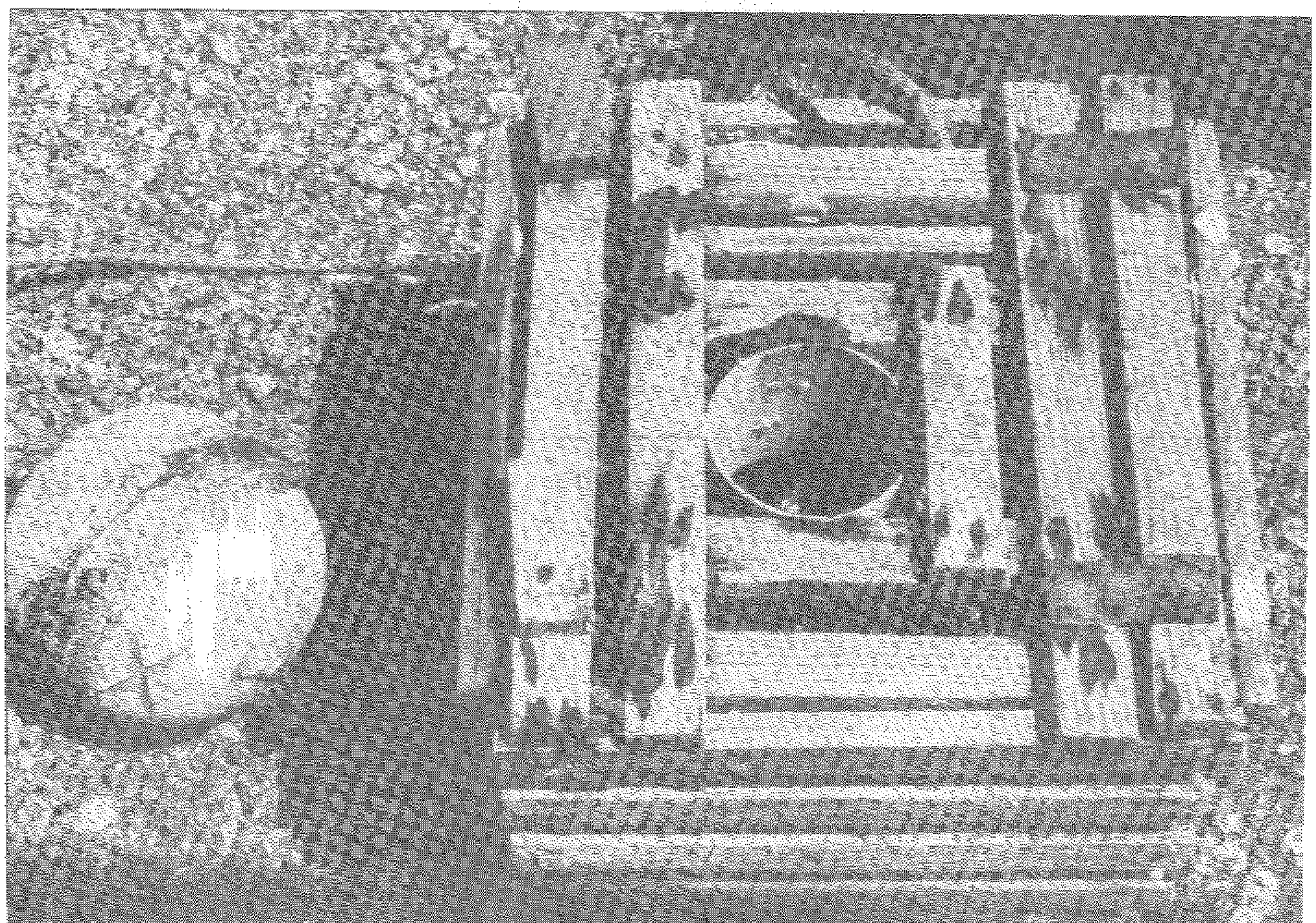
The Trap. The standard stone crab trap (Figure 9) is of either pressure-treated pine or cypress lathe or plastic. Although crabbers are supposed to adhere to stringent regulations regarding size of the trap entrance (no larger than 10.2 X 16.5 cm, or 4 X 6.5 in) and identification of their traps and buoys (370.13 Fl. Stat.), they may make other modifications in the structure of the trap. Each must be permanently marked with the permit number, and the color of the buoys must be unique and registered to the permit.

Each crabber either builds his own traps or has them built to his specifications. Crabbers experiment with the design of their traps and have found that, in certain areas, crabs will "catch better" with one trap design than another. In some cases, diligent fishermen have evolved special trap designs that appear to work better in specific areas year after year.

In addition to experimentation with trap design, crabbers modify the usual pattern of setting traps (the trap line). The traditional double line, spaced 30 to 90 m (100 to 300 ft) apart and running parallel to the bottom contour, may be modified into a grid, cross, or circular pattern. Many crabbers contend that "the best catch is where the grass and open sand meet". Possibly stone crabs find good natural feeding at the seagrass-sand junction, or merely move from their burrows to the edge of the seagrass flat and parallel to it, rather than out onto the sand. Some fishermen believe that they move to the sand to feed.

Traps are baited with trash fish and fish remnants obtained from charter boats, fish houses, or other fishermen. Fishermen have also experimented with rawhide and petfood, but most believe that fish works best, particularly the tough meat of cartilaginous fishes. From 0.5 to 1.5 kg (1 to 3 lb) of bait are used per trap. The bait may be simply thrown in the bottom, hung from the top, or set in a bait container. Depending on the method and amount used, the bait will usually last from 2 or 3 days to 2 or 3 weeks. Traps are pulled by small boat operators every few days,

Figure 9. Standard Stone Crab Trap And Bouy.



weather permitting; large boat fishermen pull their trap lines every 10 days to 21 days.

Crabbing Operations in the Everglades-Florida Bay Region. Fishermen have developed an efficient process for stone crabbing. Because the claws must be cooked before they are chilled, stone crabbing is nearly always a one-day excursion. Two modifications of a basic method exist.

Large operations (diesel powered boats with large open aft decks and measuring about 10 to 15 m (33 to 50 ft) in length) usually utilize a three-man team--two mates, or pullers, and a captain. The captain approaches the trap buoy in such a manner as to avoid entangling the boat propeller in the buoy line. The mates, stationed in the port aft section of the boat, catch the buoy line and haul the attached trap aboard, aided by a special automated winch (Figure 10). The crabs are removed and tossed into wooden bait boxes. Traps are rebaited, repaired, and tossed overboard in a single quick operation. The captain, in the interim, has been maneuvering to the next buoy in the trap line so that the mates are situated above a new trap by the time they have finished with the previous one. The crabs are kept on board until all traps have been pulled. The pullers then declaw the crabs as the captain is returning to dockside. Claws are removed by grasping them firmly from the rear (Figure 11a) and twisting downward or upward with a swift snapping motion (Figure 11b).

Large operation stone crabbers usually dock their boats free-of-charge at a fish processing house. In addition, the fish house provides the crab boat owner with some storage and maintenance facilities for his traps and boat. In exchange, the fisherman is expected to sell his catch to the processing house at the price it is offering and purchase bait and gasoline there. The processor cooks, grades, and sells the claws to wholesalers or retailers. The Florida Department of Natural Resources (DNR) and Department of Agricultural and Consumer Services regulates processing and issues licenses for these sea food dealers (Prochaska and Baarda, 1975). Grading of the claws is somewhat subjective and varies greatly among dealers. Generally, claws are separated into weight categories. Claw weights range from less then 71 g (2.5 oz) to greater than 198.5 g (7 oz) and reach maximums of nearly 454 g (1 lb) per claw.

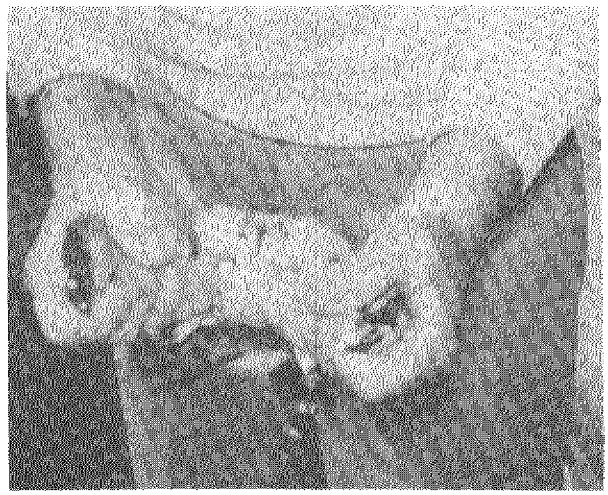
Traps are fished with the three-man system at a rate ranging from about 25 to 100 traps per hour, depending primarily on weather conditions, tides, smoothness of the operation, and condition of the equipment and personnel. Sixty traps per hour is considered a good average speed. From 300 to 700 traps per day are pulled. Many crabbers prefer to set 400 traps per line. They maintain that efficiency of the equipment and personnel is maximal when pulling 400 traps per day. These crabbers ordinarily set out from 1,500 to 5,000 or 6,000 traps per season.

Fishermen operating boats of approximately 9 m (30 ft) in length or less fall into a different category. These boats are ordinarily run by one man, who functions as both captain and puller. Sometimes an additional person, usually a family member, will be employed to assist. A diesel or outboard powered open boat, which may or may not be equipped with a winch in the stern, is used. Pulling either by hand or with the winch, the single crabber follows the same procedure as the three-man team, except that his

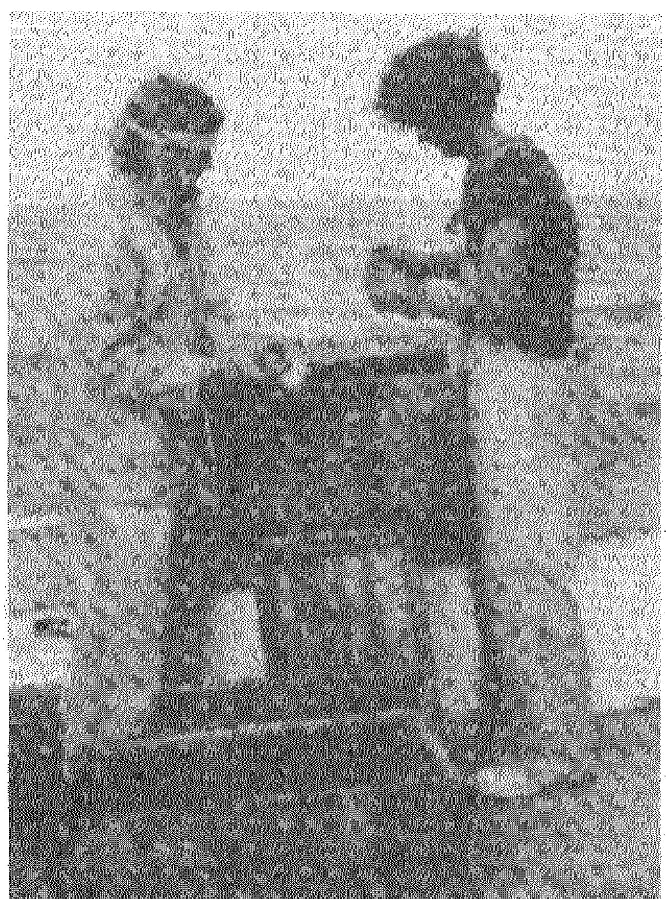
Figure 10. Trap Lift And Automated Winch For Stone Crab Traps.

Figure 11. Correct Method Of Breaking Stone Crab Claws.

a. Grasping the crab prior to snapping the claws (taken from Savage, et al., 1975).



b. Snapping the claws with a swift twisting motion.



boat cannot be advanced to the next trap until he has finished working with the trap he has pulled.

The single crabber can pull up to 50 or 60 traps per hour. The number of traps pulled per day ranges from 25 or less to 300. The number of traps set out in a season varies greatly and may be less than 50 or as many as 1,500.

Declawing procedure varies with the single-man crabber. Some will break off the claws as the traps are pulled, either throwing the crab back in the water at that time or keeping the declawed crabs on board to move them away from the area of his trap lines. Others follow the same procedure as large boat fishermen, tossing the crabs into wooden boxes until they are returning to, or have reached, dockside and declawing there. Individuals fishing ENP waters who are required to keep the whole crab on board until out of national park waters either declaw the crabs at sea after leaving the area of national park jurisdiction or upon reaching the dock.

Single man crabbers use a variety of methods in preparing and selling the claws. The crabber may cook his own claws. He then freezes them until he has a sizeable amount to market or sells them fresh (unfrozen). He may sell the catch to either a fish processing house or a retail market or restaurant. Or, he may simply sell his catch to the processor directly, similar to large boat fishermen.

4.4. Ecologically Sound Fishing Methods

Methods used by stone crab fishermen are designed for economy and expediency. In general, they attempt to employ techniques that also help perpetuate the fishery without sacrificing efficiency. In the stone crab fishery, where the organism can potentially return to the fishery, fishermen are concerned with both survival of the population in general and of the harvested population after declawing. For this reason, a number of procedures have been adapted by some fishermen that, if used by all fishermen could contribute significantly to the quantity of crabs "recycled" back into the fishery.

Gravid Females Are Not Declawed. Females are voracious eaters (Noe, 1967), probably because a tremendous amount of energy is necessary for the production of their vast numbers of eggs. Declawing gravid females may put an additional strain on the crab's metabolic processes and adversely affect behavior. Declawed gravid females do not care for their eggs for a period of time following declawing (Schleider, in press). Gravid females have been observed to drop their sponges after prolonged exposure to air and/or declawing (Schleider, in press; C. Brown, C. Brown Fish Company, pers. comm.; T.M. Bert, pers. obsn). If gravid females are declawed, some fishermen throw them immediately back into the water.

Declawing gravid females may reduce their reproductive effort for the remainder of the season. Food requirements appear to be especially large during reproductive season (Noe, 1967). Shellfish that normally compose their principal dietary constituent would no longer be easily obtainable, possibly resulting in a lower protein ratio in their diet. Available energy could be directed into growth of new claws, leaving little for reproduction.

Crabs Are Declawed And Thrown Immediately Back Into The Water. Today this is apparently done only in the single man operation. Despite the violation of state regulation on the possession of whole crabs (370.13 Fl. Stat.), many crabbers hold the crabs until they are able to move away from the area of their traps or until the end of the day. The density of traps throughout the fishery renders this endeavor futile in most cases because, as one crabber said,"At the same time I'm dumping my crabs in another guy's trap line, he's dumping his crabs in with mine." Aside from the futility of moving the crabs, their survival chances may be significantly lowered if they are thrown en mass into a less favorable environment. Schleider (in press) recently found that a stone crab's chances of survival after declawing decrease significantly with increased exposure to air prior to declawing. This problem is also encountered daily by ENP fishermen due to conflicting Florida and national park laws. This point will be dealt with in detail later.

Canopies Are Built Over The Stern Of Large Boats. Large operation fishermen contend that they cannot operate efficiently if crabs are declawed and immediately thrown back into the water. Wooden canopies built over the sterns of their large boats serve several purposes, one of which is to keep direct sunlight from the pullers and the catch until it is declawed. Stone crabs are known to be able to withstand 13 hours of anaerobic conditions while submerged (Karandeyeva and Silva, 1973); survival time out of water has recently been studied (Schleider, in press), and may be considerably lower. Although canopies are of some assistance, it would be adivsable to consider incorporating holding tanks on large boats. Immersion in water would probably reduce the amount of movement (and thus pinching and crushing) of the closely packed crabs while on deck, since they would not be attempting to reach water.

Crab Claws Are Measured Before Breaking If Their Size Is Legally Questionable. This is easily accomplished by attaching a measure to the stern of the boat where the pullers are working. In this way, sublegal claws are not wasted.

Biodegradable Traps Are Still Used By The Vast Majority Of Crabbers. Wooden traps will eventually break down and become habitats if they are lost at sea. Plastic traps, without at least one easily breakable section, become death traps indefinitely for stone crabs if the traps are lost. Many crabs can be lost to the population and market this way.

An Effort Is Made To Teach Mates The Correct Method Of Breaking Claws. A claw that is broken leaving a fracture wound greater than 14 mm (0.5 in), or a claw not broken along its natural fracture line, stands a greater chance of not healing (Davis, et al., in prep.) (Figures 12 and 13). The crab will usually bleed to death. Mortality rates from incorrectly breaking claws are extremely variable and can be quite high (J.R. Sullivan, DNR, pers. comm.). The senior writer noted a range from 3% mortality due to incorrect breakage of claws to a high of 75% in her field work. Some crabbers concern themselves with this matter and attempt to instruct their mates on the correct manner in which to break claws (Figure 11). However, because of the harsh and unpleasant nature of pulling traps, there is a great turnover rate for mates. Consequently, there is general unintentional ignorance of proper claw removal techniques. This is an especially crucial point when the fishery is based upon such techniques.

Figure 12. Incorrectly Broken Stone Crab Claw; Wound Width Is Greater Than 14 mm (0.5 in).

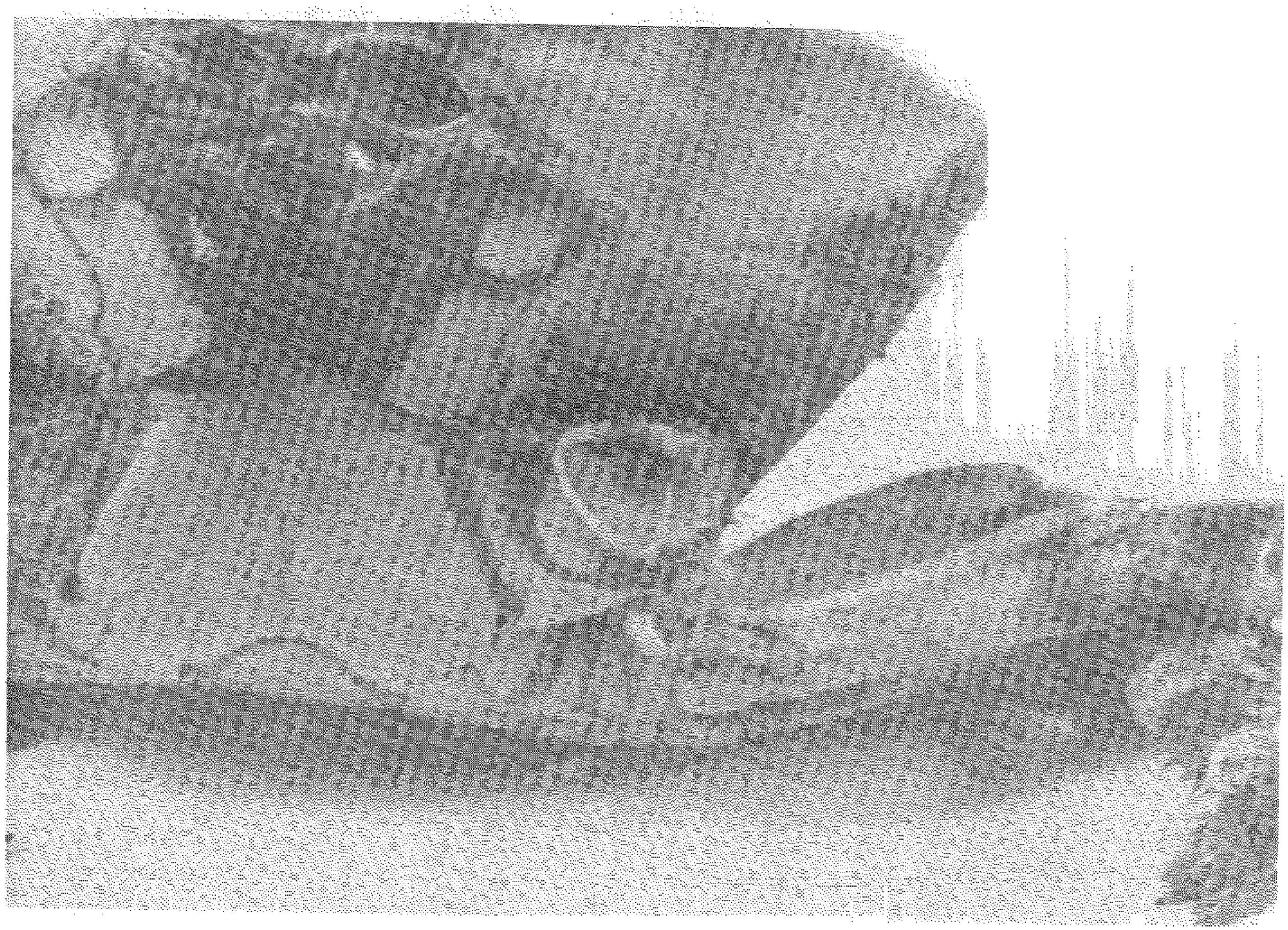
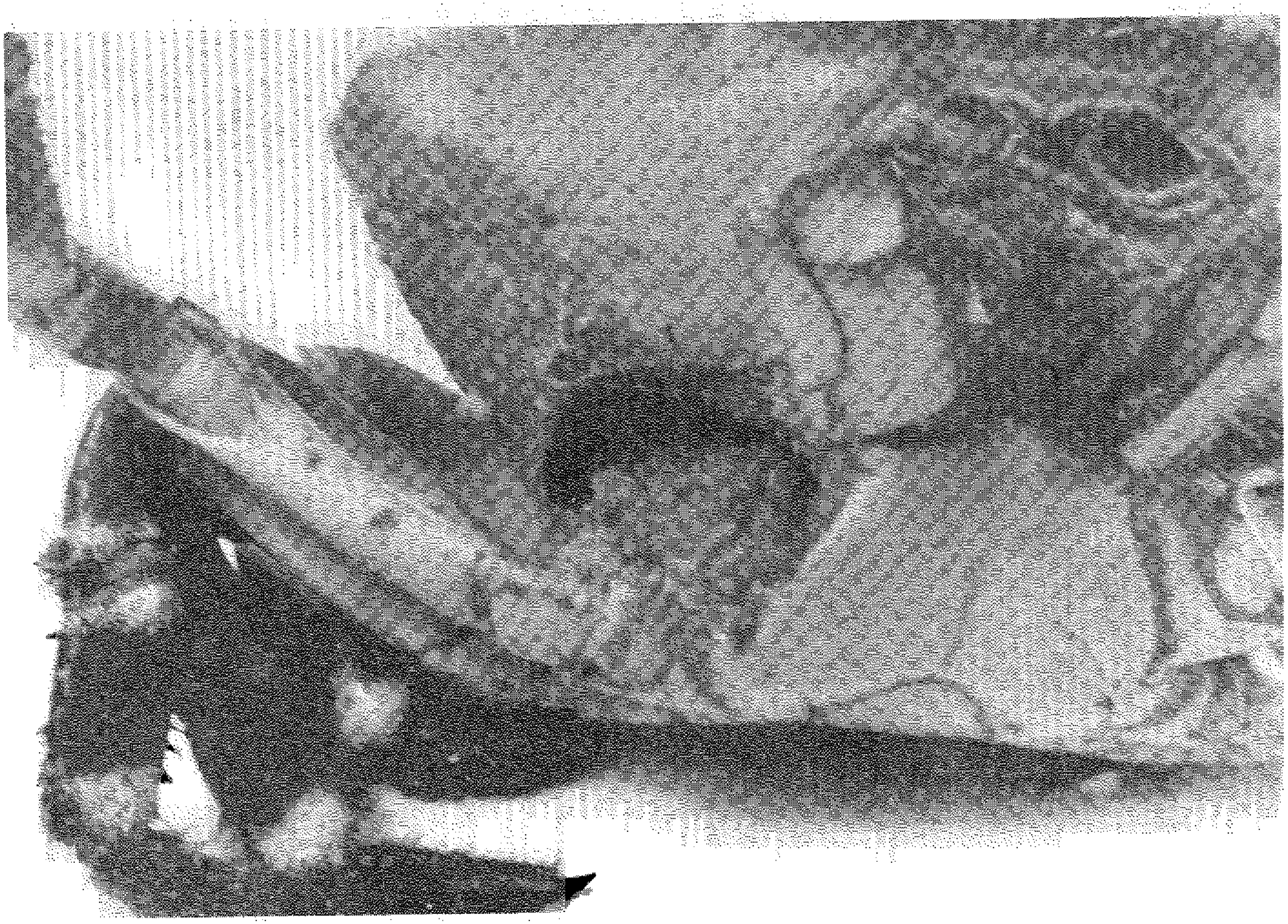


Figure 13. Open Wound From Incorrectly Broken Stone Crab Claw. The crab will bleed to death from this wound.



Most Crabbers Do Not Put Out Excessive Numbers Of Traps. The amount of time necessary to catch a profitable number of claws depends on several factors (abundance of crabs, fishing intensity, weather, length of time the bait lasts). Determining that time, without leaving traps unattended an unnecessarily long period of time is economically and ecologically the most beneficial thing to do. From a conservation standpoint, traps left unattended for an undue length of time may cause needless waste of crabs. Fishermen report that once the bait is gone, or if it is inaccessible, the crabs will feed upon one another. This waste can be substantial, when multiplied by thousands of traps.

5. UTILIZATION PATTERNS

5.1. Magnitude Of The Fishery

5.1.1. Landings

According to National Marine Fisheries Service (NMFS) statistics (NMFS, 1954-1978), the stone crab industry is among the ten most important of the fisheries in Florida (Prochaska, 1976). Following an initial period of little increase in volume of crabs landed, statewide commercial landings have continually risen, with only minor setbacks, for the past 20 years (Figure 14). The rate of increase is currently averaging approximately 30% per year.

Florida's east coast contributed significantly to total production of stone crabs only from 1961 to 1967, when from 12.8 to 25.0 percent of the total catch came from that region (Savage, et al., 1975). The west coast has always supplied the vast majority of claws and presently provides about 98% of the total volume landed. On the average, the E-FB fishing region has provided 80% of the total west coast amount in recent years. Monroe and Collier counties together supply 98% of the E-FB landings of stone crabs. In short, these two counties alone have accounted for over three-quarters of the stone crabs landed in the entire state since 1966 (Figure 15).

In Monroe county, stone crab landings rank fifth in production below shrimp, spiny lobster, and Spanish and king mackerel and have been among the top five fisheries since 1965. Prior to 1965, county landings rose fairly steadily in relative importance from the 17th position that was held in 1955.

However, landings from Monroe county have not kept pace with either statewide increases in landings or Collier county landings. With the exception of 1977, landings have shown relatively little increase since 1966 and almost none since 1968 (Figure 14), although production figures fluctuate greatly from year to year. When absolute poundage is converted to percentage of the total pounds landed statewide, it becomes evident that Monroe county has declined in relative production from a maximum in 1965 and 1966 (Figure 15). Total production of the E-FB region has maintained high levels because the increase in proportion of Collier county landings have offset the decline in Monroe county. The contribution to total pounds of all other counties combined was most significant from 1962 to 1965.

Figure 14. Total Volume Of Stone Crabs (Whole Crab Weight) Landed, 1953-1977, For The State Of Florida, West Coast Of Florida, Monroe County, and Collier County.
Note: Weight of stone crab claws only is one-half the whole crab weight.

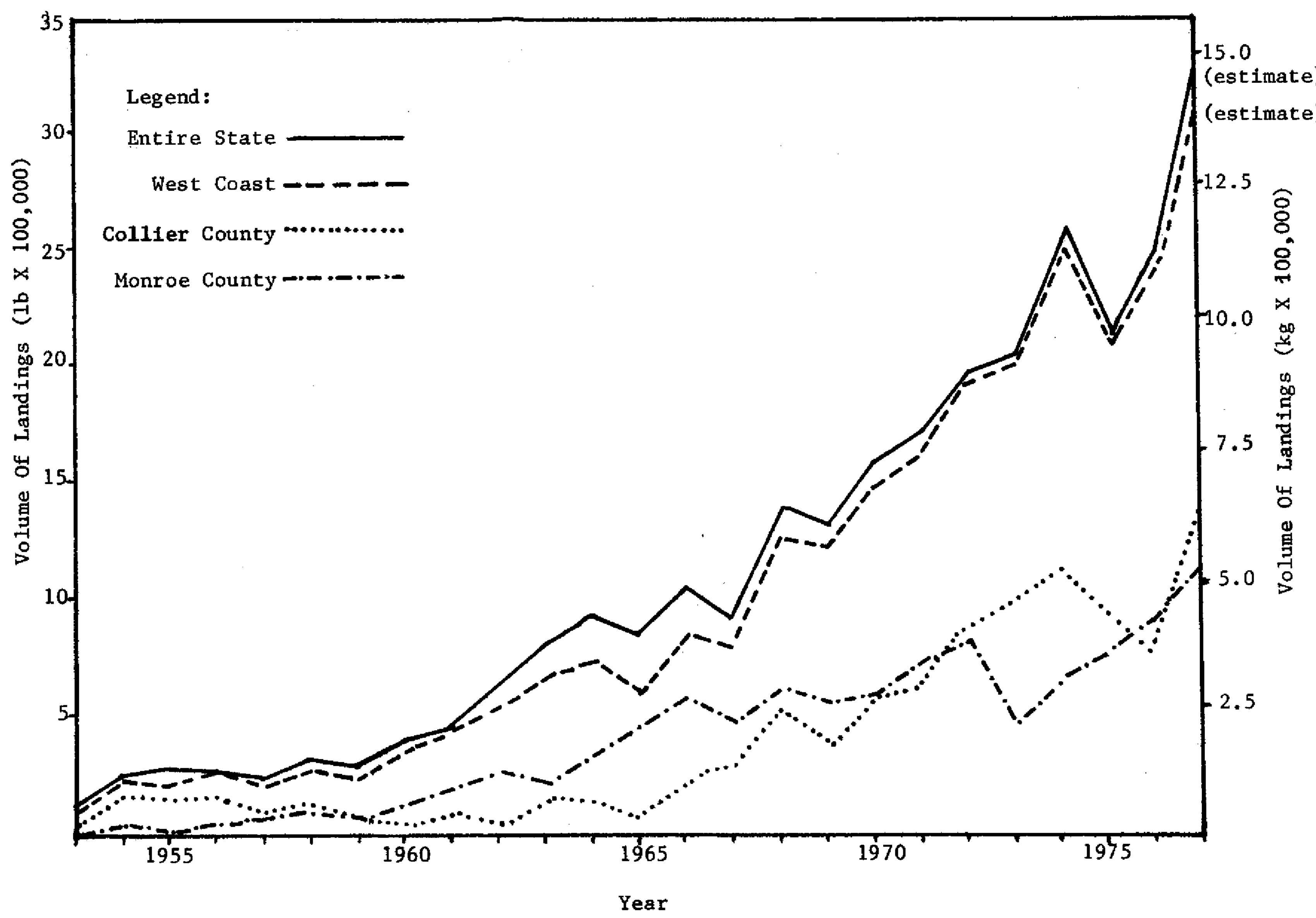
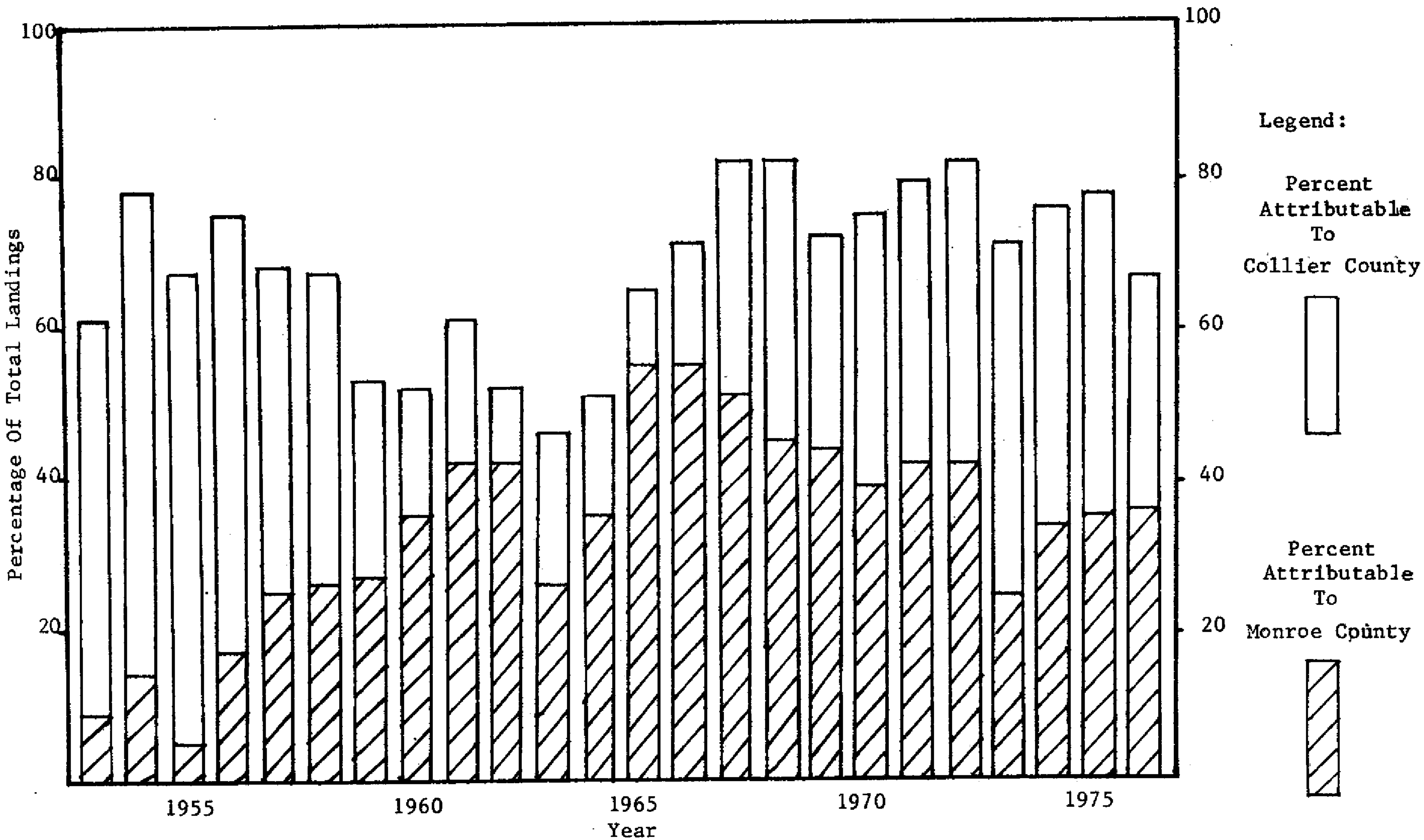


Figure 15. Percentage Of Statewide Stone Crab Landings Attributable To Monroe And Collier Counties, 1953-1976.



A monthly breakdown of landings for Monroe and Collier counties (Tables II and III) shows that seasonal peaks are variable for Monroe County. In contrast, Collier county exhibits greater stability in its seasonal peaks. In recent years, they have moved progressively closer to the beginning of the season. Peak months are currently November through January. Monroe county's inconsistencies in monthly catch can be attributed in part to many variables, several of which are:

1. prevailing weather and environmental conditions (probably this is the most influential factor);

2. recruitment into the fishery of spiny lobster fishermen when that fishery (or another fishery) becomes less productive than the stone crab fishery;

3. sporadic fishing by part-time fishermen;

4. less dependence upon the stone crab fishery as the sole or dominant income source.

It is noteworthy that production levels usually drop in both counties in April, a month before the season closes. This is due to a variety of occurrences which may include:

1. fishermen easing their intensity of fishing;

2. the population becoming "fished out";

3. the crabs not moving into the traps as frequently, for some biological or environmental reason.

5.1.2. Dockside Values

Prices offered for stone crab claws vary a great deal among localities, regulated by demand and claw size (Savage, et al., 1975). Savage found a range of $0.25 to $0.86 per pound for whole crabs in one county in 1973. Prices for claws alone are commonly considered to be double the whole crab price (E. Allen, NMFS, pers. comm.).

The average price per pound for stone crabs was comparatively high in the early days of the fishery. Prices decreased for a number of years, until a low of $0.33 per pound was reached in 1963 (Table IV). Yearly increases in dockside prices have occurred during most years since that time. From 1965 to 1970, the price increased about 30% over the 1965 price per pound. A 60% gain over the 1970 price occurred from 1970 to 1975. At the close of the 1977-1978 season, price per pound had increased 15% over the 1975 price. Total dockside value of landings from stone crabbing in Monroe and Collier counties rose at comparable levels until recent years (Figure 16). Fishermen in Collier county rely far more heavily on crabbing as a major source of income than do Monroe county fishermen. Monies from the stone crab fishery account for only 3 to 4% of Monroe county's total fishery revenue. Collier county, however, obtains from 35 to 40% of its fishery earnings from the stone crab industry. Statewide, the stone crab fishery currently contributes only slightly over 2% of the total dockside value for marine landings.

Table II. Monroe County Stone Crab Landings, By Month (1968-1978). Kilogram equivalents in parentheses. (National Marine Fisheries Service Data)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1968-69	65420 (29439)	77001 (34650)	66933 (30120)	68977 (31640)	72089 (32440)	71458 (32156)	66723 (30025)	65022 (29260)
1969-70	38055 (17125)	37106 (39198)	88712 (39920)	85094 (38292)	86122 (38755)	69169 (31126)	68632 (30884)	28758 (12941)
1970-71	56697 (25514)	52003 (23401)	07243 (48259)	66797 (30059)	118175 (53179)	107541 (48393)	61981 (27891)	18839 (8477)
1971-72	58737 (26432)	47983 (21592)	109193 (49137)	134648 (60592)	94755 (42640)	142840 (64278)	43407 (19533)	50277 (22625)
1972-73	42360 (19062)	39702 (17866)	71026 (31962)	36458 (16406)	88376 (39769)	52517 (23633)	80585 (36263)	62596 (28168)
1973-74	21654 (97443)	51870 (23341)	76737 (34532)	101008 (45454)	88874 (39993)	280513 (126231)	95127 (42807)	30910 (13909)
1974-75	50010 (22504)	67759 (30419)	117943 (53074)	92726 (41727)	114655 (51595)	84862 (38188)	77029 (34663)	13742 (6184)
1975-76	57187 (25734)	165482 (74467)	117456 (52855)	158452 (71303)	184425 (82991)	55168 (24826)	130667 (58800)	33676 (15154)
1976-77	45515 (20479)	164351 (73958)	110561 (49772)	255160* (114822)		349728* (157458)		78575 (35359)
1977-78	71973 (32388)	155468 (69961)	209553 (94279)	203017 (91358)	196996 (88748)	130096 (58533)	not yet availble	

*Landings For January-February and March-April, 1976 were combined.

Note: Values within 10% of the highest value for each season are underlined. October and May values represent only two weeks of trapping, due to opening and closing of the season.

Table III. Collier County Stone Crab Landings, By Month (1968-78). Kilogram equivolents in parentheses. (National Marine Fisheries Service Data)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1968-69	54452 (24508)	49438 (22247)	64728 (29128)	64384 (28973)	77074 (34683)	71022 (31960)	29364 (13214)	4076 (1834)
1969-70	11492 (5171)	59486 (26769)	77292 (34781)	94590 (42566)	81412 (36635)	93590 (42115)	67286 (30279)	38258 (17216)
1970-71	12728 (5728)	93288 (41979)	102616 (46177)	144644 (51590)	113028 (50863)	76526 (34437)	84790 (38156)	12850 (5782)
1971-72	15588 (7015)	70974 (31938)	129160 (58122)	158508 (71329)	178184 (80183)	177462 (79858)	97862 (44038)	17032 (76643)
1972-73	32536 (14641)	76772 (34547)	136980 (61641)	126444 (56900)	145988 (65699)	112164 (50474)	126656 (56995)	42514 (19131)
1973-74	63687 (28655)	140468 (70234)	143370 (64516)	114290 (51430)	156806 (70562)	274572 (123557)	111596 (50218)	55302 (24885)
1974-75	57186 (25734)	143656 (64645)	198506 (89328)	174809 (78664)	138671 (62402)	137998 (62099)	83682 (37657)	18648 (8392)
1975-76	64044 (28820)	170090 (76540)	125282 (56377)	149372 (67217)	90036 (40516)	56780 (25551)	73722 (33197)	27996 (12508)
1976-77	97544 (54895)	144860 (65187)	127932 (57569)	315598* (140019)		344344* (154955)		67794 (30507)
1977-78	171600 (77220)	249549 (112199)	207973 (93572)	208938 (94022)	165540 (74493)	214836 (96676)	not yet available	

* Landings for January-February and March-April, 1976 were combined.

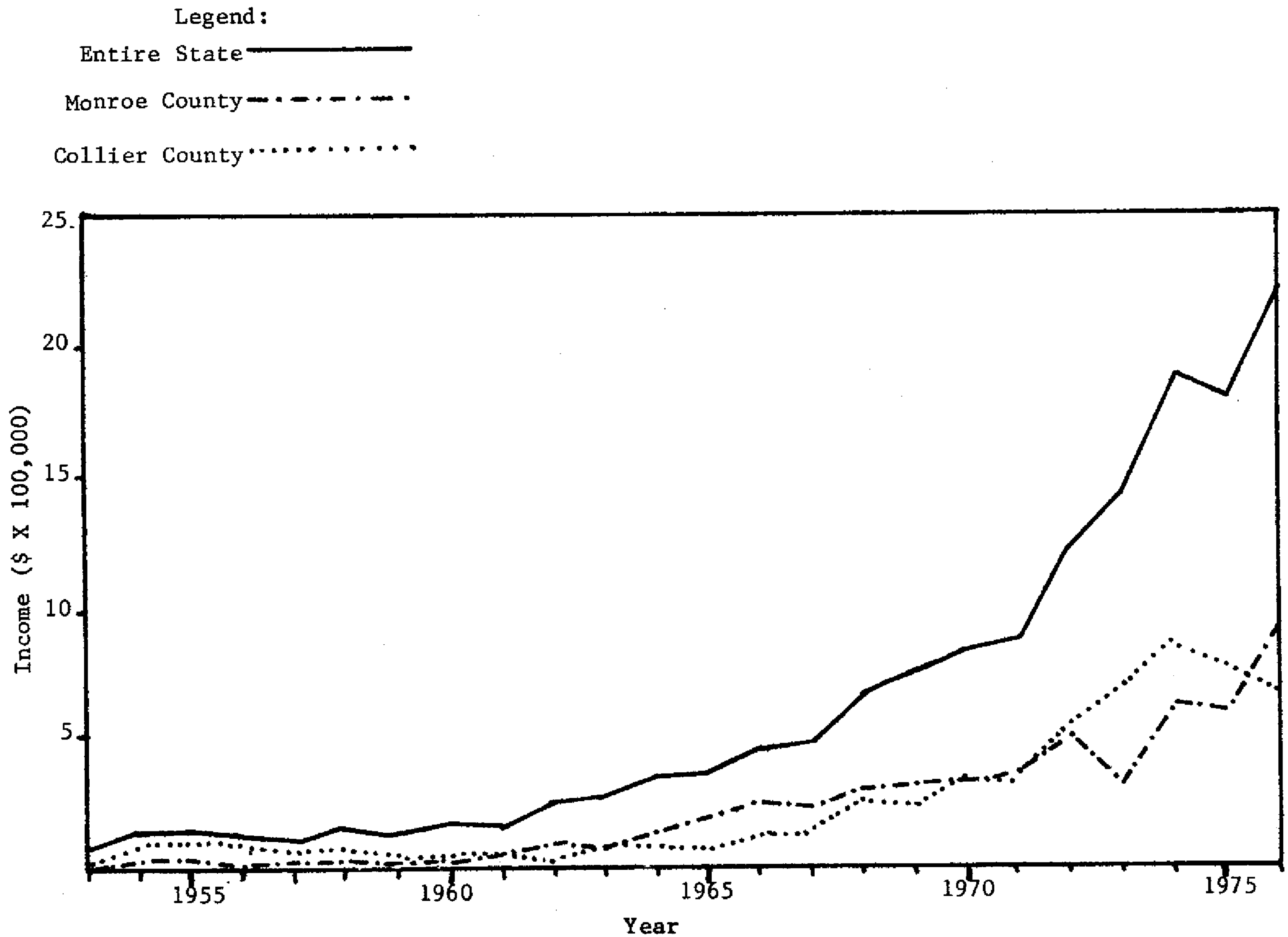
Note: **Values within 10% of the highest value for each season are underlined.** October and May values represent only two weeks of trapping, due to opening and closing of the season.

Table IV. Price Per Pound For The Stone Crab (Whole Crab Prices), 1955 to 1977 (National Marine Fisheries Service Statistics).

Year	Price Per Pound[1] (1 lb= 0.45 kg)
1955	$ 0.47
1956	0.44
1957	0.37
1958	0.41
1959	0.37
1960	0.36
1961	0.34
1962	0.36
1963	0.33
1964	0.34
1965	0.40
1966	0.40
1967	0.49
1968	0.47
1969	0.55
1970	0.52
1971	0.50
1972	0.62
1973	0.68
1974	0.73
1975	0.83
1976	0.90
1977	0.91

[1]The National Marine Fisheries Service computed price per pound, whole crab, as one-half the price for claws alone.

Figure 16. Total Dockside Value Of Landings From The Stone Crab Fishery For Monroe And Collier Counties And The State Of Florida, From 1953-1976



5.1.3. Permits

The issuing of permits and licenses protects both the fishermen and the fish by providing a means of observing the growth and current size of the fishery. This valuable information aids in determining fishing pressure on the organism and, when combined with yearly landings statistics, illustrates important trends in quantity returned per number of men supported by the industry.

Analysis of permits obtained for stone crab fishing (Figure 17) since 1968 reveals the following observations:

1. With the exception of a few brief declines, the number of permits has grown steadily statewide and in both Monroe and Collier counties.

2. Statewide, the number of permits has increased 670% in the past ten years.

3. Monroe county stone crab fishermen have increased by over 300 % during the same time period.

4. Licensed Collier county crabbers, though only one-third in number, compared with Monroe county, have increased by about 400% since 1968.

Closer examination of stone crab permits (Table V) shows that:

1. Monroe county averages slightly less than half of the total number of permits for the state, with yearly values showing a general decline.

2. The percentage of Collier county permits averages far below that of Monroe county in relation to the total number but is slowly and steadily increasing.

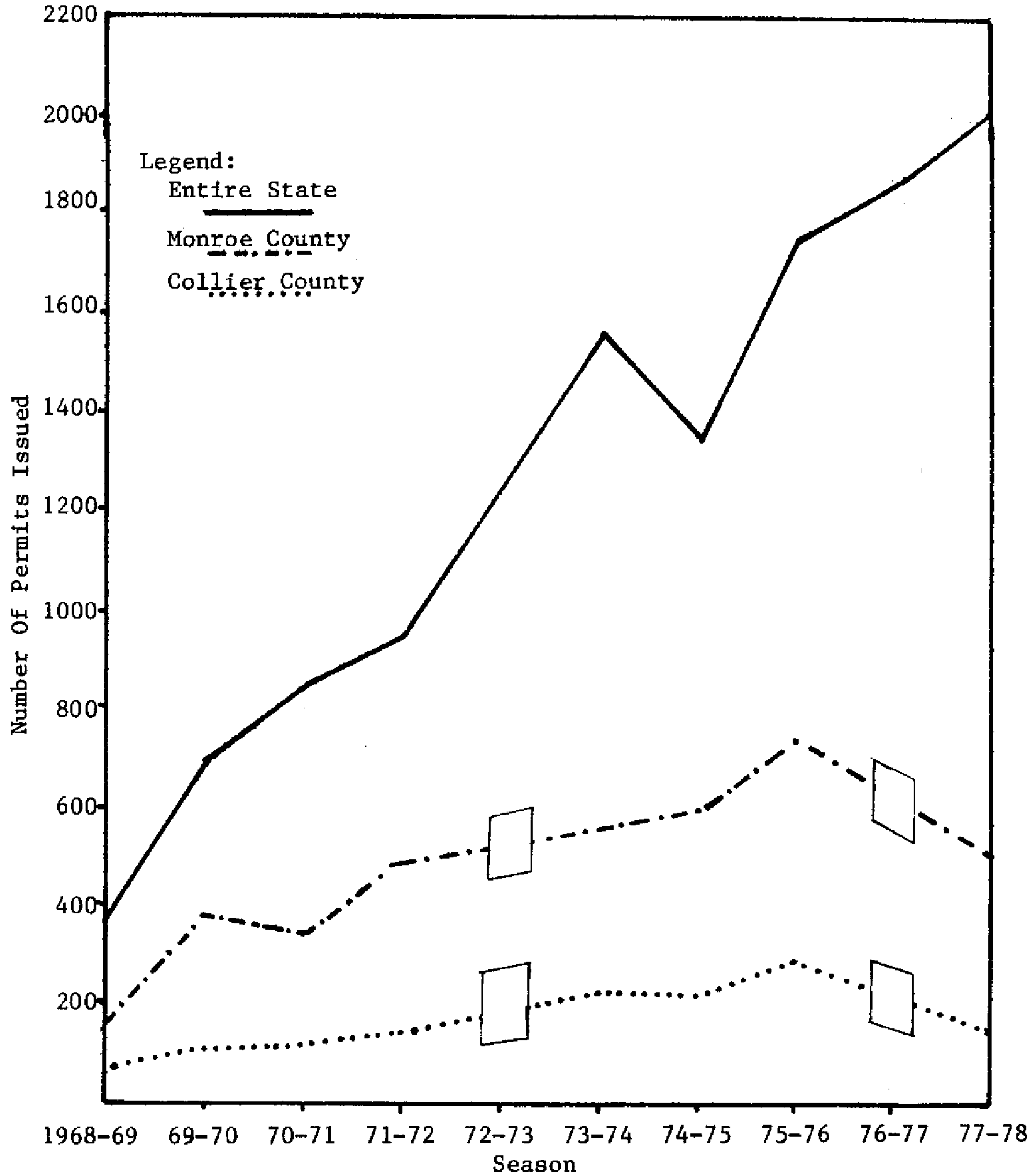
3. About three-fourths of the crabbers registered for Monroe county live in the Upper Keys (Key Vaca through Key Largo).

4. Over an 8 year period, an average of 40% of those individuals with permits to land stone crabs in Monroe county have been residents of other counties, primarily Dade and Collier counties.

5.1.4. Traps

Unfortunately, the only years for which the very important data regarding the number of traps deployed per permit were required to be reported were 1967 to 1970. During that time, the number of traps per permit statewide, fell from 451 in the 1967-68 season to 228 in 1968-69 and rose slightly in 1969-70 to 269. Using information available from fishermen on the number of traps they currently employ and considering Prochaska's (1976) finding of a gradual decrease in the number of "casual" fishermen in general (those earning less than 50% of their income from fishing) since 1958, it would seem reasonable to assume that an average of at least 200 traps are utilized per permit in Monroe county and possibly as many as 400.

Figure 17. Number Of Stone Crab Permits Issued In The State Of Florida, Monroe County, And Collier County, 1968-1977.



Note: Number of permits for Monroe and Collier counties for the 1972-73 and 1976-77 seasons were not available.

Table V. Stone Crab Permits, 1968-1975.

Year	Total Number Permits Issued	% of Total No. Permits Issued to Monroe County	% Monroe Cty. Permits Issued from Marathon to Long Key	% Monroe Cty. Permits Issued to Out-of-County Residents	% of Total No. Permits Issued to Collier County
1968-69	317	48	86	48	12
1969-70	634	52	75	36	10
1970-71	754	40	78	45	9
1971-72	901	49	72	34	11
1972-73	Data not available				
1973-74	1515	34	76	43	12
1974-75	1306	42	75	41	13
1975-76	1731	40	74	41	14

Trap Density. The only extensive field survey of trap density to date (Davis and Skagen, 1977; Davis, et al., 1977) has estimated densities of 4.8 traps/sq km (12.7 traps/sq mi) in ENP waters in January, 5.3 traps/sq km (13.8 traps/sq mi) in February, and 3.6 traps/sq km (9.4 traps/sq mi) in April of 1977.

Counts taken in December and January, 1977, by the senior writer on field trips for this study averaged 4.7 traps/sq km (12.5 traps/sq mi) in ENP. The ENP stone crab management area is approximately 542.7 sq km (209.5 sq mi) (Davis and Skagen, 1977). Only about 1.4% of the stone crabbers with permits for Monroe county also obtained permits to fish in the national park during the 1975-76 season. Low production levels and the conflicting Florida and national park regulations are reportedly the factors most influential in deterring fishermen from park waters.

The E-FB fishing region outside of national park jurisdiction (9310 sq km, or 3590 sq mi) supports at least in part the remainder of the Monroe county and Collier county fishermen (98.6%). Table VI summarizes trap density estimates at the projected lower and upper range of traps per fisherman in Monroe county for the 1975-76 season for this area. Out-of-county fishermen (fishermen with residences in other counties and permits for Monroe county) are assumed to have about one-half their traps in waters fished by Monroe county fishermen (a reasonable assumption, when one considers that many out-of-county fishermen have permits exclusively for Monroe county). Although the projected density values may appear to be high, actual in-field counts taken in December, 1976, and January, 1977 in two entirely different areas (off the Shark River basin, water depth 3-6 m (10-20 ft) and behind Mud Keys, water depth 9-15 m (30-50 ft)) considered to be outside the area of highest fishing pressure and away from spiny lobster traps, had trap densities considerably higher than the estimated value for 400 traps per permit (up to 68.7 traps/sq km, or 178 traps/sq mi).

Table VI. Estimated Trap Density In Area Of E-FB Stone Crab Fishing Region Utilized By Monroe County Fishermen (Exclusive Of Everglades National Park Waters--Approximately 520 sq km (200 sq mi)--And Those Fishermen With Permits To Fish In the Park--25 Permits) During The 1975-76 Season.

Total Number Of Traps In Area	200 traps/permit	400 traps/permit
In-county fishermen (Residing in Monroe County)	79,000	158,000
Out-of-county fishermen[1] (Residing in other counties)	28,000	56,000
Trap Density		
per sq mi	62.9	125.9
per sq km	24.3	48.6

[1]Out-of-county fishermen were assumed to put only 50% of the total number of traps per permit in waters fished by Monroe county fishermen.

5.2. Management Of The Fishery

Fishery management laws are evolved from a complex process involving scientific data, pressures by various interest groups, legislation, and implementation. The management of an open access fishery is not like the private management of a farm. Thus the management of fisheries falls largely to governmental bodies which can make and enforce laws controlling the use of an entire fishery (Prochaska and Baarda, 1975). State regulations pertaining to the stone crab are found in Florida Statutes, Section 370.13 (1975) and Florida Laws, 1973, Chapter 73-28. ENP waters are under the jurisdiction of the National Park Service (NPS) and therefore are subject to a separate set of regulations (Code of Federal Regulations, Title 36, Section 7.45).

5.2.1. Stone Crab Regulations

Historically, legal controls over the stone crab fishery have ranged from total absence of regulation to the imposition of a complete moratorium on crabbing. Although an inquiry was made, no evidence of management legislation before the 1930's was found. The rapid depletion of inshore stocks near Key West by the early 1940's (Florida Writer's Program, 1941) reportedly prompted a five-year moratorium on crabbing in the late 1940's and early 1950's. Legislation since that time has varied immensely and, in some cases, reflects the absence of sound biological data as a foundation for regulation. Among the controls that have changed through the years are:

1. the harvesting season--currently it is October 15 to May 15, with a 10 day leeway to set out traps before the season opens and a five day leeway to pull the traps after the season closes;

2. keeping the whole crab vs. keeping only the claws--only claws are kept at this time; possession of whole crabs on boats is illegal, except in ENP, where the entire crab must be kept on board while in national park waters due to differing state and national park laws;

3. taking one vs. both claws--both can be taken now;

4. harvesting males only vs. both sexes--presently both sexes may be declawed except in ENP, where only males are declawed;

5. the harvestable size of the animal--a minimum propodus length of 7.0 cm (2.75 in) is now required by the State of Florida; ENP requires 10.8 cm (4.25 in) overall claw length--these two rulings are in accordance, the corresponding whole crab size is the same for each law;

6. licensing of the operation: at this time, the boats of all fishermen with five or more working traps--those that are in the water--must obtain a free permit, and only one permit is issued per boat; each permit is licensed for a county or a number of counties to land claws in those counties; ENP fishermen are required to obtain an additional permit to fish national park waters; the permit number must be permanently engraved in both the buoy and trap;

7. limitations on the number of traps per permit: no restrictions are currently imposed except in ENP, where a limit of 400 traps per permit has been set;

8. area restriction: no restrictions on fishing grounds currently exist except in ENP, where the north half of eastern Florida Bay and all inshore areas to within 400 m (1312 ft) of the coast are closed to stone crabbing;

9. trap design: entrance size must be no larger than 10.2 X 16.5 cm (4 X 6 in).

5.2.2. Effectiveness Of The Regulations

Fisheries management regulations frequently must meet the very demanding test of political feasibility. This powerful influence can be seen in certain regulations pertaining to the stone crab fishery. As is the case with almost any set of rules, some appear very beneficial while others need to be modified and some new additions incorporated.

Apparently Effective Regulations. Several laws are ecologically sound in that they protect stocks and allow for successful replenishment of the resource.

Taking only the claws permits some fraction of the harvested population to return to the fishery and, hopefully, to the reproductive population. Since many processing houses accepted only claws prior to creation of the law, whole crabs were, in any event, declawed at the dock, a process that left countless clawless crabs in dockside waters.

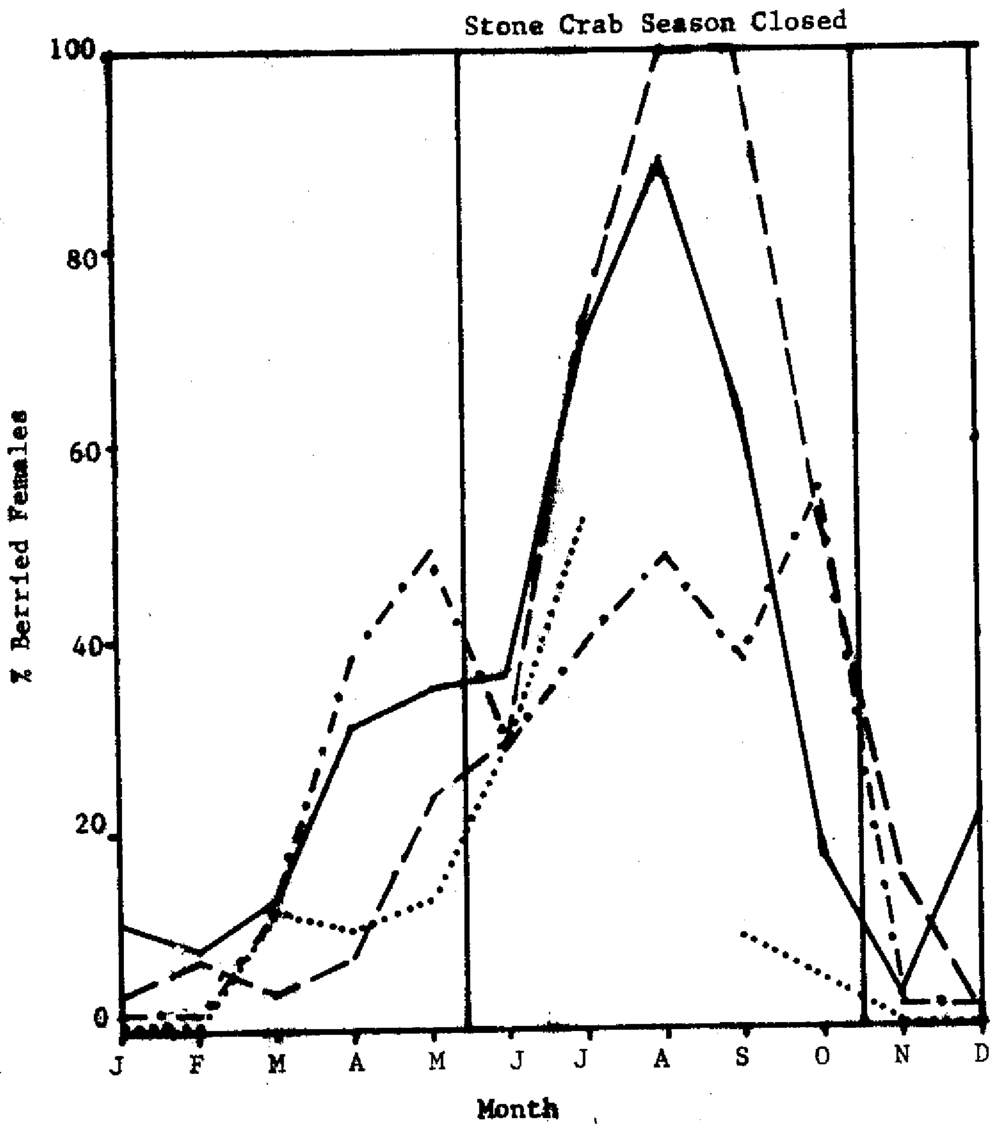
The legal harvestable size is such that females can reproduce unmolested for about a year before entering the fishery. Females have an additional advantage in that their claws attain the legal size at a carapace width 7 mm (0.25 in) larger than males (and therefore at an older age) (Sullivan, in press).

Licensing with permits allows for some type of monitoring of the size of the industry. It also provides some indication of the size of each man's operation.

Apparently Incompletely Effective Regulations. Close examination of other laws reveals that some modification may contribute more to the wellbeing of both the organism and the industry. In some instances, no regulatory program exists where some form may be advisable.

Harvesting Season. Length of the harvesting season presently overlaps the onset of intensive spawning in Florida by about two months (Figure 18). Although spawning occurs the year around, the contribution of winter spawning may be very small. Water temperatures are such that the larval phase may be greatly prolonged, increasing the chances for larval mortality through predation. Below 25°C (77°F), temperature of the water has been shown to reduce survival rates by 50% or more (Ong and Costlow, 1970). Above 25°C, larval survival begins to increase drastically. By mid-March, temperatures in shallow waters of ENP reach 25°C (T. Schmidt, NPS, pers. Comm.), considerably shortening larval time in the water column

Figure 18. Percentage Of Total Trapped Female Stone Crab Population With Eggs, By Month, In Florida, From The Cedar Key Region, Biscayne Bay, And The Lower E-FB Region.



Legend:

Biscayne Bay (Noe, 1967): ————

Biscayne Bay (Cheung, 1969): — — —

Cedar Key (Bender, 1971): ....

Lower Florida Gulf of Mexico (Sullivan, pers. comm.): —·—

and increasing survival rates. About 25% of the female population is egg bearing at this time (Figure 18).

Simultaneously with this increase in egg production, fishermen report an increase in percentage of females in the trapped population. Data from Noe (1967) substantiate this information (Figure 19). Female: male ratios in his traps were 2:1 in mid-March and increased to 5:1 by mid-May. Thus the proportion of reproductive females in the harvested population can potentially be up to nearly 170 for every 1,000 crabs caught in mid-March and 330 in mid-May.

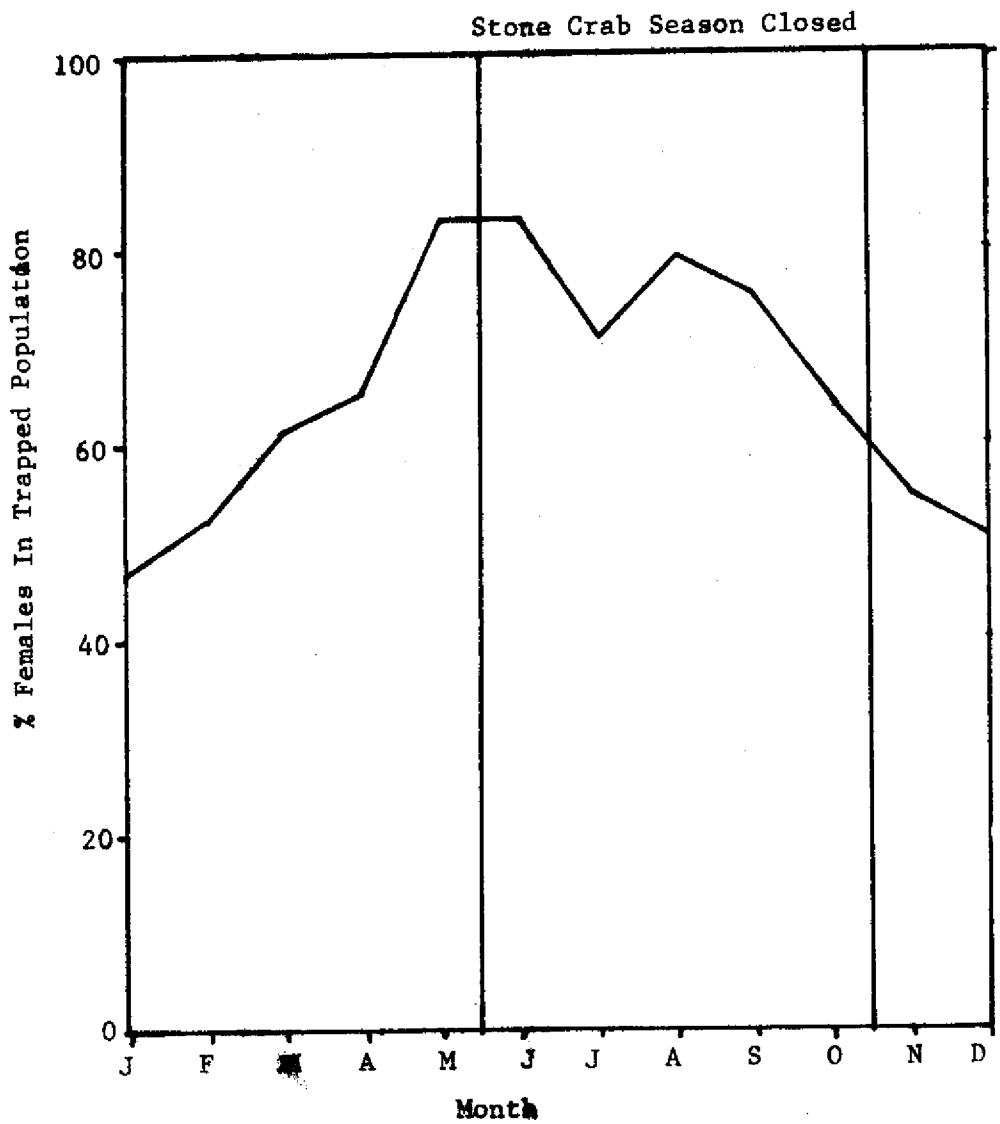
Another problem arises, involving trapping during the closed season. Many fishermen report that closed season trapping occurs illegally in the E-FB region, particularly after the onset of spiny lobster season. Summertime trapping not only jeopardizes the reproducing female population but creates a surplus of claws on the market that drives down prices at the opening of the season. Fishermen justifiably complain bitterly about this problem, since opening prices the following fall may be below the last season's closing prices. The present penalty for crabbing out-of-season is merely a fine. Obviously this is not strong enough to adequately serve as a deterrent to poaching.

Harvesting Both Sexes. Where a lack of adequate biological information exists, the general approach taken by the authorities has been to enact conservative laws aimed at insuring the perpetuation of the species while supporting a limited fishery. The former "male only" law, enforced by both DNR and NPS until October 15, 1973, embodied this philosophy by insuring survival of at least 50% of the adult population. Considering that the stone crab is polygamous and that a single copulation will provide sperm for a number of spawnings, protection of the female population was a sensible attempt to conserve a resource subjected to increasing fishing pressure. Then in 1973, after NPS had announced its intention of adhering to the existing law of taking males only, the Florida law was changed to permit the taking of claws of both sexes. This change was coincident with enactment of the Florida "claws only" law, also implemented in 1973. It was therefore practical from an enforcement point of view, since male and female claws cannot be distinguished once they are removed from the animal. The consequence of this unilateral change by the State has unfortunately been generally bitter feelings toward the NPS and a great deal of confusion about the legal technicalities of the conflicting laws.

Surprisingly, no significant increase in the landings can be attributed to the modified State regulation (Figure 14). Nor did catch per permit rise (Figure 21), interesting observations in view of the hypothetical 100% increase in available crabs. This would seem to indicate that either the previous "male only" law was not enforced, or that the increase in landings was masked by a natural population decline of stone crabs. Fishermen point out that adverse circumstances such as red tide outbreaks (*Gymnodinium breve*) or unusually cold weather have strong influences on abundance of stone crabs.

Harvesting Both Claws. There is little doubt that the removal of both claws severely restricts the selection of accessible food items and leaves the stone crab far more vulnerable to predation. The importance of the claws in obtaining sufficient food may be even greater in a gravid female. The claws also perform an essential role in courtship and mating

Figure 19. Percentage Of Female Stone Crabs In Trapped Population, By Month, In Biscayne Bay, Florida (from Noe, 1967).



behavior. In their highly ritualized behavioral interactions involving heirarchial establishment, the manner of movement of the claws is the dominant visual communication stimulus (Sinclair, 1977). In addition, crabs may have a terminal (final) molt (Cheung, 1976). If this is true, then these crabs will have no opportunity to regenerate new claws. Some of Cheung's terminal molt crabs lived two years after their final molt. Should these crabs be unable to reproduce, an important constituent of the reproductive population may be lost. This is particularly important since larger females have a much greater egg bearing capacity. Finally, females may have a difficult time regenerating their claws since reproduction and growth are both maximal in summer and reproduction can inhibit growth (Cheung, 1969).

6. UTILIZATION POTENTIALS

6.1. Present Trends

6.1.1. Trapping Effort

The following computations are based primarily on information available to the writers through interviews with fishermen and fish processing house personnel and personal observations made when accompanying fishermen on their boats. Monetary estimates were derived by combining catch estimates with fishery statistics values and personal communications regarding costs and sales from the fishermen and fish houses in Monroe county. All values presented are certainly subject to exception and are presented solely to illustrate generalities in an attempt to encompass a large percentage of the various aspects of the industry.

Production. Ideally, the ongoing return on the investment in a fishery is monitored closely by the statistic "catch per unit effort" (CPUE). Specific information on the number of traps employed per crabber, average length of time traps are fished (left in the water) before pulling, man-hours required, and average weight of the catch is needed to compute this important economic indicator. CPUE can change dramatically over the course of a season, as can the cost per unit of output, so these statistics should be continually evaluated to determine an average and as a notation on peaks and declines for the season. The data needed to calculate CPUE and cost per unit of output are not available for the stone crab industry and substitutions and estimates must be made.

Data gathered from questioning fishermen and observing landings in December, 1976, and January, 1977, and from tallies procured by the senior writer during five trips accompanying stone crabbers in verious areas of the E-FB fishery during that time period, showed that fishermen utilizing the three-man operation usually obtain between 34.0 and 96.4 g (1.2 and 3.4 oz) of crab claws per trap-night. The mean for that portion of the season, as determined using the same sources, was 48.2 to 65.2 g (1.7 to 2.3 oz) per trap-night. When questioned about their average catch five years ago, every fisherman independently presented figures that reduced to a catch of about 113.4 g (4 oz) per trap-night. However, many fewer traps were used by all fishermen at that time. Noe (1967) averaged 136.1 g (4.8 oz) of claws in Biscayne Bay during the 1964-65 season. Bender, in 1971, ranged between an estimated 567 g (20 oz) of claws to a minimum of 90.7 g (3.2 oz) at Cedar Key.

Single-man crabbing operations have a much wider range in catch weight per trap-night. One crabber has reported a catch of less than a half kilogram (approximately a pound) of claws per trap over an entire season while another said he averaged over 85 g (3 oz) per trap-night. These values are probably extremes. Using the same data base as employed for the three-man operation, a mean catch of 28.4 to 42.5 (1.0 to 1.5 oz) of claws per trap-night was estimated. Davis (1976) also reported a CPUE of 29 g (1 oz) per trap-night in ENP in January of 1975, the result of a continual decline from 113 g (3.9 oz) since 1972.

Prices. As is the situation with many industries in the country, maintenance and operating expenses for stone crabbing have increased steadily in the past few years. Rises in fuel prices account for large additional expenses despite the availability of certain state and federal tax exemptions (Cato, 1973). In-depth economic evaluation is not possible due to lack of information on relative past and present cost and return relationships. However, simple comparisons of the price of stone crab claws with important economic indicators (consumer price indices, or CPI's) can be informative. Although increases in the price paid for stone crab claws may seem to have been high in recent years, they have not paralleled average increases in raw produce wholsale prices (Figure 20). This CPI is the category into which dockside prices of stone crab claws fall. However, the price of stone crab claws has kept pace with rises in overall cost of living (for commodities and service groups). In practical terms, this means the fisherman is maintaining his income level from crabbing commensurate with the overall cost of living.

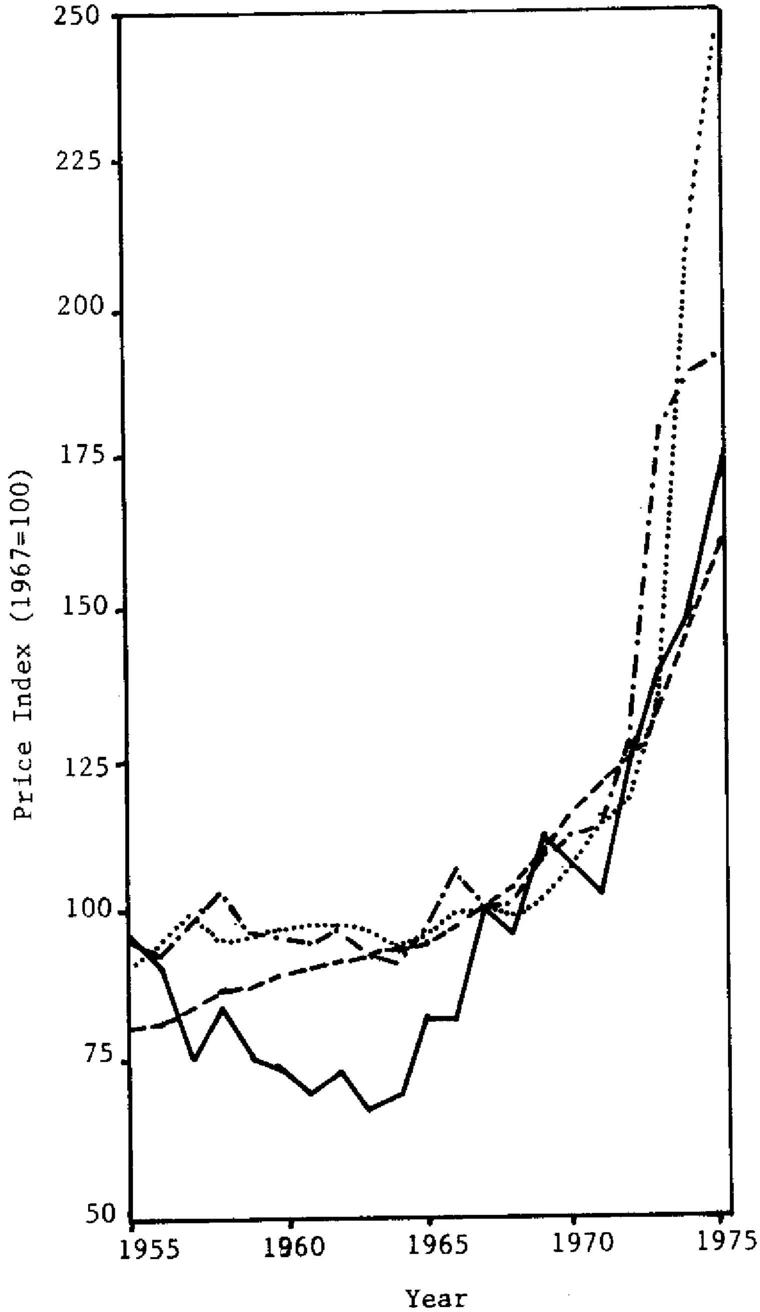
Five years ago, the catch per trap-night of all fishermen, regardless of the size of their operations, was approximately the same (Table VII). Both size classes of fishing enterprise have seen losses in poundage and dollars. This is a common market phenomenon associated with increases in the number of traps per boat. Single-man operations have undergone the greatest decrease in unit return, with nearly a 40% reduction over the past five years. (This decline is not nearly so pronounced in the Key West area as in ENP.) Three-man crabbing operations have experienced only an 8.5% drop in unit return, probably due to the greater accessibility of less heavily trapped offshore areas to larger boats. This does not necessarily mean that crabbing has not been at all profitable. Declines in return per trap can be offset by increasing the number of traps per boat, rises in dockside prices, or decreases in cost per unit of output.

In fact, rising prices in dockside values have offset decreases in the average catch per license (Figures 21 and 22). Both Monroe county and the entire state have experienced slight increases in return per licensed fisherman since 1968. Average unit return in Collier county has remained relatively stable for the past five years, with large fluctuations occurring from year to year.

6.1.2. Harvesting Pressure

Many natural adaptations enhance the chances of the stone crab for survival, even under heavy fishing pressure:

Figure 20. Dockside Price Of Stone Crab Claws (Adjusted To Consumer Price Index) And Important Consumer Price Indices, 1955-1975.



Legend:

——— Price Of Stone Crab Claws Per Pound (Adjusted To Consumer Price Index)

- - - - Consumer Price Index By Commodity And Service Groups (All Items)

········· Wholesale Price Index For Industrial Commodities (Fuels And Related Products, And Power)

-·-·- Wholesale Price Index For Crude Materials For Further Processing (Foodstuffs And Feedstuffs)--Includes Dockside Fishery Landings

Table VII. Average Estimated Value Of Claws Produced Per Trap Night For 1-Man And 3-Man Stone Crab Fishing Operations For The 1970-71 Season And 1975-76 Season.*

Size of Operation	Dockside Value ($/unit with claws)		Approximate Mean Catch (unit with claws/trap night)		Unit Value ($/trap night)	
	kg	lb	kg	lb	kg	lb
1970-71						
1-man	$ 0.47	$ 1.04	0.111	0.247	$ 0.052	$ 0.257
3-man	0.47	1.04	0.113	0.250	0.053	0.260
1975-76						
1-man	0.91	2.00	0.035	0.078	0.032	0.156
3-man	0.91	2.00	0.054	0.119	0.049	0.238

*Data from Davis (1976), with permission, and NMFS (1972) and through personal communications.

Figure 21. Volume Of Stone Crabs Landed Per Permit Issued, 1968-1975, For The State Of Florida, Monroe County, And Collier County.

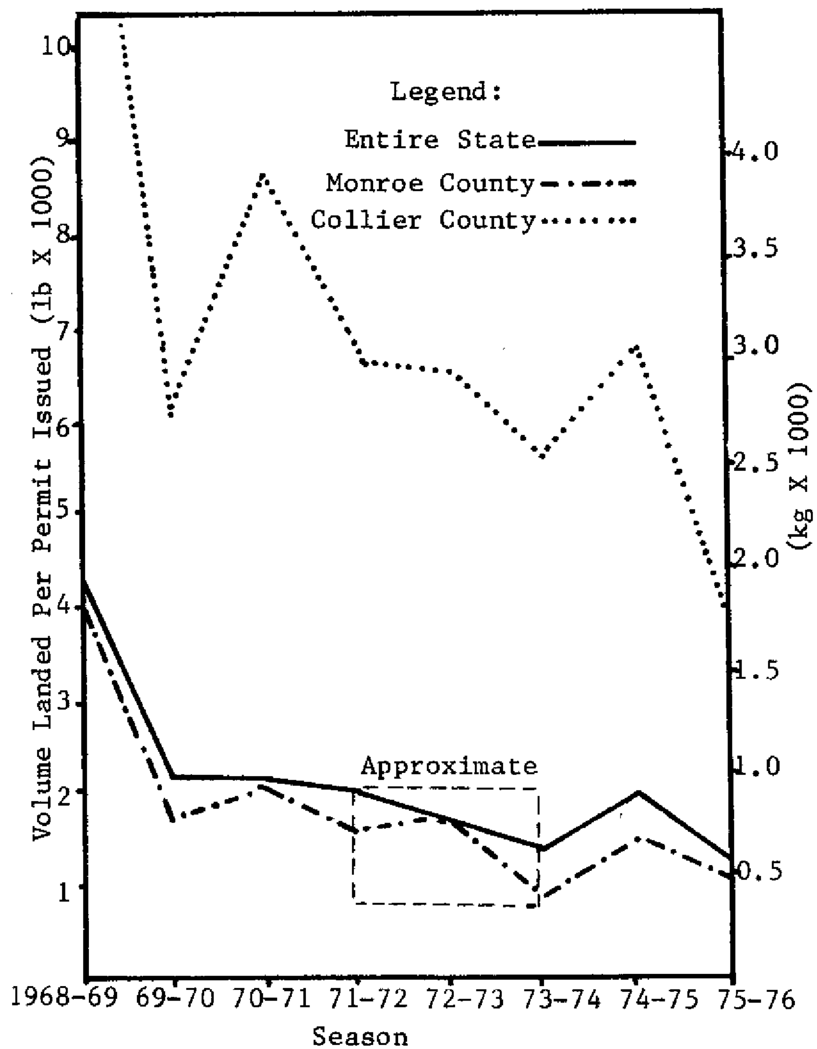
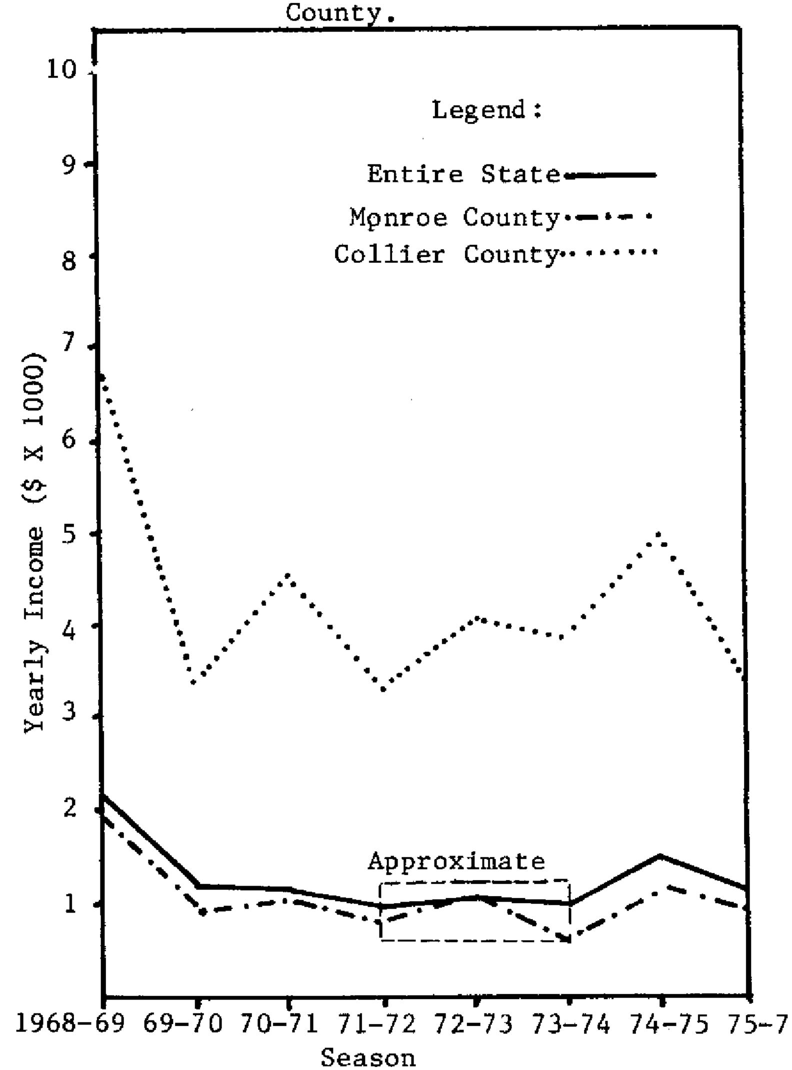


Figure 22. Yearly Income From The Stone Crab Fishery Per Permit Issued, 1968-1975, For The State Of Florida, Monroe County, And Collier County.



1. a single male can fertilize a number of females;
2. fertilization needs only to occur once per spawning season;
3. sperm retention through molting has been observed in the female, obviating the absolute necessity for copulation at every molt for successful spawning (Cheung, 1968);
4. extremely high fecundity rates, even amoung sublegal females;
5. reproductive maturity is reached at a size considerably below that which is economically feasible for harvesting (at least one year before claws are marketable size);
6. opportunistic carnivorous feeding behavior augments chances for finding enough food for survival;
7. large powerful claws and underground burrows serve as a deterrent to many would-be predators;
8. a planktonic larval strategy provides a good larval dispersion mechanism;
9. only the claws are sought for meat, and the crab can potentially survive declawing to reenter the reproductive population.

Other inherent characteristics are apparently not well adapted toward survival of the species:

1. high predation on larvae owing to their long pelagic existence;
2. high food requirement levels;
3. narrow larval temperature and salinity range for optimum development;
4. simultaneous reproduction and principal growth season in females;
5. sex and size class groupings allowing harvest of predominately one sex or size class in an area;
6. cannibalistic behavior and food-dependent territoriality (not necessarily detrimental in itself, but only allows a certain number of crabs to occupy a given area, which could be a limiting factor in harvesting);
7. organisms with pelagic larval strategies often exhibit large yearly population fluctuations (Thorsen, 1949) which may have significant annual effects on recruitment to the fished population.

These factors and others influence the size of the population available for harvest.

Harvesting pressure on the stone crab varies greatly throughout Florida, depending on profitability in relation to other fisheries in the area, developmental stage of the fishery, and abundance of the resource. Thus some regions may be overexploited and others underexploited. The geography of the E-FB region, abundance of the stone crab population, and methods of fishing vary so as to permit dividing the E-FB region into three areas:

1. National Park Area (NP)--from East Cape to Long Key, including waters adjacent to ENP;

2. Marathon to Cape Romano Area (M-CR)--from Cape Romano to the Florida Keys (Long Key to Key West), out to the 18 m (60 ft) depth contour;

3. Deep Water--west of the M-CR Area and beyond the 18 m (60 ft) contour.

National Park Area. Nearly all quantitative information available for this area has been gathered within ENP by NPS staff. About 80% of the waters in this area are within the national park. The rest are immediately adjacent and possess essentially the same characteristics; thus NPS findings are believed to be applicable to them.

As previously discussed, NPS has recorded a severe and continued decline in CPUE for the past several years within ENP boundaries. Several factors may contribute to the decline:

1. movement of the adult population out of the area to mate and/or spawn without subsequent equivalent replenishment of stocks;

2. recent or ongoing changes in water or substrate quality and food availability, either in the national park or in recruitment areas, that are detrimental to one or more phases of the stone crab's life history;

3. prevention of necessary successful recruitment from outside the NP area for potentially harvestable stocks;

4. overfishing of males or illegal fishing of females in the national park to such a degree that an insufficient population remains for reproduction.

These alternative hypotheses and others are presently being explored in a comprehensive study of stone crab ecology and of its commercial fishery in ENP by Gary Davis, Marine Research Biologist for NPS. From preliminary data it appears that the female population may move out of the national park area to spawn in the spring. If that is the case, the population within the park must depend on the movement of some life stage(s) back into the area.

Mass movements of a single sex are well documented for the stone crab (see Section 3.3.4.),.and are thought to be associated with reproduction. Salinity and temperature fluctuations in national park waters can be large and dramatic during spawning season (T. Schmidt, NPS, pers. comm.) and could account for high larval mortality rates, regardless of where spawning occurs. Small juvenile crabs appear to be absent presently from habitats they ordinarily occupy in other localities (G. Davis, NPS, pers. comm.). Thus, the major source of the population occupying the National Park Area of the E-FB region may be adults that migrate into the area.

Marathon to Cape Romano (M-CR) Area. The most intensive stone crab fishery in the state is located west of the ENP Area to the 18 m (60 ft) contour. This area is fished almost exclusively by both Monroe and Collier counties. Evidence indicates that the impact on the stone crab population has apparently not yet been noticeably detrimental, although the fishery in this area may be near, at, or slightly beyond saturation level:

1. monthly landings in Monroe county fluctuate irregularly, in part because Monroe county fishermen resort to other fisheries when landings drop in the stone crab fishery;

2. the percentage increase in Monroe county yearly landings has been very low since 1970 (5% per year average) despite far greater rises in permits (15.7% per year average) and traps;

3. Collier county fishermen, who depend strongly upon the industry, have experienced severe declines in unit catch (Figure 21), indicating that they too are putting in much more effort per unit of return despite rapid expansion into deeper water areas;

4. fishermen and scientists (Savage, et al.,1975) have reported that average claw size decreases late in the season, caused in part by an increase in percentage of females trapped (Noe, 1967) and in part by depletion of the stock of large-clawed animals (Sullivan, in press).

On the contrary, monthly landings statistics for Monroe and Collier counties do not show the large initial catch followed by continual decline as the season progresses (Tables II and III) that is associated with an overextended resource such as the spiny lobster (Warner, et al., 1977). Proportionally large drops in production do occur at the season's beginning and end, for which a number of reasons can be suggested:

1. late entry into or early withdrawal of a significant number of fishermen from the fishery;

2. less inclination or necessity for the crabs to enter traps at these times for some reason;

3. additional effort into the fishery from spiny lobster fishermen midway through the season may mask an actual continual decline in landings until very late in the season.

In combination, the above elements seem to indicate that the majority of harvestable crabs are being taken each year. Thus far, no pronounced decline in the population has been noted in the M-CR area. Whether the population can sustain the present harvest rate depends on continued successful recruitment each year.

Recruitment, in turn, depends upon reproductive success and adequate survival of all life stages. Therefore, an understanding of stone crab population dynamics is extremely important to maintenance of the health of the fishery in the M-CR area. J.R. Sullivan, marine biologist for the Department of Natural Resources, is attempting to address this topic in a comprehensive study of the stone crab population in this area. Under his supervision, 20,000 trapped crabs were tagged from October, 1975, to June, 1976.

Deep Water. Only recently have E-FB fishermen considered placing traps in water beyond the 18 m (60 ft) contour. The size of fishery the deep water stone crab could support is not known. Neither qualitative nor quantitative information exists for population density, age, or size class structure, or migratory patterns. Among the possible alternatives are:

1. deep water crabs are a self-sustaining population able to support a fishery of some finite size;

2. the deep water population depends on recruitment from shallower water and is not reproductively independent from the shallow water population;

3. the shallow water crab population depends on deep water recruitment for its supply of crabs;

4. crabs are highly migratory and are successful reproducers throughout their range so that the extent of the fishing grounds to deeper water poses no new population management problems.

Thus the deep water inhabitants may or may not be associated with the population currently fished by the industry.

6.2. Future Possibilities

Any choice has both good and bad points which should be taken into consideration. The options pertaining to the direction in which to take the stone crab fishery are no exception. The alternatives and their implications are enumerated here.

6.2.1. Continued Escalation of Fishing Pressure

Data are currently insufficient to evaluate the extent of expansion which the E-FB stone crab fishery will allow. Some scientists and fishermen believe that the fishery will support far more traps than are presently deployed. Based on resource population and profit/investment trends in the three areas within the E-FB region, prolonged maintenance of the current rate of expansion could result in continuation of the present trends:

1. further decreases in the NP area stone crab population, which may or may not be important to overall yield but could be ecologically more significant;

2. continued movement of fishermen into deeper water and farther away from traditional grounds;

3. further decreases in CPUE.

Other, as yet unencountered situations could arise:

1. population declines in the M-CR area similar to those already seen in the NP area;

2. confrontations and conflicts over offshore grounds with net and trawl fishermen (mackerel, shrimp, and pompano fishermen);

3. large investments for more seaworthy equipment associated with deep water fishing (sturdier traps, bigger boats, onboard crab claw cookers) without guarantees of equitable returns and possible substantial losses in both the quantity of the resource and return on investments.

The movement of a number of fishermen out to deeper water could alleviate the shallow water pressure somewhat, raising CPUE temporarily. However, the attraction of a more profitable fishery could draw a considerable number of new entries into the fishery, again lowering CPUE.

6.2.2. Maintenance of Present Fishing Intensity

The current magnitude of fishing pressure on the E-FB region is such that:

1. NP area is "fished out" early in the season and shows signs of serious stock depletion (Davis, 1976);

2. the M-CR area fishery is apparently sustaining present fishing pressure;

3. the Deep Water area may be underutilized.

Conflicting evidence plus a lack of biological and fisheries data make it impossible to predict the outcome of the impact of sustained fishing at present rates. Should the fishery stabilize at approximately its present level of saturation, the immediate trends could be much the same as those listed for continued escalation (Section 6.2.1.). However, the effects would probably be less pronounced and could be curtailed at some point. It is also possible that optimum or maximum sustained yield (OY and MSY) has not yet been reached and that landings would continue to rise resulting in greater returns for the industry. However, MSY (representing an "average" of the maximum sustainable harvest for a given fishery stock) is not necessarily coincident with, and often greater than, OY (a complex concept involving economic, social, and biological factors in determining the best sustainable yield). In fact, maximum economic efficiency is at a level of harvest generally conceded to be below MSY (Wallace, 1975). Thus, further increases in landings would not insure greater profits.

6.2.3. Reduction of Fishing Pressure Intensity

Decreasing the fishing pressure per unit area could produce a situation that would be analogous to past years. Overall CPUE would be higher and production in the National Park area could be enhanced, due to increased recruitment or other factors (see Section 6.1.2.). Reduction involves some form of control, with which some fishermen disagree. Reduction of a fishery through some form of limitation does have the distinct advantage of the utilization of a data base from former years. From that background information the effects of a lessening in fishing pressure can be predicted, whereas the outcome of continued expansion in an unlimited fishery must be monitored as it occurs. In the stone crab fishery, past experience has shown that fewer fishermen (and traps) allowed for a greater catch per trap-night and sustenance of the resource population throughout its range.

Some Management Options. Management in crabbing industries throughout North America has taken many forms, some of which could be easily applied to the Florida stone crab fishery. Regulations in effect in various states and Canada which could be applicable to the stone crab industry in Florida are (summarized from Miller, 1976):

1. no females are taken (Alaska--King Crab, Snow Crab; Newfoundland--East Canada Snow Crab; Washington, Oregon--Dungeness Crab);

2. no egg-bearing females are taken (Alaska, Washington, Oregon, California--Dungeness Crab; Delaware, Maryland, Florida, Texas--Blue Crab);

3. traps must be attended every two weeks (Alaska--Dungeness Crab);

4. escape holes in traps for sublegal crabs (Alaska--King Crab; Alaska, Washington, Oregon, California--Dungeness Crab; Newfoundland--East Canada Snow Crab; Maryland, Florida, Texas--Blue Crab;

5. closing of areas to fishing for various reasons (Newfoundland--East Canada Snow Crab);

6. fishing excluded in nursery areas (Alaska--King Crab);

7. trap limits per boat (Alaska--King Crab, Snow Crab, Dungeness Crab; Newfoundland--East Canada Snow Crab; Delaware, Maryland--Blue Crab);

8. registration area restricted (Alaska--King Crab, Snow Crab, Dungeness Crab);

9. limited entry of boats (Newfoundland--East Canada Snow Crab);

10. catch quotas by area (Alaska--King Crab, Snow Crab);

11. overall catch quota (Newfoundland--East Canada Snow Crab);

12. areas reserved for sport fishery (Washington, California--Dungeness Crab);

13. smaller size limit for sport (Washington, Oregon--Dungeness Crab);

14. limits on catch, gear type, gear quality for sport (Alaska--King Crab, Snow Crab; Alaska, Washington, Oregon, California--Dungeness Crab; Delaware, Maryland, North Carolina, Florida--Blue Crab);

15. traps may not be set in water shallower that a specified depth (Maryland--Blue Crab);

16. shrimp trawling, groundfish trawling and scallop dragging are excluded from good crab fishing areas (Alaska--King Crab, Snow Crab; Oregon--Dungeness Crab);

17. areas of female concentration closed (North Carolina, Texas--Blue Crab);

18. dredging prohibited when crabs are buried in the sediment (Maryland, Delaware, North Carolina--Blue Crab);

19. registration of number of traps (Alaska--King Crab, Snow Crab);

20. reporting fishing area, number of trap lifts, and quantity of landings (Alaska--King Crab, Snow Crab; Newfoundland--East Canada Snow Crab).

Additional regulations for limitation of the stone crab fishery that fishermen and scientists have suggested include:

1. trap limiting prorated on investment: fishermen view this as the fairest method of partitioning the total catch;

2. taking only the crusher claw on both females and males: although landings would decrease in the first year of enactment of this regulation, the long-term benefit to the industry in larger claws (bringing greater prices) and greater crab survival rates (permitting increased return of declawed crabs into the fishery) would probably easily offset the initial decline (J.R. Sullivan, DNR, pers. comm.);

3. catch quotas by individual, based on investment or number of traps: this method would not only enable equitable apportionment of the resource, but would also help limit the overall catch;

4. reduction of the season by one month in spring: the overlap of the onset of intense spawning in spring and the end of crabbing season would be eliminated;

5. subsidization or compensation for fishermen obeying catch quotas: this approach has many economic and social entanglements but would aid in protecting the resource from overfishing;

6. imposing a permit fee (up to $500 has been suggested) accompanied by proof that at least 50% of the individual's income is obtained by fishing;

7. increasing legal claw size: females would be able to reproduce a greater length of time before entering the fishery.

6.3. Mariculture Possibilities

6.3.1. Review of Research to Date

The mass culturing of economically valuable marine plants and animals is currently the focus of intensive research throughout the world. The stone crab has not been excepted in these endeavors. For the past several years, a number of attempts to raise stone crabs intensively have been undertaken with varying degrees of success.

Savage and Mc Mahan (1968) conducted a controlled preliminary growth study with a few small crabs (1.4-33.3 mm CW, or 0.06-1.3 in CW) in a variety of indoor habitats. A second attempt to raise small crabs was initiated by Savage (1971b) under somewhat more rigidly controlled environmental surroundings and on a diet of oysters.

Larval rearing has been more intensely investigated (Porter, 1960; Ong and Costlow, 1970; Yang, 1971, 1972; Mootz and Epifanio, 1974; Yang and Krantz, 1976) under a wide range of salinity and temperature conditions, again with widely varying degrees of success. The most comprehensive survey of salinity and temperature requirements was done by Ong and Costlow (Table VII). The results available from other researchers are summarized in the following table (Table VIII) for comparison. All researchers other than Yang and Krantz listed in these tables utilized a limited number of larvae and reared them in small indoor containers (watch glasses and finger bowls). Thus, they were able to monitor the environment more closely than were Yang and Krantz.

Mootz and Epifanio (1974) analysed the energy requirement for stone crab larvae raised on brine shrimp (Artemia spp.) nauplii and found that they can consume up to an average of 91 Artemia per day. Although invertebrates in general only utilize 10-20% of their total energy expenditure on growth and reproduction (Phillipson, 1966), it has been reported that the stone crab channels from 45-82% of its assimilated food energy into these processes throughout its life (Sushenya and Claro, 1973).

Dr. W.T. Yang (RSMAS, University of Miami) is the only researcher to date to attempt cultivation through successive generations (Yang, 1971, 1972) and mass rearing of the stone crab from egg to marketable adult (Yang and Krantz, 1976). They presented details on mass culture rearing, including complete descriptions of equipment and procedures. Survival rates produced by their method are summarized in Table IX. Major difficulties they encountered in culturing crabs were:

1. crab zoeae have relatively restricted water quality requirements for optimal growth and are highly susceptible to adverse environmental changes in mass culture procedures;

2. juveniles and adults have poor survival rates due to cannibalism and aggressive behavior;

3. high food and space requirements make economic feasibility questionable;

Table VIII. Comparison Of Survival And Developmental Rates At Different Temperatures And Salinities For Larvae Of M. mercenaria (taken from Ong and Costlow, 1970).

Temperature		20 C (68°F)					25 C (77°F)					30 C (86°F)				
		Salinity $^0/_{00}$					Salinity $^0/_{00}$					Salinity $^0/_{00}$				
Molt	Results	20	25	30	35	40	20	25	30	35	40	20	25	30	35	40
Meg. to c.l	Survival*	0	0	0	0	0	3	22	34	37	19	11	31	36	30	33
	Mean time (days)	–	–	–	–	–	35.3	32.8	32.4	32.9	33.6	22.5	22.2	20.6	20.9	20.5
	Range (days)	–	–	–	–	–	33–37	31–38	30–35	30–38	31–37	20–24	19–26	18–24	18–24	19–23
Z.V to Meg.	Survival	1	11	32	29	32	44	39	40	46	45	32	42	40	43	41
	Mean time (days)	42	40.8	38.1	38.5	38.4	23.9	22.1	21.7	22.1	22.8	15.6	15.1	13.8	14.3	13.5
	Range (days)	–	37–45	35–46	35–44	35–44	22–26	20–27	20–25	20–25	20–27	13–19	13–18	12–19	12–17	12–16
Z.IV to V	Survival	37	45	46	46	47	46	48	49	49	49	47	50	47	48	48
	Mean time (days)	33.6	29.3	27.4	28.0	28.3	17.2	16.1	15.7	16.2	16.3	12.6	11.8	10.5	11.3	10.5
	Range (days)	30–37	27–33	25–30	25–33	25–32	16–19	14–19	14–18	14–18	14–19	10–15	10–14	9–12	9–13	9–12
Z.III to IV	Survival	40	45	46	47	47	46	48	49	50	49	47	50	48	49	48
	Mean time (days)	24.7	21.2	19.9	20.0	20.1	12.7	11.8	11.3	11.7	11.8	9.5	8.7	8.0	8.5	8.0
	Range (days)	22–30	19–24	18–22	17–22	18–23	12–15	11–14	10–13	10–14	10–14	7–12	7–10	7–10	7–10	7–10
Z.II to III	Survival	42	46	48	49	47	47	48	49	50	50	50	50	49	49	50
	Mean time (days)	16.6	14.4	13.3	13.4	13.5	9.2	7.9	7.4	7.9	8.0	6.5	5.8	5.5	5.5	5.3
	Range (days)	15–19	13–17	12–14	12–16	12–15	8–11	7–9	7–9	7–9	7-10	5-9	5–7	5–7	5–7	5–7
Z.I to II	Survival	46	48	50	50	47	47	49	49	50	50	50	50	50	50	50
	Mean time (days)	10.4	8.1	7.7	8.0	8.2	5.1	4.5	4.3	4.7	4.8	3.8	3.5	3.2	3.4	3.2
	Range (days)	8–12	6–10	7–8	7–10	7–9	5–7	4–6	4–5	4–6	4–7	3–5	3–4	3–4	3–5	3–4

*Percentage survival may be obtained by doubling the figures for No. of larvae, as the initial number of larvae in each T–S combination was 50.

Table IX. Summary Of Results From Larval Culture (Egg To First Crab) Of The Stone Crab (excluding Ong and Costlow, 1970).

Investigator	Growth Period (days)	System	Food	Salinity Range (ppt)	Temperature Range °C	°F	Percent Survival
Porter, 1960	27	Small scale, indoor	Artemia nauplii	27-33	27-30	82-86	7-27 (approx.)
Mootz and Epifanio, 1974	28.5	Small scale, indoor	Artemia nauplii	29-31	24-26	74-77	25 (approx.)
Yang and Krantz, 1976	14.5	Large scale, outdoor	Rotifers, Artemia nauplii, zoo-plankton, blended invertebrate meat	0-36 (33.7 avg.)	30-32	86-90	9.2-15

Table X. Survival Rate For Stone Crab Mariculture Encountered By Yang And Krantz, 1976.

Life Stage	Length of Observation	Size of Tank Metric	Size of Tank English	Stock Density Metric	Stock Density English	Percent Survival For the Period	Percent Survival Cumulative
Egg to Second or Third Crab	14 days (approx.)	1800 1	476 gal	2.9/1	11/gal	12.7	8.6
				8.0/1	30.3/gal	7.6	
Second or Third Crab to Small Juvenile	85 days	1.5 sq m (bottom surface)	1.8 sq yd (bottom surface)	100/sq m	83.6/sq yd	5.7	0.65
		10 sq m (bottom surface)	12 sq yd (bottom surface)	100/sq m	83.6/sq yd	8.1	
Small Juvenile to Young Adult	307 days	0.4 hectares	1 acre	.11/sq m	.09/sq yd	20.7	.01

4. growth, even under somewhat controlled conditions, is extremely variable, precluding a single harvest period.

Additional problems in stone crab mariculture revealed in other studies include:

1. difficulties in obtaining viable egg masses from females that had been raised in the laboratory and mated with laboratory-raised males (Yang, 1972);

2. second generation males may not be well oriented in courtship and mating behavior (Yang, 1972);

3. spawning and molting cannot as yet be selectively induced (Cheung, 1969);

4. selective breeding for larger claws may not be advantageous for best survival of the population (Cheung, 1976).

6.3.2. Practicality and Applicability of Stone Crab Mariculture

A number of natural survival adapatations of the stone crab would indicate that it might be a suitable species for mass culture:

1. high fecundity;

2. efficient food conversion for growth and reproduction;

3. moderate salinity and temperature tolerance;

4. good (although variable) survival rates in controlled environments;

5. opportunistic feeding habits;

6. ease of obtaining eggs;

7. good resistance to anaerobic or oxygen-impoverished water (Karandeyva and Silva, 1973).

However, the agressive behavioral characteristics, excessive food requirements, and length of time to reach legal size (about 2 years) present difficult problems that must be solved before large scale mariculture of stone crabs would be economically feasible.

Although the rearing of juvenile and adult crabs has proven generally unsuccessful to date, mass cultivation of larvae holds greater promise. Serious difficulties remain, however, in maintenance of optimum water quality, finding cheap high quality food sources, and decreasing mortality rates. The present-day expense of brine shrimp, the high degree of food demand, and low optimum stocking densities in culture tanks presently preclude successful mass larval culture.

A possible utilization of large quantities of artificially cultured stone crab larvae would be to "seed" areas depleted of adult crabs in an effort to replenish stocks. Yang and Krantz (1976) believe that:

"larval culture procedures have an important role in providing stone crabs for natural resource management for rehabilitation of declining natural fisheries."

The NP area, where natural reconstitution of the population has been unsuccessful, would be an ideal area to test this hypothesis.

Unless the mortality rates encountered by Yang and Krantz could be drastically reduced, even this application would be unfeasible. For example, restocking the NP area with 100,000 second crabs (crabs that have molted once since metamorphosis) would require, at the optimum density suggested by those investigators, 143 tanks holding 1800 l (476 gal) each. At their survival rates, the expected yield would be 7,000 juveniles and only 140 adults. Survival rates in nature may be somewhat higher than those Yang and Krantz recorded, if competition for habitat and food is minimal.

7. ENVIRONMENTAL NEEDS

7.1. Basic Requirements Of The Animal

7.1.1. For Daily Maintenance

Aside from the myriad practices previously mentioned that would contribute toward survival of a greater proportion of the harvested population (Section 4.4.), some general considerations need to be made regarding the "needs" of the stone crab--what environment does the species require to successfully maintain its position in the marine ecosystem. The most obvious answers to this question lie in the necessary requirements for the animal's daily maintenance--favorable water quality, enough food, and suitable habitat.

Favorable Water Quality. Stone crabs are most commonly found in warm water of moderate to oceanic salinities. Their larvae require these factors for optimal survival and rapid maturation. Turbidity (the amount of suspended sediment in the water column) does not seem to greatly influence the selection of habitat by the adult. Of course, many other variables enter into optimal water quality, such as dissolved gases, nutrients, and pollutants.

Suitable Habitat. Each stone crab life stage has different habitat requirements. For larvae, clean water of oceanic salinities and free from chemical and thermal aberrations is conducive to high percentages of larval survival. Juveniles require protective hiding places and adults inhabit bottom into which they can burrow.

Sufficient Food. In the words of Powell and Gunter (1968), "Stone crabs will eat almost anything to keep from starving". The stone crab is a carnivore with high energy requirements in all growth phases. Opportunistic feeding habits enhance its ability to meet these requirements. Preservation of its animal food sources is essential for continuation of this species, particularly in heavily fished areas. Undisturbed seagrass and algal beds, with their associated epiphytes and epizoa are necessary, not only for habitation of the crabs, but as food sources for declawed crabs.

7.1.2. For Species Continuation

Succeeding generations of a species can only be maintained if enough members of each generation are able to survive and successfully reproduce to enable the following generation to continue the cycle. Involved in the complex cycle are several essential requirements that must be met for its continuance. Net reproductive potential must maintain levels that keep pace with natural mortality and fishing pressure. Spawning and juvenile nursery grounds must be kept intact. Water quality, food sources, and habitat must be acceptable for survival of the organism. Predation on any life stage cannot accelerate to excessive degrees. The failure of any one of these requisites for an extended period of time could result in severe decreases in the population with subsequent repercussions to both the ecology and the fishery.

7.2. Meeting The Requirements

7.2.1. The Problems

In the extensive shallow water tracts of the NP area and Florida's Gulf of Mexico continental shelf, man can be most influential in shaping underwater environmental conditions. Almost any major (or a composite of minor) alteration(s) of coastal wetlands (marshes, swamps, and adjacent areas) or shallow water coastal bottomland can have far-reaching ecological ramifications. This, of course, would most likely have some effect upon the stone crab population, particularly if the perturbation was done in areas of enhanced spawning or in nursery grounds.

Bottom Disturbances are of two basic types--dredging and filling, which displaces large quantities of bottomland within a relatively localized space, and trawling, which displaces little bottomland but over greater areas. Dredging and filling for industrial or developmental purposes is common throughout the Florida coast. They can cause drainage pattern and inshore current pattern alterations, remove habitat, increase turbidity, and alter water temperature or salinity. The general ecological ramifications associated with dredging have been the topic of numerous environmental impact statements.

In south Florida, land development for agricultural, urban, and industrial uses has threatened the Everglades watershed. For example, one result of the building of U.S. Highway 1 dividing Blackwater Sound and Barnes Sound and a mutual demand on fresh water by the national park and various land practices has been a gradual increase in the salinity of the ENP area (G. Davis, NPS, pers. comm.). This increase may have affected the stone crab population in that area directly by altering metabolic or reproductive processes, or indirectly by providing a suitable environment for predators that were previously unable to withstand the more estuarine environment, or eliminating a once abundant food source. Adult stone crabs have an excellent capacity for withstanding salinity changes (Karandeyva and Silva, 1973) but, although they can survive, they may not be able to reproduce throughout their salinity range.

The dredging and filling of submerged shallow bottomlands along the Keys has eliminated tracts of turtle grass flats inhabited by stone crabs, and increased suspended sediment loads that could adversely affect one or more life stages of the stone crab or of its food sources. In addition, the temperature, salinity, or current modifications associated with dredging and filling could greatly influence survival rates and distribution of the larvae within the vicinity.

Trawling, primarily for shrimp, is extensively conducted immediately adjacent to the present principal trapping grounds. Occasionally trawling fishermen find their best catch within trapping grounds. The amount and permanency of damage attributable to trawling is not known. Trawling can level low rocky bottom and overturn small coral heads (D.R. Gregory, Jr., Florida Sea Grant Prog., pers. comm.). It is reasonable to assume that it can disturb the bottom inhabited by stone crabs.

Pollutants. Pollutants find their way to the ocean from countless sources and in a vast array of forms. Two of the more commonly seen types are discussed here.

Thermal pollution (elevation of water temperature above ambient by an artificial means) is not an immediate problem in the E-FB fishing region. However, with the increasing trend toward the utilization of sea water as a coolant for seaside power and industrial plants, it may soon become an issue within the region.

Thermal pollution can be a sensitive problem in tropical and subtropical climates, because most marine organisms live at or near their thermal limits (Mayer, 1914). Many invertebrates cannot reproduce at temperatures only 1-2°C (2-4°F) above their normal temperature range (Andronikov, 1975). Sublethal responses (changes in an organism's system that modify its capacity to grow and/or reproduce) to elevated temperatures can be even more ecologically significant than direct mortality (Coutant, 1971).

Elevated temperatures can indirectly influence the stone crab by altering the balance of life around it. Phytoplankton productivity rates can be increased or decreased by higher temperatures (Gorman and Hopkins, 1974). Because phytoplankton is the base of the food chain, significant changes in production could have ramifications throughout the food web.

Solid and liquid water pollutants originate from both industrial and domestic waste products. Pesticides, detergents, metallic compounds, sewage, and other byproducts are a few examples of this type of pollution. The addition of these substances to sea water usually initiates a host of detrimental repercussions. Some of these materials are toxic to marine life at extremely low concentrations. For instance, chemicals sprayed for mosquito control near Naples, Florida in 1976 were found to be lethal to shrimp larvae at 66 parts per trillion or less (EPA, Region IV, Atlanta, Ga.) and in Monroe county, were alleged to have caused mass mortality of brine shrimp (Ocean Farming Systems, Inc., vs. Monroe County Mosquito Control District, Key West Citizen, June 21, 1977).

Studies are presently underway in ENP to determine the degree of intrusion of toxic agricultural pesticides into the Everglades estuary and to marine life. Some problems associated with industrial pollutants are:

1. depletion of oxygen in the water by high concentrations of bacteria;

2. lethal or sublethal physiological toxicant-induced abnormalities that can modify growth and reproduction of the stone crab or its food sources;

3. concentration of toxic substances in the stone crab's tissues, since the species occupies a relatively high level in the food chain (stone crabs near Florida's Big Cypress swamp were found to have approximately 8-12 ppt arsenic in a study conducted by NPS);

4. stone crab larvae may be far more sensitive to the above situations than adults.

Overharvesting. Continual harvesting of a marine resource beyond its MSY for an extended length of time can lead to depletion of that resource. The stone crab has several adaptations in its life history to enable it to withstand strong fishing pressure. The depletion of the NP area stone crab population and decrease in CPUE elsewhere in the E-FB region could be interpreted as an indication that pressure may be somewhat too great. From an industrial and economic standpoint, localized population depletion due to overharvesting in some areas may not be significant for overall continual yield. However, the ecological ramifications can be significant since the stone crab is a voracious carnivore that was once present in relative abundance in ENP.

7.2.2. The Alternatives

One alternative to the question of environmental quality is to disregard it. Eventually, however, it must be reckoned with, if the ecological balance and the esthetic beauty of the environment are to be kept, not to mention the importance of the fisheries that depend upon plentiful supplies of certain species in the ecosystem.

The undeveloped nature of the lower Florida Gulf coast, the presence of Everglades National Park, and the environmental awareness of the people in Monroe and Collier counties have prevented widespread irreparable damage from industrialization and urbanization in the E-FB region. Preservation of the integrity of the region depends largely on continual maintenance of an intact and healthy ENP ecosystem, avoidance of large developmental projects in the Florida Keys that could disturb substantial tracts of submerged bottomland, and prevention of overexploitation of the resources of the region. It would be wise for all concerned to closely monitor the uses of the E-FB coastal zone and bottomland. Sensible precautions taken now could avoid severe detriment to the ecology and setbacks in the fisheries later.

8. CONCLUSIONS AND RECOMMENDATIONS

Conclusion 1

The Everglades-Florida Bay stone crab fishery region is relatively new and does not show signs of severe population depletion. While production remains at consistently high levels, some factors that could be interpreted as early warning signs of a saturated fishery are beginning to appear:

1. catch per unit effort is down for all income levels;

2. some traditional fishing areas have shown great reduction in production levels;

3. fishermen are moving to new areas, despite a lower profit margin, to maintain production levels.

Conclusion 2

Some evidence indicates that the stone crab population in the Everglades-Florida Bay region (the area between Key West and Cape Romano and shallower than 18 m or 60 ft) has been harvested at or near its upper limit of productive potential since about 1970. Fishing pressure varies in the different areas of the region, such that:

1. The National Park area (East Cape Sable to Long Key) population is decreasing each year. Superficial and preliminary evidence indicates that the population may not be completely self sustaining, but may depend upon recruitment from adjacent locations in the Marathon-Cape Romano area. These areas are not heavily fished.

2. The Marathon-Cape Romano area (Cape Romano to the Florida Keys--Long Key to Key West--to the 18 m contour) population appears to be sustaining the current fishing pressure, possibly because of a high recruitment rate owing to its proximity to a principal spawning or nursery area, and because part of the population is protected by National Park Service regulations.

3. The Deep Water area (west of the Marathon-Cape Romano Area and beyond the 18 m contour) population has not yet been adequately investigated by either scientists or the industry and may now be underutilized.

Conclusion 3

High market demand and increasing dockside prices have made stone crabbing profitable although catch per unit effort has declined in recent years. In the present situation of a moderately regulated fishery, this trend will probably continue. Two risks are inherent in the present trend: a) the resource may become severely depleted before the size of the industry stabilizes; b) once depleted, it may not recover to its present high rate of production.

Conclusion 4

Because of rapid growth of the fishery, management strategy has not kept pace with development of the stone crab fishery. There has been a steady increase in the number of individuals entering this fishery, and fishermen report using an increasing number of traps. The resulting increase in fishing pressure has created the need for a more comprehensive management plan.

Recommendation A. A comprehensive management plan for the stone crab fishery in Florida should be developed. Formulation and execution of the plan will be a highly complex process involving a) research to understand the organism and its interactions with the ecosystem and the fishery; b) joint user group/management agency decisions on a philosophy of management (i.e., who harvests the resource and how much, where, and how to harvest it); c) joint user group/management agency selection of preferred management options; d) design and execution of the management plan.

Conclusion 5

While much is currently being accomplished by the National Park Service and Department of Natural Resources toward understanding the population dynamics of the stone crab and its response to the impact of harvesting practices, certain problems should receive immediate attention.

Recommendation A. Research needed: establishment of adult molt frequency and claw regeneration rates for both males and females by size class to determine the number of potential harvests available from various size classes and from each sex. This information would assist in more accurate determination of the best size class and sex to harvest.

Recommendation B. Research needed: determination of survival rates and reproduction potentials after exposure to air for various lengths of time, followed by declawing, for both sexes, and including gravid females. This would assist in identifying measures needed to avoid waste of harvested animals through exposure and subsequent embryonic mortality.

Recommendation C. Research needed: establishment of overall population dynamics--including population density and distribution in different habitats and throughout the range of the animal, natural survival rates, migratory patterns, sex or size class aggregations of all life stages, and identification of spawning and nursery grounds and recruitment areas. These studies would provide a better understanding of the actual size of the industry that the resource can support and the population elements to be protected for restocking.

Recommendation D. Research needed: studies of the deep water stone crab population for population density and structure, source(s) of recruitment, and reproductive success. Since movement of the industry into deeper water may be imminent, definition of that population is essential to establish its utilization potential.

Recommendation E. Research needed: investigation of rates of accumulation of pesticide, fertilizer, and industrial process residues, and their toxicities in various life stages of the stone crab. It is possible that certain of these compounds may be contributing to the population decline in the National Park area and may eventually effect the entire Everglades-Florida Bay region.

Recommendation F. Research needed: exploration of potential fisheries to ease pressure on the stone crab and augment the industry. The incidental catch of the spider crab (Mithrax spp.) or Octopus spp. would be possibilities. Some fishermen have indicated their willingness to rent their equipment and expertise to scientists for research such as this. Scientists should avail themselves of this opportunity to become acquainted with the industry and make use of this practical method of conducting research.

Recommendation G. Research needed: a study comparing the impact of removing one vs. both claws of the stone crab. Data from the Department of Natural Resources have shown that only 0.4% of tagged stone crabs that were returned to them had regenerated both claws to legal size within one year, and these were male crabs only (Sullivan, in press). However, about 10% of statewide landings are regenerated claws (natural regeneration rates are unknown, though) (Savage, et al., 1975). If these data represent a low return to the fishery, this could effect legislation in the future. Therefore, this question demands immediate further attention.

Conclusion 6

One obvious problem in the formulation of a comprehensive management strategy is for whom to manage the resource. Traditionally, the Everglades-Florida Bay stone crab region has provided an income source for both small operation and large operation commercial fishermen, as well as provided food and recreation for those individuals who fish solely for their own needs. Other considerations regarding the use of the resource and the region itself must be taken into account:

1. extensive tracts of protected, shallow water in the Everglades-Florida Bay region have lent much toward making the stone crab industry successful for fishermen operating all sizes of boats and vessels. Stock depletions in these easily accessible waters could deal (and in some cases already have delt) an economic blow to hundreds of small operation fishermen in an area where the cost of living is very high and the economy fragile;

2. economic indicators may not justify the preservation of the resource in the National Park area and other depleted localities as most conducive to optimum yield and overall economic gain;

3. disputes over bottomland used for both trawling and trapping must be reconciled if the trapping industry is expanded;

4. methods of replenishing or sustaining stocks in traditional fishing grounds may need to be investigated if it is decided that they are to be maintained;

5. additional stress may be imposed on other resources also harvested by stone crab fishermen (such as the sponges, spiny lobster, and various fishes and invertebrates) if stone crab production declines;

6. a few large enterprises may attempt to take over the industry if limits are set on the fishery.

The various factions utilizing the stone crab resource necessitate application of the optimum sustained yield approach in formulation of the management plan.

Conclusion 7

Irrespective of the management strategy chosen, maintenance of the natural integrity of the Everglades National Park ecosystem should have highest priority in formulation of the management plan. An intact Everglades National Park estuary is indispensable to the health of south Florida's commercial and recreational fisheries. Second and no less important, there exists a national commitment to protect the ecological integrity of Everglades National Park. No management strategy should violate that principle.

Conclusion 8

At this point, the writers wish to reemphasize that the design of this manuscript is not intended to present mandates for governing the stone crab fishery nor display partisan views. Decisions regarding future utilization and management of the fishery should originate from a user group/management agency association, working toward the best interests of the resource and its fishery. Therefore, of the alternatives for directing the fishery and protecting the organism discussed throughout this paper, the writers view the following as the most viable and impartial interim regulatory measures for the stone crab industry in Florida, pending the development of a comprehensive management plan.

Recommendation A. Shortening the season by one month in spring.

1. This represents a compromise in the overlap of the onset of intensive spawning in Florida and the last two months of the crabbing season.

2. Reducing the length of the season by one month can potentially protect up to 3 gravid females for every 10 crabs that would have been harvested that month.

3. Based on an average of the past five years, the yearly landings loss to the Everglades-Florida Bay fishery would only be 10% of the total catch during the initial year that such a regulation would be in effect. The subsequent contribution to stocks in succeeding years could offset this loss.

4. Monetarily, the loss is even less than 10%, since the vast majority of claws taken during the last month are the smaller female claws. In addition, the market frequently becomes saturated with small claws during this period, driving prices down further. Finally, if these animals were allowed to grow over the closed season, their claws would be larger the following fall.

Recommendation B. Imposing a permit fee, accompanied by restrictions to all wholesale and retail buyers that would only allow them to buy from licensed fishermen with permits.

1. Fees for permits to fish a specific resource have been shown to provide a more accurate representation of the actual number of fishermen utilizing their permits (such as in the Florida spiny lobster fishery).

2. By reducing the number of individuals who obtained permits and do not use them, a better estimate of the actual size of the industry is provided.

3. The monies accrued from licensing should be channeled toward stone crab biological and fishery research, promotion of stone crab claws as a Florida seafood delicacy, and better policing of existing regulations.

Recommendation C. There is a need for fisheries data for the long-term good of both the fishing industry and the resource. Data collection has begun on the spiny lobster fishery with the initiation of the keeping of voluntary log books reporting information such as length of time traps have been left in the water before pulling, number of lobsters caught, sex of lobsters caught, amount of bait used, location of traps, date, etc. Information such as this would also be useful for the stone crab fishery. While individuals in the industry may not be interested in reporting such detailed information, reporting the number of traps deployed would be extremely useful. The only true measure of actual impact on the resource and magnitude of the fishery is the number of traps being fished. Reports of traps deployed by each licensed fisherman should be mandatory, held confidential, and immune to prosecution.

Recommendation D. Self-regulation of the commercial fishery. In lieu of adequate information on the level of harvesting that the resource will sustain, fishermen should monitor production and catch per unit effort trends. If a situation develops indicative of significant over-harvesting before an effective management plan can be deployed, they could then formulate and impose their own guidelines for control of the resource. This, in fact, would be the most productive step that could immediately be taken, in that a few relatively nonrestrictive self-imposed regulations now may forestall imposition of more severe restrictions necessary in a few years.

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10. APPENDIX

10.1. Definitions

Abdomen. The posterior portion of the body composed of a group of similar segments.

Aliquot samples. The division of the total amount into representative samples of equal parts.

Appendage. Protruding structural part used for locomotion, sensory reception, feeding, or other purposes; e.g. legs, mouth parts, tentacles.

Autotomize. To self-amputate, especially with respect to the five pairs of legs of decapod crustaceans; if such an animal is roughly handled and seized by a leg, reflex action will break the leg off across a special breaking joint near its base; during subsequent molts a normal leg is regenerated.

Basal. Located at the base, or origin.

Biogeography. Study of the geographic distribution of organisms.

Carapace. Dorsal and lateral shield-like plate covering the cephalothorax (head-thorax) of decapods and certain other crustaceans.

Carnivore. Any animal which is solely or chiefly dependent upon catching other animals for its food.

Cartilaginous Fishes. (Class Chondrichtyes) Sharks, rays, skates, and chimaeras; these fishes have skeletons that are without true bone, but of cartilage only.

Chelate. Pertaining to an appendage modified to form a claw.

Chelicerae. First pair of appendages of Arachnoidea; usually modified for seizing and crushing.

Crepuscular. Active in dim illumination.

Cuticle. General term for a dead non-cellular organic layer secreted by the external epithelium of many types of invertebrates, including arthropods, nematodes, earthworms; the chief functions are support and protection.

Detritus. Any fine particulate debris of organic or inorganic origin.

Diurnal. Activity by daylight.

Dorsal. The posterior or back surface.

Ecdysis. Periodic shedding or molting of the exoskeleton to permit an increase in size and/or change of form; the newly exposed exoskeleton quickly hardens a size larger than the old one.

Epiphytic. Living on or attached to the surface of a plant, but not parasitic upon it.

Epizoic. Living on or attached to the surface of an animal, but not parasitic upon it.

Exopod. Outermost (lateral) branch of typical crustacean appendage; the structure is often greatly modified in accordance with a variety of functions.

Fecundity. Relative number of eggs, sperm, or young produced by an animal.

Gonopore. General term for an opening through which eggs and/or sperm are released.

Gravid. Same as pregnant, but used more commonly, to apply to invertebrates.

Larva. General term for any independent, active, immature stage of an animal which is morphologically quite unlike the adult.

Lateral. The side; away from the center or midline; the outermost.

Lateral teeth. Protrusions on the side of the carapace.

Mariculture. The artificial culture of marine plants and animals for increased population.

Maxilliped. Paired thoracic appendage modified for feeding, food handling, and locomotion.

Metamorphosis. Period of abrupt transformation from one distinctive stage in the life history to another, such as tadpole to adult frog.

Nauplius. Free-swimming microscopic larval stage.

Niche. Ecological role of a plant or animal with reference to its special place in its environment; food and nutrition relationships are of primary importance.

Nocturnal. Activity by night.

Omnivore. Any animal which uses a variety of living and dead plants and animals in its diet.

Orbit. The depression containing the eyestalk, to which the eye is attached.

Pelagic. Pertaining to the open waters of the sea.

Penes. Male copulatory organs through which sperm are deposited in the female reproductive tract.

Pereiopod. Paired appendage on most of the thoracic segments of Malacostracans; usually modified for seizing and handling food and for locomotion.

Phytoplankton. Minute plants that live in the water column and are incapable of directional movement; thus they are at the mercy of water currents.

Pleopod. Swimmeret; paired appendage of certain abdominal segments in many Decapods; by beating back and forth, they create a current and ensure an adequate supply of oxygenated water in contact with the body.

Recruitment. Provided with sufficient new animals needed to correct or prevent exhaustion; replenishment of the stock.

Rostrum. Pointed process at the anterior end of the head-thorax region.

Sternum. The chief ventral plate of most of the body segments of arthropods.

Stridulation. Production of sounds in some arthropods by rubbing two modified parts of the body together.

Stridulation organ. Any device for producing sounds by rubbing two parts together; usually one part is file-like and the other is scraper-like.

Systematics. The study of the kinds and diversity of organisms and of their relationships.

Taxonomy. Scientific naming of organisms and their classification with reference to their precise position in the animal or plant kingdom.

Telson. Broad median projection of the last body segment in many decapod crustaceans.

Thorax. The central portion of the body between head and abdomen; in Xanthid crabs, the thorax is fused with the head to form the cephalothorax.

Trap night. Referring to a day (approximately a 24-hour period) in which the baited trap has been left in the water to catch fish.

Ventral. The lower surface; underside.

Zooplankton. Minute animals that live in the water column and are incapable of much directional movement; thus they are at the mercy of water currents; these forms include larval stages of many large marine animals as well as small animals that live their entire lives in the planktonic state.

10.2. List of Acronyms

CL Carapace length.

CPI Consumer price index.

CPUE Catch per unit effort.