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TECHNICAL SERIES

NO. 57

**GROWTH AND TAGGING STUDIES
ON PANULIRUS ARGUS (LATREILLE)
IN THE FLORIDA KEYS**

by

Donald E. Sweat

December 1968

Marine Research Laboratory
Salt Water Fisheries Division
Florida Board of Conservation
St. Petersburg, Florida

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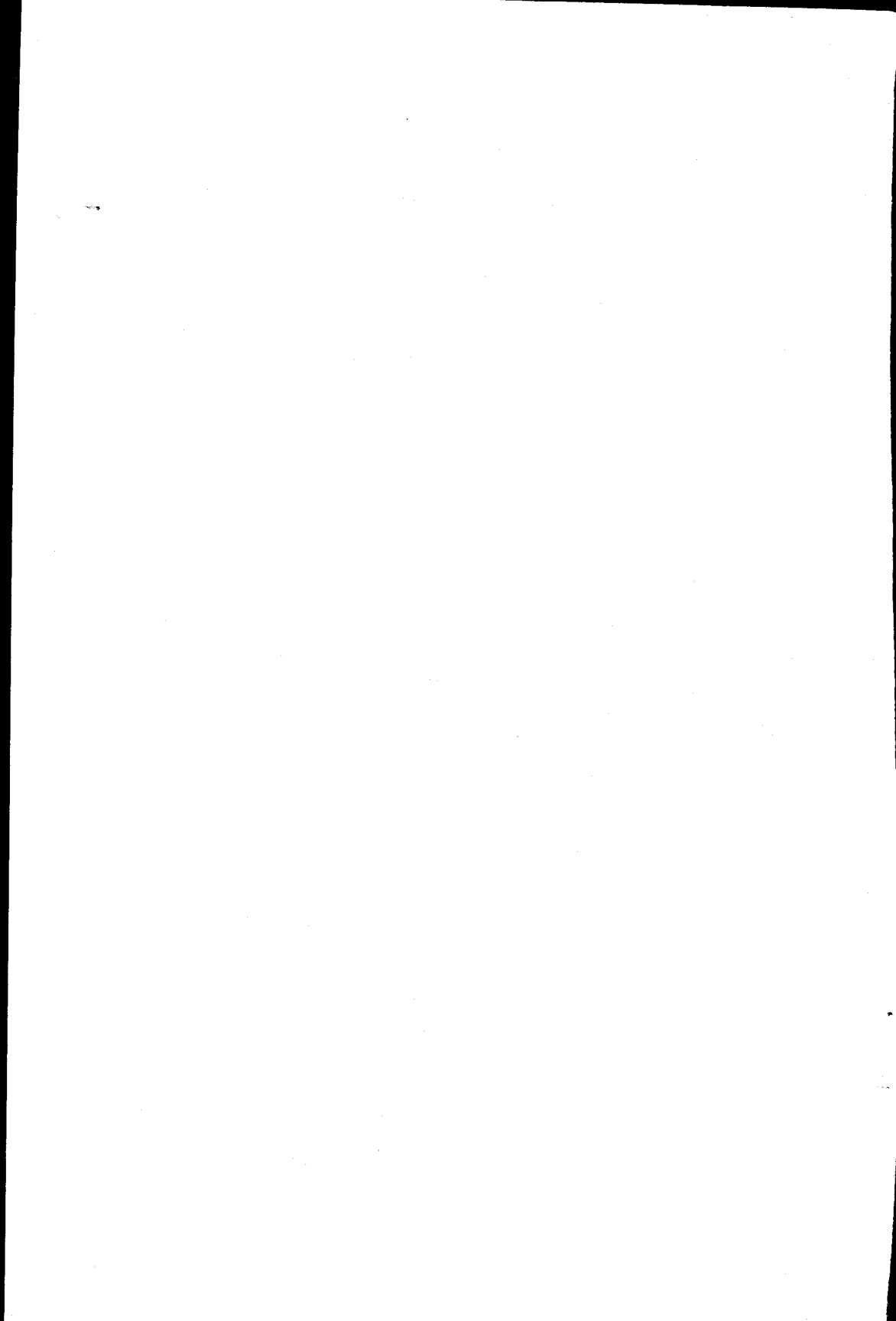
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GROWTH AND TAGGING STUDIES ON *PANULIRUS ARGUS* (LATREILLE) IN THE FLORIDA KEYS

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INTRODUCTION

The Florida spiny lobster fishery, based on *Panulirus argus*, is located almost entirely in the Florida Keys.

Since accurate statistical records were initiated in the mid-1950's, lobster production has generally increased (Figure 1), reaching an all-time high of 5.7 million pounds in 1966 (F. G. W. Smith, 1958; Robinson and Dimitriou, 1963; U.S. Bur., Comm. Fish.). Even with increased production, Florida fishermen have been unable to produce sufficient poundage to meet demands. Imports of this "gourmet's delight" remain high, with a total of 22.2 million pounds brought into the United States during the first seven months of 1968 (U.S. Bur. Comm. Fish., 1968).

Realizing the need to increase catches to meet this demand and that accomplishment of this goal can only be made through a thorough knowledge of the biology of the animal, the Florida Board of Conservation Marine Research Laboratory initiated this study in March 1966.

Previous lobster studies have indicated that periodic influxes of first-stage postlarvae occur in various areas of this state (Lewis *et al.*, 1952; Witham *et al.*, 1964; Witham *et al.*, 1968). We were interested in seeing if similar influxes occurred in the Florida Keys and in what numbers. The theory of Caribbean recruitment (Sims and Ingle, 1966) indicated the probability of this occurrence.

In view of the above, these studies have emphasized recruitment, habitat preference, and growth rates in the Keys area.

*Contribution No. 124 .

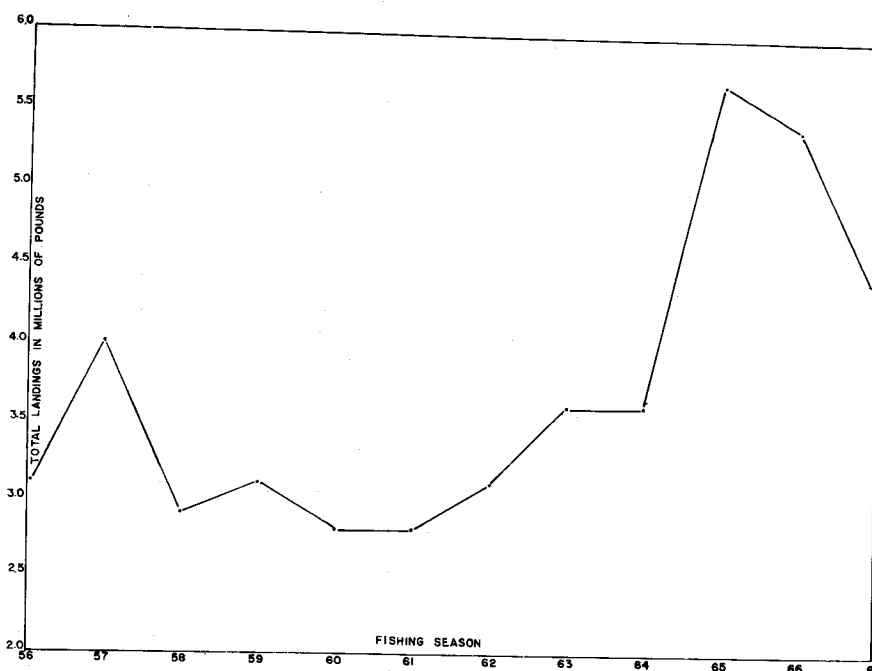


Figure 1. Florida commercial lobster landings, 1956-1967.

ACKNOWLEDGMENTS

Thanks are extended to Messrs. R. K. Cissel, L. B. Williams, M. F. Godcharles, R. M. Maloney, and F. S. Kennedy, who served as staff members during various parts of the program. Appreciation is also due to the management of the Key West Municipal Aquarium who provided laboratory space, equipment, and assistance during the study. I would also like to thank Mr. Edwin A. Joyce, Jr. and Mr. William G. Lyons for critically reviewing the manuscript, and Mr. James Moore who assisted in preparation of the figures.

METHODS AND MATERIALS

Postlarval lobsters used in this study were obtained in a variety of ways, though most were taken using the Witham Habitat (Witham *et al.*, 1968) or from special plankton samples. Various submersible habitats and other collecting devices were tested in different areas to find the most efficient collecting method and the areas of highest recruitment. Data concerning seasonality and periodicity of recruitment were also obtained.

I. Description of Areas Tested

- A. *Airport Lagoon.* Within 100 yards of the southeastern edge of the island of Key West, just opposite Key West International Airport, is a man-made lagoon approximately 75 yards wide by 100 yards long. This lagoon was dredged for fill material about 20 years ago and has long since been overgrown with marine life. It is 12 to 15 feet deep in the center and the dredged edges drop off quite steeply from a surrounding depth of 3 to 4 feet. Plant life in the central portion is limited almost exclusively to *Thalassia*. The soft sand/mud bottom seems attractive only to several species of marine worms. The area immediately surrounding the lagoon has a lime rock bottom. Plant life consists primarily of *Halimeda*, *Penicillus*, and patches of *Thalassia*. Gorgonians are also very abundant. The Gulf Stream is located approximately six miles due south of the lagoon and, with prevailing southeasterly winds, furnishes a constant supply of clean water.
- B. *Marquesas Keys.* The Marquesas Keys are situated approximately 23 miles west of Key West and 45 miles east of the Dry Tortugas. Our testing area was located about 100 yards offshore of the south side of this island group, between Eastern Harbor entrance and the entrance to Mooney's Harbor. Depths averaged 8 to 12 feet and the bottom was mainly sand with some exposed rock. Dense *Thalassia* was predominant in this area, with *Diplanthera*, *Hypnea*, and *Acanthophora* also present in much lesser quantity. Phillips (1959) reported no *Diplanthera* in this region. Gorgonians were also abundant.
- C. *Sand Key.* Sand Key, located approximately seven miles southwest of Key West, was selected for its proximity to the Gulf Stream which passes within one mile of the Key. The test area surrounding the Key was quite rocky and ranged in depth from 10 to 20 feet. There was very little plant life in this area, although stony corals were very abundant.
- D. *Whale Harbor Bridge.* This bridge crosses one of the major channels linking Florida Bay to the Atlantic Ocean. The bridge is located on U. S. Highway 1, 85 miles northeast of Key West between Upper Matecumbe and Windley Keys.

- E. *Boca Chica, Bow, and Niles Channels.* These are three major channels linking Florida Bay to the Atlantic Ocean. They are located 8, 23, and 31 miles from Key West on U. S. Highway 1 between Key West and Boca Chica, Sugarloaf and Cudjoe, and Summerland and Ramrod Keys. The Boca Chica samples were taken from a boat anchored in mid-channel. Bow and Niles Channels were sampled from their bridges.
- F. *Grass Flat Areas.* Since extensive grass beds cover the major shallow water areas throughout the Florida Keys, a large number were sampled with various collecting devices. Although locations varied, all areas were characterized by an underlying mud layer covered with dense *Thalassia* interspersed with *Halimeda* and *Penicillus*.

II. Sampling Procedures

- A. *General.* On each occasion that a habitat was checked or a plankton sample taken, standard hydrographic and meteorological data were recorded. This included surface and bottom temperature and salinity, tidal information, air temperature, wind velocity and direction, and moon phase. Postlarval lobsters taken from habitats and from the special plankton collections were transported to the laboratory for growth studies. Regular plankton samples were preserved in approximately 10% formaldehyde for several days, after which they were washed with fresh water and stored in 40% isopropyl alcohol. Throughout the study daily temperatures (Figure 2) and weekly salinities (Figure 3) were taken from laboratory tanks and aquaria. In all cases, temperatures were read to the nearest tenth degree from a centigrade 76 mm immersion thermometer, and salinities were determined by silver nitrate titration in the laboratory (Mohr titration).

B. *Habitats.*

1. *Surface*

These floating devices (Figure 4) were placed at a number of sites around Key West, both inshore and offshore (Figure 5). Beginning in June 1966 and continuing for 18 months, the inshore sites were checked daily and the offshore sites were checked twice a week. The usual method of checking this habitat was to remove the float from the water and invert it, exposing the "pages." Each

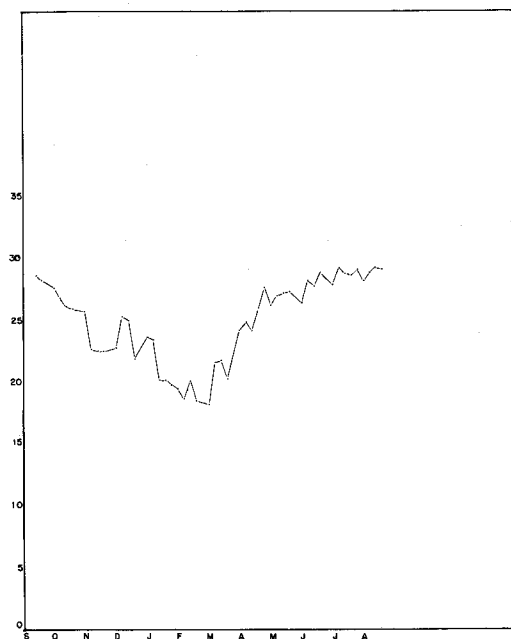


Figure 2. Average monthly temperatures in laboratory tanks and aquaria.

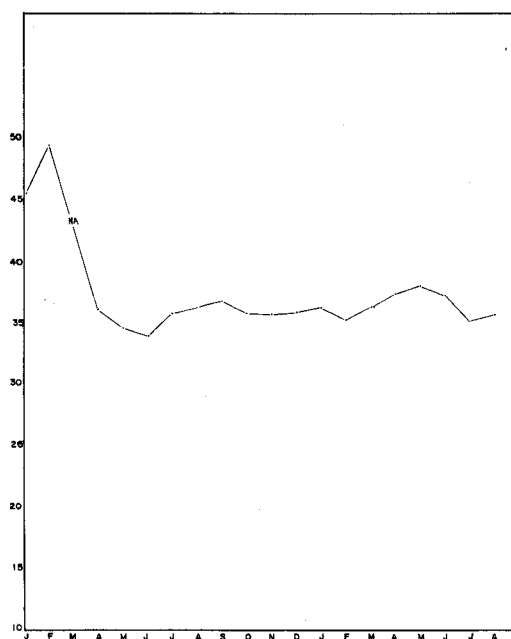


Figure 3. Average monthly salinities in laboratory tanks and aquaria.

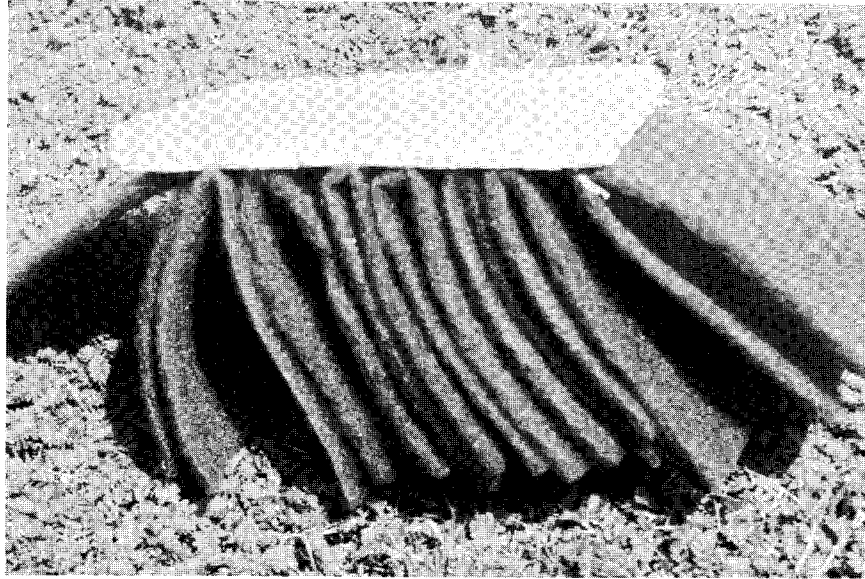


Figure 4. Witham habitat.

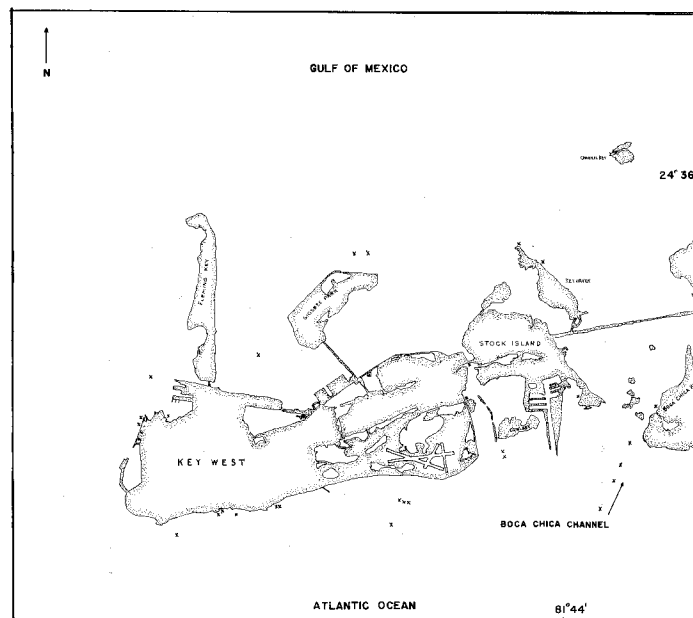


Figure 5. Sites of Witham habitats set in Key West area.

page was then turned and visually inspected for presence of postlarval lobsters.

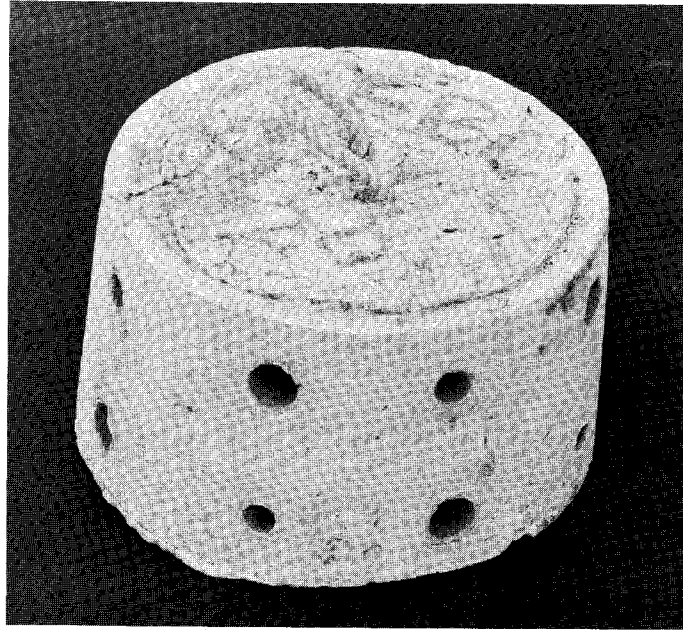


Figure 6. Concrete habitat.

2. Bottom

- a. Concrete: Concrete habitats (Figure 6) were made, using plastic trash cans as molds. The habitats measured 10 inches in diameter at their base, 8 inches on their surface, and were approximately 6 inches high. Two rows of various sized holes were arranged radially around the sides. These were fashioned by inserting dowels of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 inch diameters through the sides of the plastic molds prior to pouring the concrete. The dowels were set to penetrate a depth of 3 inches. It was necessary to carefully remove the dowels after the concrete was set but before it hardened completely. A loop of polyethylene line was added to the top of each habitat after the concrete was poured. This was later used to raise the device from the water for inspection.

The concrete habitat was first tested in the laboratory in the following manner. An epoxy-coated plywood tank, measuring 3 x 5 x 1.5 feet was set up with a recirculating water system and subsurface sand/gravel filter. The tank was then divided into equal halves by a piece of nontoxic plastic window screen and filled with unfiltered seawater. Three concrete habitats were placed in one side and three similar habitat forms without dowel holes were placed in the opposite side. The side containing the smoothsided or control forms was designated Side A, while the side containing the experimental habitats was designated Side B (Figure 7).

On November 23, 1966, 33 transparent postlarvae were placed in the tank, 17 on Side A and 16 on Side B. On January 3, 1967, seven second-stage postlarvae were added to each side, bringing the total to 24 on Side A, 23 on Side B. Feeding was initiated on November 23, 1966 and followed a triweekly schedule. Food consisted of crushed mollusks (*Littorina*, *Nerita*, and *Astraea*) and cut fish fillets. Both groups were fed at the same time and food amounts were equal. Temperature and salinity were recorded weekly.

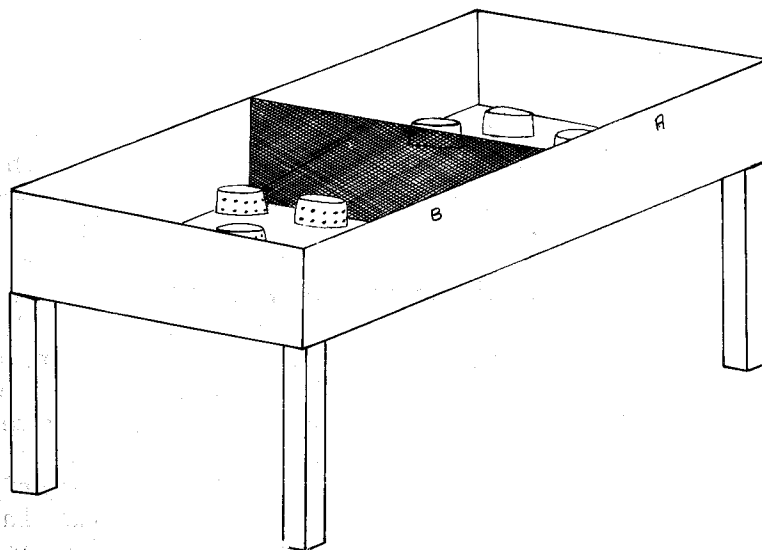


Figure 7. Concrete habitat evaluation tank.

During the last week of April 1967, 50 of these concrete habitats were set out in the Marquesas area, four at Sand Key and four at the Airport Lagoon. These were placed in depths ranging from 4 to 20 feet. All were buoyed. Additionally, 12 of the Marquesas group and all of the Sand Key group had Witham Habitats attached to their buoys. Beginning in May 1967 and continuing until September 1967, these habitats were checked on a weekly basis, weather permitting. Each habitat was raised slowly out of the water and examined. Periodically, SCUBA inspections were made to insure that no animals were being lost during the checking procedure.

- b. Box Habitat: Several boxes measuring 24 x 15 x 8 inches were made of $\frac{1}{2}$ inch plywood, painted with a nontoxic epoxy resin, and weighted with two inches of poured concrete. A hinged lid was attached to each box and $\frac{3}{8}$ inch holes were drilled at random intervals through all sides and lids (Figure 8). These were placed around Airport Lagoon and checked with SCUBA periodically from May to September 1967.
- c. PVC Pipe Habitats: PVC pipes of 1, 2, and 3 inch diameters were cut into 1 foot lengths, stacked in pyramid forms, bound together with bailing wire and weighted by sinking the base of the pyramid into a wet slab of concrete measuring approximately one foot square and two inches thick (Figure 9). Some of these pyramids were constructed of one diameter size pipe, others were of mixed sizes. All were placed, without buoys, around the periphery of Airport Lagoon and checked from May to September 1967 by periodic SCUBA dives.
- d. Modified Witham Habitat: A $\frac{1}{2}$ inch thick, rubberized hair matting, used commercially as air-conditioning filter material, was cut into "pages" measuring 1 x $1\frac{1}{2}$ feet and anchored in wet concrete which hardened to form a base 1 foot square and approximately $1\frac{1}{2}$ inches thick (Figure 10). These were placed around Airport Lagoon and checked with SCUBA.

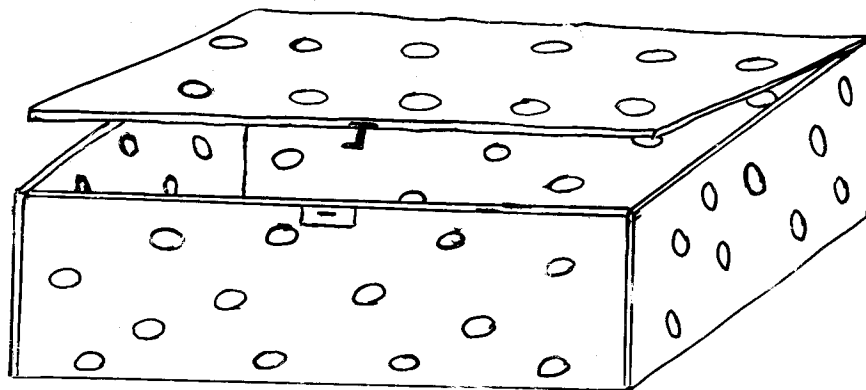


Figure 8. Box habitat.

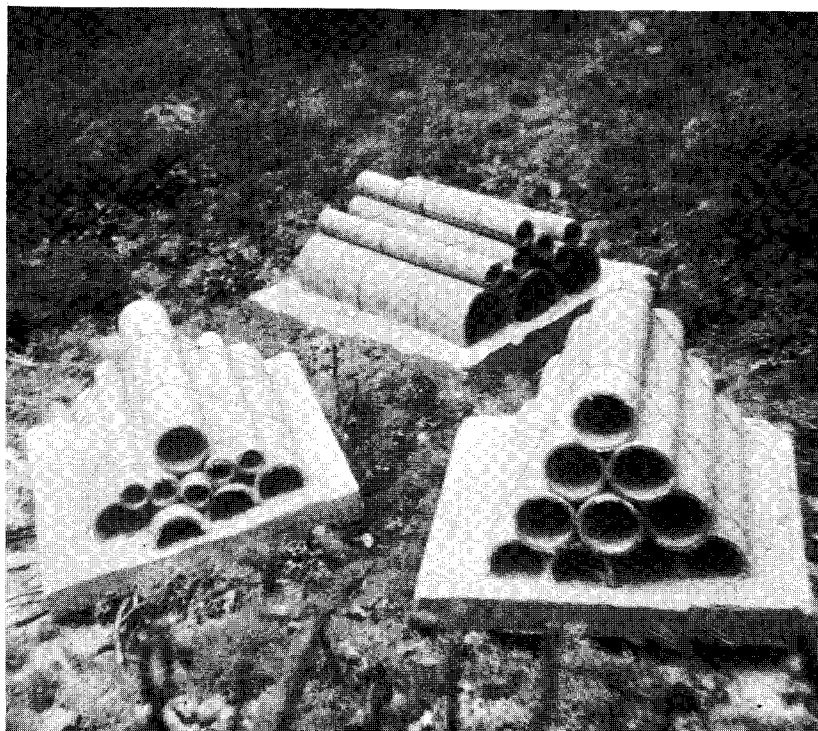


Figure 9. PVC pipe habitats.

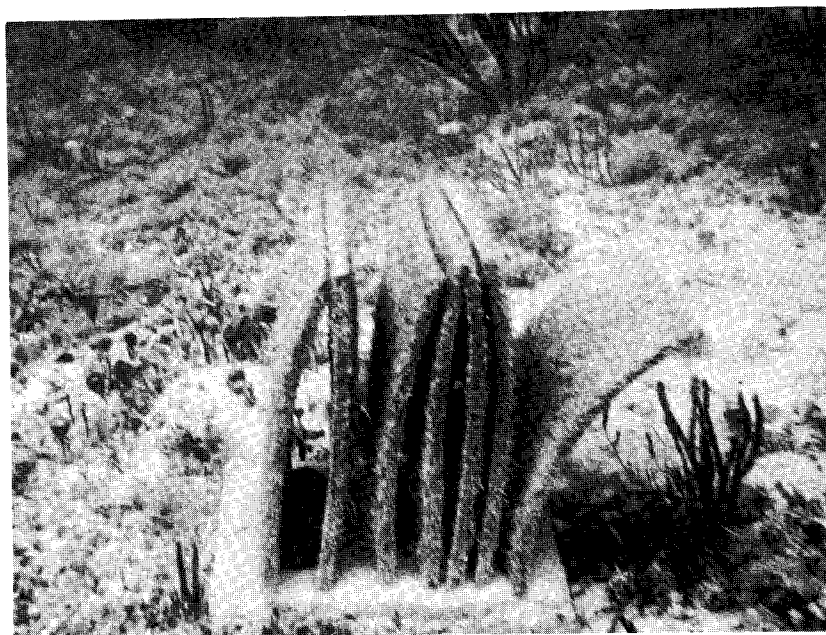


Figure 10. Modified Witham habitat.

- e. Tires: Old automobile tires were tied together in chains of six to eight and submerged in shallow water surrounding Airport Lagoon. Others were cut into two half-circle sections and submerged individually in the center of the lagoon. All were checked periodically with SCUBA.
- f. Apartment-type: Layered wooden habitats were constructed of white pine, painted with epoxy resin and weighted with lead ingots nailed to their bases. Each habitat contained 40 openings large enough to accommodate juvenile lobsters up to about 80 mm in total length. They were placed in and around the lagoon and checked periodically by diving.

C. Plankton

Plankton samples were taken at regular intervals at a variety of stations, both inshore and offshore. The Whale Harbor Bridge station featured a unique vertical array which consisted of an A-frame (permanently attached to the bridge)

and three removable nets. The 12-inch-diameter nets were set to sample surface, mid-depth (4 feet), and bottom (8 feet) and were made of No. 706 Nitex netting (Figure 11). This apparatus was designed and built in early 1966 by Bureau of Commercial Fisheries biologists from the Tropical Atlantic Biological Laboratory, Miami, Florida, and was turned over for our use shortly thereafter. Whale Harbor samples were taken on the new moon each month during evening flood tides and were of two hours' duration.

Other inshore and offshore stations were taken with $\frac{1}{2}$ meter nets made of Brussels-type nylon netting with 20 meshes per inch. These stations were taken during the new moon period and were of 30 minutes' duration. Bow and Niles Channel samples were always taken at night during the flood tide. The Boca Chica samples were taken four times during a 24-hour period, sampling both daylight and dark flood and ebb tides.

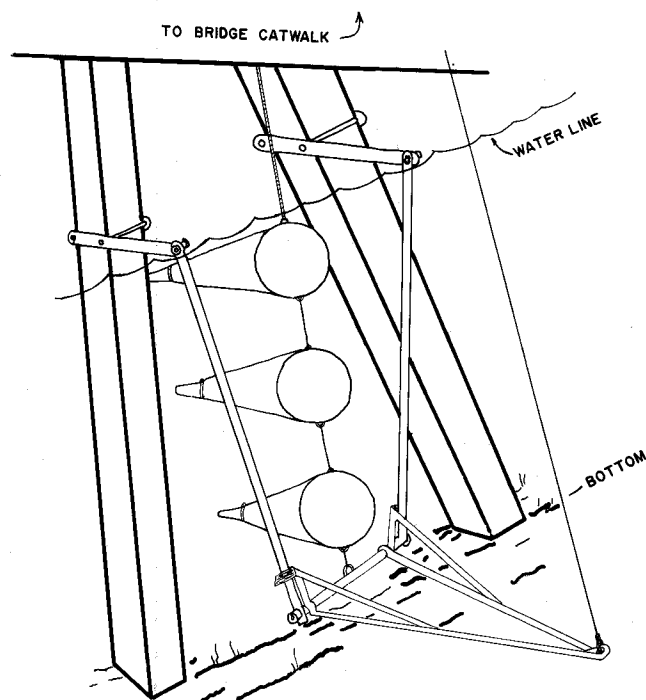


Figure 11. A-frame plankton sampler.

D. Other Gear Tested

1. Pushnets

Pushnet frames approximately 3 feet square were constructed of 1 inch PVC pipe. These were covered loosely with fiberglass screening to allow shallow pockets to form in their centers. Samples were taken on grass flats by pushing one edge of the frame slowly across the bottom, allowing grass, algae, and other organisms to collect in the shallow pocket. The samples were then checked for postlarval lobsters.

Following Witham's procedure (Witham *et al.*, 1964), the net was also placed under submerged mangrove roots which were broken off and allowed to fall into the pocket of the net along with the fouling organisms associated with them. This material was then sorted for postlarvae.

2. Vacuum Dredge

To more thoroughly search the grass flats, a vacuum dredge was designed (Allen and Hudson, 1968) utilizing a 3 HP gasoline-driven water pump. A venturi system provided suction to a 16 foot vacuum hose. This in turn was attached by a hose clamp to a 4 foot section of 3 inch PVC pipe. To prevent clogging of the apparatus a large-mesh wire screen was placed over the end which served as an intake. A bag sewn of plastic window screen was used to contain the vacuumed sample (Figure 12). The dredge was used primarily on *Thalassia* and *Halimeda* flats.

3. Roller-frame Trawl

A bait shrimp roller-frame trawl with a 4 x 2 foot opening was modified to accommodate a net 6 feet long. The net was made of ½ inch stretched mesh nylon (Figure 13). This was towed by boat over various types of bottom in the Key West area.

E. Growth Studies

1. Individual

Individual growth records were kept on 510 postlarval lobsters from April 1966 through August 1968.

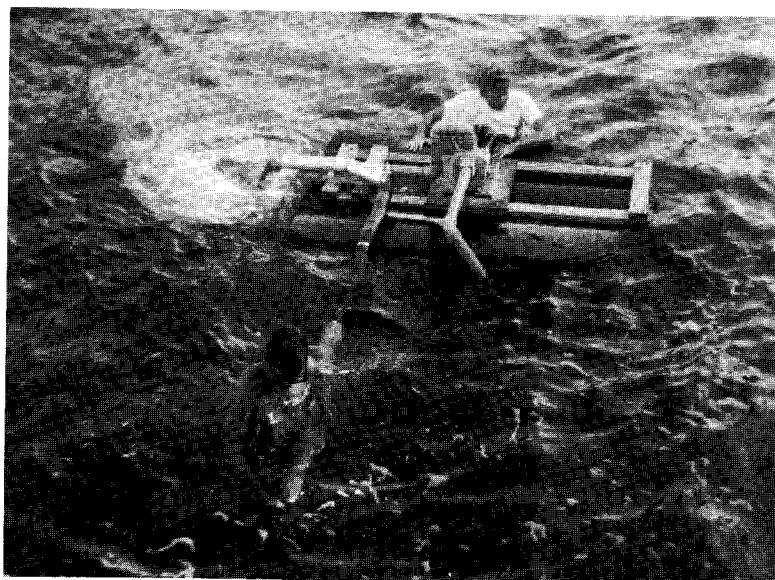


Figure 12. Vacuum dredge.

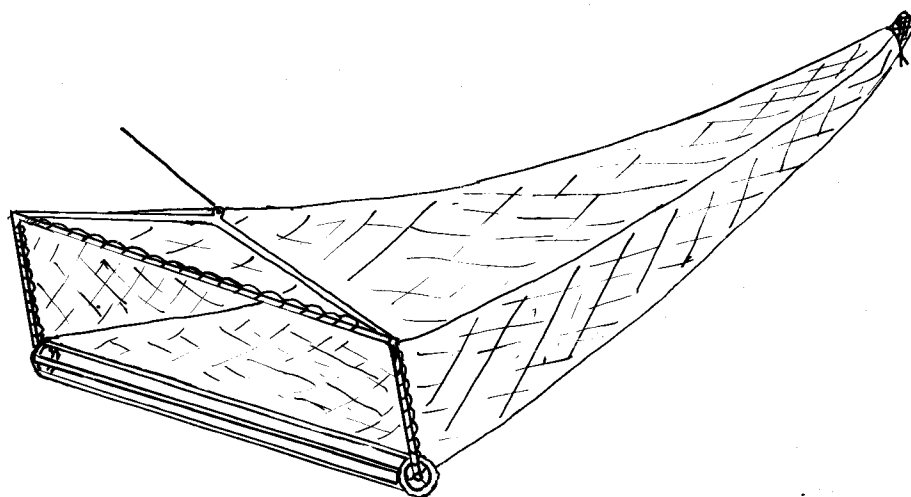


Figure 13. Roller-frame trawl.

Growth increases and days between molts were recorded. (Similar data are being kept on the animals which remain alive.) Pueruli were collected from Witham Habitats or taken from special plankton samples and brought back to the laboratory. They were then placed in one-gallon jars of aerated, unfiltered seawater and fed a variety of food-stuffs daily, including cut up fish fillets, crushed snails, and marine worms. Unfiltered seawater was provided from a shallow well located approximately 100 feet from the main ship channel into Key West Harbor. As the lobsters increased in size they were transferred individually into 5-gallon aquaria which contained sand/gravel filters. Temperatures were monitored daily and salinities weekly. As their size continued to increase, the animals were transferred into one of two compartmented tanks. These tanks, measuring 3 x 8 x 1.5 feet, were made of ½ inch plywood painted with epoxy resin and were divided into 12 compartments by nontoxic plastic window screen. Aeration was provided by a water spray system with an air compressor backup system which operated simultaneously. The water was kept clean by a dual system which featured a subsurface sand/gravel filter in a recirculating arrangement as well as a continual seawater flow. These systems could be run individually or simultaneously. The usual procedure was to run continual flow for two hours each day and then switch to the recirculating system for the remainder of the day. In the 5-gallon aquaria and the larger tanks, lobsters were fed as before with the exception that snails did not have to be crushed prior to feeding because of the increased size of the lobsters. Each lobster was checked daily and if it had molted, the molt was removed, measured, and preserved. The date of molting was recorded, along with the measurement. Molts were preserved by fixing them in 10% formaldehyde for two to three days and then transferring them to 40% isopropyl alcohol.

2. Group Feeding

In an attempt to find what foods might be accepted by the juvenile lobsters, a wide variety of materials were selected. Feeding experiments were begun by placing

groups of from 10 to 50 pueruli in aquaria ranging from 5 to 30 gallons. All aquaria were equipped with subsurface sand/gravel filters. Each group of lobsters was offered a different foodstuff and fed triweekly. Foods which were tried included: five varieties of commercial cat and dog food, Shrimp-el-ettes (a commercial fish food), lettuce, *Ulva*, cabbage, garbanzo beans, navy beans, macaroni, raw potato, boiled potato, hard-boiled egg (white and yolk, separately), chocolate bars, raw hamburger, amphipods, isopods, barracuda, mullet, grunt, snapper, various annelids, *Astraea*, *Littorina*, *Batillaria*, *Nerita*, *Strombus gigas*, and soybean presscake.

F. Tagging

Tagging studies were initiated in August 1967. A group of 35 adult lobsters were tagged with a modified sphyryon tag (Scarrat, 1963) and held in tanks in the laboratory. This tag was originally modified for use with the American lobster, *Homarus americanus* (Dr. Richard Cooper, Bureau of Commercial Fisheries, Boothbay Harbor, personal communication), but proved adaptable for work with the spiny lobster.

The composite tag consisted of an external spaghetti sleeving (obtained from Floy Tag Co., Seattle, Washington) of Resinite EP-2, connected to a stainless steel anchor hook (obtained from Gemco Manufacturing Co., Southington, Connecticut) by means of a polyethylene filament (Figure 14). Coded information was printed on the spaghetti sleeve. Insertion into the extensor muscle of the tail was made with a 19 gauge hypodermic needle. It was necessary to position the needle to either side of the middorsal line to avoid hitting the intestine or dorsal abdominal artery. During insertion, one of the anchor hooks was held by the groove of the needle and the connecting filament and tag sleeving were held alongside the needle barrel between the thumb and forefinger. The animal was held with the free hand over the carapace and the abdomen was forced to curl underneath the body by rolling its dorsal side on a solid surface. This exposed a narrow space between the posterior edge of the carapace and the anterior edge of the first abdominal segment and allowed needle and tag penetration through the connective tissue into the extensor muscle. The needle was inserted at an angle of

approximately 45°, $\frac{3}{4}$ to 1 inch deep into the muscle and withdrawn, leaving the anchor imbedded and the filament trailing externally with its spaghetti tag.

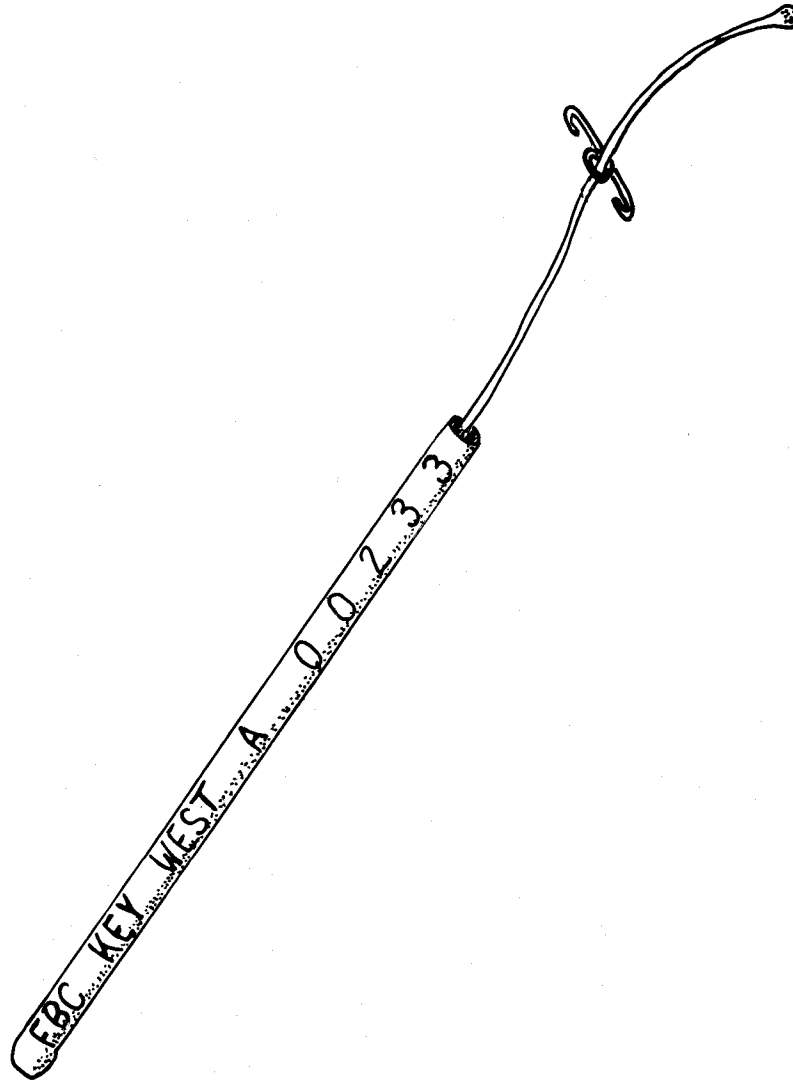


Figure 14. Composite lobster tag.

RESULTS AND CONCLUSIONS

I. Habitats

A. Surface

The Witham Habitat (Witham *et al.*, 1968) proved very effective in the capture of postlarval lobsters. Most lobsters taken were in the transparent or lightly pigmented puerulus stage, although one large juvenile measuring 108 mm in total length was taken during the test period. This is the largest recorded lobster ever taken from this type of habitat. Another record was established on April 19, 1967 when 112 first and second-stage postlarvae were taken from a single habitat at the Airport Lagoon. Postlarvae were taken year round and their occurrence followed a lunar pattern similar to that described by Witham *et al.* (1968). Most were taken during the new moon—first quarter phase. A monthly periodicity graph for June 1966 through January 1968 is shown in Figure 15. Although in the early part of the study habitats were placed on both sides of Key West, only three lobsters

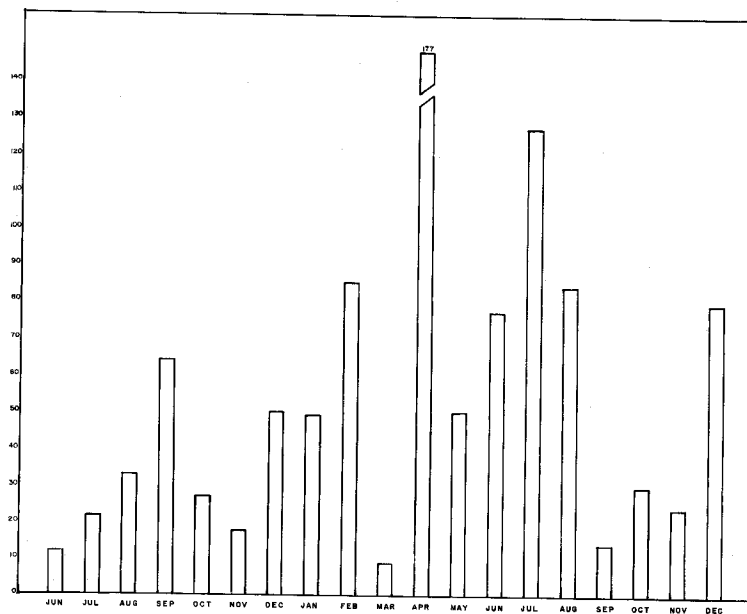


Figure 15. Monthly occurrence of pueruli, June 1966–December 1967.

were taken from the Gulf side while several hundred were taken from the Atlantic side. The most productive of these were on the immediate south side of the island. In the Marquesas Keys, 12 Witham habitats collected 62 lobsters between May 1967 and September 1967, only 23 of which were pueruli.

B. Bottom

1. Concrete Habitat

Postlarval lobsters readily accepted the concrete habitats in the laboratory experiment. Lobsters on the control side congregated mainly on the separating screen near the attachment to the walls of the tank, while those on the experimental side took up residency in the habitats within a few hours after being placed in the tank. On February 15, 1967, three months after the beginning of the experiment, 17 of the 23 (74%) remained on the control side while 22 of the 24 (92%) were still alive on the experimental side. All were removed from the tank on this date, measured, and returned to their respective sides.

The control side contained larger lobsters (minimum, maximum, and mean) than the experimental side with its protective habitats (Table 1). The reason for this probably lies in the fact that the unprotected animals did more foraging for food than those which were "holed up." The protected animals were rarely seen during hours of daylight and apparently fed only at night. Cannibalism did occur in the unprotected side with the victims in every observed case being the smaller animals. This may also have contributed to the increased size of the control animals.

In field tests, only two juvenile lobsters were ever found in the concrete habitats and these were taken from the Marquesas Keys group. Habitats were attractive to blennies, toadfish, octopuses, worms, starfish, mantis shrimp, arrow crabs, spider crabs, and topshells. Several times egg masses were found attached to the smooth bottom sides of the concrete habitats. Samples of these egg masses were twice brought into the laboratory, placed

in aerated aquaria, and hatched. In both cases the resulting larvae were toadfish (*Opsanus* sp.).

TABLE 1. CONCRETE HABITAT EXPERIMENT*

Side A (Control)			Side B (Experimental)		
Carapace Length	Carapace Width	Total Length	Carapace Length	Carapace Width	Total Length
6.2	4.8	18.0	6.2	4.2	16.5
6.5	4.8	18.5	6.0	4.5	18.0
6.7	4.8	18.2	6.2	4.4	18.2
6.5	4.8	18.8	6.2	4.8	18.9
6.0	4.4	17.5	6.7	5.0	19.0
6.5	5.0	18.6	6.2	4.5	18.2
6.8	5.0	19.0	6.0	4.4	18.0
7.0	5.8	22.0	6.1	4.8	18.2
6.8	5.0	20.0	6.8	4.8	19.0
7.2	5.8	22.6	6.9	5.0	20.5
8.0	6.2	25.0	6.2	4.8	19.0
7.8	6.0	24.8	6.9	5.0	20.0
8.0	6.2	24.0	7.0	5.0	20.0
8.0	6.2	23.8	7.6	6.0	23.2
8.3	6.5	25.8	7.5	6.0	24.0
9.0	7.1	29.5	8.0	6.2	25.0
9.1	7.9	30.0	8.0	5.8	24.0
			8.0	6.1	26.0
			8.3	6.4	26.0
			8.0	6.4	25.8
			8.2	6.8	26.2
			9.0	7.0	28.0
Minimum					
6.0	4.4	17.5	6.0	4.2	16.5
Maximum					
9.1	7.9	30.0	9.0	7.0	28.0
Average					
7.3	5.7	22.1	7.1	5.4	21.4

* Lobsters measured February 15, 1967

2. Other Habitats (Box, PVC, Modified Witham, Tires, and Apartment-type)

Although a large variety of other marine organisms were found in several of these habitat types, no lobsters were ever taken from them.

II. Plankton

During the period from October 1966 through August 1968, over 500 plankton samples were taken. From these samples, 638 transparent pueruli were collected. These include 595 from Whale Harbor Bridge, 19 from Bow Channel, 11 from Niles Channel, and 13 from Boca Chica Channel. A monthly breakdown of the Whale Harbor samples (Figure 16) shows that over 70% of the pueruli were taken in the middepth net. No pueruli were taken in the 88 ebb tide plankton samples collected in this survey.

Thirty-four phyllosome larvae were taken from these samples but only 10 have been identified as Palinuridae, all others being Scyllaridae. Sims and Ingle (1966) previously reported only seven phyllosomes from over 1200 samples taken in the Keys during 1962 and 1963. At no time were any pigmented pueruli taken from plankton samples. We therefore conclude that these transparent postlarvae settle to the bottom sometime prior to their postmetamorphic molt.

Transparent postlarvae were taken from plankton samples and from Witham habitats throughout the year. Since the spawning season in the Florida Keys occurs primarily from April to July, our data further substantiate the theory of Caribbean origin suggested by Ingle *et al.* (1963) and Sims and Ingle (1966) and supported by Witham *et al.* (1968).

III. Other Gear Tested

A. Pushnets

Witham *et al.* (1964) reported relatively good catches of postlarval lobsters obtained from the marine growths found on mangrove roots. W. G. Lyons (Florida Board of Conservation Marine Laboratory, St. Petersburg, Florida, personal communication) captured several pueruli and early juveniles, using the same method, at North Sound, Grand Cayman

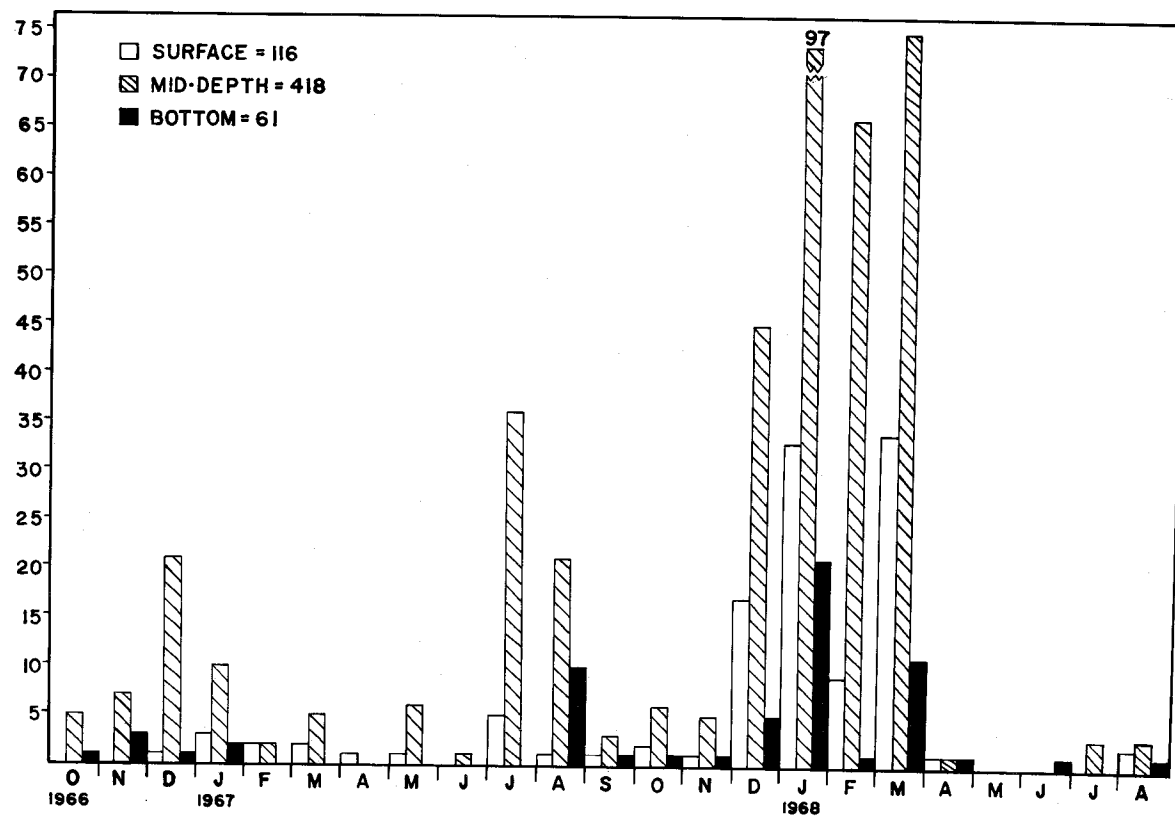


Figure 16. Pueruli taken by A-frame plankton sampler at Whale Harbor station, October 1966--August 1968.

Island, in July, 1965, where the marine growths appear quite similar to those found in the Florida Keys. Dr. Rene J. Buesa Mas (Director, Centro de Investigaciones Pesqueras, Habana, Cuba, personal communication) also reports that pueruli are taken regularly in Rhodophycean algal growths associated with aerial roots of the mangrove (*Rhizophora mangle*) at Casilda, Cuba. However, none were taken by this manner during our study. Pushnetting at many different locations in the lower Keys was also unproductive.

B. *Vacuum Dredge*

The dredge collected many shrimps, crabs, and small mollusks but no lobsters were taken.

C. *Roller-frame Trawl*

No lobsters were taken by this apparatus although its worth as a biological sampling device cannot be denied. Fish were taken in large quantity in the majority of the samples, with lesser numbers of shrimps, crabs, and mollusks present.

IV. Growth Studies

A. *Individual*

Growth of individual postlarval lobsters in our laboratory study was not as rapid as that described by Witham in his mass rearing experiments (Witham *et al.*, 1968). However, our growth rates (Table 2) were comparable to those of Lewis *et al.* (1952). Witham provided a much greater area per lobster than did Lewis or the present study and this probably contributed to the accelerated growth rate of his lobsters. In our studies, molting frequency varied with individuals and increased during the summer months when water temperatures were higher. Almost all molting occurred during the night.

Figure 17 shows the average increase per molt for the three variables: carapace width, carapace length, and total length in captive juvenile lobsters raised from pueruli to the 18th molt.

One hundred sixty-nine of the transparent pueruli which were maintained in the laboratory molted. Since the dates of metamorphosis were unknown, it is difficult to determine the

TABLE 2. COMPARISON OF GROWTH FIGURES FOR
CARAPACE LENGTH IN STAGES I-VIII

Stage	Lewis <i>et al.</i>	Sweat
I	6.1 (25)	6.1 (321)
II	6.2 (32)	6.3 (105)
III	7.0 (19)	6.8 (60)
IV	7.5 (10)	7.6 (44)
V	8.5 (8)	8.6 (39)
VI	9.3 (4)	11.1 (31)
VII	10.1 (2)	13.3 (27)
VIII	11.9 (3)	15.4 (26)

Numbers in parentheses represent lobsters considered.

interval to the first postmetamorphic molt. The average observed length of time before the molt was 8.13 days; however, it would appear that the puerulus maintained the longest prior to molting would be a better indicator of the actual intermolt period. In these studies this period was 26 days. Fourteen other pueruli ranged from 13 to 21 days with an average of 15 days. This indicates that the first intermolt period is roughly comparable to the other early juvenile molt periods observed (Table 3).

Late stage phyllosomes were never taken in inshore waters. It appears that metamorphosis takes place in deeper water and the transparent pueruli then move into the shallower areas. Comparison of the observed average intermolt period of the pueruli and the estimated total intermolt time indicate that this inshore migration apparently takes from two to three weeks.

A field tagging program has yielded some preliminary growth data on adult lobsters. This data is based on returns from 20 tagged animals which molted during approximately four months of freedom (April through July, 1968). Comparative growth data were also obtained from 24 lobsters held in the laboratory during the same period of time (Table 4). From this comparison it is evident that adult lobsters molting in the field generally increased in size more than laboratory-maintained animals.

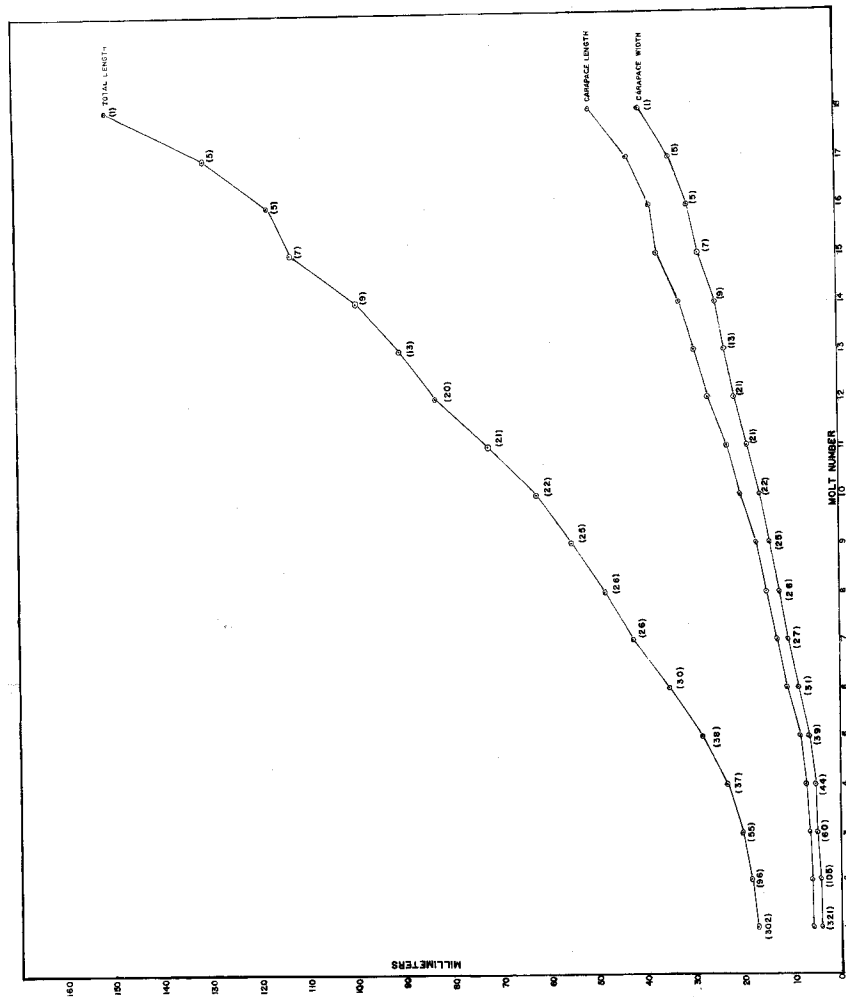


Figure 17. Average carapace increase, postlarval molts 1 through 18.

TABLE 3. AVERAGE DAYS BETWEEN MOLTS*

Molt Number	Days Between Molt	Number of Lobsters
1	8.13	169
2	26.88	72
3	24.04	42
4	26.33	27
5	28.46	24
6	30.00	19
7	34.26	15
8	39.80	15
9	33.14	14
10	34.50	12
11	35.18	11
12	33.20	10
13	49.20	8
14	46.83	6
15	59.60	6
16	73.50	4
17	118.00	3

* Based only on pueruli which were completely transparent at the beginning of the study.

TABLE 4. CARAPACE LENGTH (CL) COMPARISON IN MOLTING ADULT LOBSTERS

	Number Molting	Initial Avg. CL	Total CL Increase	Avg. CL Increase	Max. CL Increase	Min. CL Increase
Laboratory						
Animals	24	91.0 mm	63.8 mm	2.7 mm	8.0 mm	-1.8 mm
Field						
Animals	20	87.2 mm	130.1 mm	6.5 mm	20.0 mm	.4 mm

Maximum and minimum CL increases were greater in the field group than in the laboratory-maintained individuals. In the laboratory group there was molting without growth with one animal actually displaying a loss of 1.8 mm. Molting without growth has been previously reported by Travis (1954), Marshall (1948), and others.

B. Group Feeding

There was no observed feeding while the pueruli were in the transparent stage. The first observed feeding occurred two or three days after the first postmetamorphic molt. Natural marine foodstuffs were eaten much more readily by the juvenile lobsters than were any of the other preparations offered. The best food for early juveniles (up to about three months) appeared to be small amphipods and isopods which inhabited *Ulva* colonies. Annelids and mollusks were also accepted readily. However, the mollusks had to be cracked prior to feeding and overfeeding caused the water to foul rapidly. Annelids were presented alive and caused no fouling. Cut fish was usually eaten readily but quickly caused fouling if not eaten.

Puss-N-Boots fish-flavor cat food, raw hamburger, and the yolk of hard-boiled eggs were eaten but broke up quickly, causing severe fouling. None of the other foods were accepted by the lobsters.

V. Tagging

Thirty-five lobsters were tagged in the laboratory in August 1967 and 22 molted, retaining the tag. Several of these have molted a second time and one lobster has molted a third time, still retaining the tag. Of the 13 animals which died prior to molting, only one death could be attributed to infection around the tag site. All lobsters which died were examined and the stainless steel anchor hooks were found to be encapsulated in muscle tissue with little or no discoloration in the surrounding flesh.

Due to tag success in laboratory tests, a field tagging program was initiated in November 1967. Approximately 2500 lobsters were tagged and released in waters around the Florida Keys during the first year. This project is continuing and results will be published at a later date.

SUMMARY

A study of juvenile *Panulirus argus* in the Florida Keys was initiated in March 1966 and continued through August 1968.

Various submersible habitats and other collecting devices were tested in different regions of the Keys in an attempt to find the best areas and the most efficient methods for collecting postlarval lobsters.

Individual growth records were kept on 510 postlarval lobsters and are presented in this paper. Several of these have molted over 15 times. Growth rates approximate others carried out under similar conditions but are much less than those reported by Witham *et al.* (1968).

Over 500 plankton samples taken during the study yielded 638 pueruli. These same samples yielded only 10 phyllosome larvae of the family Palinuridae. Absence of late phyllosomes inshore, presence of large numbers of transparent pueruli in the plankton, and analysis of time required to attain pigmentation indicate that metamorphosis from the phyllosome probably takes place offshore, followed by an inshore migration of pueruli whose arrival coincides with the new moon—first quarter phase.

An experimental tagging program proved successful in the laboratory. A field tagging experiment is under way. Approximately 2500 lobsters were tagged and released in waters surrounding the Key West area. Lobsters that were tagged, released in the field, and recaptured at a later date showed greater growth than those held in the laboratory during the same time period.

PERTINENT LITERATURE

- ALLEN, D. M. and J. H. HUDSON
1968. A unit area suction sampler for benthic organisms. (On file at Tropical Atlantic Biological Laboratory, *Bur. Comm. Fish.*, Miami, Fla.)
- BACKUS, J.
1960. Observations on the growth rate of the spiny lobster. *California Fish & Game*, 46(7): 177-181.
- BUESA MAS, R. J.
1961. Segunda pesca exploratoria y datos biologicos de la langosta *Panulirus argus* en Cuba. *Centro Invest. Pesqueras*, Contrib. No. 12: 1-70.
- BURKENROAD, M. D.
1951. Measurement of the natural growth rates of Decapod crustaceans. *Proc. Gulf Carib. Fish. Inst.*, 3rd Ann. Meet: 25-26.
- CRAWFORD, D. R. and W. J. J. DESMIDT
1922. The spiny lobster, *Panulirus argus*, of southern Florida: its natural history and utilization. *Bull. U. S. Bur. Fish.*, 38: 281-310.
- DAWSON, C. E. and C. P. IDYLL
1951. Investigations on the Florida spiny lobster *Panulirus argus* (Latreille). *Fla. Bd. Conserv. Tech. Ser. No. 2*: 1-39.
- FLORIDA BOARD OF CONSERVATION
1966. Summary of Florida commercial marine landings. Tallahassee, Fla. n.p.
- INGLE, R. M., B. ELDRED, H. W. SIMS and E. A. ELDRED
1963. On the possible Caribbean origin of Florida's spiny lobster populations. *Fla. Bd. Conserv. Tech. Ser. No. 40*: 1-12.
- LEWIS, J. B., H. B. MOORE, and W. BABIS
1952. The postlarval stages of the spiny lobster *Panulirus argus*. *Bull. Mar. Sci. Gulf Carib.*, 2(1): 324-337.
- LINDBERG, R. G.
1955. Growth, population dynamics and field behavior in the spiny lobster, *Panulirus interruptus* (Randall). *Univ. Calif. Publ. Zool.*, 59(6): 157-248.
- MARSHALL, N.
1948. The molting without growth of spiny lobsters, *Panulirus argus*, kept in a live car. *Trans. Amer. Fish. Soc.*, 75: 267-269.

- PHILLIPS, R. C.
1959. Notes on the marine flora of the Marquesas Keys, Florida. *Quart. Jour. Florida Acad. Sci.*, 22(3): 155-162.
- ROBINSON, R. K. and D. E. DIMITRIOU
1963. The status of the Florida spiny lobster fishery, 1962-63. *Fla. Bd. Conserv. Tech. Ser. No. 42*: 1-30.
- SCARRAT, D. J. and P. F. ELSON
1965. Preliminary trials of a tag for salmon and lobsters. *J. Fish. Res. Bd. Canada*, 22(2): 421-424.
- SIMS, H. W., JR.
1966. An annotated bibliography of the spiny lobsters, family Palinuridae and Scyllaridae. *Fla. Bd. Conserv. Mar. Lab. Tech. Ser. No. 48*: 1-84.
- SIMS, H. W., JR. and R. M. INGLE
1966. Caribbean recruitment of Florida's spiny lobster population. *Quart. Jour. Florida Acad. Sci.*, 29(3): 207-242.
- SMITH, F. G. W.
1958. The spiny lobster industry of Florida. *Fla. Bd. Conserv. Ed. Ser. No. 11*: 1-36.
- SUTCLIFFE, W. H., JR.
1957. Observations on the growth rate of the immature Bermuda spiny lobster, *Panulirus argus*. *Ecology*, 38(3): 526-529.
- TRAVIS, D. F.
1954. The molting cycle of the spiny lobster, *Panulirus argus* Latreille. I. Molting and growth in laboratory-maintained individuals. *Biol. Bull.*, 7(3): 433-450.
- U. S. BUREAU OF COMMERCIAL FISHERIES
1968. Shellfish situation and outlook. *Curr. Econom. Analysis-S10*: 34 pp.
- WITHAM, R., R. M. INGLE, and H. W. SIMS, JR.
1964. Notes on postlarvae of *Panulirus argus*. *Quart. Jour. Florida Acad. Sci.*, 27(4): 289-297.
- WITHAM, R., R. M. INGLE, and E. A. JOYCE, JR.
1968. Physiological and ecological studies of *Panulirus argus* from the St. Lucie estuary. *Fla. Bd. Conserv. Tech. Ser. No. 53*: 1-31.

