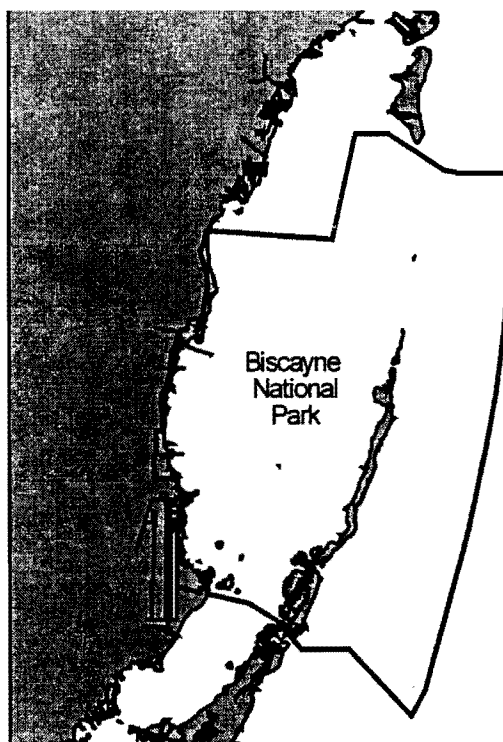


**Impacts of Commercial Fishing on Key Habitats
within Biscayne National Park**



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EXECUTIVE SUMMARY

Recreational and commercial harvesting of fishes and invertebrates is permitted in Biscayne National Park (BNP). While there are obvious economic and social benefits associated with fishing in BNP, there may also be insidious effects that reduce ecosystem productivity. Specifically, these effects are in the form of habitat modification and degradation resulting from the use of certain fishing gears. The purpose of the present study was to determine the extent of the effects of commercial activities which predominate in terms of both human participation and areal coverage, namely, bait shrimp trawling and trapping of spiny lobster, stone crab, and blue crab. This project was comprised of three principal components: (1) analysis of existing data; (2) field surveys and ground-truthing; and (3) field experiments. Techniques in scientific data visualization and advanced statistical analysis were used to facilitate assessment and modeling. The major activities and findings of our research program are summarized below.

- Existing data, reports and literature were compiled and analyzed to provide syntheses of the historical development, landings and effort, and current gear and practices for each fishery.
- Spatially-explicit databases pertaining to submerged natural habitats within BNP and adjacent areas of Biscayne Bay were obtained, integrated, and analyzed. The areal extent of each of BNP's five major benthic communities (i.e., seagrass, hardbottom, mixed seagrass/hardbottom, bare bottom, and offshore coral reef) were quantified and mapped.
- Questionnaires were designed and distributed to commercial trap and trawl fishermen to characterize temporal and spatial fishing effort patterns. About 25% of the bait shrimp trawlers responded. No questionnaires were returned from lobster, stone crab or blue crab fishermen. Bait shrimp trawlers operating within BNP fish areas measuring about 165 km² during the wet season (June-November) and 350 km² during the dry season (December-May). These areas represent about 24.6% and 52.2% of BNP's entire submerged substrate, respectively. Seagrass habitats are the primary habitats trawled, followed by mixed seagrass/hardbottom, and then hardbottoms.
- A series of aerial overflights were conducted to estimate the location and numbers of commercial traps from their surface buoys within BNP. Traps were then inspected using SCUBA and snorkeling techniques to characterize the immediate microhabitat upon which the respective traps were set. Trap "footprints" were also captured on video tape. Lobster and stone crab traps were found primarily over *Thalassia* beds, while blue crab traps were found primarily over *Halodule* beds.
- Controlled trawling experiments were conducted over seagrass and hardbottom communities. Pre-trawl underwater video recordings were compared with post-trawl recordings of five linear transects that had received from one to five rollerframe trawl passes. While we were unable to detect any damage along the seagrass bed transects, damage to sessile invertebrates along the hardbottom transects was conspicuous after one pass. The rate of damage appeared to decrease with subsequent trawling efforts. The sponge *Ircina felix* and the corals of the genus *Pseudoplexaura* appeared to be the taxa most vulnerable to breakage or dislodgement by trawling.

- Trap experiments revealed that damage to underlying seagrasses depended on soak time, trap type and plant species. For lobster traps, mean *Thalassia* loss was approximately 1% of initial plant cover after one day, 7% after one week, and 26% after one month. For stone crab traps mean loss of *Thalassia* cover was 4% after one day, 27% after one week, and 74% after one month. Blue crab traps reduced *Halodule* coverage by 4% after one day, by 24% after one week and by 70% after one month.
- The bait shrimp fishery regularly comes in contact with a largest contiguous area of BNP's submerged habitat resources. Restriction of commercial bait shrimp fishing in BNP's seagrass habitats cannot be justified solely on the basis of physical habitat damage. However, the issue of juvenile fish and crab bycatch deserves further attention, if not directed research.
- While rollerframe trawling does not appear to damage seagrasses, damage to sessile invertebrates (i.e., sponges and soft corals) in hardbottom communities is conspicuous and is likely to be long-lasting. Hardbottom habitats would undoubtedly benefit from closure of commercial bait shrimping in areas that support high densities of sponges and corals. The feasibility of accurately marking the boundaries of BNP's hardbottom areas and preventing nocturnal trawling within them should be investigated.
- It is essential to conduct a limited number of additional trawl effects experiments in conjunction with areal closures to obtain precise estimates of habitat recovery rates for sponge and soft-coral habitats damaged by commercial trawling activities.
- The primary benthic resource that the three major trap fisheries affect is seagrass habitat. The extent of damage to the habitat is a function of gear soak time, trap type, and the particular seagrass species which constitute the habitat. We strongly recommend that additional field experiments be conducted which focus on the rate at which *Thalassia* and *Halodule* recolonize after being impacted by trap-damage.
- We further recommend that additional measurements of size and spatio-temporal extent of each of the trap fisheries be conducted. These studies are required before definitive estimates of cumulative Park-wide resource damage resulting from commercial trap fishing can be made.

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1.0 INTRODUCTION

Biscayne National Park (BNP) is a unique national treasure. Park boundaries encompass approximately 710 km² of coral reef, seagrass, hardbottom, barrier island, lagoonal and estuarine habitats spread over a subtropical seascape. There is a wide diversity of extremely valuable fishes and invertebrates that depend upon these interconnected environments. Many of these animals support economically important commercial and recreational fisheries, as well as provide substantial aesthetic value for thousands of recreational divers and boaters. An intact mosaic of seagrass, bay hardbottom (sponge-coral matrices), sandy-substrate, and offshore reef habitats is required for many fishes and invertebrates to complete their respective life cycles. The protection of these distinct, yet interconnected, habitats is critical.

Sound conservation and sustainable management of habitats has been a primary goal of managers since the establishment of the Park. Recreational and commercial harvests of fishery resources have been permitted within BNP under the original legislation establishing Biscayne National Monument in 1968. There are obvious human economic and social benefits of exploitation in BNP, however, there may also be an insidious component, namely habitat modification and degradation resulting from the use of specific fishing gears in certain areas resulting in declines of fisheries and resource productivity (Rothschild et al., 1994).

In concept, this problem can be defined as the interaction of four factors: fauna, gear, and habitat and humans. Commercial fishermen operating in BNP employ a variety of gears to harvest six major groups of organisms: spiny lobster (*Panulirus argus*), blue crab (*Callinectes sapidus*), stone crab (*Menippe mercenaria*), penaeid shrimp (*Penaeus* spp.), ballyhoo (*Hemiramphus brasiliensis*), and the "snapper-grouper complex". Coined by the South Atlantic Fisheries Management Council, the term "snapper-grouper complex", in addition to species of Lutjanidae and Serranidae, also includes various wrasses, porgies, grunts and triggerfishes, among others. The above resources are targeted with five main categories of gear: trap, trawl, spear, purse seine and hook-and-line. While specific gear is used to target specific animals, many species are also caught in a bycatch mode. Table 1.0.1A indicates each of the fishery resources targeted and incidentally caught with each gear type (fauna-gear interactions). Four broad habitat types are fished: seagrass, sand, bay hard bottom, and offshore coral reef. Table 1.0.1B indicates 13 gear-habitat interactions that require consideration in the overall problem. Our focus in the present study is on modes, effects and recovery rates of those commercial activities which predominate in terms of both human participation and areal coverage, namely, trapping and trawling.

Table 1.0.1- Conceptual diagram showing major faunal, habitat, and gear inter-relationships relevant to analysis of commercial fishing on key habitats in Biscayne National Park. (A) Gear-species interactions. Target (T) and non-target bycatch (BC) organisms potentially affected by principal gear types; and (B) Gear-habitat interactions. Distribution of gear types amongst several classes of key habitats. Traps for lobster, stone crab and blue crab indicated by "Lob", "Sto" and "Blu", respectively. Bold square indicates areas of focus in present study.

(A) **Gear-Species Interactions**

Species	Trap			Gear			
	Lob	Sto	Blu	Trawl	Spearfishing	Purse Seine	Hook & Line
<i>Spiny Lobster</i>	T	BC	BC	BC			
<i>Stone Crab</i>	BC	T	BC	BC			
<i>Blue Crab</i>	BC	BC	T	BC			
<i>Penaeid Shrimp</i>				T			
<i>Ballyhoo</i>						T	
<i>Snapper-Grouper Complex</i>	BC	BC	BC	BC	T		T
<i>Tropical Fish Complex</i>	BC	BC	BC	BC			BC

(B) **Gear-Habitat Interactions**

Habitat	Trap			Gear			
	Lob	Sto	Blu	Trawl	Spearfishing	Purse Seine	Hook & Line
<i>Seagrass</i>		x	x	x			x
<i>Bay Hard Bottom</i>				x			x
<i>Sand</i>							x
<i>Coral Reef</i>					x	x	x

Due to the size and complexity of both BNP and the commercial fishing operations therein, a realistic assessment of the impacts on multiple habitats requires that several integrated components be addressed over space and time scales appropriate to both the habitat resources and the fisheries. Fairly limited research has been conducted within BNP on human impacts on target stock and incidentally-caught species (e.g., Berkeley et al. 1985; Campos and Berkeley 1986) or on the effects of recreational use on seagrass, hardbottom and reef habitats (Zieman 1976; Tilmant 1979; Tilmant and Schmahl 1981). Little attention has focused on the immediate, short-term, or long-term impacts of commercial fishing operations on physical habitats within BNP. Consequently, the effects of ongoing commercial fishing activities on the Park's major habitat types and fishery resources remain poorly understood.

Project Components

This project had three components: analysis of existing data on habitats and fisheries; field surveys and ground-truthing; and field experiments.

2.0 ANALYSIS OF EXISTING DATA ON HABITATS AND FISHERIES

2.1 Habitat distribution within BNP

Various spatially-explicit databases pertaining to submerged natural habitats and their aquatic animal resources within BNP and adjacent areas of Biscayne Bay were obtained, integrated, and analyzed. Habitat information was obtained primarily from NOAA and DERM (Dade County Environmental Resource Management). These data were converted to digital Arc/Info coverages and/or "point data," considering such factors as land use, bathymetry, water quality, and bottom community types. DERM's bottom community coverages represent 18 categories of bottom type and many of these differ only subtly. Therefore we reduced the number of bottom types from 18 to five aggregated habitats that are fished, namely, barebottom, seagrass, bay hardbottom, mixed seagrass/hardbottom, and offshore coral reef.

Next we quantified the areal extent of BNP's component habitat types within a range of depth strata. Figure 2.1.1 depicts BNP boundaries, emergent land, and the geographic extent of the five aquatic community types. Figure 2.1.2 is a spatially-explicit rendition of seven depth strata within the park boundaries: 0 - 1 m; 1 - 2 m; 2 - 3 m; 3 - 4 m; 4 - 6 m; 6 - 10 m; and >10 m. Table 2.1.1 provides submerged habitat resource matrices of areal estimates of each of the habitat components within each of the depth strata above.

Figure 2.1.1- Biscayne National Park habitat distribution. White line delineates BNP boundary.

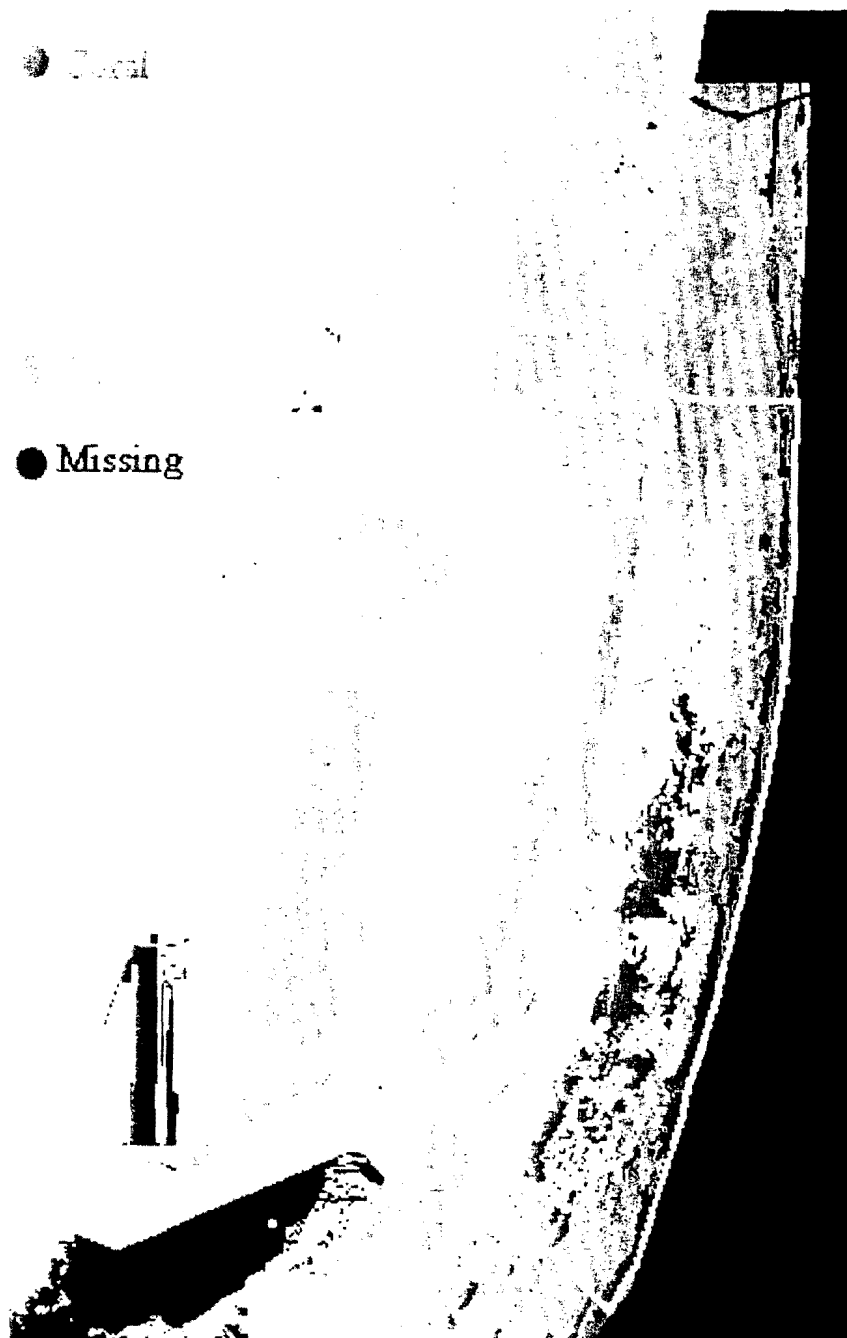


Figure 2.1.2- Depth contours of Biscayne Bay. Ranges are in meters (m). White line delineates BMP boundary.

0-1 m
1-2 m
2-3 m
3-4 m
4-5 m
6-10 m



Table 2.1.1- Submerged habitat resource matrices. (A) Terrestrial and submerged area of BNP. (B) Quantities of each submerged habitat type within a given depth range. Areas are in square kilometers. Depth ranges are in meters (m).

(A)	Land	38.29
	Submerged	671.95
	Total BNP Area	710.24

(B) Habitat Type	0-1 m	1-2 m	2-3 m	3-4 m	4-6 m	6-10 m	>10 m	Total
Bare	1.26	2.69	6.56	5.89	14.43	34.14	16.47	81.43
Seagrass	42.71	76.28	95.84	76.90	41.26	36.42	0.24	369.65
Seagrass / Hardbottom	3.26	40.23	37.37	4.01	0.00	0.00	0.00	84.87
Hardbottom	5.85	41.79	24.30	1.91	0.00	0.00	0.00	73.85
Coral	0.00	0.00	0.23	2.04	17.48	20.30	8.21	48.27
Uninterpreted	3.22	1.17	0.11	0.00	0.04	0.89	8.44	13.88
Total	56.30	162.16	164.41	90.75	73.21	91.75	33.36	671.95

BNP boundaries encompass an area of approximately 710 km², of which about 38 km² is land, and 672 km² (i.e., 94.6%) is submerged (Table 2.1.1A). The primary benthic community type within the Park is seagrass which covers approximately 55% of the Park's aquatic substrate (Table 2.1.1B). After seagrass, the bottom coverages of bare, mixed seagrass/hardbottom, and hardbottom substrates predominate, each ranging from 11% to 13% of the Park. The area of offshore coral reef habitat is relatively small covering only about 48 km² (7.2%) of the Park's underwater resources. The distribution of benthic communities across the seven depth strata is shown in Figure 2.1.3. Fifty-seven percent of BNP's submerged land is overlain by < 3 m of water. In general, bare bottom and coral reef coverages tend to increase with depth. Seagrass coverage is greatest in waters 1-4 m deep. The coverage of the hardbottom and seagrass/hardbottom communities within BNP is greatest in waters 1-3 m deep.

2.2 Historical overview of fisheries

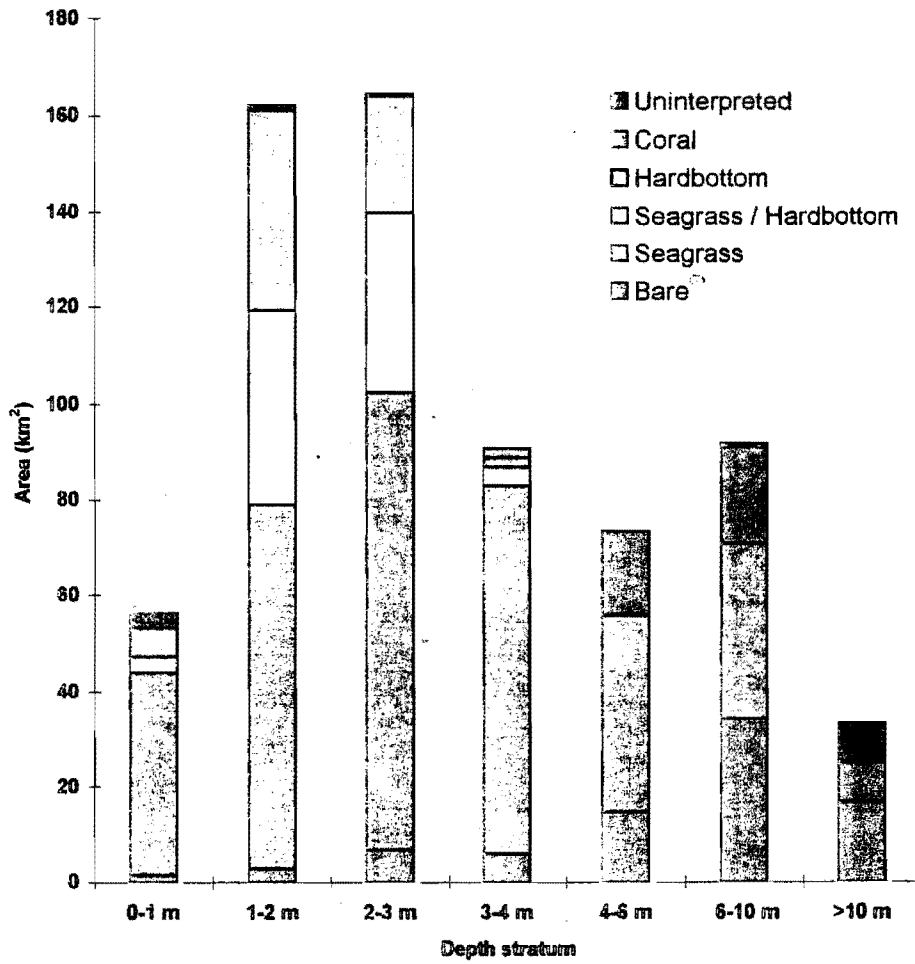
2.2.1 Bait shrimp fishery

Since the beginning of the century, the spotted seatrout (*Cynoscion nebulosus*) fishery has been one of the most important in Biscayne Bay. The bait-of-choice for catching spotted seatrout continues to be live shrimp (Smith 1896; de Sylva 1954). Prior to the 1950s, the main source of bait shrimp for local hook-and-line fishermen were the waters off northeastern Florida, between Cape Kennedy and Jacksonville (Tabb 1960). Northeast Florida bait shrimpers used a variety of gears to provide Biscayne Bay fishermen with pink shrimp (*Penaeus duorarum*), and white shrimp (*P. setiferus*). Early gears included dip nets, cast nets, and haul seines which were often used in conjunction with lanterns as penaeids tend to be attracted to light at night.

As the human population of South Florida grew, so too did its popularity as a tourist destination. This resulted in a sharp increase of seasonal recreational anglers. Increased demand for live bait shrimp prompted the invention and widespread use of the "push net", a human-driven device which enabled the capture of up to 5,000 shrimp in a single night. Today's methods of holding and transporting large numbers of live shrimp can be traced to the emergence of the push net. With time, however, push netting could not meet orders, and it became less and less economical to "import" shrimp from northeastern sources.

Biscayne Bay's bait shrimp fishery began in the early 1950s by which time the skid-equipped channel net had developed (Higman 1952). Towed behind a vessel with a shallow draft, this was simply a rectangular metal frame with two skids attached to its bottom edge.

Figure 2.1.3- Areal coverage of each habitat type within selected depth strata in BNP. Areas are in km²; depths are in meters (m).



The replacement of skids with wheels was experimented with, but abandoned because gear made insufficient contact with the bottom. This led to the addition of a circular arrangement of metal rods along the entire bottom edge -- hence the earliest known rollerframe trawl design (Tabb 1958). Relatively unchanged since the 1960s, the rollerframe trawl design consisted of a net attached to a metal frame with a slotted roller along the entire lower portion of the frame. This design proved more efficient than the otter trawl and was therefore used by virtually all commercial shrimpers by 1965.

The driving force behind the rollerframe trawl design was the perceived need for less-destructive alternative to the otter trawl. As early as 1952, the Florida State Board of Conservation initiated studies to investigate reports of damage to seagrass beds and incidental mortalities of game and forage fishes (Seibenaler 1953; Woodburn et al. 1957; Tabb 1958; Tabb and Kenny 1969). Collectively, these early studies concluded that use of rollerframe trawls was not deleterious to seagrasses and that incidental mortalities of fishes were negligible. As a result, the fishery was tolerated by recreational fishermen and environmental groups for several years. However, one study did warn of permanent alteration of hardbottom communities off Turkey Point. Tilmant (1979) recorded significant damage to sponges, hard corals and soft corals within 50 m x 50 m plots and transects. However, with growth of the fishery, essentially the same questions about habitat destruction and juvenile fish mortality re-emerged by the early 1980s. This prompted the Florida Sea Grant investigation conducted by Berkeley et al. (1985) which considered fleet size, seasonality, shrimp catch and fish bycatch up to 1983. Although Berkeley et al. (1985) did not assess physical impacts on habitats directly, they made the following statement:

If the gear destroyed or uprooted seagrasses, or was otherwise destructive to the habitat, a decline of the abundance of organisms, including shrimp, or a change in [fish] community structure might be expected.

Berkeley et al. (1985) concluded that: (1) the relatively stable pattern of mean annual catch-per-unit-effort of shrimp from 1971-1983 suggested the fishery had not significantly affected the habitat's ability to function as a shrimp nursery area; and (2) because fish species composition and structure had not changed dramatically since the 1960s, the fishery's impact on fishes was apparently "not severe". The authors acknowledged, however, that because physical damage was not directly assessed "Certain communities could be severely impacted, but go undetected if they

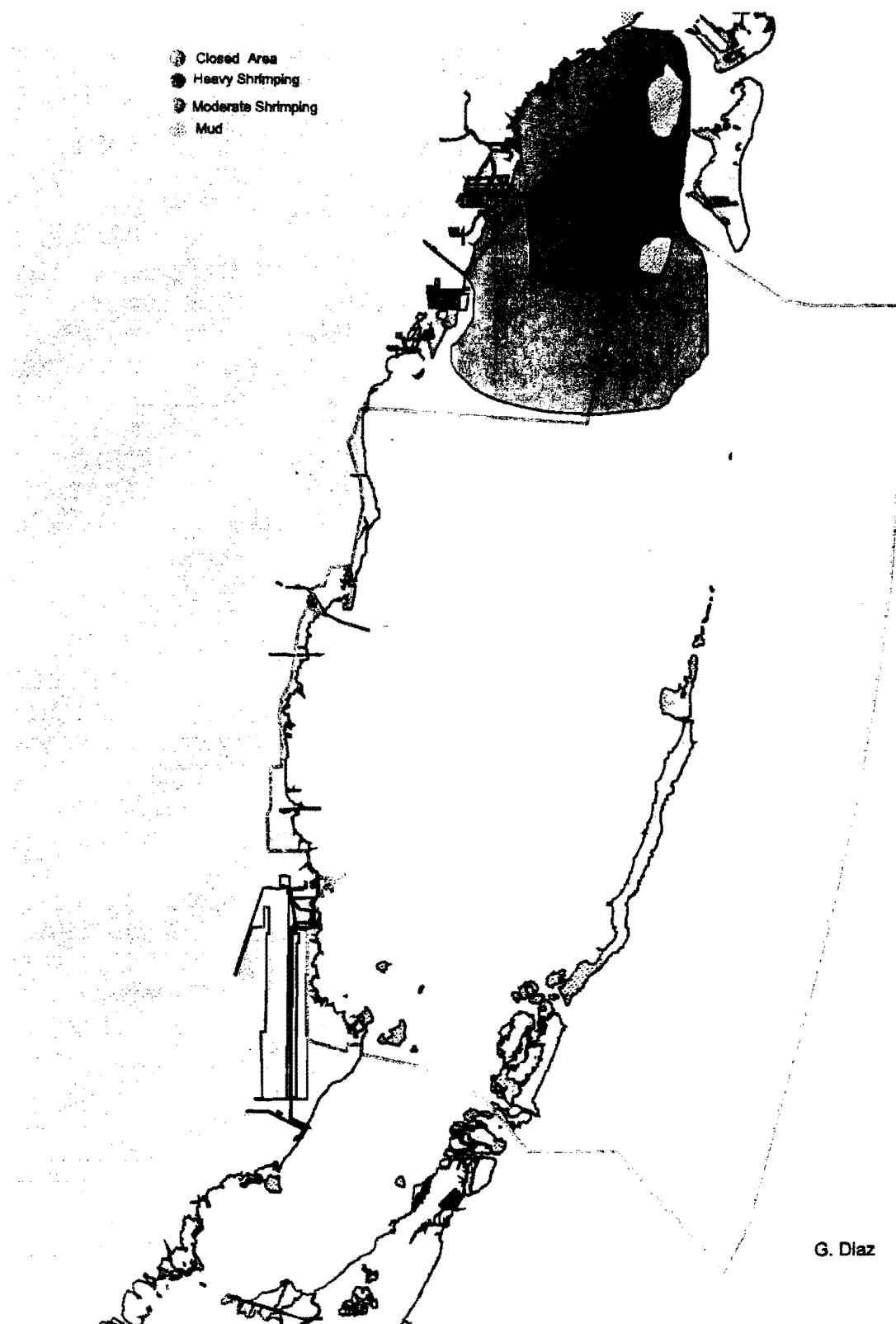
constituted a small fraction of the total bay bottom community". The present study represents the first attempt to quantitatively assess impacts of trawling on Biscayne Bay habitats since the 1970s.

Bait shrimp fishery fleet size and fishing grounds

In 1954, three bait shrimp boats worked Biscayne Bay, primarily from December to March (Siebenaler 1953). By 1958, Tabb (1958) reported 12 boats in the bait shrimp fishery which worked throughout the entire year. Tabb and Kenny (1969) reported for 1966 that there were 46 shrimp boats in the bay. Berkeley et al. (1985) stated that while the number of vessels in the bay varied in 1983, it never exceeded 28 boats at any one time and averaged 22-23 boats. Spatially, the area trawled by commercial shrimpers has expanded, reflecting both increases in access and dockage locations as well as increased participation. In 1958, trawling was conducted exclusively in the northern part of the bay, between Chicken Key and what is now Rickenbacker Causeway (Figure 2.2.1). Virtually all fishing effort emanated from Dinner Key and directly adjacent areas were the most heavily exploited. Interestingly, there was a closed area near the shoreline, which Berkeley et al. (1985) reported was a result of belief that this was an important nursery ground for spotted seatrout. However, from conversations with fishermen of that time, D. Pybas (pers. comm.) learned this area was actually deemed off limits for social rather than environmental reasons. The area in question was adjacent to Mercy Hospital, where, for cooling and ventilation purposes, windows were left open at night. The area was closed, therefore, as a measure to minimize noise from the trawler engines from disturbing patients. According to those shrimping at that time, the opening of the area coincided with the installation of central air conditioning in Mercy Hospital in the early 1960s.

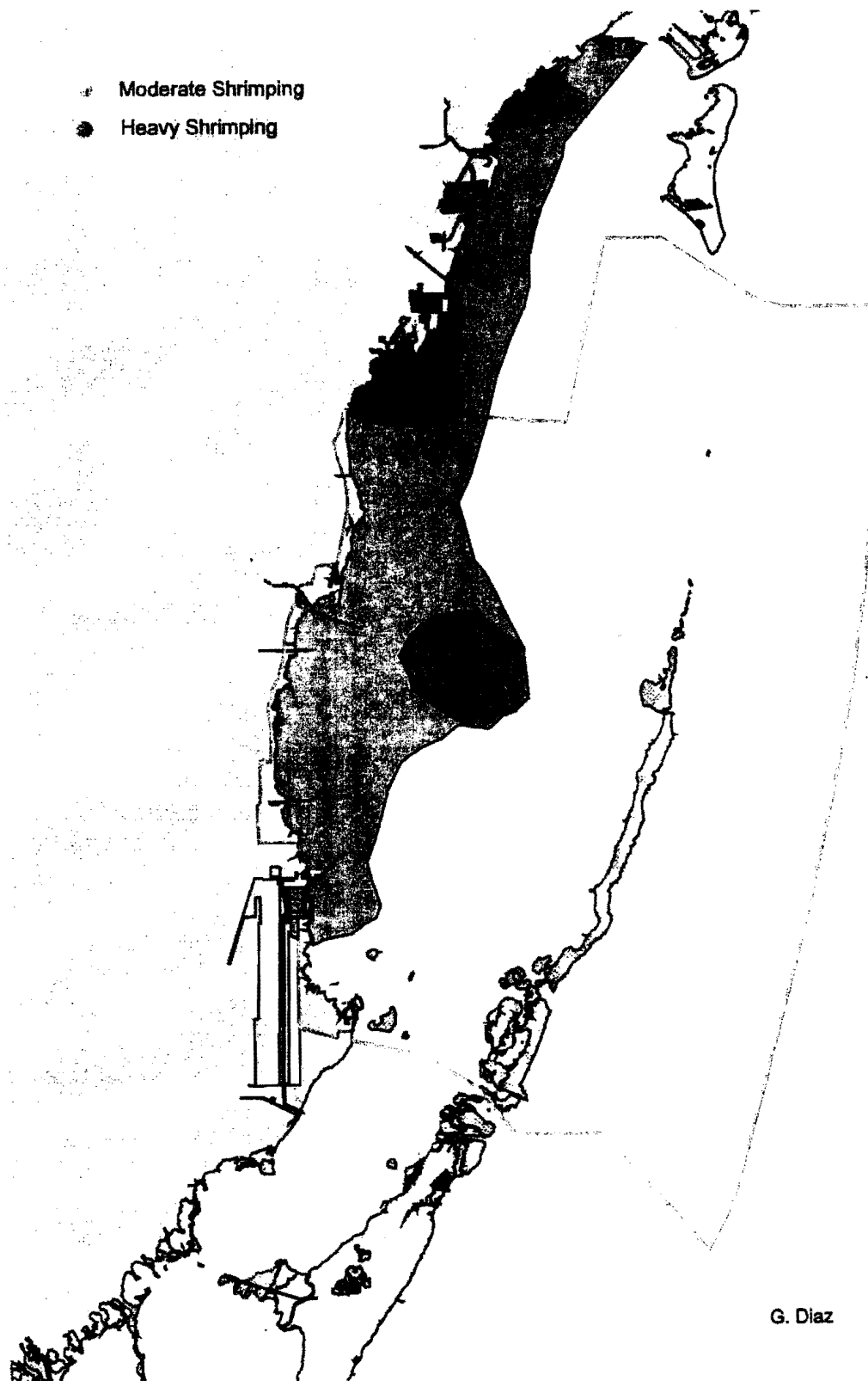
Figure 2.2.2 presents the areal extent of bait shrimping in 1982 based on interviews and questionnaires conducted by Berkeley et al. (1985). Expansion of shrimping into the southern part of the bay, and well within present-day Park boundaries, was undoubtedly facilitated by the construction of southern marinas, particularly Black Point. As an increased number of bait shrimp boats docked at Black Point, the trawl areas expanded to the adjacent areas. Berkeley et al. (1985) estimated that commercial shrimp trawlers swept approximately 20% of Biscayne Bay's bottom four times annually. In 1982, they found four areas were most heavily exploited: 1) near Rickenbacker Causeway; 2) adjacent to Dinner Key; 3) south of Snapper Creek to Chicken Key; and 4) over the central-Bay system of shallow grass banks known as the "Featherbeds".

Figure 2.2.1- Estimated areal extent of bait shrimp fishery in 1958. Red line delineates BNP boundary.



G. Diaz

Figure 2.2.2- Estimated areal extent of bait shrimp fishery in 1982. Red line delineates BNP boundary.



2.2.2 Spiny lobster fishery

The spiny lobster commercial fishery began in the late 1800's when the population centers in south Florida were Key West, Indian Key and Miami. The fishery started primarily to provide bait to support the Florida Keys finfish fishery, especially for large snapper and grouper. Much of the finfish take was then exported to Cuba. While most of the spiny lobster was taken for bait, there was a small demand for spiny lobster as a food source in the lower Keys. In 1868, due to a deteriorating political climate between the United States and Cuba, the Cuban government imposed a heavy duty on imported finfish from the U.S., thus the finfish industry, and in turn spiny lobster fishery also dwindled. In 1895 spiny lobsters sold at 2 cents per pound (Brice 1898). The first boon to the spiny lobster fishery came with the construction of the Overseas Railroad which was completed in 1912. With easy and reliable transportation to and from the Florida Keys it was now possible to ship spiny lobster to all points north. Markets for spiny lobster opened in Miami, Jacksonville, Atlanta, Philadelphia, New York and Boston (Schroeder 1924). From 1915-20, the estimated annual spiny lobster catch was 350,000 pounds, 40% of which was shipped, 40% was consumed locally, and 20% was used as bait (Schroeder 1924).

As the market for spiny lobster expanded, so did fishing. To accommodate the increase in demand, the fishing areas immediately surrounding Key West also expanded to include a 25-mile zone that encompassed the southern shores of the lower Florida Keys and the shallow Atlantic reef areas both east and west of Key West (Crawford and De Smidt 1922). The geographic boundaries for this fishery were dictated by the limited capabilities of the fishing vessels which were small, shallow draft sail boats or gasoline powered motor boats. The techniques used to catch the spiny lobster were largely based on the ability to visually identify the spiny lobster, which was not hard given their abundance in the shallows. Spearing with "grains" (a type of spear) and seining were the tools by which the vast majority of the spiny lobster were taken.

By the 1920's spears and seines were replaced by "bully nets", which accounted for about 50% of the spiny lobster catch (Crawford and De Smidt 1922). The second means by which spiny lobsters were fished was through the use of a 36 x 24 x 20 inch wire mesh trap. The benefit of this development was that it was no longer necessary for the fisher to visually identify the lobster. Also, the traps could be left in the sea during periods of rough weather; therefore, fishing could actually take place on days that were too inclement for the fisher to bully net, spear or seine (Schroeder 1924). In 1924, these traps accounted for about 20% of the catch (Crawford and De Smidt 1924). By the end of the 1920's spiny lobster production rose to about 900,000 pounds, and for the first time a minimum legal size limit of 1 pound was established by the Florida legislature (Prochaska and Baarda 1975).

The Great Depression, destruction of the Overseas Railway by the Labor Day hurricane of 1935, and Key West's economic difficulties resulted in a decrease in spiny lobster production in the 1930's to about 500,000 pounds annually. The price of spiny lobster remained at about 5 to 8 cents per pound. The destruction of the Overseas Railroad led to the construction of the Overseas Highway which was completed in 1938, thus reestablishing transportation between the Florida mainland and the Keys.

The 1940's experienced a revitalization of the Florida Keys and of the spiny lobster fishery. The familiar wooden slat traps were introduced and quickly became the gear of choice for spiny lobster fishers. The commercial fishing grounds also expanded. In the Florida Keys the main fishing areas paralleled the offshore reef of the Atlantic. Production of spiny lobster rose from a low of 400,000 pounds in 1940 to almost 4,000,000 pounds by the end of the decade. A number of factors contributed to the dramatic increase in spiny lobster production, these were: the newly developed ability to deep freeze lobster tails; the completion of the Overseas Highway, which supplied spiny lobster to the hotels and restaurants up and down the east coast; and a new U.S. Navy base which opened in Key West, thus dramatically boosting the population. Another key factor was an increase in competition which resulted from an increase in foreign import of spiny lobster tails, principally from the Caribbean, South Africa and Australia (Chase and Dumont 1949).

Using a gasoline-powered boat, a crew of 2-3 could fish 100-400 traps, checking up to 100 traps per day. This work was slow and arduous due to the fact that the traps were hauled aboard ship by hand. A good day's catch could be as much as 400-500 spiny lobsters, or about 600-700 pounds (Smith 1948). Because the traps were hauled by hand this also limited the depth to which the traps were deployed. Fish heads were initially used as bait for the spiny lobsters but was eventually discontinued due to the fact that it also attracted stone crabs. Stone crabs would enter the traps and when the fish heads were consumed they would then kill or otherwise mutilate the spiny lobster in the traps.

The spiny lobster fishery continued to expand in the 1950's with an increase of 102 boats in 1952 to 254 boats in 1959. The number of traps tripled from 17,000 in 1951 to 52,000 in 1959 and the demand for spiny lobster resulted in an increased price from 18 cents per pound in 1950 to 30 cents per pound in 1959. The boats used in the fishery ranged from 14-foot skiffs propelled by outboard, gasoline engines to larger 26-36 foot, wooden hulled motor launches (Cope 1959), powered by diesel, marine gasoline or converted automobile engines. These larger boats were typically based on the west coast of Florida. There were three main developments in the 1950's which accelerated spiny lobster fishing, these were: the advent of the SCUBA apparatus and thus of the recreational spiny lobster fishery; baiting the spiny lobster traps with short lobsters, in

addition to food-bait (which kept the traps relatively clean as well as attracted other spiny lobsters); and the use of a "gypsy head" powered from the main boat engine to haul the traps aboard the boat (Moe 1991). With a powered haul this meant that a crew could haul more traps per day and could deploy their traps in deeper waters which were previously impractical to fish. The main fishing grounds continued to be centered on the southern or reef side of the Florida Keys in depths from 3-15 fathoms (Cope 1959).

In the 1960's the increasing demand for spiny lobster forced the fishery from it's traditional center of operations in Key West and Miami out to the Bahama banks and into the Caribbean. Bahamian sovereignty only extended out 3 miles at the time and Floridian spiny lobster fishers took full advantage of this fact. In 1967, only 43% of the spiny lobsters landed in Florida came from State waters, the remainder came mostly from Bahamian waters, outside of their three-mile limit. In response to this increased fishing pressure on the Bahama banks, in 1969 the Bahamian government extended its sovereign fishing zone out to 12 miles. Despite this new closed area, Florida landing continued to increase through 1974 as Floridian spiny lobster fishers extended their range further south into the Caribbean.

There were two important developments in the fishery during the mid-1960's. The first was the introduction of salted cowhide to bait the traps. This was cheap, easy to use and did not attract the stone crab into the traps. The second was new legislation in 1965 that further defined the minimum size limit for spiny lobster. This was a carapace length of 3 inches and a tail length of 5.5 inches. Additionally, the practice of stripping the eggs from egg-bearing females was outlawed.

In 1971 the landings of spiny lobster in Florida increased dramatically from 8.2 million pounds in 1972 to 11.4 million pounds. A likely reason for this increase was that in 1971 it became legal to harvest spiny lobster in international waters during Florida's off-season. In 1972, 58 percent of the total harvest was comprised of spiny lobster caught in international waters. Landings remained above 10 million pounds until 1975 when it dropped to 7.4 million pounds. This drastic drop in landings was the result of the Bahamian government closing their waters to fishing by non-Bahamian vessels. As a result of the closing of the Bahamian continental shelf, about 260 Florida-based spiny lobster boats were displaced, some to other parts of the Caribbean (Prochaska 1976b). As the commercial spiny lobster fishery expanded so did the recreational fishery and the poaching of spiny lobster traps. In 1975 the Florida State legislature responded to the increasing conflict between the commercial and recreational spiny lobster fisheries by establishing the 2-day recreational season one week prior to the opening of the commercial season. This practice is still in effect.

2.2.3 Stone crab fishery

The historical literature on the Stone Crab (*Menippe mercenaria*) in Biscayne Bay is sparse. Research has focused on Florida's west coast populations since the fishery on the west coast is much larger than the east coast's. Bert (1985) reported that the relative abundance of stone crabs decreased from the Gulf of Mexico, into Florida Bay and then along Florida's Atlantic coast.

Stone crabs are burrowers, excavating dens within the benthic substrate. The type of den they construct is a function of the type of benthic sediment. A mud bottom with emergent rocky outcroppings is preferred (Bert, personal communication), most likely due to the ease of den construction. In areas in which a harder bottom exists, stone crabs will excavate under sessile organisms (e.g., loggerhead sponges, *Spheciospongia vesparia*) that will provide overhead protection. The same behavior also occurs in seagrass beds. There is also some evidence of sexual preference for habitat with females occupying more seagrass burrows and males more rock holes (Bert 1985).

2.2.4 Blue crab fishery

As with the spiny lobster fishery, the blue crab fishery traces back to the late 1800's. In 1884, Rathbun reported that, "although very large quantities of blue crab can be easily procured along the east coast of Florida, they have as yet to give rise to a regular industry, and are merely taken for home consumption in towns along the coast." Because blue crab spoiled quickly, the fishery did not expand until the development of the Overseas Railroad in 1912. The impact this railroad had on the blue crab industry parallels that of the bait shrimp and spiny lobster fisheries; as the available markets increased so did fishing effort.

During the early history of this fishery a variety of gear was used to harvest the blue crab. This gear included, scoop-nets, baited hoop-nets, seines, trotlines, trawls, handlines, and hook-and-lines (Steele and Bert). The blue crab fishery in Chesapeake Bay began using traps in 1927 which allowed for a higher catch per unit effort (CPUE) as the crabbers could leave their traps for extended periods of time and return when they were able. In 1938 the Lewis trap was introduced which allowed the crabs to enter the trap but made it difficult for them to escape (Steele, unpublished). The concept of using traps eventually found its way to southern Florida where their widespread use began in the 1950's (Steele & Bert, unpublished).

2.3 Landings and effort

2.3.1 Bait shrimp fishery

Commercial bait shrimp landings and fishing effort data for Dade county, was provided by the Florida Department of Environmental Protection (DEP). This information is compiled from "trip tickets" that commercial bait shrimp wholesalers have been required to complete since 1986. Annual landings of bait shrimp are highest in Dade County where landings have fluctuated between about 200,000 to 375,000 pounds per annum (Table 2.3.1A). Fishing effort fluctuates between 3,000 and 5,000 trips per year. Catch-per-unit-effort (CPUE) appears to have been relatively stable since 1986.

2.3.2 Spiny lobster fishery

Since 1993-94, there has been a slow but steady decline in landings for Dade County from a high of 680,000 pounds to 518,000 pounds reported for 1995-96 (Table 2.3.1B). Previous to 1990-91 the fishery's landings, total annual trips, number of fishers and CPUE all remained fairly constant. However, all fluctuated considerably between 1990-91 and 1993-94, with the range of landings exceeding 250,000 pounds from 1990-91 to 1991-92. This pattern was repeated the following two seasons, first falling then rising to the 1993-94 high. The number of spiny lobster trappers peaked during the 1991-92 season at 199, and fell off to the 1995-96 season total of 129.

2.3.3 Stone crab fishery

The stone crab fishery has undergone an annual cycle of high and low landings (Table 2.3.1C). Since reporting for this fishery in Dade county began in 1985-86, the lowest landings occurred in 1988-89 with total of 11,751. pounds. A high of 44,458 pounds was experienced in 1994-95 and since then has dropped to 21,925 for 1995-96. The 1994-95 season also reported the most number of trips (730) which was most likely aided by significant entry into the fishery beginning with the 1992-93 season. Prior to 1992-93 the average number of stone crabbers remained at about 31, while in 1994-95 the reported number of licenses for stone crab was 85. The 1995-96 season ended with 51 trappers. The CPUE has decreased by half since 1991-92, from 99 pounds per trip to 50 pounds per trip reported last year.

Table 2.3.1- Effort and landings for each of the major commercial fisheries in Biscayne Bay beginning with the 1986-87 license year. Number of Fisherman indicates the number of licenses sold for that license year. Total Annual Pounds is the total yearly harvest. CPUE is the catch-per-unit-effort in units of pounds per trip.

(A)

Bait Shrimp				
LICENSE YEAR	NUMBER OF FISHERMEN	TOTAL ANNUAL TRIPS	TOTAL ANNUAL POUNDS	CPUE
86-87	35	4337	282559	65.15
87-88	62	4197	291109	69.36
88-89	66	3499	251662	71.92
89-90	64	2660	184239	69.26
90-91	32	2068	162824	78.74
91-92	40	3206	242070	75.51
92-93	54	2902	249786	86.07
93-94	60	3785	297870	78.70
94-95	66	4870	361696	74.27
95-96	67	5074	421784	83.13

(B)

Spiny Lobster				
LICENSE YEAR	NUMBER OF FISHERMEN	TOTAL ANNUAL TRIPS	TOTAL ANNUAL POUNDS	CPUE
86-87	35	2628	463417	176.34
87-88	77	2652	373159	140.71
88-89	97	2519	363499	144.30
89-90	117	2893	381111	131.74
90-91	130	3027	377723	124.78
91-92	199	4057	652632	160.87
92-93	128	2758	395202	143.29
93-94	153	3371	679936	201.70
94-95	138	3337	585045	175.32
95-96	129	3117	518313	166.29

(C)

Stone Crabs				
LICENSE YEAR	NUMBER OF FISHERMEN	TOTAL ANNUAL TRIPS	TOTAL ANNUAL POUNDS	CPUE
86-87	4	117	5845	49.96
87-88	21	149	25369	170.26
88-89	31	205	11751	57.32
89-90	34	230	33160	144.17
90-91	29	234	15650	66.88
91-92	40	294	29165	99.20
92-93	33	153	14123	92.31
93-94	60	698	35035	50.19
94-95	85	730	44458	60.90
95-96	51	432	21925	50.75

(D)

Blue Crabs				
LICENSE YEAR	NUMBER OF FISHERMEN	TOTAL ANNUAL TRIPS	TOTAL ANNUAL POUNDS	CPUE
86-87	4	6	210	35.00
87-88	4	35	3229	92.26
88-89	5	45	12988	288.62
89-90	5	27	3881	143.74
90-91	7	69	7511	108.86
91-92	19	546	39281	71.94
92-93	19	670	66843	99.77
93-94	26	1243	103339	83.14
94-95	25	931	74696	80.23
95-96	32	1328	119779	90.20

2.3.4 Blue crab fishery

While hard-shell blue crab landings have historically remained consistently low for Dade county as compared to any other Florida county (Philip Steele, Florida DEP, pers. comm.), there has been a recent increase in landings, beginning with the 1990-91 fishing season (Table 2.3.1D). This increase in landings closely parallels the total annual trips and the number of fishers in blue crab fishery. The CPUE has drastically declined from a high of 288 pounds per trip in 1988-89 to 72 pounds per trip in 1991-92. Since 1992 the CPUE has remained relatively constant, varying between 80 and 100 pounds per trip. In an unpublished study by Philip Steele and Theresa Bert of Florida DEP, information was collected on the three predominant fishing methods for the state of Florida for hard-shell blue crab from 1948 to 1976. The average catch using traps was over 10 million pounds per year, while trawls and trotlines only landed about 80,000 and 1 million pounds per year respectively.

2.4 Current gear and fishing practices

2.4.1 Bait shrimp fishery

Commercial trawling in BNP is directed towards assemblages of juvenile penaeids which are primarily pink shrimp (*Penaeus duorarum*). Pink shrimp reside primarily in inshore seagrass-predominated habitats throughout the Bay. Commercial bait shrimping is conducted at night using almost exclusively rigid, steel-framed "rollerframe" trawls (Figure 2.4.1). Rollerframe trawls, by virtue of their rollers, are designed to reduce bottom damage by rolling over, rather than dragging through, the substrate. Typically, bait shrimp vessels range from 25 to 40 feet in length and are rigged with a boom on each side to tow two nets simultaneously (Figure 2.4.2). Each trawl is attached to the vessel by a galvanized wire which runs from the tow yoke on the trawl, through a block at the end of each boom, and then to a winch mounted on the deck or top of the wheel house. Most shrimpers use hydraulic winches to raise and lower the booms as well as haul the nets. Trawl frames typically range between 10 and 16 feet. The nets are approximately 25 feet long, and are generally made of $\frac{3}{4}$ to 1 inch stretched mesh nylon or dacron bulk netting. A distinguishing feature of the rollerframe trawls is the row of excluder bars which cover the opening to the net. These bars are arranged vertically in front of the net from 1.5-2 inches apart, but not more than 3 inches, according to the 1989 Florida Statutes which regulate this fishery. The main purpose of these bars, in addition to helping to exclude non-target species such as turtles, is to prevent large amounts of algae and debris from entering the net and subsequently crushing the live catch. In the early 1980s, trawl times averaged 25 minutes (Berkeley et al. 1985). Typically, the

DIMENSIONS

- | | |
|-------------------------------------|---------------------------------------|
| (1) 117.5cm (3' 8 $\frac{7}{8}$ ") | (16) 1.1 cm (7/16") Rod |
| (2) 368.0cm (12' 2 $\frac{7}{8}$ ") | (17 & 18) See text |
| (3) 54.0cm (21 $\frac{1}{4}$ ") | Center of axle to band |
| (4) 15.2cm (6") | Radius of inside edge |
| (5) 100.0cm (39 $\frac{3}{8}$ ") | Bend to middle of support |
| (6) 42.0cm (16 $\frac{1}{2}$ ") | |
| (7) 1.2cm (1/2") | I.D. (Inside diameter) |
| (8) 57.2cm (22 $\frac{1}{2}$ ") | Center of frame to near edge |
| (9) 1.2cm (1/2") | I.D. |
| (10) 121.0cm (4' 0") | Center of frame to middle of junction |
| (11) 1.9cm (3/4") | I.D. |
| (12) 62.1cm (24 $\frac{3}{8}$ ") | Center of frame to front edge |
| (13) 12.7cm (5") | |
| (14) 1.1cm (7/16") | Rod |
| (15) 2.5cm (1") | I.D. |

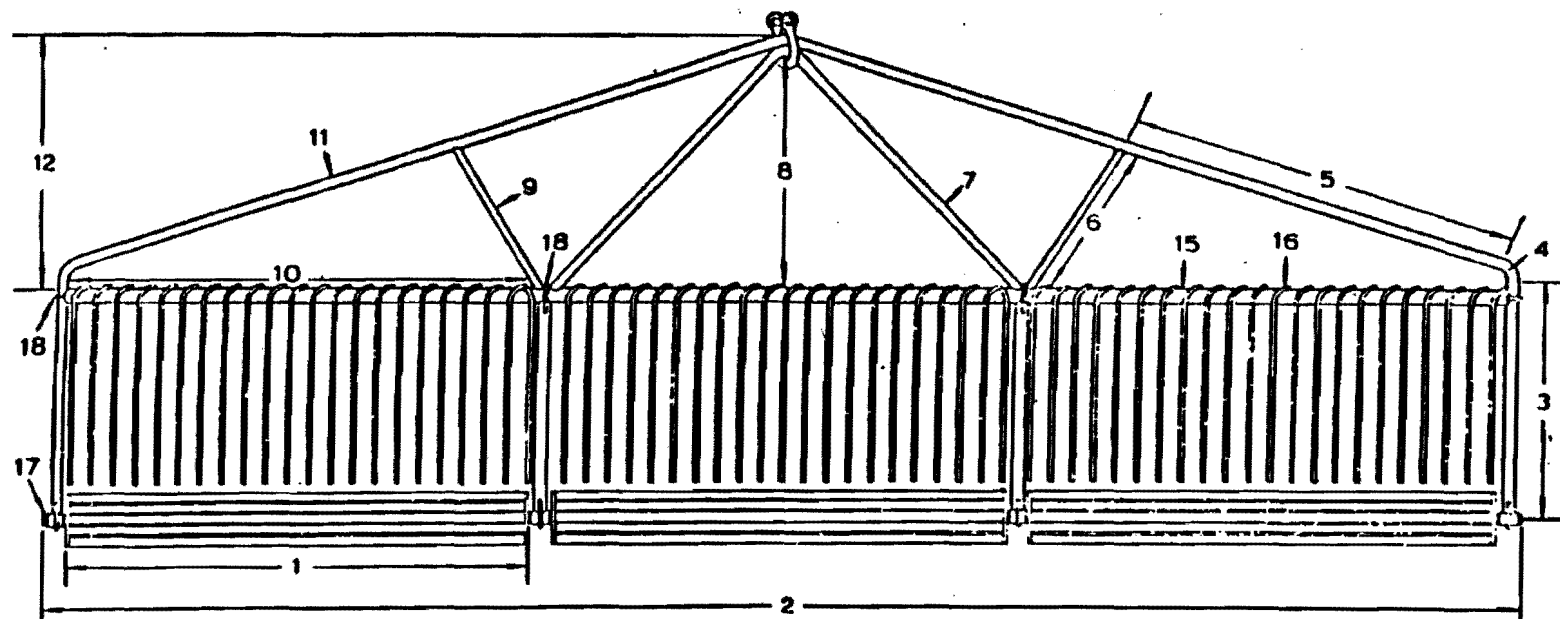
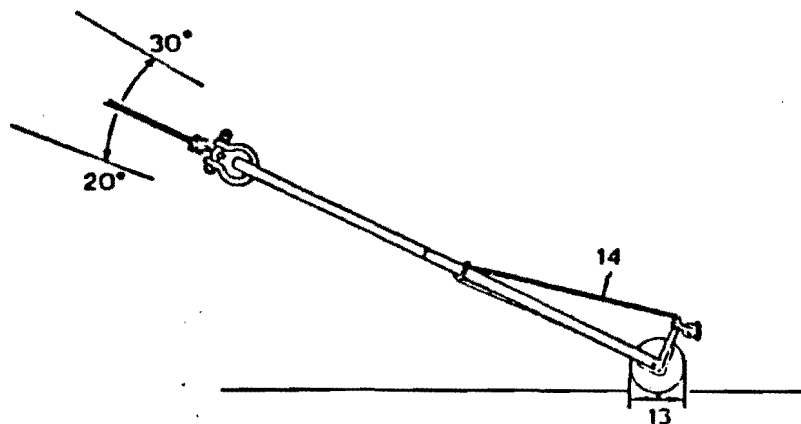
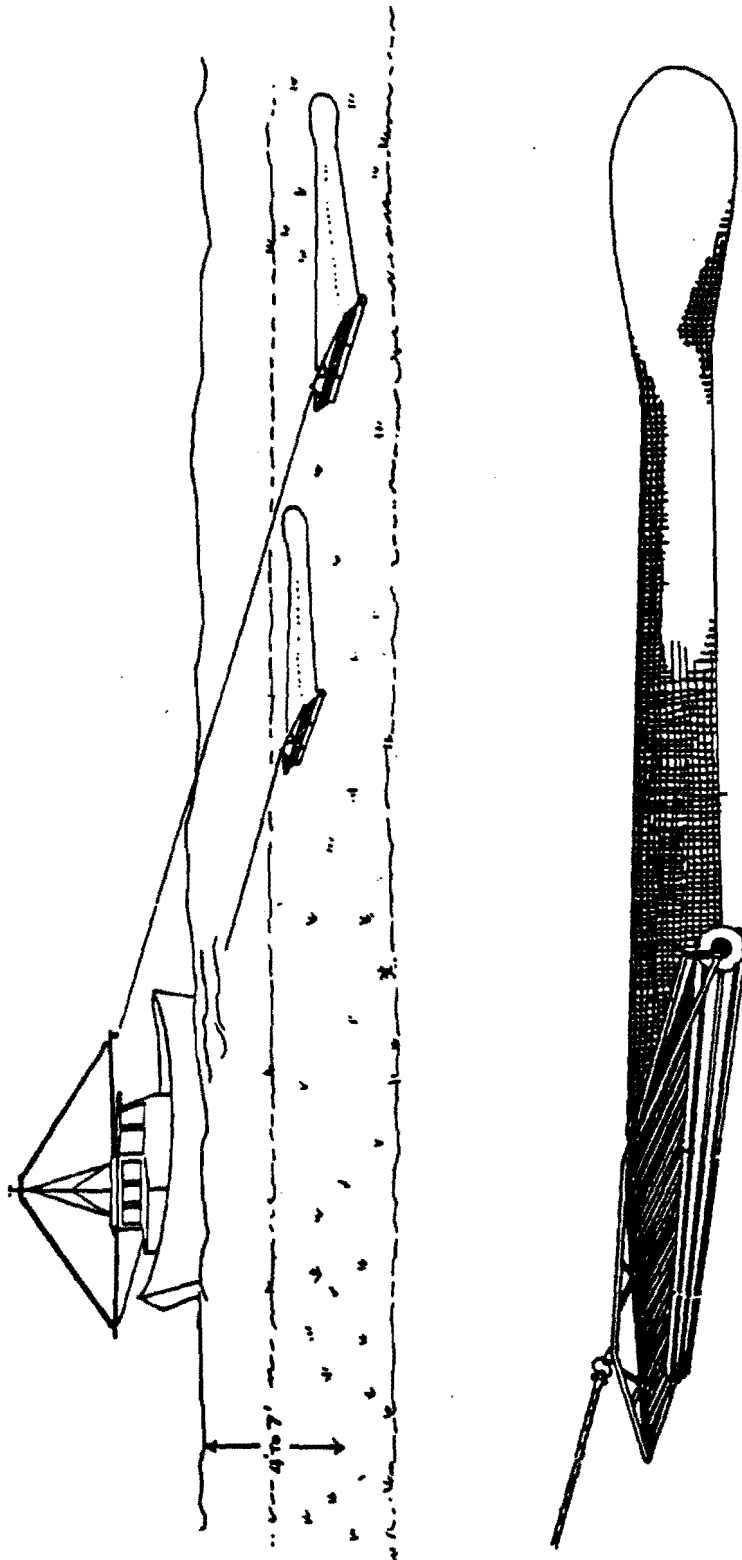


Figure 2.4.1 - Design and dimensions of the roller frame trawl.

Figure 2.4.2- Shrimp trawl with dual rollerframe assembly deployed.



trawls are conducted at a depth of approximately 3-5 ft, but they are efficient at greater depths as well. On average, the boats operated for approximately eight hours per night and a typical order size was 10,000 shrimp.

There are basically two bait seasons in Biscayne Bay: the relatively cool, dry season which begins in November and lasts until approximately April; and the relatively warm, wet season which runs from May through October. Live shrimp landings are highest during the cool dry season coinciding with the period of time when the shrimp concentrate and migrate out of the bay to spawn (Berkeley et al. 1985). Precisely where Biscayne Bay shrimp spawn is unknown. Because few shrimp are caught during the summer season (i.e., May-October), some Biscayne Bay shrimpers will move their boats to other bays in Monroe and Collier counties to satisfy their Miami-based clients. While other bays may yield more shrimp during summer, shrimpers fishing outside Biscayne Bay must incur the additional costs and risks associated with transporting their live catches back to the Miami area.

2.4.2 Spiny lobster fishery

The current commercial season for spiny lobster runs from August 6 to March 31. Most traps are already in the water by August 1 for "soak time," so that spiny lobsters will have five days to enter the traps before they may be removed. The minimum legal size for spiny lobster is currently 3 inches of carapace length or a tail length of 5.5 inches. Spiny lobster traps must measure no larger than 3 by 2 by 2 feet and are baited primarily with salted cowhide and, until 1993, lobster "shorts" (lobster under legal size). The purpose of baiting with shorts was two-fold, to keep the traps clean of epiphytes and to lure other lobsters into the trap. As of August, 1993, "the possession of undersized spiny lobster for the purpose of luring, decoying, or otherwise attracting noncaptive spiny lobster is prohibited" [Florida Administrative Code, Chapter 46-24.003(4)]. Although this precludes the possession of shorts to place in the traps, it does not necessitate their removal from the traps either. Therefore, many spiny lobster traps contain shorts. Pressure-treated pine wood is quickly replacing Florida cypress as the building material for traps (Craig, 1974). Traditionally, cypress has been used due to its capacity to repel marine boring organisms. The practice of dipping traps in oil was banned in 1990, with elimination of oil-dipped traps by 1995. Spiny lobster fishers are now using black, water-based paint to darken the traps, presumably making them more attractive as a refuge (Moe 1991).

In order to weight the traps so that they will sink quickly and settle on the bottom in an upright attitude, concrete is poured into the bottom of the traps. Because these traps weigh

approximately 70 pounds, they are also resistant to movement by storm-surge, although the degree to which they are able to do so has not been quantitatively determined.

Within Biscayne Bay the spiny lobster traps are either on a trot line (up to 30 traps attached by a common line) with two buoys marking the beginning and end of the line, or will be individually marked by their own buoy. In our field surveys, we have yet to find traps located near the patch reefs on the east side of the barrier islands on a trot line. The traps are pulled at least twice a week during the beginning of the season and less frequently as the season progresses (Moe 1991). Few, if any commercial traps are pulled by hand. Rather, the buoy line is attached to a powered winch and hauled onto a stainless steel davit that tips into a horizontal position as the trap hits the back of the frame. The legal size spiny lobsters are then removed, shorts are left in the trap, the trap is rebaited and is then dropped overboard. The entire process takes about 5 minutes and a crew can work up to 100 traps per day (Moe 1991).

There are approximately 1,500,000 licensed traps in the Florida spiny lobster fishery. Of these, it is estimated that only 200,000-300,000 traps are needed to capture the available lobster (Moe 1991). Additionally, according to Amendment 2 of the Fishery Management Plan, GMFMC (1989) and SAFMC (1989), the loss of short spiny lobsters costs the fishery between 63% and 83% of its potential future yield. In 1990, the Florida Marine Fisheries Commission estimated that by banning the use of shorts to bait traps would increase the fishery yield by over 50%. Finally, a major problem in the management of this fishery is the fact that more and more fishers are selling directly to the public and thus not recording their catch on Florida Department of Environmental Protection Trip Tickets.

2.4.3 Stone crab fishery

Approximately 80% of all U.S. annual landings of stone crab take place in Florida's three most southern counties: Dade, Broward and Collier, with Broward and Collier counties' production far surpassing Dade (Bert et al. 1986). The season for stone crab within Biscayne National Park is consistent with the state of Florida which runs from October 15 through May 15. Commercial trappers are allowed to presoak their traps for 10 days prior to the opening of the season and must remove their traps from the water within 5 days following the close of the season (370 FL State Statutes). There are no trap limits within Biscayne National Park.

The claws of both sexes are sought and may be harvested on the spot by twisting the propodus claw off and immediately returning the stone crab to the water. The minimum length of the propodus is 2.75 inches (7 cm) (370.13 FL State Statutes; Fed. Reg. 4(65): 19445-19496). Only a stone crab with both right and left claws may have a claw removed. It takes approximately

one year for a removed claw to regenerate, assuming it survived the declawing process (Sullivan 1979).

The majority of the stone crab traps are of wooden construction, although plastic traps are also used. If a plastic trap is used, it must have a biodegradable section (usually wood) that will decay if the trap is lost. The trap must have one entrance port and the dimensions must not exceed 22 × 16 × 12 inches. Traps are deployed with either a buoy marker, or are attached to a trotline, the terminal ends of which are marked by buoys. Stone crab traps are typically checked every one or two days at the beginning of the season and less frequently as the end of the season approaches. A weighted stone crab trap weighs approximately 40 pounds. Therefore, a powered winch is usually used to pull the traps which are then placed on a trap table, the stone crabs are removed and declawed. The trap is then rebaited (with fish or a perforated can of catfood), sometimes cleaned with a high pressure hose, and dropped overboard.

2.4.4 Blue crab fishery

The traps currently in use by this fishery are constructed of wire mesh, with a minimum mesh size of 1.5 inches. The opening (throat) is only on the vertical surface and there must be three 2-3/8 inch escape rings, a degradable panel and a maximum trap dimension of 24 × 24 × 24 inches, or an equivalent volume of 8 cubic feet. Each trap must also be buoyed. In addition to establishing trap configurations, Florida Statutes 370.135 and Florida Administrative Code, Chapter 46-45 also define other allowable gear types, prohibit the harvest or sale of egg-bearing females, establish recreational bag limits and set the minimum legal size at 5 inches carapace width. Some of the lesser used, allowable gear types include dip nets, folding traps, hook-and-line, push scrapes and trotlines (Steele and Bert, unpublished). Blue crabbing, commercial or recreational, must also take place only during daylight hours.

While the Florida Department of Environmental Protection has kept detailed records of commercial fishery landings since 1985, there is no record of the recreational harvest. There are at least two areas of concern if this recreational fishery is to be managed. First, recreational harvesters are not subject to a minimum size limitation as long as they do not sell their catch. This can have deleterious and obvious effects on juvenile recruitment into the fishery. Second, recreational blue crabbers do not need a saltwater fishing license if they conduct their harvest from the shore or wading depths, provided they do not have more than 5 traps. These two factors make it extremely difficult to generate valid landings data for the fishery as a whole.

The hard-shell blue crab harvest takes place throughout the year and in a variety of habitats, including freshwater, estuarine and oceanic waters. In 1994 this fishery ranked second

in volume and seventh in value of all commercial fisheries (Steele and Bert, unpublished). Gulf coast landings historically exceed those of the east coast. Peak commercial landings on the Gulf coast occur from May to June, while the peak months on the east coast are from May to October. Although the peak season is longer on the east coast, landings are higher during a shorter season on the Gulf coast. From 1985-1995 the Atlantic coast hard-shell blue crab landings averaged 5.1 million pounds per year with 1995 realizing a drastic decline to 3.4 million pounds (Steele and Bert, unpublished). Blue crab landings are consistently low from Dade County north to St. Lucie County.

2.5 Fishery Questionnaires

Questionnaires were designed and disseminated to commercial trap and trawl fishermen in order to supplement and update information reported in previous studies. The questionnaires had five main areas of focus: demographic information, description of gear, description of effort, historical status and trends, and current and past fishing grounds. Examples of each of these questionnaires are given in Appendices I-IV.

2.5.1 Bait shrimp fishery

The *de facto* representative of the bait shrimp fishers from each marina was contacted and a meeting arranged. The representatives agreed to distribute the questionnaires to each shrimper and subsequently collect them. The rationale behind this strategy was to let the shrimpers deal with "one of their own" since there is frequently the perception that studies of this kind may negatively affect the shrimpers. The representatives have assisted RSMAS many times over the years and were the main contact persons during the Berkeley et al. (1985) study. These questionnaires were distributed to all commercial bait shrimpers known to fish in Biscayne bay.

The shrimp fisher questionnaire was designed to update and supplement information from bait shrimp landings statistics and previous studies (Table 2.5.1).

Bait shrimp fishery questionnaire results are shown in Table 2.5.1. Currently, there are 25 shrimping boats operating in Biscayne Bay during the cool, dry season; a smaller, undetermined number work in the warm, wet season. Home marinas for the fleet are Black Point, Dinner Key, and Virginia Key. All 25 boat owners received the questionnaire, only six have been returned thus far. Though small, this number nevertheless represents approximately 20% of the fishery. From the returned questionnaires, the results may be summarized as follows. The average age of the boat owners is 42, the age of the captains varies and is subject to frequent change. Three shrimpers operated with one or two deckhands, one shrimper operated alone. The number of

Table 2.5.1- Bait shrimp fisher questionnaire responses. H, M, L stands for (H)igh, (M)edium or (L)ow. N, I, D indicates (N)o, (I)ncrease or (D)ecrease. N, B, S is (N)o, (B)igger or (S)maller.

<u>Boat</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>MEANS</u>
3. Dock or marina	Din Key	Din Key	Din Key	Blk pnt			
4. Boat size (ft)	34	34	24	28	32	38	32
5. Hull (Wood or Fibreglass)	f	f	f	f	f	f	
6. Years boat operated in fishery	16	11	8	8	15	15	12.17
7. Do you own the boat?	y	y	y	y	y	y	
8. Rollerframes (Single / Pair)?	p	p	p	p	p	p	
9. Rollerframe width (first)	14	14	12	12	10	10	
10. Rollerframe width (second)	14	14	12	12	10	10	
11. Mesh size (inches)							
Main	1.25	1.25	1.25-1.5	1.25			
Tail	1	1		1			
12. Age of gear (years)	2	2	1	6	2	2	2.5
13. Your age (owner)	44	44	42	39	42		42.2
14. Number of deckhands	1	1	0	2	0		
15. Average age of deckhands	18-65	18-65		25			
16. Years fished shrimp in Bay							
Full-time	22	22	15	8	27		16.75
Part-time	8	8					
17. Weeks per year	52	52	50	52	52		51.5
18. Average order size/night (1000)							
Sunday	10	10	13	9			10.5
Monday	7.5	7.5	6	9			7.5
Tuesday	9	9		9	5		8
Wednesday	8.5	8.5	11	9			9.25
Thursday	12	12	14	9			11.75
Friday	14	14	14	9	10		12.2
Saturday	15	15	14	9	10		12.6
19. Average catch per season							
November-April	16000	16000	13000				
May-October	8000	8000	7000				
20. Average catch/month (h, m, l)							
November	m	m	h	m			
days/week	7	7	4				
hours/night	8	8	8	10			8.5
December	h	h	h	m			
days/week	7	7	4				
hours/night	8	8	8	10			8.5
January	h	h	h	m			
days/week	7	7	6				
hours/night	8	8	10	10			9
February	h	h	h	m			
days/week	7	7	6				
hours/night	8	8	10	10			9
March	h	h	m	m			
days/week	7	7	5				
hours/night	8	8	9	10			8.75

April	m	m	m	m			
days/week	7	7	5				
hours/night	8	8	8	10			8.5
May	m	m	m	m			
days/week	7	7	5				
hours/night	8	8	8	10			8.5
June	l	l	l	m			
days/week	7	7	5				
hours/night	8	8	7	10			8.25
July	l	l	l	m			
days/week	7	7	5				
hours/night	8	8	7	10			8.25
August	l	l	l	m			
days/week	7	7	5				
hours/night	8	8	7	10			8.25
September	l	l	m	m			
days/week	7	7	4				
hours/night	8	8	8	10			8.5
October	m	m	m	m			
days/week	7	7	4				
hours/night	8	8	8	10			8.5
21. Monthly distribution changed (n, i, d)	d	d	n	n	i	i	
22. Catch/trip changed (n, i, d)	n	n	d	n	n	n	
23. Size changed (n, b, s)	n	n	s	n	n	n	
24. Operate Live-haul truck (y, n)	y	y	n	n	n	n	
25. If Y, how many	2	2					
27. Average price/1000 shrimp							
Winter	34	34	34	40	40	40	37
Summer	34	34	35	40	40	40	37.17
28. Price changed (y, n)	n	n	n	n	n	n	
29. How changed							
30. Fish outside Biscayne Bay (Y, N)	n	n	y	y	n	n	
31. More/less/same than previous years (m//s)			s	s			
32. Do you keep a logbook (Y, N)	y	y	n	y	n	n	
33. Is it available for data collection (Y, N)	y	y		n			
34. Total average trip costs							
per trip							
per week			1200				
per month							
Average order size / night	10,857.14	10,857.14	10,285.71	9,000.00			10250
Total order size / week	76,000.00	76,000.00	72,000.00	63,000.00			71750
Projected boat income / week							
Winter	\$2,584.00	\$2,584.00	\$2,448.00	\$2,520.00			2534
Summer	\$2,584.00	\$2,584.00	\$2,520.00	\$2,520.00			2552
Projected Owner income / week							
Winter	\$1,292.00	\$1,292.00	\$1,224.00	\$1,260.00			
Summer	\$1,292.00	\$1,292.00	\$1,260.00	\$1,260.00			

Effort

Hours / week

35370	56	56	32	0	48
35400	56	56	32	0	48
35065	56	56	60	0	57
35096	56	56	60	0	57
35125	56	56	45	0	52
35156	56	56	40	0	51
35186	56	56	40	0	51
35217	56	56	35	0	49
35247	56	56	35	0	49
35278	56	56	35	0	49
35309	56	56	32	0	48
35339	56	56	32	0	48

Average hours / week

Winter	56.0	56.0	44.8	0.0	52
Summer	56.0	56.0	34.8	0.0	49
Year	56.0	56.0	39.8	0.0	51

years the owners have shrimped in the bay varies from 8 to 22 years, the average being 16.8 years. All respondents possessed fiberglass-hulled vessels which averaged 30 feet in length. The mean length of time these boats had operated in the fishery was 10.75 years. For each respondent, shrimping was conducted 52-weeks of the year. All respondents towed rollerframe trawls in pairs; with frame widths were either 12 or 14 feet. Mean age of the rollerframe trawls was 2.75 years. The average order size per night varies from about 9000 shrimp in the middle of the week to 13,250 shrimp on the weekend. Average nightly catch varied from 7,000 shrimp in the warm, wet season, to 16,000 shrimp in the cool, dry season. Mean hours of fishing per night was 8.5 hours, irrespective of season.

Responding shrimpers sketched their current and past fishing grounds on an attached map of Biscayne Bay. This information was transferred into our GIS database and is discussed in the next section. The extent to which the current fishing areas for these boats can be considered representative of the entire fleet is uncertain, however, some general trends were evident. Generally, trawling during the warm, wet season occurred close to shore (within 2 miles), from just below the Rickenbacker Causeway to Turkey Point. During the winter season the shrimpers venture further offshore, trawling anywhere from Coconut Grove/Coral Gables to the Sands Key/Totten Key area. Some shrimpers have stated that the areas around Coconut Grove/Coral Gables have realized a decrease in the numbers of shrimp. They feel that this decline in size is due to an increase in "slime and algae", possibly the result of nutrient-loaded freshwater runoff from land. Other areas identified by the respondents that experienced a decrease in both size and numbers were the Featherbed Banks, Pelican Bank and between Dinner Key and the Rickenbacker Causeway. While the shrimpers stated that this change occurred over the last 10 years, it has not been quantitatively determined. The respondents made it particularly clear in the "Comments" section of the questionnaire that they were very skeptical of this study and felt that they had nothing to gain by completing the questionnaires.

2.5.2 Trap fisheries

As with the bait shrimp fishery, questionnaires were designed for the local blue crab, spiny lobster and stone crab fisheries to increase our understanding of their impacts on BNP habitats (Appendices II-IV). These questionnaires were delivered to Biscayne National Park personnel for distribution to trap fishermen during their routine activities and patrols in BNP. To date, we have received no responses.

3.0 FIELD SURVEYS AND GROUND-TRUTHING

The distribution of commercial fishing activity across habitats within BNP was obtained from shrimp trawler questionnaire results, and from an aerial survey followed by snorkel/SCUBA-based surveys conducted from small boats. The purpose of the overflight was to identify clusters of traps which could be subsequently inspected for their identity and effects. Since buoys may indicate either a single trap or the terminal ends of a line connecting multiple traps, the overflights served primarily to locate sampling effort for the next tier of our design conducted from small boats. A sample of buoys were sampled from boats, position was fixed with a portable global positioning system, and the specific trap type was recorded. The most labor-intensive task was the actual SCUBA-based inspection of each trap's impact on microhabitat.

3.1 Spatial extent of trawling over BNP communities

The distribution of bait shrimp trawling within BNP was determined from questionnaires returned from shrimp fishermen. They were asked to sketch their general fishing grounds by season on attached maps of Biscayne Bay and Card Sound which did not bear BNP boundaries. We digitized each of the respondents sketches and superimposed them onto an Arc/Info coverage of Biscayne Bay replete with BNP boundaries, depth strata and bottom community information.

A total of six bait shrimp fishermen sketched their fishing grounds on maps of Biscayne Bay. We digitized each respondent's map and computed the areal extent over habitat types and depth strata for both the wet (i.e., May - October) and dry (i.e., November - April) seasons (Appendix V; Table 3.1.1). Two of the six responding shrimpers, who both operate from Virginia Key, apparently do not fish within BNP boundaries during either season. The remaining four boats operate in areas measuring about 165 km² during the wet season and 350 km² during the dry season. These areas represent 24.6% and 52.2% of BNP's entire submerged substrate, respectively. During both seasons seagrass is the primary habitat trawled, followed by mixed seagrass/hardbottom and then hardbottom. Bait shrimp trawling is concentrated in waters ≤ 3 m deep along the mainland shoreline during the wet season, but expands eastwards into deeper waters (i.e., especially waters 2-4 m deep) during the dry season.

A relative measure of trawling intensity over specific habitats can be gleaned by examining the degree to which our sample of bait shrimp fishermen share fishing grounds. Maps of boat overlap areas for each season are shown in Figures 3.1.2 and 3.1.3. Table 3.1.2 presents the corresponding areal estimates for each depth strata and habitat type trawled by three or more bait shrimp vessels. This analysis suggests that there is a consistent "hot spot" of trawling activity within the Park during both the wet and dry seasons that extends west to east along the BNP

Table 3.1.1- Distribution of fishing effort over habitats and depth strata by six shrimp trawlers within BNP. The Wet Season is from May to October, and the Dry Season is from November to April. Values are areas swept (in km²) by shrimp trawlers. Depth strata are in meters (m).

Wet Season							
(A) Habitat Type	Boat 1	Boat 2	Boat 3	Boat 4	Boat 5	Boat 6	Total
Bare	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Seagrass	13.9909	13.9909	16.2190	44.7152	0.0000	0.0000	88.9160
Seagrass / Hardbottom	5.4244	5.4244	5.1249	38.6378	0.0000	0.0000	54.6113
Hardbottom	0.0000	0.0000	0.0111	21.1604	0.0000	0.0000	21.1716
Coral	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Uninterpreted	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	19.4152	19.4152	21.3550	104.5134	0.0000	0.0000	164.6989

(B) Depth strata	Boat 1	Boat 2	Boat 3	Boat 4	Boat 5	Boat6	Total
0-1 m	5.3803	5.3803	5.5696	21.4576	0.0000	0.0000	37.7878
1-2 m	11.9525	11.9525	15.1394	70.0129	0.0000	0.0000	109.0573
2-3 m	2.0825	2.0825	0.6461	13.1772	0.0000	0.0000	17.9882
3-4 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4-6 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6-10 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>10m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	19.4153	19.4153	21.3551	104.6477	0.0000	0.0000	164.8333

Dry Season							
(C) Habitat Type	Boat 1	Boat 2	Boat 3	Boat 4	Boat 5	Boat 6	Total
Bare	0.3673	0.3673	0.0000	5.2645	0.0000	0.0000	5.9991
Seagrass	19.2442	19.2442	56.2145	127.6633	0.0000	0.0000	222.3661
Seagrass / Hardbottom	4.0092	4.0092	14.1291	57.3672	0.0000	0.0000	79.5146
Hardbottom	0.0223	0.0223	5.2501	37.3433	0.0000	0.0000	42.6379
Coral	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Uninterpreted	0.0000	0.0000	0.0000	0.3790	0.0000	0.0000	0.3790
Total	23.6429	23.6429	75.5936	228.0172	0.0000	0.0000	350.8967

(D) Depth strata	Boat 1	Boat 2	Boat 3	Boat 4	Boat 5	Boat6	Total
0-1 m	0.2117	0.2117	0.6019	20.1586	0.0000	0.0000	21.1840
1-2 m	6.3718	6.3718	8.2473	93.9119	0.0000	0.0000	114.9028
2-3 m	10.3052	10.3052	44.7518	84.5078	0.0000	0.0000	149.8700
3-4 m	6.6151	6.6151	21.9925	28.2064	0.0000	0.0000	63.4290
4-6 m	0.1447	0.1447	0.0000	1.2355	0.0000	0.0000	1.5249
6-10 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
>10 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	23.6485	23.6485	75.5935	228.0202	0.0000	0.0000	350.9107

Figure 3.1.2- Areas swept by one, two and three or more shrimp trawlers during the wet season (May-October). White line delineates BNP boundary.

- 1 boat

- 3 or more boats



Figure 3.1.3- Areas swept by one, two and three or more shrimp trawlers during the dry season (November-April). White line delineates BNP boundary.

• 1 boat

• 2 boats

• 3 boats

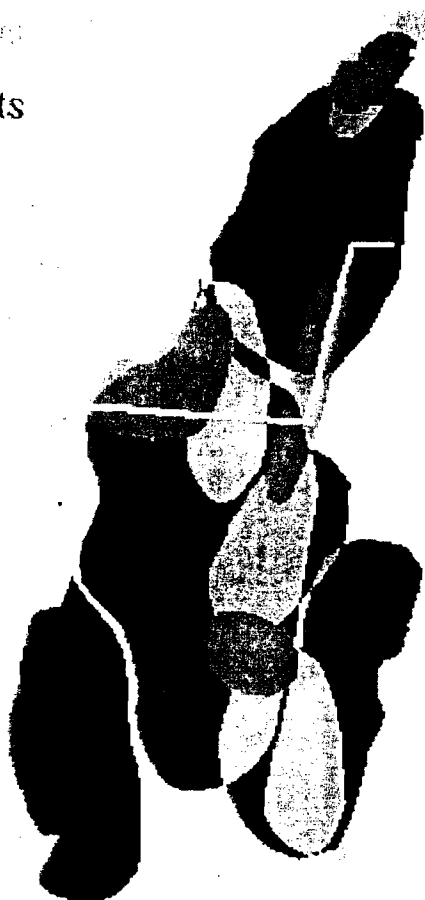


Table 3.1.2- Habitat distribution of fishing overlap area of 3 or more boats in Biscayne National Park. The Wet Season is from May to October, and the Dry Season is from November to April. Values are areas swept (in km²) by shrimp trawlers. Depth strata are in meters (m).

(A)

Wet Season

Habitat Type	0-1 m	1-2 m	2-3 m	3-4 m	4- 6m	6-10m	>10m	Total
Bare	0.2670	0.0222	0.0445	0.0000	0.0000	0.0000	0.0000	0.3337
Seagrass	7.4156	17.4475	11.9875	0.5344	0.0000	0.0000	0.0000	37.3849
Seagrass / Hardbottom	0.0000	3.8096	5.7788	0.0000	0.0000	0.0000	0.0000	9.5883
Hardbottom	0.0000	0.0779	0.2004	0.0000	0.0000	0.0000	0.0000	0.2783
Coral	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Uninterpreted	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	7.6825	21.3572	18.0112	0.5344	0.0000	0.0000	0.0000	47.5852

(B)

Dry Season

Habitat Type	0-1 m	1-2 m	2-3 m	3-4 m	4- 6m	6-10m	>10m	Total
Bare	0.2225	0.0779	0.4227	1.1463	0.1113	0.0000	0.0000	1.9806
Seagrass	3.5498	11.5243	13.3200	9.2532	0.0334	0.0000	0.0000	37.6807
Seagrass / Hardbottom	0.0000	1.1470	6.9260	0.1002	0.0000	0.0000	0.0000	8.1731
Hardbottom	0.0000	0.0779	0.2227	0.0000	0.0000	0.0000	0.0000	0.3006
Coral	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Uninterpreted	0.0111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0111
Total	3.7834	12.8270	20.8913	10.4997	0.1447	0.0000	0.0000	48.1461

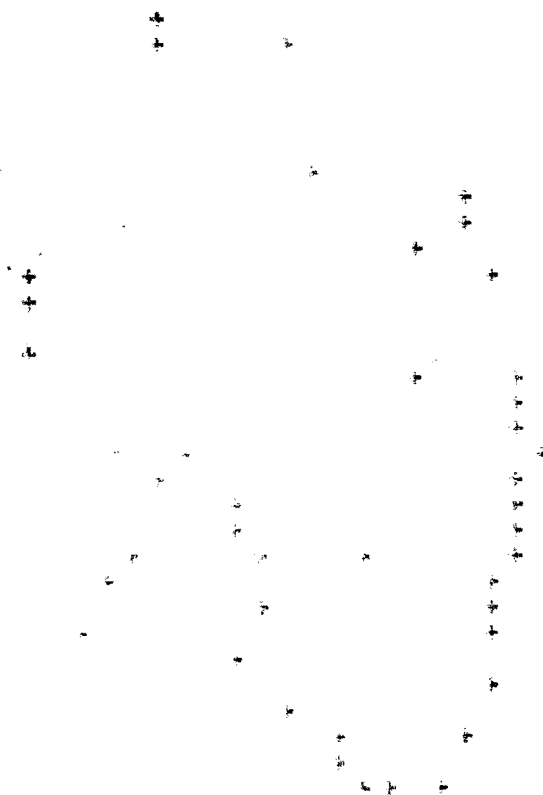
boundary just south of Chicken Key. Because three or more boats trawl this area during both seasons, it is here that one would expect habitat damage, if any, to be most severe. Seasonal "hot spots" (i.e., fished by three or more boats) are located off Black Point during the wet season, and over Featherbed Bank during the dry season. During both seasons, seagrass in water 1 m to 3 m deep is the primary habitat that receives three boats or more of trawling pressure.

3.2 Trap fishery overflight

Our overflight of BNP was conducted during daylight hours on December 6, 1996, to locate trap buoys and record their relative densities. We contracted a pilot with a single-engine, four-seater Cessna 172 plane to fly at an average airspeed of 75 miles per hour about 500 feet above sea level (i.e., the minimum legal altitude). We recorded the position of all observed buoys using a hand-held global positioning system (GPS; Magellan NAV DLX-10). The day was sunny, visibility was 10+ miles, and wave height east of the barrier islands was minimal. Buoys were clearly visible for approximately one km on either side of the plane. As each buoy was spotted within 0.5 km either side of the plane (i.e., directly adjacent to the plane, or directly east and west of the midsection of the plane), its GPS coordinates were recorded. While there was some error in designating exact buoy position from the air, the method proved sufficient for directing boat-based operations to clusters of traps at which point more accurate GPS coordinates were recorded.

A map showing trap buoys observed during the overflight is shown in Figure 3.2.1. The first flight path began approximately four km east of Caesar Creek and progressed north to Cape Florida. It was on this path that the majority of the trap buoys were spotted. There is a high frequency of what were presumed to be spiny lobster traps on the eastern side of Elliott Key that extended northward directly parallel to the patch reef system nearby. It appeared that most of the traps were located on the western edge of the reef system, very close to the reefs themselves. A more southerly flight path brought us closer to the eastern edge of Elliott Key, within 200 meters of its windward shore. The third flight path began approximately 300 meters west of Caesar Creek and progressed north to Virginia Key. Several trap buoys were recorded within 200 meters of the eastern edge of Elliott Key. On the southerly flight path from Virginia Key to the Arsenicker Keys several buoys located near the intracoastal waterway were seen. On the final northerly flight path, the route began at the Arsenicker Keys and progressed north along the mainland. Several buoy clusters were recorded within 100 meters of shore.

Figure 3.2.1- Aerial survey buoy cluster locations. White line delineates BNP boundary.



3.3 Spatial extent of trapping over BNP communities

Using information gleaned from our aerial survey, we located clusters of buoys from small boats. We visited 245 trap buoys, identified the attached trap types and obtained GPS coordinates on each. We then plotted trap locations over our GIS bottom community coverages to reveal the major community types (i.e., bare bottom, seagrass, seagrass/hard bottom, hard bottom, and offshore reef) in which each of the trap fisheries operates. We found that approximately 52% of the spiny lobster traps that we inspected were located within seagrass communities, 33% were located within offshore patch reef communities, and 14% were located within bare substrate communities. All stone crab traps inspected were more-or-less equally distributed over seagrass, hardbottom and mixed seagrass/hardbottom habitat. The blue crab traps were located almost exclusively over seagrass substrates located close to the southwestern shoreline between Black Point and Turkey Point.

3.4 Affected microhabitats

While knowledge of the general community type fished is important, identification of precisely which taxa were potentially being damaged required information on a scale commensurate with the dimensions of each trap (i.e., 1 - 4 m² scale). To this end, we began characterizing and quantifying the microhabitats under fishery traps as well as that immediately adjacent to them. This was accomplished through underwater inspection using SCUBA, snorkeling and video techniques. The microhabitat upon which the respective traps were set was characterized by quantifying the co-occurrence of traps over four main substrate types, namely, plant, bare, coral and sponge. These four categories were then subdivided further. For example, plants were identified as *Thalassia*, *Syringodium*, *Halodule*, *Ruppia*, red algae, calcareous algae or some combination thereof. Bare bottom was identified as some combination of mud, sand, broken shell, rock or rubble. Coral were identified as hard, gorgonian or plexauran coral. And sponges were identified as vase, tube, branching, massive or encrusting.

Our microhabitat assessment area was a 4 m² meter area in which the trap was at the center. We inspected the area immediately around a given trap as well as underneath it. Characterization of the area immediately adjacent to the traps was necessary in the event that damage prior to inspection had obscured the type of microhabitat affected. Percent coverage of each of the detailed microhabitat categories adjacent to each trap was determined visually. Inspection of the area directly underneath the trap was accomplished by tilting the trap on its edge

and noting the organisms and substrate beneath. The trap "foot print" was also recorded on video tape.

Spiny Lobster Traps

A total of 29 spiny lobster traps was visited by boat and microhabitat data were collected for each (Figure 3.4.1). Spiny lobster traps were found on plants 86% of the time and were located on bare habitat 100% of the time. The mean habitat coverage was 59% plant, and about 41% bare. Sixty-three percent of the plant coverage was *Thalassia* and 86% of the bare coverage was sand. Further analysis shows that 68% of the traps were located on plants that covered from 80-100% of the trap area. Therefore, the predominant organism upon which spiny lobster traps are placed is *Thalassia*. Whether the bare, sandy patches observed were natural or created by the traps is unknown.

Stone Crab Traps

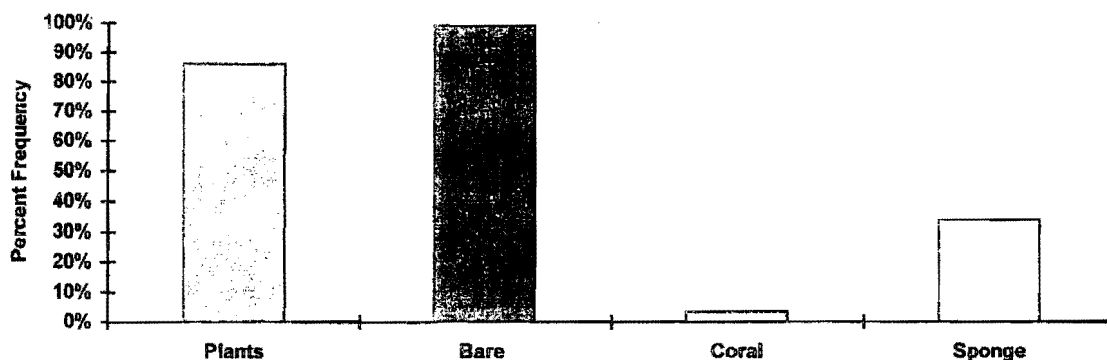
A total of 99 traps was visited, all located west of the barrier islands. Plants of some type were found under and directly adjacent to the stone crab traps in all cases. Sponges were found in about one third of all cases (Figure 3.4.2). The average coverage of stone crab microhabitat was 25% plant (70% *Thalassia* and 17% red algae), 72% bare (59% sand and 22% broken shell), and less than 2% each for soft coral and sponge. Therefore, stone crab trapping primarily affects *Thalassia*, with soft corals and sponges potentially impacted to a lesser degree.

Blue Crab Traps

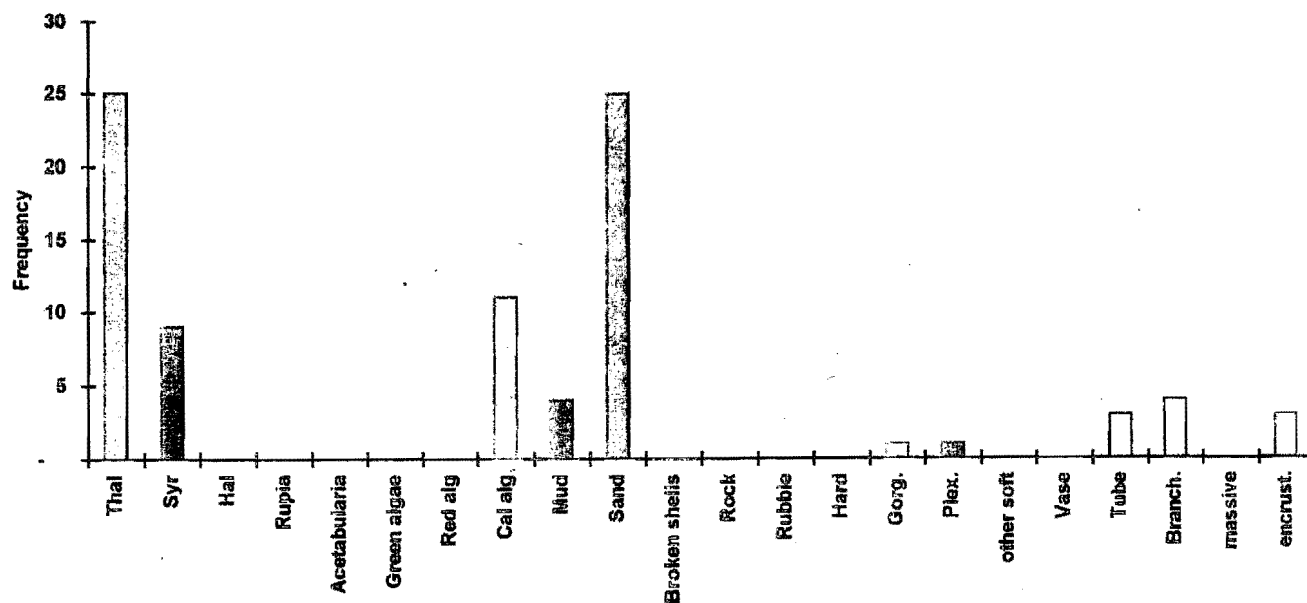
A total of 56 blue crab traps was inspected for microhabitat information (Figure 3.4.3). Blue crab trapping within BNP is conducted almost exclusively within 200 meters of the western shore of the Bay between Turkey Point and Black Point. All blue crab traps inspected were found over plants and/or bare areas with no coral or sponges present. The average blue crab trap microhabitat composition was 55% plant (80% *Halodule*) and 45% bare (34% sand, 29% mud and 23% broken shell). Again, we could not ascribe the bare areas observed to trap damage during this phase of the study.

Figure 3.4.1- Microhabitat data pertaining to the lobster trap fishery. Plants indicate seagrasses and macroalgae. Thal is *Thalassia*; Syr is *Syringodium*; Hal is *Halodule*; Red alg is Red Algae; Cal alg is Calcareous algae; Hard is Hard Corals; Gorg. is Gorgonians; Plex. is Plexauran; Other Soft is Other Soft Corals; Branch. is Branching Sponges; and Encrust. is Encrusting Sponges.

(A)



(B)



(C)

Average percent cover

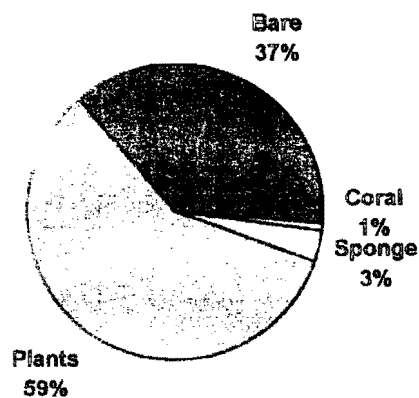
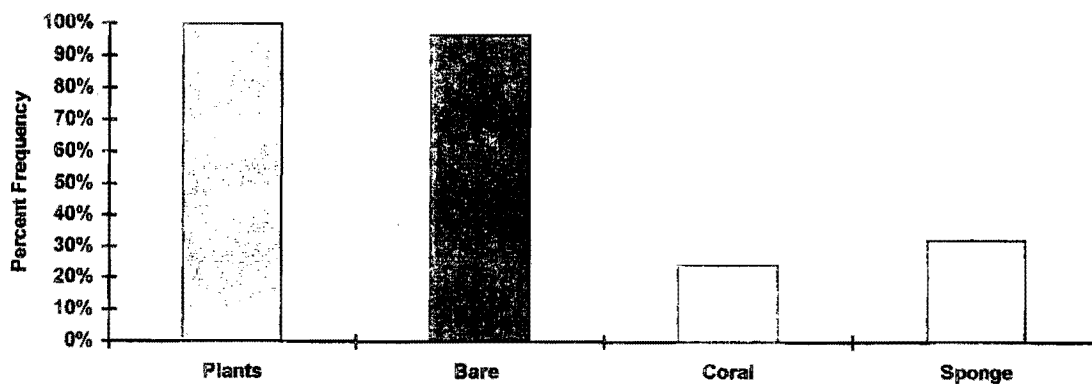
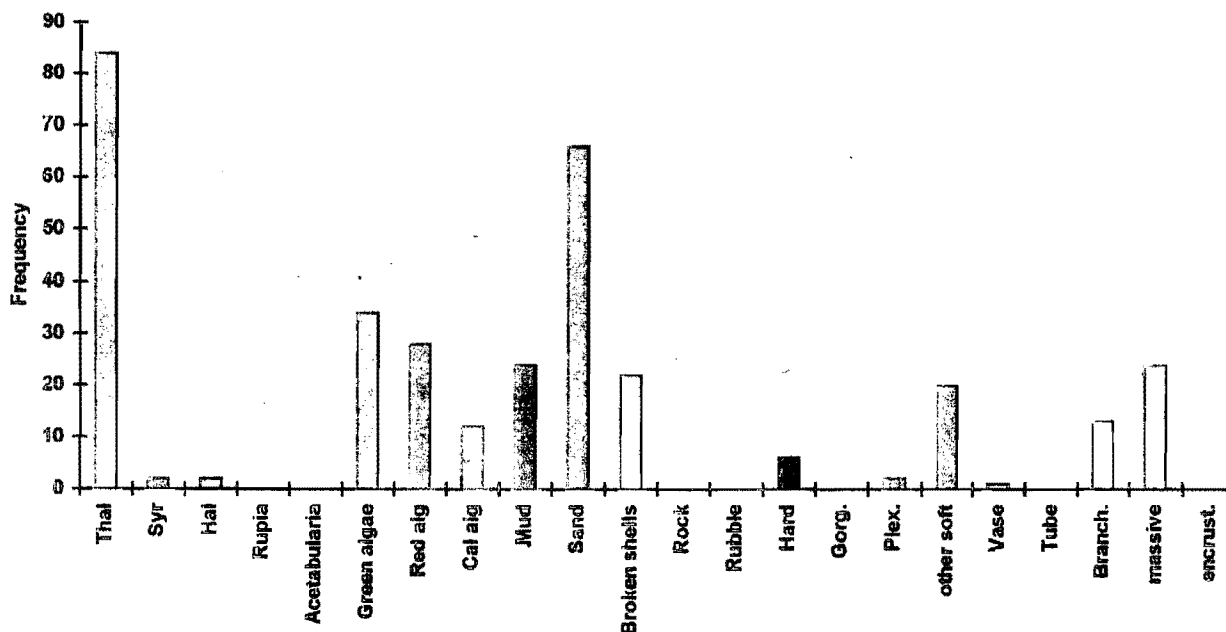


Figure 3.4.2- Microhabitat data pertaining to the stone crab trap fishery. Plants indicate seagrasses and macroalgae. Thal is *Thalassia*; Syr is *Syringodium*; Hal is *Halodule*; Red alg is Red Algae; Cal alg is Calcareous algae; Hard is Hard Corals; Gorg. is Gorgonians; Plex. is Plexauran; Other Soft is Other Soft Corals; Branch. is Branching Sponges; and Encrust. is Encrusting Sponges.

(A)



(B)



(C)

Average percent cover

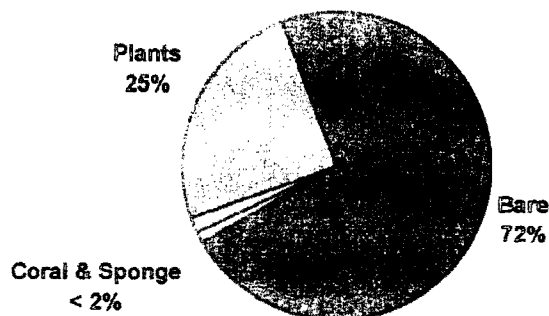
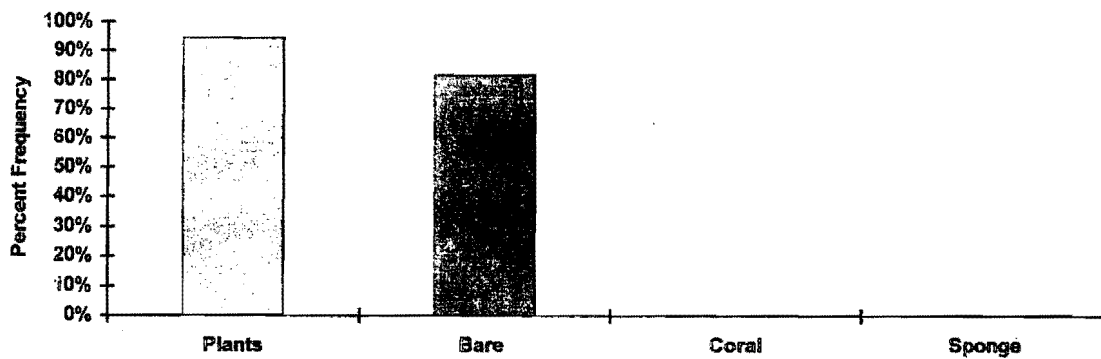
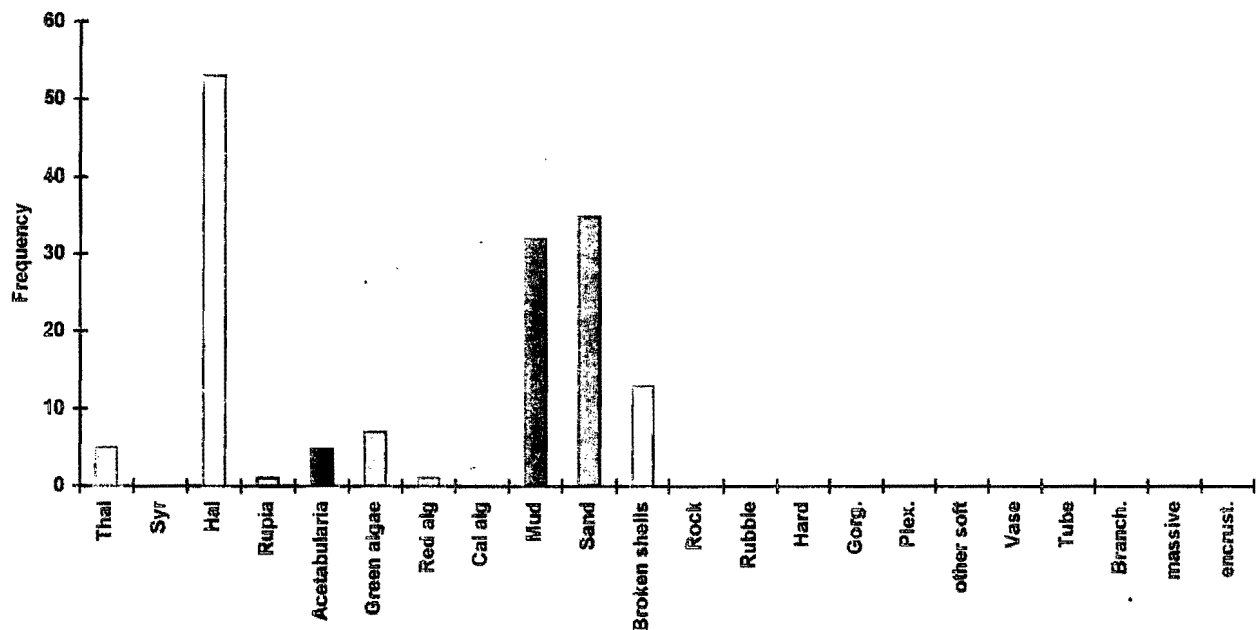


Figure 3.4.3- Microhabitat data pertaining to the blue crab trap fishery. Plants indicate seagrasses and macroalgae. Thal is *Thalassia*; Syr is *Syringodium*; Hal is *Halodule*; Red alg is Red Algae; Cal alg is Calcareous algae; Hard is Hard Corals; Gorg. is Gorgonians; Plex. is Plexauran; Other Soft is Other Soft Corals; Branch. is Branching Sponges; and Encrust. is Encrusting Sponges.

(A)

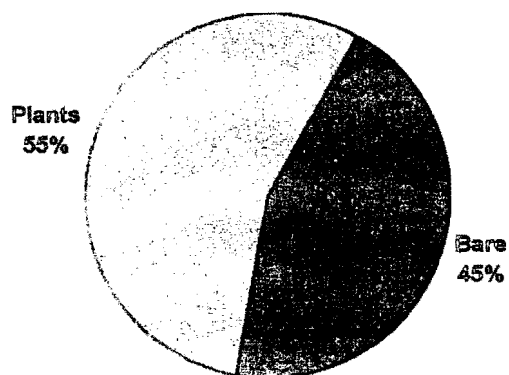


(B)



(C)

Average percent cover



4.0 FIELD EXPERIMENTS

Concentrating on trawling and trapping in relevant habitat types, we conducted field experiments in which specific experimental sites were monitored over time. Experimental treatments were several levels of simulated (i.e., investigator controlled) fishing. In most cases, impacts were examined over several time scales: (1) initial conditions (i.e., prior to disturbance); (2) short-term (days); and (3) longer-term (after one week and after one month).

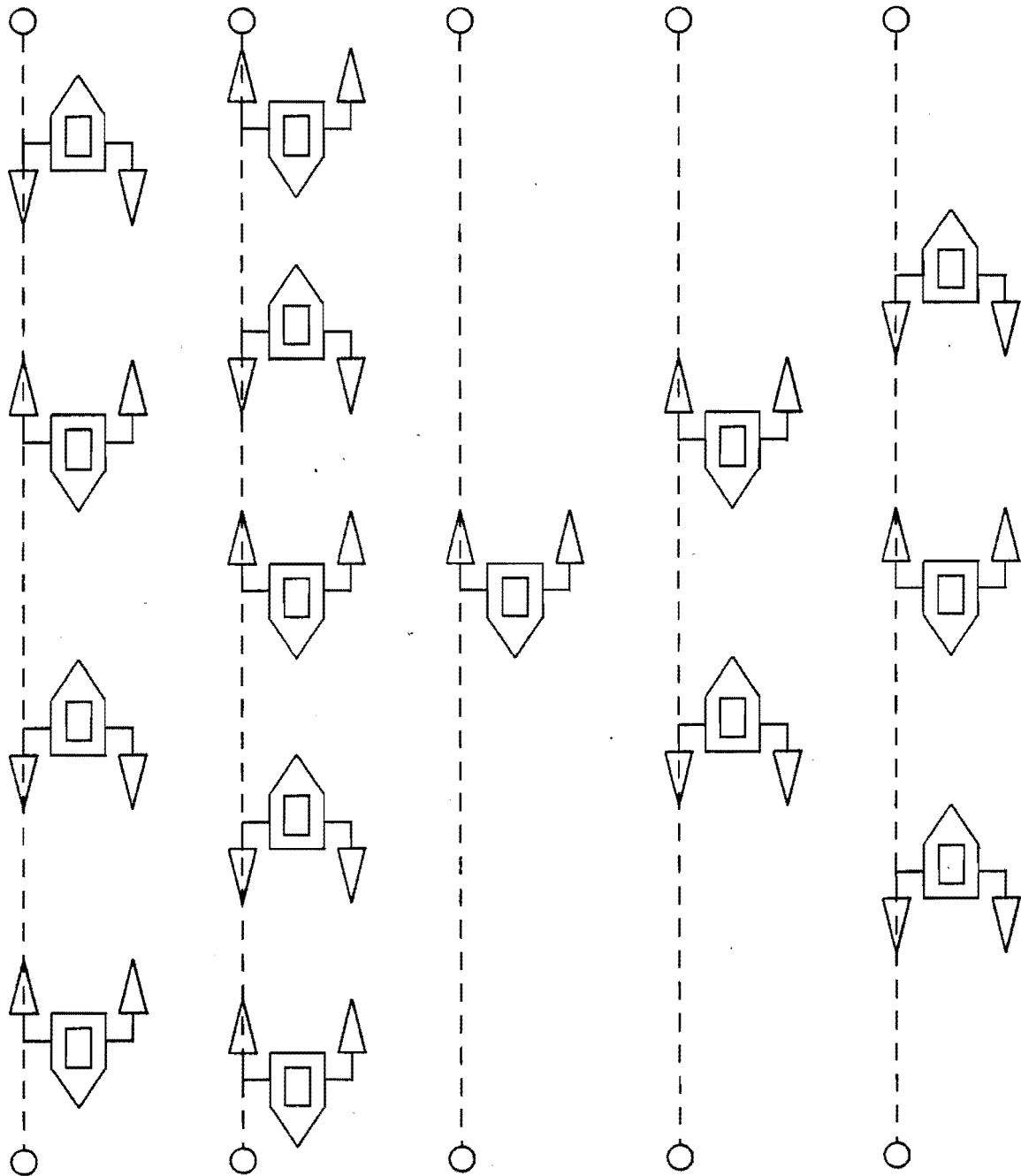
4.1 Experimental rollerframe trawling

Bottom damage by rollerframe trawls was assessed by collecting pre- and post-trawl data along linear transects within the two community types most trawled, namely, seagrass and hardbottom. Before experiments, preliminary diver surveys were conducted to locate areas that were representative of habitats trawled (i.e., in terms of species composition and organism density), yet showed only limited signs of physical damage prior to experimentation. The seagrass area selected for field experimentation was located just north of the Viscaya channel, near Coconut Grove, where water depths ranged from 1.6 m to 2.6 m. The hardbottom area selected for controlled disturbance was located within BNP just south of the Featherbed Bank where water depths ranged from 2.5 m to 3.0 m.

Within each habitat type, five linear transects, 200 m in length, were demarcated with surface floats and cinder blocks. Transects were parallel to one another and spaced approximately 50 m apart (Figure 4.1.1). The length of each transect was measured using a 200 m floating line with two anchors attached to each end. This line was deployed by setting one anchor, stretching the line taught, and then setting the second anchor. We photographed the substrate along the entire length of each transect using an 8 mm video camera with wide-angle lens inside an underwater housing. A second 200 m line, with lead weights placed every 10 m, was also deployed along the transect and served to keep the photographer within the "alley" designated for trawling. During filming, the camera was held approximately 60 cm above the substrate tilted about 10° towards the bottom. Upon completion of initial condition filming, each transect was trawled by a commercially-licensed bait shrimp fisherman using his regular boat and gear. Prior to trawling, transects were randomly designated to receive from one to five trawl passes. Post-trawl filming ensued within 24 h of trawling disturbance.

Pre- and post-trawl footage of each transect was processed in the laboratory. Footage resulting from the seagrass trawl experiments was digitized and analyzed to provide estimates of percent cover for every 0.5 meter of each transect. Footage resulting from the hard bottom trawl

Figure 4.1.1- Experimental design to measure the impact of rollerframe shrimp trawlers on benthic habitats in Biscayne Bay. Each line represents a 200 by 3 meter transect spaced 50 meters apart. Transects were randomly selected to receive 1-5 passes. Each transect was video taped immediately prior to and 24 hours after the trawls were performed.



experiments could not be effectively digitized using our equipment. Hence, it was viewed by trained technicians who identified and counted numbers of damaged versus undamaged sponges, soft corals, hard corals and bottom-attached *Sargassum* plants. Damage was assigned to an individual organism or individual colony if any of the following characteristics were clearly observable on the video images: uprooted, toppled, broken branches or limbs, severely bent branches or limbs, cut or torn tissue.

Though the five hard bottom transects were all within a 0.5 km² area, they were not identical prior to experimentation. Indeed, each transect had varying numbers and types of sponges and corals as well as differing levels of damage prior to experimentation. Consequently, we focused on proportional comparisons in our analyses. First, the proportion of damaged organisms was calculated for each transect twice: once before it was trawled and once afterward. Next, the proportion of additional damage incurred by investigator-controlled trawling was calculated as the difference between the pre- and post-trawl damage proportions divided by the proportion of undamaged organisms prior to trawling. Finally, the relationship between number of trawl passes and the additional damage expected to result to sponges (or corals) was analyzed using nonlinear regression analysis (SAS 1990). We fit the model

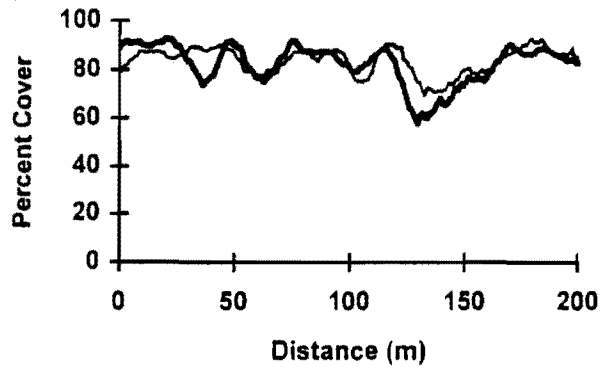
$$D_T = b_0[1 - e^{-(b_1 T)}]$$

where D_T is the proportional damage incurred after T trawl passes and b_0 and b_1 are estimated coefficients.

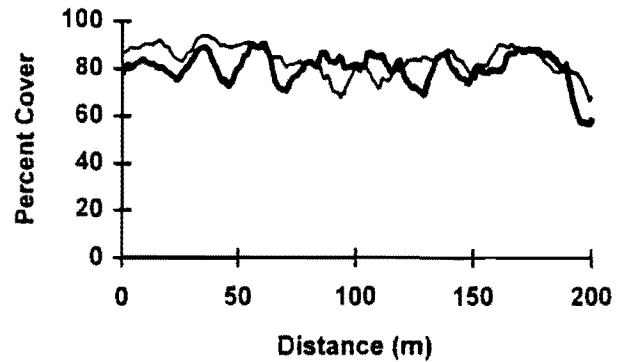
Results of the trawl experiments conducted over the seagrass transects are presented in Figure 4.1.2. As has been reported in several previous studies, we were unable to detect any damage along the seagrass bed transects, regardless of the number of times they were trawled. However, damage to sessile invertebrates along the hardbottom transects was conspicuous after one pass with the damage rate tending to diminish with each subsequent increment of trawling effort (Tables 4.1.1 and 4.1.2; Figures 4.1.3 and 4.1.4). For example, one trawl pass led to the damage of about 9% of all sponges and 17% of all corals, while five trawl passes resulted in damage to 25% of all sponges and 30% of all corals. The sponge *Ircina felix* and the corals of the genus *Pseudoplexaura* appeared to be the taxa most vulnerable to trawling disturbance.

Figure 4.1.2- Trawling effects on seagrass coverage. Distance represents distance along the transect in meters (m). Pre-trawl plant cover indicated by thin line. Post-trawl plant cover indicated by bold line.

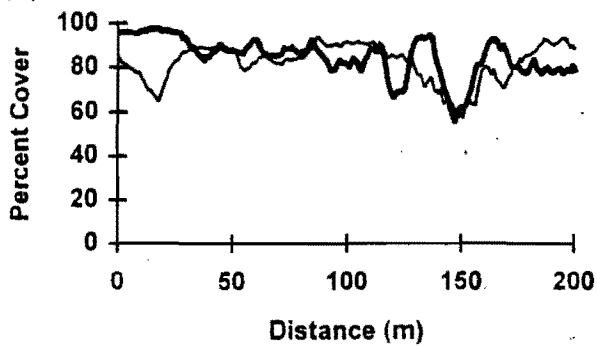
(A) One Trawl Pass



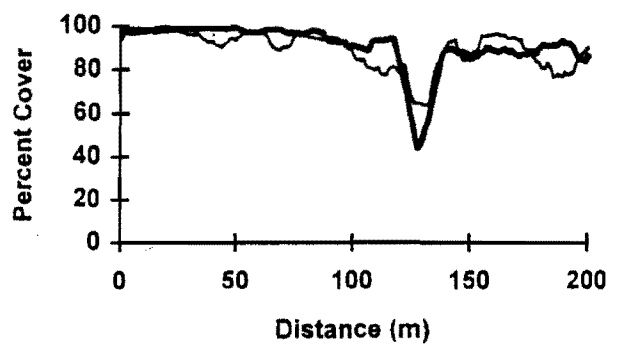
(B) Two Trawl Passes



(C) Three Trawl Passes



(D) Four Trawl Passes



(E) Five Trawl Passes

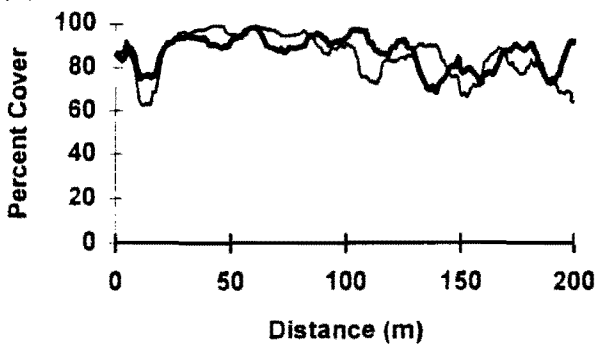


Table 4.1.1- Sponge damage observations pre- and post- trawling. Prop. stands for proportion.

Sponges	One Pass	
	Pre-Trawl	Post-Trawl
Number Undamaged	74	65
Number Damaged	4	13
Prop. Undamaged	0.949	0.833
Prop. Damaged	0.051	0.167
Prop. Damage Incurred	0.122	

Sponges	Two Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	51	38
Number Damaged	8	14
Prop. Undamaged	0.864	0.731
Prop. Damaged	0.136	0.269
Prop. Damage Incurred	0.155	

Sponges	Three Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	107	72
Number Damaged	2	13
Prop. Undamaged	0.982	0.847
Prop. Damaged	0.018	0.153
Prop. Damage Incurred	0.137	

Sponges	Four Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	95	136
Number Damaged	7	59
Prop. Undamaged	0.931	0.697
Prop. Damaged	0.069	0.303
Prop. Damage Incurred	0.251	

Sponges	Five Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	115	93
Number Damaged	3	35
Prop. Undamaged	0.975	0.727
Prop. Damaged	0.025	0.273
Prop. Damage Incurred	0.254	

Table 4.1.2- Coral damage observations pre- and post- trawling. Prop. stands for proportion.

Corals	One Pass	
	Pre-Trawl	Post-Trawl
Number Undamaged	160	126
Number Damaged	17	40
Prop. Undamaged	0.904	0.759
Prop. Damaged	0.096	0.241
Prop. Damage Incurred	0.160	

Corals	Two Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	103	84
Number Damaged	8	35
Prop. Undamaged	0.928	0.706
Prop. Damaged	0.072	0.294
Prop. Damage Incurred	0.239	

Corals	Three Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	178	169
Number Damaged	30	95
Prop. Undamaged	0.856	0.640
Prop. Damaged	0.144	0.360
Prop. Damage Incurred	0.252	

Corals	Four Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	202	207
Number Damaged	17	157
Prop. Undamaged	0.922	0.569
Prop. Damaged	0.078	0.431
Prop. Damage Incurred	0.383	

Corals	Five Passes	
	Pre-Trawl	Post-Trawl
Number Undamaged	293	84
Number Damaged	25	35
Prop. Undamaged	0.921	0.706
Prop. Damaged	0.079	0.294
Prop. Damage Incurred	0.234	

Figure 4.1.3- Experimental trawling impact on sponges. (A) Pre- and post-trawl damage observations versus number of passes. (B) Relationship between number of trawl passes and amount of sponge damage incurred.

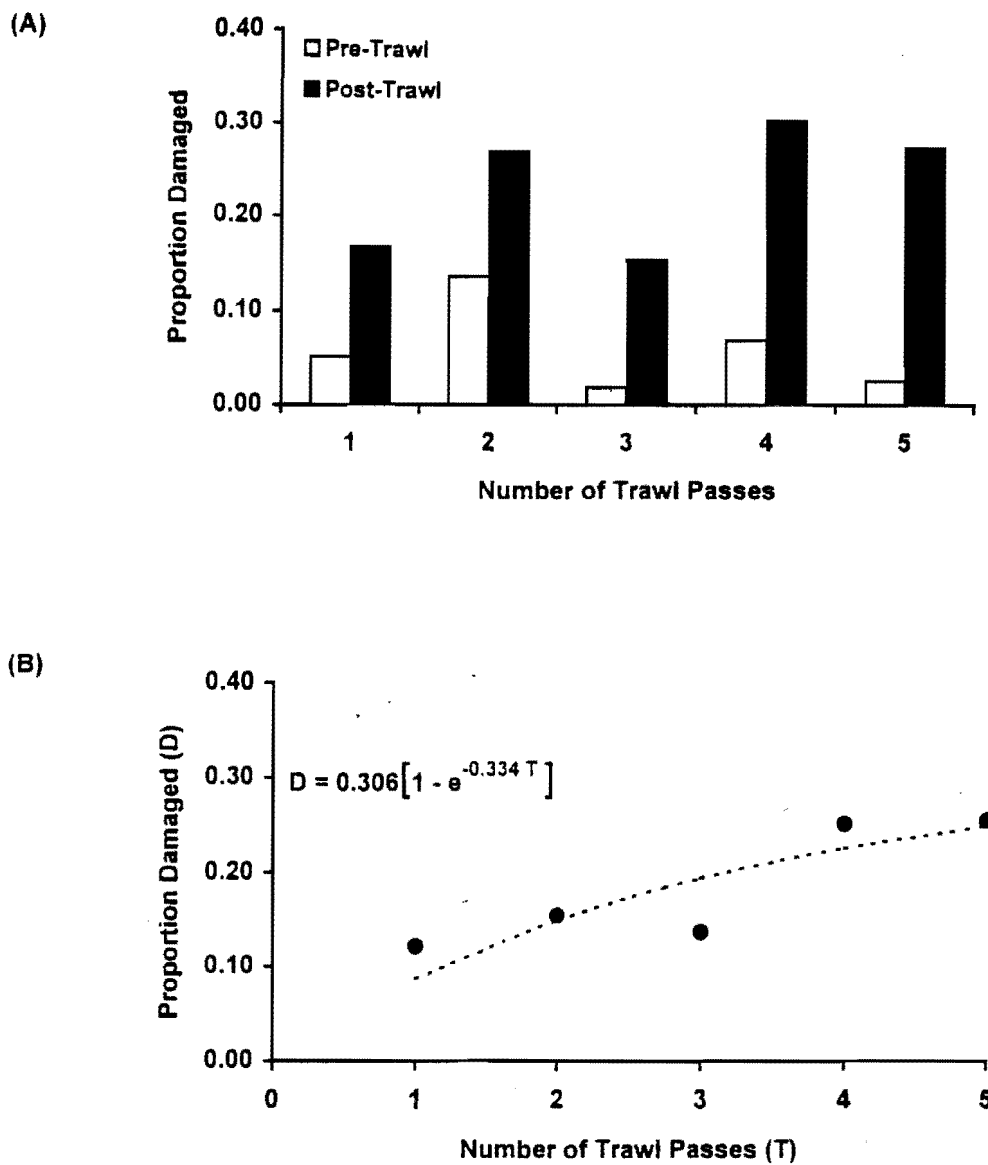
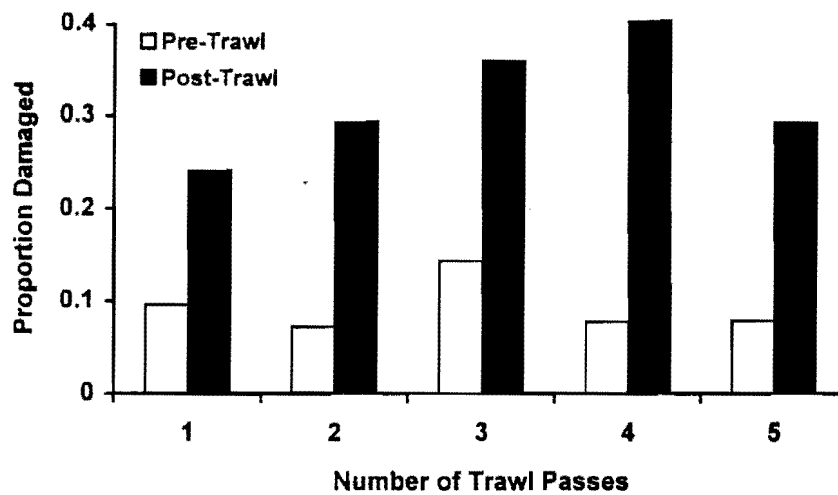
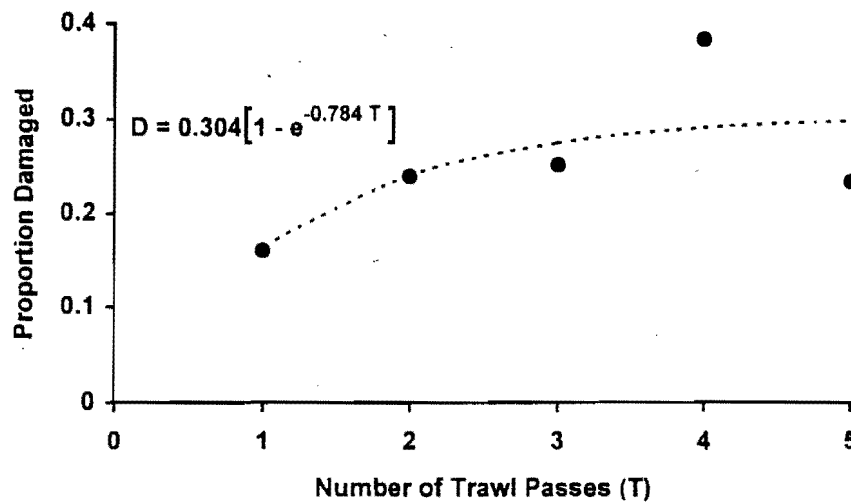


Figure 4.1.4- Experimental trawling impact on soft corals. (A) Pre- and post-trawl damage observations versus number of passes. (B) Relationship between number of trawl passes and quantity of soft coral damage incurred.

(A)



(B)



4.2 Trap experiments

Spiny lobster, stone crab, and blue crab are targeted with traps of heavy, medium and light construction, respectively. Each trap type can potentially inflict habitat damage through extended physical contact with the living substrate, but harm may also occur during deployment, recovery and/or as a result of gear loss (Van der Knaap 1993). The potential for spiny lobster trapping to cause habitat damage warrants particular attention because: (1) spiny lobster traps alone can number in the tens of thousands in Park waters; (2) they are typically set near structurally complex and fragile offshore reefs; (3) they are of especially heavy construction and are dragged during deployment and recovery; and (4) they are frequently abandoned at the end of the fishing season, thus effects can be very long term (i.e., "ghost" traps).

We applied our knowledge of the type of microhabitat and/or taxa most disturbed by each fishery for our trap experiments. In other words, we placed our experimental gear over those microhabitat types that our ground-truthing assessments indicated were most frequently fished by the respective fisheries. Therefore, spiny lobster and stone crab traps were set over *Thalassia* beds and blue crab traps were set over *Halodule* beds. We did not assess impacts on non-living substrates (i.e., bare sand, rock rubble, etc.) nor did we evaluate habitat damage associated with dragging during deployment and recovery. The traps that we used were standard gear purchased from a commercial supplier.

Two sets of experiments on each of the trap types were conducted. In the first set, we placed a group of traps within the respective fishing grounds of each of the fisheries: four spiny lobster traps were placed offshore approximately three miles northeast of Caesar Creek; six stone crab traps were placed west of central Elliot Key; and six blue crab traps were placed just south of Black Point, within 200 meters from shore. Using underwater video photography, the "foot print" of each trap was recorded on days 0, 7, and 30 post-placement. Video frames were then selected, digitized and analyzed to provide estimates of percent cover at each of the time intervals above. In the second set of experiments, we were interested in quantifying daily effects. Because poor weather conditions can frequently interfere, if not preclude, small boat-based operations, we placed traps within 1 km of the Rosenstiel School in areas accessible by land. Again, four spiny lobster traps were set over *Thalassia*, six stone crab traps were set over *Thalassia*, and six blue crab traps were set over *Halodule*. Trap footprints were recorded, digitized and analyzed to yield percent plant cover as described above.

To describe the temporal pattern of plant cover reduction under traps we used nonlinear regression (SAS 1990) to fit a negative exponential model to each trap's series of percent plant cover estimates. The model took the form

$$P_t = P_0 e^{-Zt}$$

where P_t is percent plant cover on day t post-deployment, P_0 is the initial percent plant cover estimate prior to disturbance (i.e., on day 0), and Z is the instantaneous (daily) plant cover loss rate. We then computed a mean Z value to represent an average plant loss rate for each trap type and plotted predicted and observed values dependent on time (days).

Results of the effects of spiny lobster traps and stone crab traps on *Thalassia* substrates are shown in Figures 4.2.1 and 4.2.2, respectively. In the spiny lobster trap experiments, about 1% of plant cover was converted into bare substrate after one day, approximately 7% *Thalassia* cover was lost after one week, and about 26% was lost after one month. *Thalassia* reduction appeared to be more rapid in our stone crab trap experiments. Mean loss of *Thalassia* cover was about 4% after one day, about 27% after one week, and about 74% after one month. Effects of blue crab traps on *Halodule* are shown in Figure 4.2.3. Blue crab traps reduced *Halodule* coverage by about 4% after one day, by about 24% after one week. We estimate about 70% *Halodule* cover loss would occur after one month.

Because stone crab traps have both smaller dimensions and weigh less than spiny lobster traps, we expected the spiny lobster traps to have greater impact on underlying *Thalassia*. Careful inspection of the two trap designs, however, revealed a subtle difference that may explain our finding. Unlike the stone crab trap, the weight of the spiny lobster trap is not equally distributed across its bottom. Three of the 10 - 12 narrow wooden slats across the base of the spiny lobster trap are approximately 1 cm thicker than the remaining slats that make up the bottom. Located on two outer edges and across the middle of the base, most of the weight of the trap is therefore focused on these three narrow "legs" and thus pressure under the rest of the trap's bottom is reduced accordingly. Though effects undoubtedly will vary with substrate hardness, it is possible that the slightly raised spiny lobster trap design may lead to marginally better water flow, gas exchange and light penetration for underlying plants. In contrast, every wooden slat making up the base of the flat-bottomed stone crab trap will make contact with the underlying substrate and this may, therefore, represent more of a stressor to the vegetated area beneath it. Further research in this area seems warranted. Blue crab traps are constructed of plastic-coated wire mesh, rather

Figure 4.2.1- Lobster trap effects on *Thalassia* coverage over time. Z is the daily instantaneous loss rate.

Experiment	Trap Number	Days post-deployment						Inst. Loss rate (Z)
		0	1	3	4	7	30	
1	1	91.16				78.22	73.66	-0.00631
1	2	87.56				75.68	68.11	-0.00776
1	3	86.85				75.32	64.39	-0.00952
1	4	83.99				69.50	55.82	-0.01323
2	1	99.09	98.82	96.06	96.33			-0.00849
2	2	96.14	95.02	90.74	90.92			-0.01583
2	3	92.11	92.21	89.73	88.12			-0.01152
2	4	88.24	88.69	88.12	84.52			-0.00910
Mean: -0.01022								SE: 0.001104

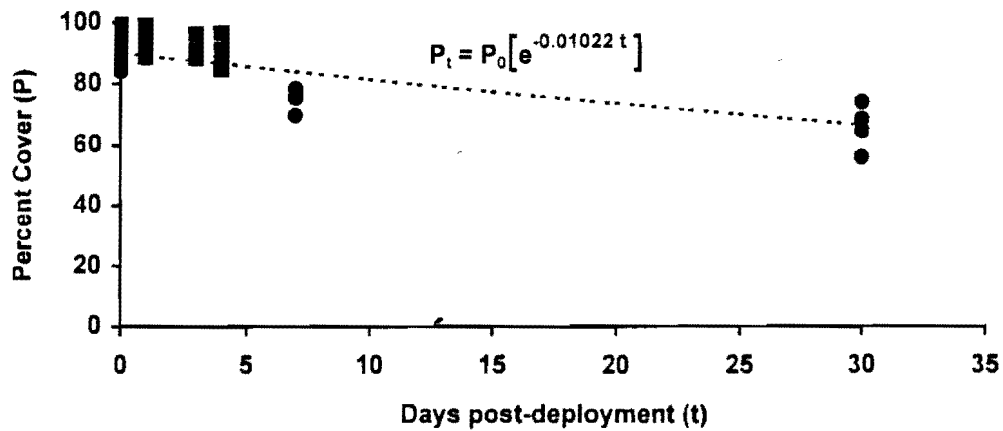


Figure 4.2.2- Stone crab trap effects on *Thalassia* coverage over time. Z is the daily instantaneous loss rate.

Experiment	Trap Number	Days post-deployment							Inst. Loss Rate (Z)
		0	1	2	3	4	7	30	
1	1	58.49					50.28		
1	2	53.83					32.78		
1	3	67.97					32.78		
1	4	63.17					33.42	20.80	-0.04546
1	5	69.36					39.56	14.49	-0.06187
1	6	72.99					28.93	25.22	-0.05464
2	1	97.32	93.88	92.67	86.64	84.00			-0.03712
2	2	97.28	92.09	87.70	87.63	80.59			-0.04251
2	3	96.66	93.84	90.08	88.08	83.00			-0.03650
2	4	97.97	94.95	91.85	88.24	84.15			-0.03745
2	5	97.74	95.42	92.11	88.20	84.30			-0.03708
2	6	96.65	89.62	82.18	80.89	78.52			-0.05351
Mean:									-0.04512
SE:									0.00314

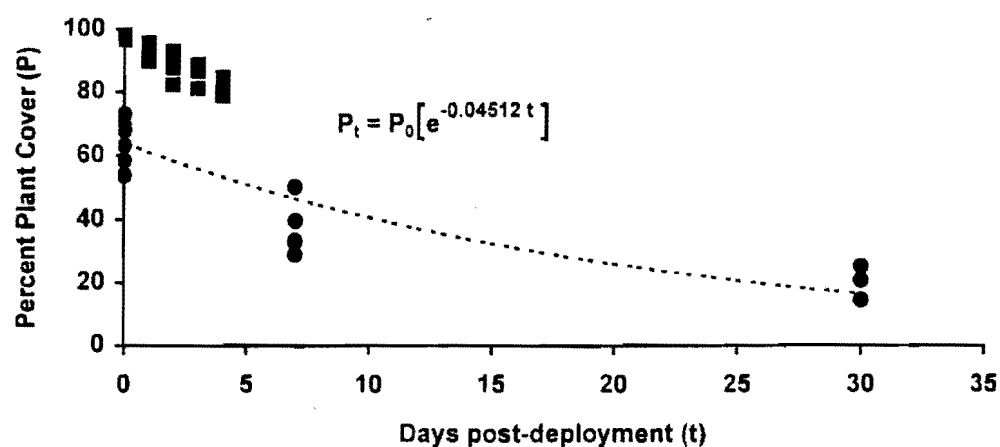
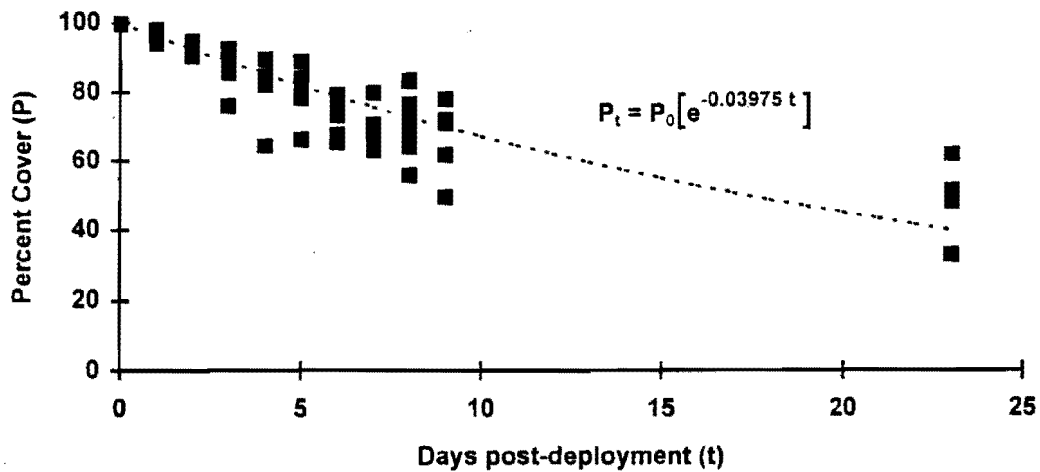


Figure 4.2.3- Blue crab trap effects on *Halodule* coverage over time. Z is the daily instantaneous loss rate.

Trap Number	Days post-deployment											Inst. Loss Rate (Z)
	0	1	2	3	4	5	6	7	8	9	23	
1	99.99	94.11	91.94	85.51	81.97	78.28	79.22	69.20	55.86	49.41	32.96	-0.05773
2	99.98	97.99	92.53	92.44	89.48	88.80	65.22	69.47	68.41			-0.05195
3	100	95.83	94.55	90.57	84.61	79.35	67.81	66.38	72.77	71.99	50.16	-0.03582
4	100	94.61	90.21	75.92	64.26	66.10		62.86	64.14	61.67	48.27	-0.04027
5	99.40	96.93	92.48	90.62	82.87	83.78		79.82	83.31	70.90	62.00	-0.02235
6	99.88	95.77	93.29	89.38	84.24	83.94	75.40	70.63	76.57	78.05	51.52	-0.03037
Mean: -0.03975												
SE: 0.00541												



than wood and concrete. Although of relatively light construction, the effects of blue crab traps on *Halodule* were quite dramatic most probably because of the very fragile nature of this species which has minimal underground biomass in comparison to *Thalassia*. On the other hand, the ability of a given bed of *Halodule* to recolonize areas made bare by a trapping is much more rapid than that for a *Thalassia* bed. Further research into species specific recovery rates would be prudent.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The bait shrimp fishery regularly comes in contact with a largest contiguous area of BNP's submerged habitat resources. Depending on season, from 25% to 52% of BNP's entire area is swept by the fishery. Restriction of commercial bait shrimp fishing in BNP's seagrass habitats cannot be justified solely on the basis of physical habitat damage. However, the issue of juvenile fish and crab bycatch deserves further attention, if not directed research. While rollerframe trawling does not appear to damage seagrasses, damage to sessile invertebrates (sponges and corals) in hardbottom communities is conspicuous and is likely to be long-lasting. Hardbottom habitats would undoubtedly benefit from closure of commercial bait shrimping in areas supporting high densities of sponges and corals. The feasibility of accurately marking the boundaries of BNP's hardbottom areas and preventing nocturnal trawling within them should be investigated. Further trawl damage experiments in conjunction with closure are essential for obtaining accurate estimates of rates of recovery for trawl-damaged sponges and corals.

The primary resource that the three major trap fisheries affect is seagrass with damage to underlying plants dependent on trap type and soak time. Loss of underlying *Thalassia* averages about 13% of trap area per week for lobster traps and 28% per week for stone crab traps. For blue crab traps, loss of underlying *Halodule* averages 30% of trap area per week. Further measurements of size and spatio-temporal extent of each of the trap fisheries is required before reliable estimates of trap-induced damage can be made. Additional field experiments which focus on the rate at which *Thalassia* and *Halodule* recolonize areas trap-damaged areas are strongly recommended.

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APPENDIX I
Bait shrimp fishery questionnaire



Rosenstiel School of Marine and Atmospheric Science,
University of Miami

Thank you for spending 10 minutes to complete this questionnaire! This is part of a University of Miami, Rosenstiel School of Marine and Atmospheric Science/ *Sea Grant* study of the bait shrimping industry in Biscayne Bay. Results of this study will update a 1985 *Sea Grant* study and will greatly enhance our understanding of the local commercial shrimp fishery. This information will help RSMAS continue to understand and aid the fisherman of Southern Florida and Biscayne Bay. All questionnaires are confidential and the private property of the Rosenstiel School.

Shrimp Fishery Questionnaire

Boat name: _____

Captain's name: _____

Dock or marina: _____

Size Boat: _____ feet

Hull: ☐ wood ☐ fibreglass

How many years has this boat operated in the shrimp fishery?: _____ years

Do you own this boat?: ☐ Yes ☐ No

If yes, do you own additional shrimp boats?: ☐ Yes ☐ No

If yes, Boat name(s): _____ Size: _____ feet

Do you trawl with a single or pair of rollerframes? ☐ Single ☐ Pair

Width of rollerframe(s): _____ feet, _____ feet

Mesh size: _____

How old is the gear? _____ years.

Your age: _____ years

Number of deck hands: _____

Average age of deck hands _____ years

How many years have you fished bait shrimp in Biscayne Bay? _____ years

How many weeks per year do you fish? _____ weeks

What is your average order size per night?:

Sun _____ Mon _____ Tue _____ Wed _____

Thur _____ Fri _____ Sat _____

May-October (summer) _____

Nov. 1991 (11/11/91 - 11/20/91)						May 1992 (5/1/92 - 5/10/92)					
	H	M	L	avg days per wk	avg hrs per night		H	M	L	avg days per wk	avg hrs per night
Nov.	☐	☐	☐	_____	_____	May	☐	☐	☐	_____	_____
Dec.	☐	☐	☐	_____	_____	June	☐	☐	☐	_____	_____
Jan.	☐	☐	☐	_____	_____	July	☐	☐	☐	_____	_____
Feb.	☐	☐	☐	_____	_____	Aug.	☐	☐	☐	_____	_____
Mar.	☐	☐	☐	_____	_____	Sep.	☐	☐	☐	_____	_____
Apr.	☐	☐	☐	_____	_____	Oct.	☐	☐	☐	_____	_____

Has the average size of bait shrimp changed in the last five years? ☐ No ☐ Bigger ☐ Smaller

If yes, how has it changed? _____

What do you see as emerging issues in the Biscayne Bay shrimp fishery?

Do these areas change seasonally? If so, please indicate on attached map for SEASONS.

APPENDIX II
Spiny lobster fishery questionnaire



Rosenstiel School of Marine and Atmospheric Science,
University of Miami

Thank you for spending 10 minutes to complete this questionnaire! Results of this study will greatly enhance our understanding of the local commercial lobster fishery. All questionnaires are confidential.

Lobster Fishery Questionnaire

Boat name: _____ Registration #: _____

Owner's name: _____

Dock or marina: _____

Size Boat: _____ feet

Hull: ☐ wood ☐ fiberglass

How many years has this boat operated in the lobster fishery?: _____ years

How old is the boat? _____ years

Your age: _____ years

Number of deck hands: _____

Average age of deck hands _____ years

How many years have you trapped for lobster? _____ years

Do you fish primarily for lobster or another species? ☐ lobster ☐ other _____

What other species do you commercially fish for DURING lobster season? _____

What other species do you commercially fish for OUTSIDE of lobster season? _____

How many traps do you own (total)? _____ traps

How many do you set each year? _____ traps

Typically, how many traps do you run on a trot line? _____ traps

Typically, do you put a bouy out for: ☐ each trap ☐ one for each trot line

How often during the year will you reposition a trot line of traps? Average _____

What equipment do you use: ☐ hauler console ☐ swinging davit
☐ swivel trap table ☐ haul by hand

MOST of my traps are: ☐ wood ☐ plastic

What things do you look for in determining trap locations (e.g. bottom type, topography, etc)?

How many days does it take you to set all your traps? _____ days

How long does it typically take to retrieve, check, remove lobster, rebait, and return a trap? _____
 How many traps do you check per day? _____ traps

On the average, how many traps do you need to replace each year? _____ traps

Do you set your traps in the same locations each year? ☐ Yes ☐ No

What is your average catch/trap?: _____

Please indicate average catch per month as (H)IGH, (M)EDIUM, or (L)OW, AND indicate the average number of days/week and hours/day you lobster.

	H	M	L	avg days per wk	avg hrs per day		H	M	L	avg days per wk	avg hrs per day
Aug.	☐	☐	☐	_____	_____	Dec.	☐	☐	☐	_____	_____
Sep.	☐	☐	☐	_____	_____	Jan.	☐	☐	☐	_____	_____
Oct.	☐	☐	☐	_____	_____	Feb.	☐	☐	☐	_____	_____
Nov.	☐	☐	☐	_____	_____	Mar.	☐	☐	☐	_____	_____

Has the average catch per trip changed in the last five years? ☐ No ☐ Increased ☐ Decreased

Has the average size of lobster changed in the last five years? ☐ No ☐ Bigger ☐ Smaller

Is there competition with other lobstermen for good areas? ☐ No ☐ Some ☐ A lot

What wholesaler, live-haul trucks or stores do you sell to? _____

What pricing scheme do you use (e.g. large and small prices, etc)? _____

Has this price significantly changed in recent years or seasons? ☐ Yes ☐ No

If yes, how has it changed? _____

What do you figure your total average trip costs are (gas, captain/crew costs, insurance, etc.) either per trip, per week or per month?

per trip \$ _____, or per week \$ _____, or per month \$ _____

Any other historical information you think would be useful (trends in catch, effort, gear, poaching etc.)?

What do you see as emerging issues in the lobster fishery?

On the back of this page please use circles to indicate the general areas in which you set traps. If the areas you currently set traps have changed significantly since 1989, please indicate the locations of these areas and put a '1989' within the circle.

APPENDIX III
Stone crab fishery questionnaire



Rosenstiel School of Marine and Atmospheric Science,
University of Miami

Thank you for spending 10 minutes to complete this questionnaire! Results of this study will greatly enhance our understanding of the local commercial stone crab fishery. All questionnaires are confidential.

Stone Crab Fishery Questionnaire

Boat name: _____ Registration #: _____

Owner's name: _____

Dock or marina: _____

Size Boat: _____ feet

Hull: ☐ wood ☐ fiberglass

How many years has this boat operated in the stone crab fishery?: _____ years

How old is the boat? _____ years

Your age: _____ years

Number of deck hands: _____

Average age of deck hands _____ years

How many years have you trapped for stone crab _____ years

Do you fish primarily for stone crab or another species? ☐ stone crab ☐ other _____

What other species do you commercially fish for DURING stone crab season? _____

What other species do you commercially fish for OUTSIDE of stone crab season? _____

How many traps do you own (total)? _____ traps

How many do you set each year? _____ traps

Typically, how many traps do you run on a trot line? _____ traps

Typically, do you put a bouy out for: ☐ each trap ☐ one for each trot line

How often during the year will you reposition a trot line of traps? Average _____

What equipment do you use: ☐ hauler console ☐ swinging davit
☐ swivel trap table ☐ haul by hand

MOST of my traps are: ☐ wood ☐ plastic

What things do you look for in determining trap locations (e.g. bottom type, topography, etc)?

How many days does it take you to set all your traps? _____ days

How long does it typically take to retrieve, check, remove crab, rebait, and return a trap? _____

How many traps do you check per day? _____ traps, OR per week _____

On the average, how many traps do you need to replace each year? _____ traps

Do you set your traps in the same locations each year? ☐ Yes ☐ No

What is your average catch/trap?: _____

Please indicate average catch per month as (H)IGH, (M)EDIUM, or (L)OW, AND indicate the average number of days/week and hours/day you crab.

	H	M	L	avg days per wk	avg hrs per day		H	M	L	avg days per wk	avg hrs per day
Aug	☐	☐	☐	_____	_____	Jan.	☐	☐	☐	_____	_____
Sep.	☐	☐	☐	_____	_____	Feb.	☐	☐	☐	_____	_____
Oct.	☐	☐	☐	_____	_____	Mar.	☐	☐	☐	_____	_____
Nov.	☐	☐	☐	_____	_____	Apr.	☐	☐	☐	_____	_____
Dec.	☐	☐	☐	_____	_____	May	☐	☐	☐	_____	_____

Has the average catch per trip changed in the last five years? ☐ No ☐ Increased ☐ Decreased

Has the average size of stone crab changed in the last five years? ☐ No ☐ Bigger ☐ Smaller

Is there competition with other stone crab fishermen for good areas? ☐ No ☐ Some ☐ A lot

What wholesaler, live-haul trucks or stores do you sell to? _____

What pricing scheme do you use (e.g. large and small prices, etc)? _____

Has this price significantly changed in recent years or seasons? ☐ Yes ☐ No

If yes, how has it changed? _____

What do you figure your total average trip costs are (gas, captain/crew costs, insurance, etc.) either per trip, per week or per month?

per trip \$ _____, or per week \$ _____, or per month \$ _____

Any other historical information you think would be useful (trends in catch, effort, gear, poaching etc.)? _____

What do you see as emerging issues in the stone crab fishery? _____

On the back of this page please use circles to indicate the general areas in which you set traps. If the areas you currently set traps have changed significantly since 1989, please indicate the locations of these areas and put a '1989' within the circle.

Thank you again for completing this questionnaire.

APPENDIX IV
Blue crab fishery questionnaire



Rosenstiel School of Marine and Atmospheric Science,
University of Miami

Thank you for spending 10 minutes to complete this questionnaire! Results of this study will greatly enhance our understanding of the local commercial blue crab fishery. All questionnaires are confidential.

Blue Crab Fishery Questionnaire

Boat name: _____ Registration #: _____

Owner's name: _____

Dock or marina: _____

Size Boat: _____ feet

Hull: ☐ wood ☐ fiberglass

How many years has this boat operated in the Blue crab fishery?: _____ years

How old is the boat? _____ years

Your age: _____ years

Number of deck hands: _____

Average age of deck hands _____ years

How many years have you trapped for blue crab _____ years

Do you fish primarily for blue crab or another species? ☐ blue crab ☐ other _____

What other species do you commercially fish for DURING blue crab season? _____

How many traps do you own (total)? _____ traps

How many do you set each year? _____ traps

Typically, how many traps do you run on a trot line? _____ traps

Typically, do you put a bouy out for: ☐ each trap ☐ one for each trot line

How often during the year will you reposition a trot line or traps? Average _____

What equipment do you use: ☐ hauler console ☐ swinging davit
☐ swivel trap table ☐ haul by hand

What things do you look for in determining trap locations (e.g. bottom type, topography, etc)?

How many days does it take you to set all your traps? _____ days

How long does it typically take to retrieve, check, remove crab, rebait, and return a trap? _____

How many traps do you check per day? _____ traps. OR per week _____

On the average, how many traps do you need to replace each year? _____ traps

Do you set your traps in the same locations each year? ☐ Yes ☐ No

What is your average catch/trap?: _____

Please indicate average catch per month as (H)IGH, (M)EDIUM, or (L)OW, AND indicate the average number of days/week and hours/day you crab.

	H	M	L	avg days per wk	avg hrs per day		H	M	L	avg days per wk	avg hrs per day
Jan.	☐	☐	☐	_____	_____	July	☐	☐	☐	_____	_____
Feb.	☐	☐	☐	_____	_____	Aug	☐	☐	☐	_____	_____
Mar.	☐	☐	☐	_____	_____	Sep.	☐	☐	☐	_____	_____
Apr.	☐	☐	☐	_____	_____	Oct.	☐	☐	☐	_____	_____
May	☐	☐	☐	_____	_____	Nov.	☐	☐	☐	_____	_____
June	☐	☐	☐	_____	_____	Dec.	☐	☐	☐	_____	_____

Has the average catch per trip changed in the last five years? ☐ No ☐ Increased ☐ Decreased

Has the average size of blue crab changed in the last five years? ☐ No ☐ Bigger ☐ Smaller

Is there competition with other blue crab fishermen for good areas? ☐ No ☐ Some ☐ A lot

What wholesaler, live-haul trucks or stores do you sell to? _____

What pricing scheme do you use (e.g. large and small prices, etc)? _____

Has this price significantly changed in recent years or seasons? ☐ Yes ☐ No

If yes, how has it changed? _____

What do you figure your total average trip costs are (gas, captain/crew costs, insurance, etc.) either per trip, per week or per month?

per trip \$ _____, or per week \$ _____, or per month \$ _____

Any other historical information you think would be useful (trends in catch, effort, gear, poaching etc.)? _____

What do you see as emerging issues in the blue crab fishery? _____

On the back of this page please use circles to indicate the general areas in which you set traps. If the areas you currently set traps have changed significantly since 1989, please indicate the locations of these areas and put a '1989' within the circle.

Thank you again for completing this questionnaire.

APPENDIX V

Shrimping areas of respondents to the bait shrimp fishery questionnaire

Figure A.V.1- Shrimping grounds of vessels 1 and 2 during the dry Season (November-April).
White line delineates BNP boundary.

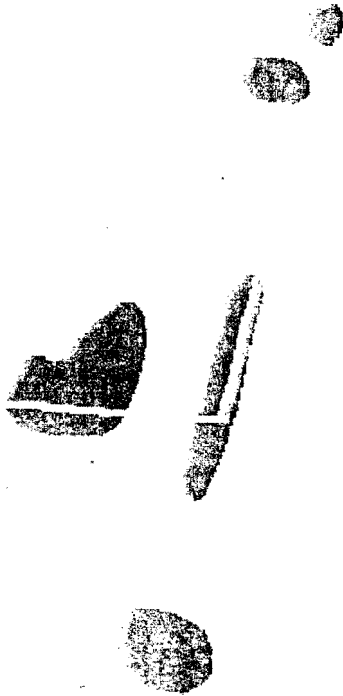


Figure A.V.2- Shrimping grounds of vessels 1 and 2 during the wet season (May-October). White line delineates the park boundary.

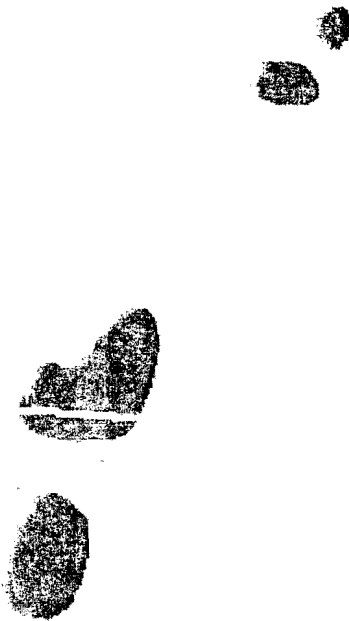


Figure A.V.3- Shrimping grounds of vessel 3 during the dry Season (November-April). White line delineates the park boundary.

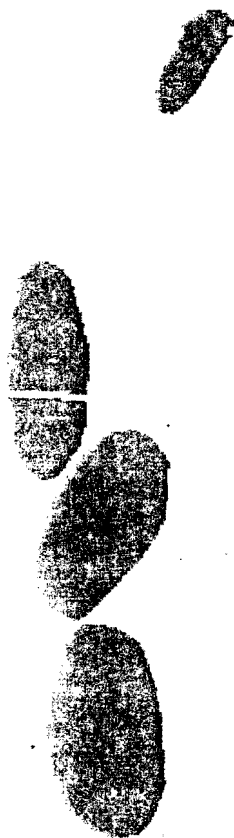


Figure A.V.4- Shrimping grounds of vessel 3 during the wet season (May-October). White line delineates the park boundary.

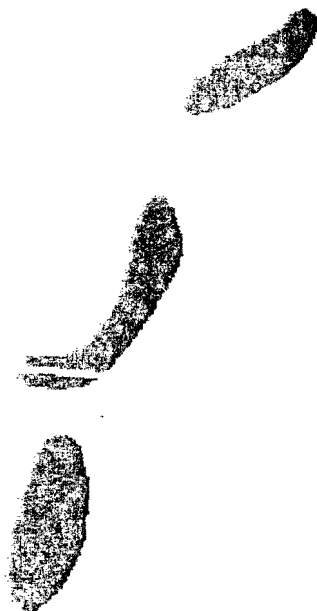


Figure A.V.5- Shrimping grounds of vessel 4 during the dry Season (November-April). White line delineates the park boundary.



Figure A.V.6- Shrimping grounds of vessel 4 during the wet season (May-October). White line delineates the park boundary.



Figure A.V.7- Shrimping grounds of vessels 5 and 6 during the dry season (November-April). White line delineates the park boundary.

Figure A.V.8- Shrimping grounds of vessels 5 and 6 during the wet season (May-October). White line delineates the park boundary.

