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Studies of the Rock Shrimp, *Sicyonia Brevirostris*, a New Fishery Resource on Florida's Atlantic Shelf

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Florida Department of Natural Resources

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ABSTRACT

Kennedy, F. S., J. J. Crane, R. A. Schlieder, and D. G. Barber. 1977. Studies of the rock shrimp, *Sicyonia brevirostris*, a new fishery resource on Florida's Atlantic shelf. Fla. Mar. Res. Publ. No. 27, 69 p. Life history, fishery dynamics and potential stock locations of the Florida East Coast Continental Shelf population of rock shrimp were studied over a two year period.

A life history survey was conducted monthly at four stations located in 26, 40, and 64 m depths near Cape Canaveral. Rock shrimp distribution fluctuated, but major concentrations of adults occurred at 40 m. Major population recruitment occurred from late spring through summer, although some recruitment occurred all year. Adult abundance followed a yearly cycle, peaking in fall and exponentially declining until a new year class appeared the next spring.

Five ovarian developmental stages were defined, one more than previously described for penaeids. Although some females were mature by a 17 mm carapace length (CL) the majority were mature by 24 mm CL and were multiple spawners during one season. All males were mature by 18 mm CL and able to impregnate females during the remainder of their life. Peak spawning occurred for three months during winter and early spring, but some was apparent all year. Seasonal temperature increases initiated gonadal maturation, thus influencing seasonal spawning; intra-monthly spawning coincided with full moon.

Males gained weight slightly faster than females of equal carapace length. Carapace length - weight relationships were non-linear in small sizes, linear in larger sizes. Increase in total length occurred at the same rate for males and females until 20 mm CL. Rate of increase in female total length then slowed, most likely in response to onset of sexual maturity and spawning. Juvenile growth averaged 2 - 3 mm CL per month. Adult growth averaged 0.5 - 0.6 mm CL per month. Females grew faster as juveniles and adults. Natural mortality was directly related to abundance. Adult females had slightly lower natural mortality than males. Maximum age was 20 - 22 months. Male/female ratio was 0.93 overall, with seasonal fluctuations attributed to growth and mortality rate disparities. Diet consisted mostly of crustaceans and mollusks, but many other organisms were occasionally eaten.

Fishery survey sampling included the stations of the monthly life history survey and single samplings of 163 stations located along 31 east-west transects in 18 - 73 m depths between St. Lucie Inlet and Amelia Island. Major concentrations of adult shrimp were found between 34 m and 55 m depths in two regions covering most of the continental shelf from Cape Canaveral northward. Smaller concentrations were found south of Cape Canaveral. Juveniles were observed in all depths between 18 and 73 m, but adults were absent from the shallowest zone. Annual abundance and seasonal initiation of major recruitment varied in different fishery regions, but generalized trends were similar. Generalized distribution, life cycle, and seasonal abundance are explained in fishery terminology for use by the industry.

Contribution No. 294, Florida Department of Natural Resources Marine Research Laboratory

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INTRODUCTION

Rock shrimp, *Sicyonia brevirostris*, Stimpson 1871, have been caught in small quantities in deeper water fishing grounds since the early years of Florida's penaeid shrimp fishery. Prior to 1970, rock shrimp were usually captured incidentally while trawling for other commercially important penaeids; they occasionally were kept for personal use. In 1970, the first Florida landings of rock shrimp were recorded, 1200 pounds (headed) worth $642 (U.S. Department of Commerce, 1970). Landings in 1972 totaled 443,035 pounds valued at $258,528. By that time the rock shrimp fishery was emerging as a viable Florida industry. Today, it is continuing to prosper (Table 1).

TABLE 1. FLORIDA *S. BREVIROSTRIS* LANDINGS (1970-1974) AND CASH VALUE (FROM U.S. DEPARTMENT OF COMMERCE, 1970, 1971c, 1972-1974).

	Pounds (heads-off)	Dollars
1970	1,281	$ 642
1971	207,926	103,821
1972	443,035	258,528
1973	697,581	400,333
1974	1,683,218	908,619

In 1972 there was insufficient information on rock shrimp to make sound resource management decisions. Information consisted of: taxonomic efforts, summarized in Cobb et al. (1973); descriptions of *S. brevirostris* developmental stages (Cook and Murphy, 1965); geographic and bathymetric distributions of rock shrimp on the U.S. Atlantic Shelf (Anderson, 1956; Lunz, 1957; Bullis and Rathjen, 1959) and in the northwest Gulf of Mexico (Brusher et al., 1972); and an ecological analysis of rock shrimp collected in the eastern Gulf of Mexico (Cobb et al., 1973).

In 1972 the Florida Department of Natural Resources (FDNR) initiated a project to study the relatively unexploited rock shrimp population on Florida's Atlantic Shelf. Its purpose was to develop life history and population dynamics data necessary for resource management and to define potential fishery stocks. The project was partially funded through a research grant from Public Law 88-309 (Commercial Fisheries Research and Development Act) administered through the Fisheries Management Division, NMFS, NOAA, U. S. Department of Commerce.

METHODS AND MATERIALS

MATERIALS

An Interocean CSTD probe, Model 513, was used to measure salinity, temperature, and depth at each sampling station. Instrument accuracy was ±0.05 $^{0}/_{00}$ salinity, ±0.05°C temperature, and ±1% depth. All data were recorded on paper tape.

When the CSTD was inoperative, several alternative procedures were used to obtain physical data. Standard thermometer and refractometer readings were found inadequate and were replaced by bathythermograph readings in conjunction with bottom, mid-depth, and surface Niskin bottle water samples.

Benthic infauna and sediment samples were taken using a Hydro Products Shipek Sampler, Model 860 with a sample bucket size of 0.04 m^2.

Larval *Sicyonia* were collected with a one meter, 223 μ mesh nylon plankton net with a one-liter plastic collecting bottle. An Interocean TSK flowmeter, Model 313, centered in the net mouth, measured the quantity of water filtered. A 50 kgm weight was attached to the net bridle with a 7 m chain to reduce cable angle.

Otter trawls for the life history survey were semi-balloon design, 2.5 cm (1 in) stretch mesh, head line 6.5 m (21 ft), lead line 8.0 m (26 ft), and mouth height 1.2 m (46 in) at wings (Figure 1). Head line flotation was with six 5.1 x 4.0 cm (1.5 x 3.0 in) cylindrical floats and the lead line was weighted with three sections of 0.6 cm (¼ in) chain. A 0.6 cm (¼ in) tickler chain of 7.4 m (24 ft) was attached to 61 x 122 cm (2 x 4 ft) doors, rigged with 2 x 10 cm (¾ x 4 in) steel runners, 0.8

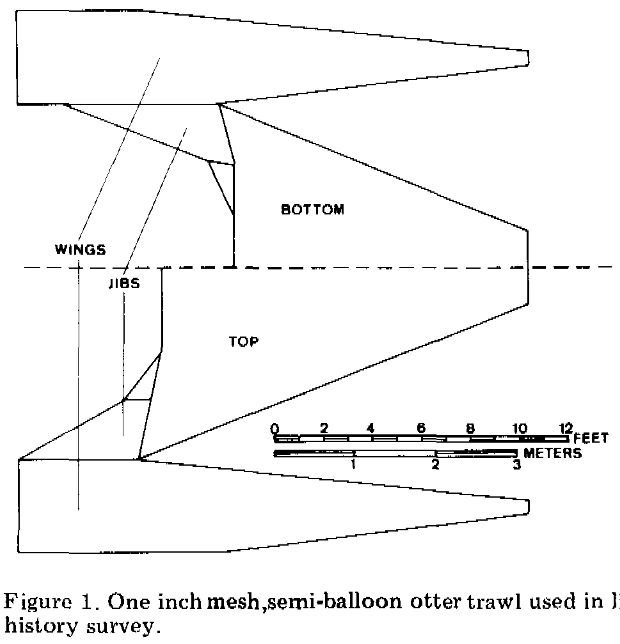


Figure 1. One inch mesh,semi-balloon otter trawl used in life history survey.

cm (5/16 in) door chains, and a 9.1 m (30 ft) bridle. The catch bag was enclosed in plastic chafing gear.

Otter trawls for the fishery survey were semi-balloon design, 5.1 cm (2 in) stretch mesh, head line 6.7 m (22 ft), lead line 7.8 m (26 ft), and mouth height 1.1 m (42 in) at wings (Figure 2).

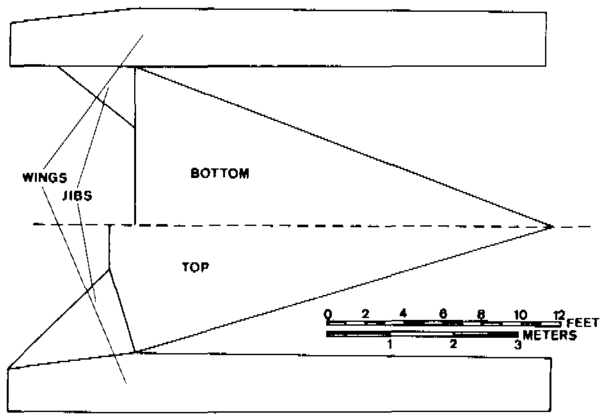


Figure 2. Two inch mesh, semi-balloon otter trawl used in fishery survey.

Head line flotation was with a plastic cylindrical float 21.6 cm x 11.4 cm (8.5 x 4.5 in) and the lead line was weighted with sections of 0.6 cm (¼ in) chain. A 7.2 cm (24 ft) tickler chain was attached to the doors and bridle.

FIELD METHODS

Field sampling was conducted along the Florida Atlantic Continental Shelf aboard the R/V *Hernan Cortez* from January 1973 through December 1974. The research program consisted of life history and fishery surveys. Sampling was conducted at night since previous rock shrimp investigators reported highest catches then (Anderson, 1956; Lunz, 1957; Joyce, 1965; Brusher et al., 1972; Cobb et al., 1973). Cobb et al. (1973) reported that rock shrimp are nocturnally active, burrowing into the substrate during daylight.

Four stations for the life history survey were established east-north-east of Cape Canaveral, Florida, between latitudes 28°31.3′N and 28°35.3′N, a zone of *S. brevirostris* concentration (Anderson, 1956). Two stations were located at 40 m within the main population, and single stations were positioned at 26 m and 64 m on the inshore and offshore fringes of this zone. The inshore station (001) was located originally at 33 m, but after three months was moved to 26 m and renamed 01A because 33 m depth was in the main population. Each station was plotted as a circle encompassing all tow paths taken in each area, with the center of the circle recorded as the exact coordinate of the station (Figure 3). Life history survey stations were occupied as near the beginning of each month as possible. Station sequence was rotated monthly to randomize possible effects of moon phase and time of night. Stations were located using two intersecting Loran A readings and depth.

The fishery survey consisted of 23 monthly samplings of the life history survey stations and single samplings of 163 stations located from the Georgia-Florida border, 30°33.2′N, to south of St. Lucie Inlet, Florida, 27°6.7′N. These stations were established along 31 east-west Loran transects from 18 m to 73 m depths (Figure 4). Depth profiles were constructed from sounding data provided by Coast and Geodetic Survey Charts (U.S. Department of Commerce, 1971a, 1971b).

Hydrographic, meteorological, and temporal data were recorded, and a CSTD cast was made. The probe was lowered at approximately 0.6 m/sec, obtaining a salinity, temperature, and depth reading for every two meters depth; readings at maximum depth were manually recorded.

An alternating sequence of three plankton net tows and three otter trawl tows were taken at each station. Plankton tows were step oblique, bottom, mid-depth, and surface, of 2-3 min duration at each step. Beginning time and location, tow direction and duration, wire length and flow meter readings were recorded. The net's contents were washed into the sample container with salt water and preserved in 3-5% seawater formalin. At stations 001-01A, 003, and 004, otter trawls were towed in a north or south direction to maintain the correct station depth. Strong northerly Gulfstream currents at station 005 made southerly tow results unreliable; therefore, these tows were made northerly. Time and location at the beginning and end of each 30-min otter trawl tow and direction of tow were recorded. Otter trawl contents were sorted on deck for rock shrimp. If fewer than 200 rock shrimp were caught, all were identified to species, sexed and measured to 1 mm carapace length (CL) size classes. Carapace length was measured from the posterior margin of the orbit to the posterior margin of the carapace. Up to ten females from each size class and all rock shrimp less than 12 mm CL were preserved in 10% seawater formalin. If more than 200 rock shrimp were captured, a subsample of approximately 200 was randomly selected for analysis; the remainder were counted to obtain total catch size.

Three replicate benthic grab samples were taken every other month, starting January 1973. Depth, approximate bucket fullness and time were recorded. Samples were preserved in 10% seawater formalin for laboratory analysis. An additional

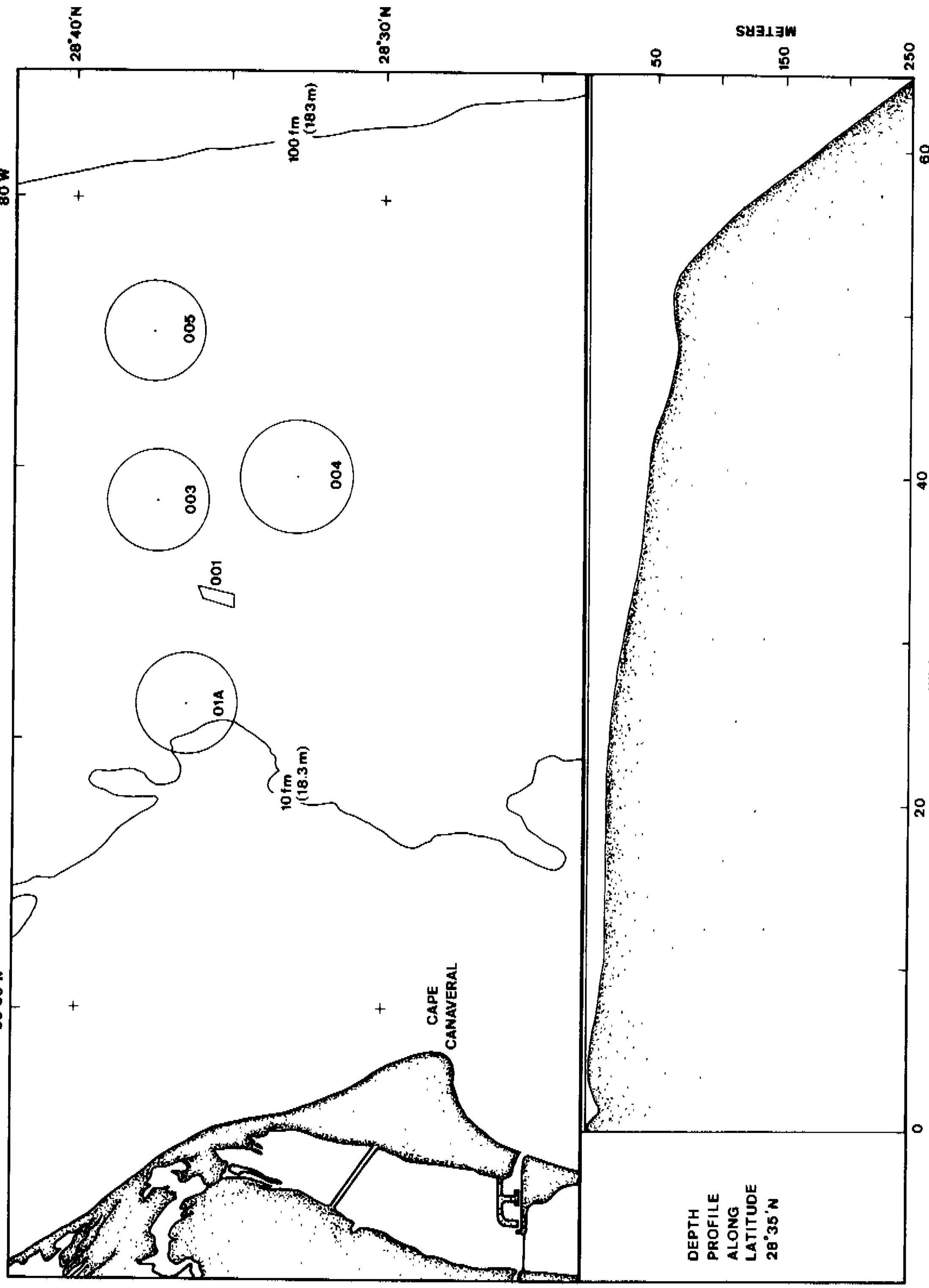


Figure 3. Life history survey area, station locations, and bottom profile.

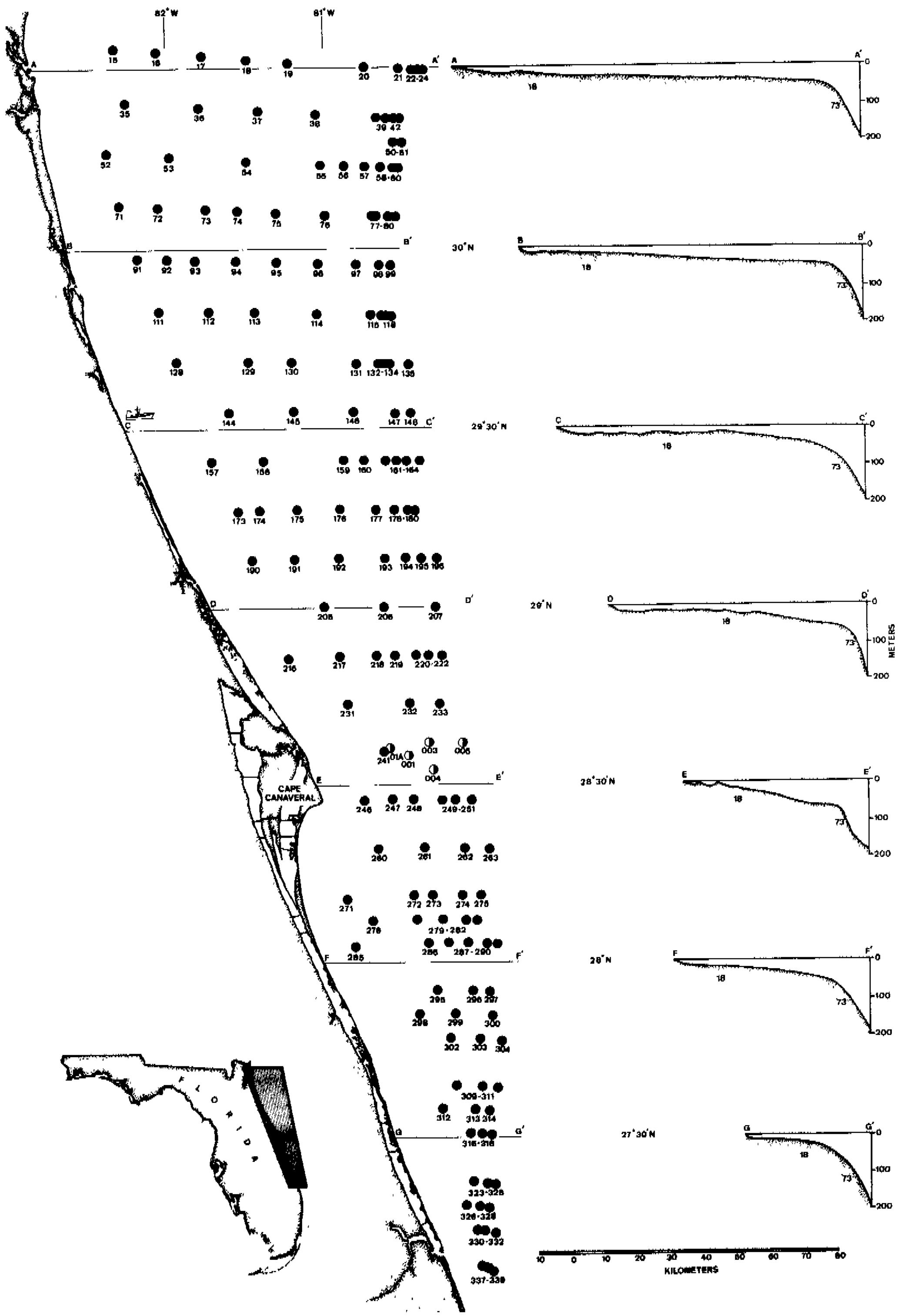


Figure 4. Fishery survey station locations and bottom profiles transecting selected latitudes in the study area.

benthic sample was obtained for sediment analysis every fourth month, starting May 1973.

Fishery survey stations were occupied following monthly life history survey work. Pre-determined stations were located using two intersecting Loran A coordinates and depth. Hydrographic, meteorological, and temporal data were recorded. A 15-min otter trawl tow was made; Loran A coordinates and tow times were recorded. Samples were sorted on deck and rock shrimp data recorded. Rock shrimp less than 22 mm CL were preserved in 10% seawater formalin.

Hydrographic, meteorological, and catch data for life history and fishery surveys are presented in Appendices I and II, respectively.

LABORATORY METHODS

LARVAL ANALYSES

A one percent subsample of each plankton sample was examined for rock shrimp larvae. The sample was mixed and 2 ml Hensen-Stempel pipette subsamples were taken until the aliquot volume was reached. All rock shrimp larvae were picked from the subsample and identified to developmental stage following Cook (1964) and Cook and Murphy (1965). Results were recorded as number of larvae of each stage per cubic meter of water.

JUVENILE AND ADULT ANALYSES

Approximately ten males and ten females were randomly selected from each size class from the first six months samples combined, and remeasured for statistical comparison of carapace length with total length and wet weight. Carapace length was measured to the nearest 0.1 mm and total length to the nearest 1 mm. Shrimp were patted dry on absorbent paper and weighed to the nearest 0.01 g on a Mettler top load balance.

Ovaries were removed from a maximum of two randomly selected females in each 1 mm CL size class represented from each month from every depth zone. This procedure was expected to yield over 20 gonads for each depth zone (60 to 80 per month, the most that could be handled in this time period). Ovarian tissue was taken from the mid to rear posterior lobe beginning at the posterior edge of the first abdominal segment because rapid breakdown of the hepatopancreas after death caused deterioration of the anterior and middle lobes and the anterior section of the posterior lobe. Cummings (1961) reported no significant difference in oocyte diameters among the three lobes for *Penaeus duorarum* and Cobb et al. (1973) reported similar results for *S. brevirostris*. Tissues were dehydrated in Technicon S-29, embedded in paraffin, sectioned at 6 μm mounted on glass slides, and stained with Harris Hematoxylin/ Eosin Y. The most advanced group of viable oocytes was used to determine stages of ovary development. Ovaries were independently classified to stage by two persons. When the readings did not agree, another reading was obtained.

As an *a posteriori* analysis, the male reproductive system was removed from a maximum of three randomly selected shrimp in each 1 mm size class represented from each season. This provided about 50 animals from each season. Tissues were prepared in the manner described for ovarian slides, with sections taken through the vas deferens, gonopore, and testes, then examined for developmental stages. The petasma of each male sampled was examined for presence of fusion.

Eighteen stomachs (ten from the 40 m depth zone and four each from 26 m and 64 m depth zones) from the shrimp selected for ovarian analyses were removed for stomach content analysis. Stomachs were opened with fine dissecting scissors, washed with 30% isopropanol, and the contents examined with a dissecting microscope. Initially food items were categorized into general taxonomic groups; later mollusks and arthropods were re-examined for generic and species identification. Food items were classified as predominant or residual following Hall (1962) and Cobb et al., (1973). Predominant items were those which clearly composed most identifiable remains. Residual items were those identifiable remains present in smaller amounts.

BENTHIC SAMPLE ANALYSES

Benthic samples were washed through box screen sieves to > 3 mm and 1 - 3 mm size fractions. Fauna were manually picked from the associated sediment, counted, and sorted into phyla. Mollusks and arthropods were subdivided; mollusks into species, arthropods into orders or subclasses, then to genus or species whenever possible.

Sediment samples were oven-dried for approximately eight hours at 56°C to constant weight. Dried sediments were sieved for 1-2 hrs, depending on sample volume, into seven size fractions using a Ro-Tap sieve shaker. Sieve mesh sizes (mm) were 2.000, 1.000, 0.500, 0.250, 0.125, and 0.062. Each size fraction was weighed to 0.01 g on a Mettler top load balance. Size fraction weights were recorded as percentages of total sample weight.

STATISTICAL ANALYSES

Statistical methods were found in Steel and Torrie (1960), Sokal and Rohlf (1969), or Ricker (1958, 1973). Variates were transformed where necessary and samples tested for homogenity of variance or normality using Bartlett's Chi-Square. When the basic assumptions of parametric analyses were met, analysis of variance (ANOVA) and Tukeys' w-procedure were used to test hypotheses and individual sample differences. When the basic assumptions of parametric statistics could not be met, the non-parametric STP test proved adequate.

Model I least squares regression and correlation, with logarithmic transformations when necessary, provided morphometric relationships. Geometric mean regressions were fitted when functional equations for back-calculation were needed (Ricker, 1973). Analysis of covariance was used to test sexual differences in morphometric relationships.

Instantaneous rates were used to compare growth and mortality estimates and their interactions (Ricker, 1958). These rates were computed on a daily basis and converted to monthly rates for comparison.

TABLE 2. STP TEST FOR STATION DIFFERENCES IN JUVENILE CPUE (UPPER) AND ADULT CPUE (MIDDLE), STP TEST FOR AREA DIFFERENCES IN ADULT CPUE (LOWER).

	001-01A	003	004	005
001-01A	XXX	245	244.5	253
003		XXX	249	250.5
004			XXX	262.5
005				XXX

$U_{0.05}[4,22] = 351.4$ is significant

	001-01A	003	004	005
001-01A	XXX	372.5	362.5	304
003		XXX	250.5	433.5
004			XXX	434.5
005				XXX

$U_{0.05}[4,22] = 351.4$ is significant

	Area I	Area III	Area V
Area I	XXX	373	304
Area III		XXX	439.5
Area V			XXX

$U_{0.05}[3,22] = 342$ is significant

RESULTS AND DISCUSSION

LIFE HISTORY SURVEY

POPULATION DISTRIBUTION AND DYNAMICS

Bathymetric Distribution

Station locations were selected so that bathymetric distribution and recruitment patterns could be examined. Bartlett's Chi Square test indicated large between-tow variability; therefore, individual catches were averaged to obtain monthly station catch per unit effort (30 min CPUE). Differences in juvenile and adult patterns were examined. Shrimp 24 mm CL or larger were classified as adult based on analysis of female sexual maturity. Using the non-parametric STP test, between-station differences in juvenile abundance (CPUE) were examined to disclose areas of juvenile concentration. No significant station differences (P=0.05) were found in juvenile CPUE values during both years (Table 2). The extreme range of values, 1-2678 at 01A, 1-1051 at 003, 3-1149 at 004, and 4-869 at 005, obscured any station differences. Although station differences were not statistically evident, some seasonal differences were apparent and will be discussed later.

Adult abundance (CPUE) was tested for station differences during both years. Stations 003 and 004 were not significantly different (P=0.05), but adult abundance was significantly higher than at either station 01A or 005 (Table 2). Since 003 and 004 were the same depth, adjacent, and statistically compatible, an average adult CPUE for the depth was calculated. Three areas were thus defined: area I in 26 m (station 01A), area III in 40 m (station 003, 004), and area V in 64 m (station 005).

Jones (1950) cited temperature, salinity, and substrate as the significant physical factors determining distribution of bottom fauna in coastal regions. Accordingly, the three areas were examined for differences in these physical factors that might have contributed to observed rock shrimp distribution.

Average bottom temperatures exhibited a slight gradient from the shallow area I to the deep area V, directly related to increasing depth (Table 3). Shrimp were exposed to ranges of 17.8 - 27.2°C in area I, 16.5 - 27.6°C in area III, and

TABLE 3. LIFE HISTORY SURVEY TEMPERATURE AND SALINITY VALUES FOR BATHYMETRIC AREAS.

AREA	I		III		V	
	Avg.	*Range*	*Avg.*	*Range*	*Avg.*	*Range*
Temperature, °C						
Warm water (Aug.-Jan.)	23.3	17.8-27.2	22.8	17.3-27.6	19.4	15.6-25.8
Cold Water (Feb.-July)	20.4	18.4-22.9	19.1	16.5-22.6	17.2	13.8-22.0
Salinity, 0/00 Jan.73-Dec. 74	35.72	34.00-36.57	35.56	32.00-36.57	35.65	34.00-36.75

13.8 - 25.8°C in area V. Average salinity values were similar for all bottom areas. The salinity ranges experienced by shrimp were 34.00 - 36.57 ⁰/oo in I, 32.00 - 36.57 ⁰/oo in III, and 34.00 - 36.75 ⁰/oo in V.

Bottom sediments in the three areas were similar. Samples showed little annual change in sediment type. Sediments were typically quartzose and shell sands, fine to medium grained, consisting primarily of mollusk, foraminiferal, and barnacle fragments. Sediment fractions included gravelly shell sands and scallop shell in area III and deep banks of the scleractinian coral *Oculina* in area V.

Both salinity and substrate appeared to be uniform throughout, although the coral banks in area V may have been responsible for reduced CPUE, by reducing available sand habitat. Temperature differences may have partially accounted for the bathymetric zonation observed. The ranges encountered in all areas, however, were well within tolerance ranges reported for other penaeids (Perez-Farfante, 1969). Other factors independent of the physical environment, such as relationships with food supply or competition with other species, especially other penaeids, may have also contributed to this zonation.

Seasonal Dynamics

Juvenile recruitment was observed both years. Monthly length frequencies for the combined areas I and III clearly showed seasonal influxes of recruits. Males (Figure 5) and females (Figure 6) have been presented separately for subsequent growth analyses, although their recruitment patterns were identical.

Major seasonal juvenile recruitment was first observed in April 1973 and again in April 1974. Continuing occurrence of the smallest size classes supported an April to August recruitment season. Recruitment occurred in pulses, with two or more influxes taking place during one major recruitment season. At least two groups of juveniles were observed in July and August, 1973 and 1974. Recruitment of a few juveniles occurred through most of the year. During successful recruitment seasons like 1973, off season recruitment probably added little to total year class success. Off season recruits may have contributed to the stability of the population during less successful seasons like 1974.

Monthly adult, juvenile, and total CPUE were plotted by area to show seasonal trends and differences in abundance between areas (Figure 7). Area III dynamics were considered the most representative of the general rock shrimp population. Adult CPUE slowly decreased from about 100 to slightly less than 50 from January to July 1973. Juveniles were reaching adult size by August; and thereby increased adult CPUE through October. Total CPUE for 1973 peaked in October. Juvenile CPUE declined rapidly after October as juveniles reached adult size and few new recruits entered the area. Adult CPUE also declined through the remainder of 1973 and into spring of 1974. Since no commercial fishery was present in this area, declining adult stocks were caused by natural mortality and possible migration. Seasonal recruitment in 1974, minimal compared to 1973, greatly affected subsequent total adult abundance. Seasonal cycles were similar; but the minimal supply of potential new adults in 1974 caused adult CPUE to peak at 124 compared to almost 700 in 1973. Minimal adult abundance appeared less affected by success or failure of a particular year class. Decreased natural mortality, off season recruitment, or migration from other more densely populated areas may have moderated annual minimal abundance.

Area I was apparently the initial juvenile recruitment area for the 1973 season. All recruits in May, most recruits in June, and half of the July recruits appeared in this area. Although recruits

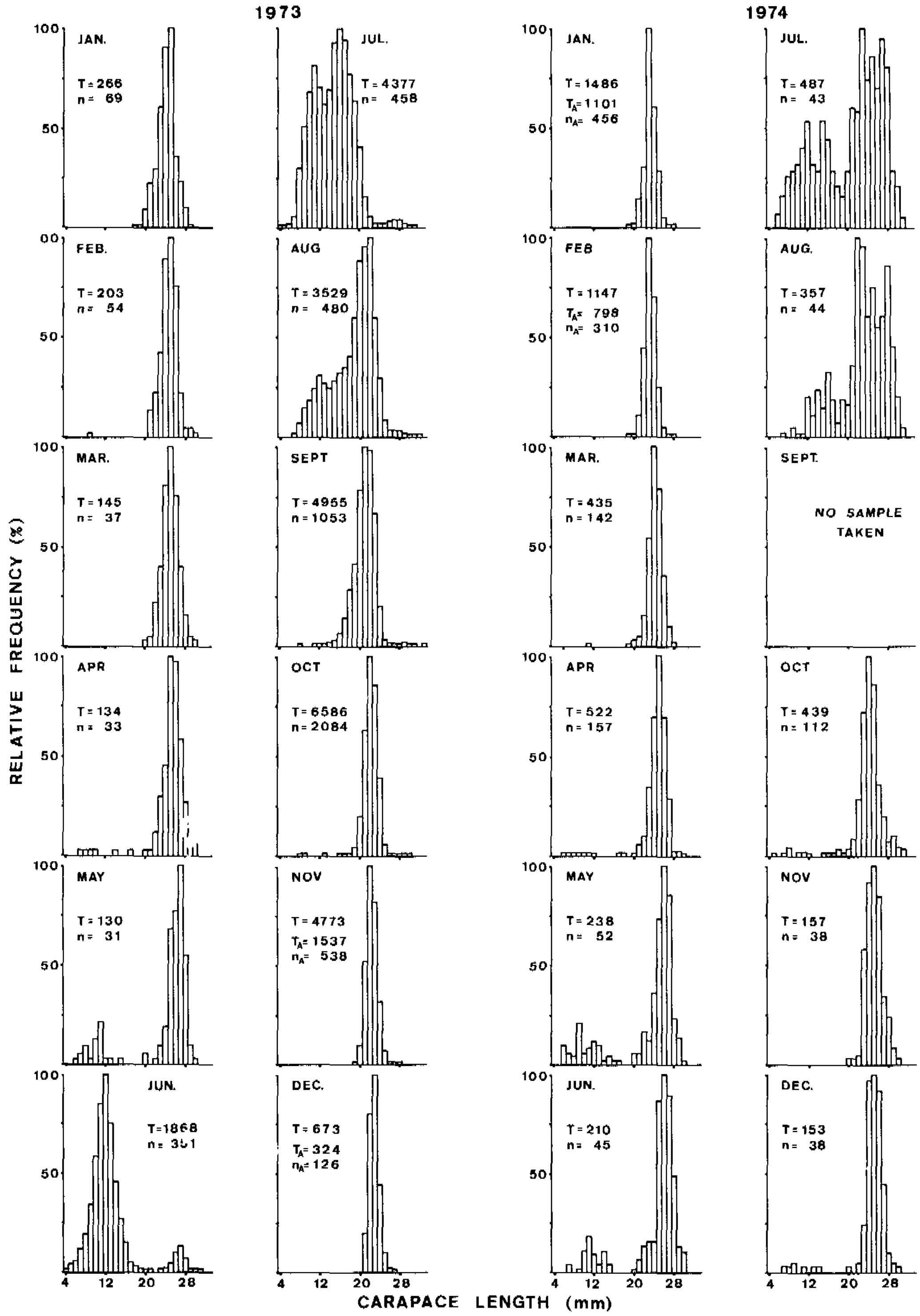


Figure 5. Length frequency distribution of male *S. brevirostris* in the life history survey areas I and III combined from January, 1973 through December, 1974. T is total shrimp, Ta is total shrimp in aliquot and n is the number of shrimp in the largest modal size class.

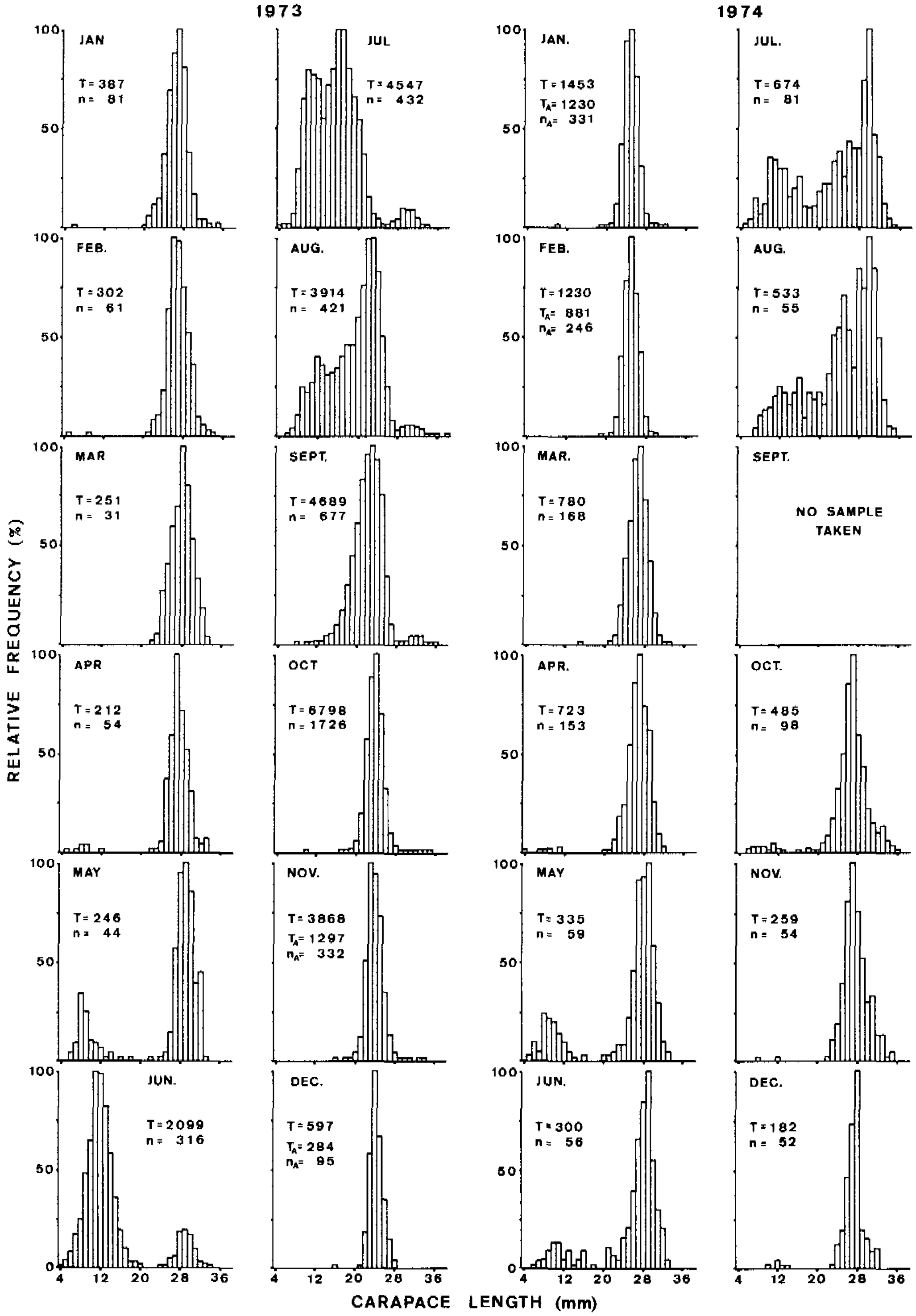


Figure 6. Length frequency of female *S. brevirostris* in the life history survey areas I and III combined from January, 1973 through December, 1974. T is total shrimp, Ta is total shrimp in aliquot and n is the number of shrimp in the largest modal size class.

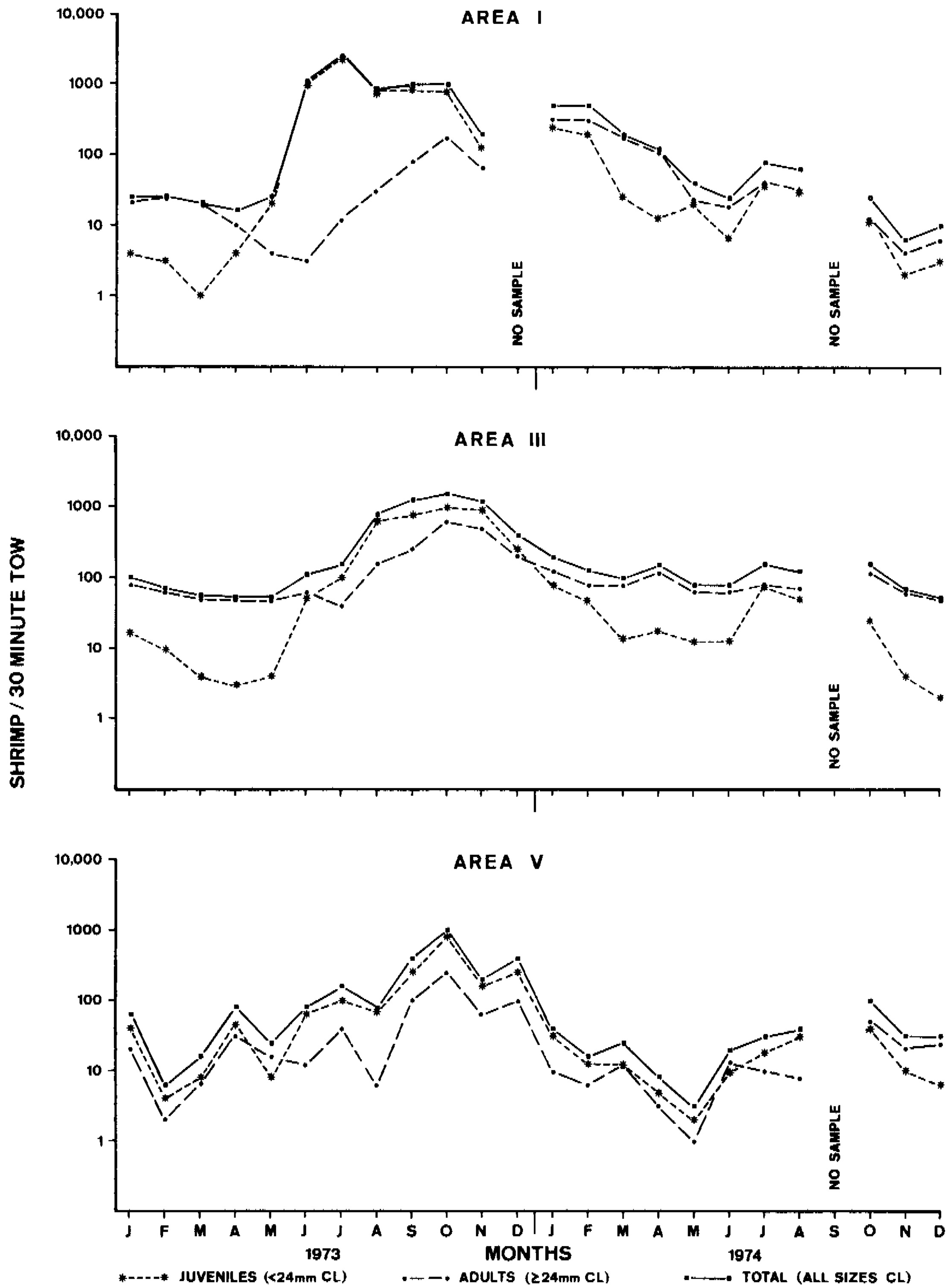


Figure 7. Seasonal abundance in life history survey areas, expressed as catch per unit effort (CPUE) per 30 minute tow.

appeared in area III in June and July, their abundance was immensely increased by migration from area I in August. This increase in area III abundance corresponded to an equivalent decrease in area I of similar sized juveniles. Large area I recruitment produced a large adult stock in this area through late 1973 and early 1974. Competition for food and space in area III may have increased stock density inshore. Few adults were found in area I in early 1973. And due to poor recruitment in spring, 1974, few were observed there later that year. The 1974 juvenile catches were similarily low in areas I and III from June through November 1974. Most adults did not remain in area I, but may have migrated to area III as evidenced by much slower decreases in adult abundance there.

Area V exhibited CPUE maximums in October, 1973 and 1974, and peak recruitment from June through August, similar to those of areas I and III, but was otherwise very dissimilar. CPUE values fluctuated erratically. Juvenile size classes not present in other areas appeared in April, 1974, disappeared from the entire study area in May, and reappeared in June. Other length frequency disparities were common. This supports the previous bathymetric distinction of area V and suggests a basic instability of the rock shrimp population in this deep water fringe area.

LIFE HISTORY

Ovarian Development

Approximately 1900 females were examined for ovaries. Ninety-four percent of the prepared slides contained sufficient material for analysis. Ovaries in young animals, present only as a fine filament attached to the intestine wall, were extremely small and difficult to extract.

Previous analyses of penaeid ovarian development have used gross ovarian morphology, oocyte morphology, or oocyte diameter to identify the most advanced group of oocytes and thus ovarian stage. Four ovarian developmental stages and one spawned or spent stage have been described for *S. brevirostris* (Cobb et al., 1973) and for other penaeids (Perez-Farfante, 1969). Based on our histological examination of oocyte morphology, five stages were apparent: 1) *Undeveloped*(U) with nucleus comprising majority of oocyte cross-sectional area, evenly textured with no chromosomes visible; 2) *Developing* (D) with chromosomes condensed to rod-like bodies and dispersed around periphery of nucleus, no yolk globules present; 3) *Nearly Ripe* (NR) with chromosomes condensed in nucleus, yolk globules filling nearly all cytoplasmic region; 4) *Ripe* (R) with chromosomes condensed, nucleus distinguishable in cross-section, nuclear membrane not distinct, round or rod-like peripheral bodies near or attached to cell membrane; 5) *Advanced Ripe* (AR) with peripheral bodies well formed and large, nucleus absent (Figure 8, a-e).

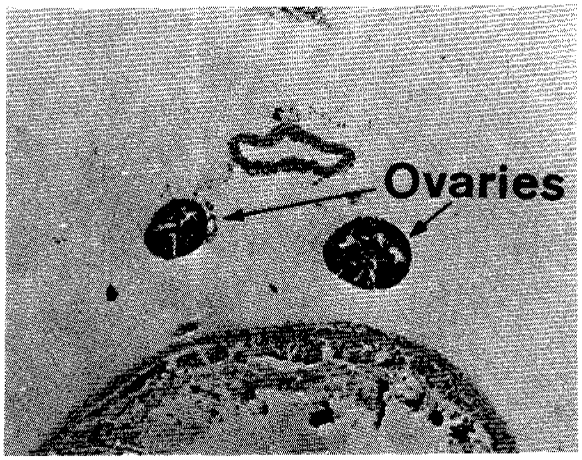
The first four stages were the same as previously described for *S. brevirostris* and other penaeids. The fifth stage (AR) has not previously been described for any penaeid. Only fourteen ovaries were found in this stage of development. Three to six sequential sections of each ovary showed no nuclei in any AR-stage ova. Loss of a distinct nucleus marks the beginning of reduction or maturation divisions and occurs very near spawning (Balinsky, 1965).

Three additional ovarian stages were described based on the presence of degenerative AR-stage ova or absence of oogonia: 1) *Spawned but viable* (-S) with several degenerative AR-stage ova in the ovary or interovarian oviduct; 2) *Possibly spawned but viable* (-S?) with interstitial yolk globules in the ovary; 3) *Terminally Spent* (TS) without viable oogonia or oocytes in the ovary (Figure 9, a-c). The first two stages were always suffixed to one oocyte developmental stage, usually D-stage. Spawning was not always complete and some AR-stage ova remained as evidence. Incomplete spawning has also been observed for *P. duorarum* (Cummings, 1961; Cobb et al., 1973: Martosubroto, 1974) and *P. setiferus* (King, 1948). Ovaries in D-S and NR-S stages were spawned and redeveloping. The few R-S stage ovaries were interpreted as either spawned and redeveloping or the result of prematurely developed ova.

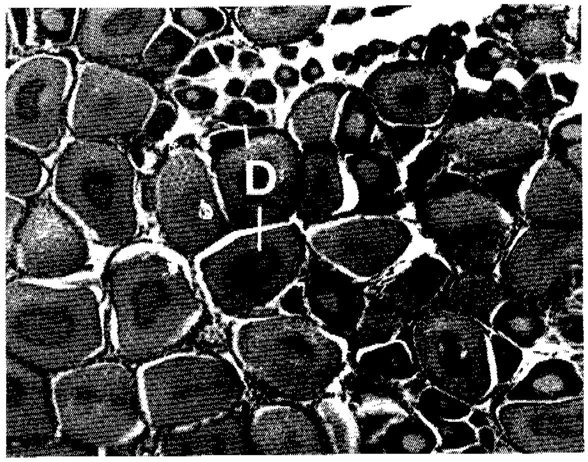
Approximately 35% of all D-stage and more advanced ovaries contained interstitial yolk globules so were designated as (-S?). Since yolk globules are integral components of NR-stage and more advanced ova, their presence interstitially was not conclusive evidence of spawning. Interstitial yolk in D-stage ovaries probably indicates degenerative ova, evidence of previous spawning; however, some were suspected to be terminally spent due to the poor overall condition of the ovary and the presence of very few viable D-stage ova. Terminally spent females were apparently incapable of spawning again, because no viable oocytes or oogonia were present, at least in the posterior ovarian lobes. The complete distribution of ovarian stages in relation to carapace length is shown in Table 4.

Sexual Maturity

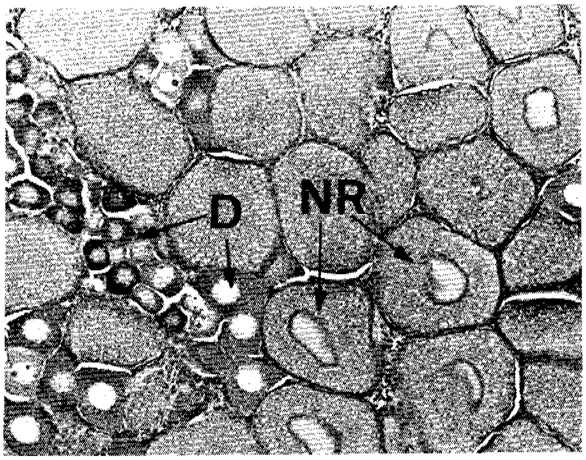
Females were grouped by size to three developmental stages; U, D, and reproductively mature (Table 5). Reproductively mature females included NR, R, AR, D-S, D-S? and TS. Females transitional between U and D or D and NR were removed. D-S?



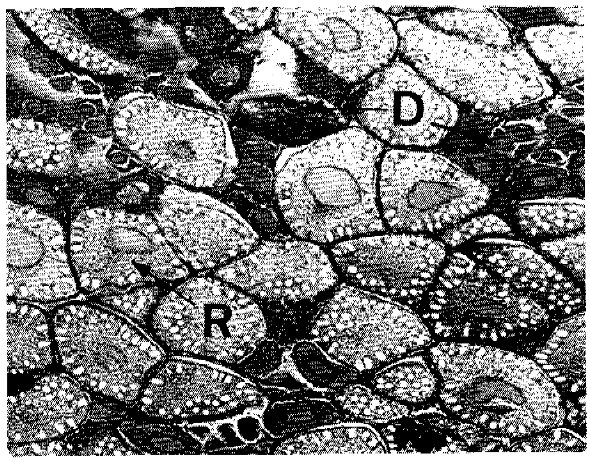
a. Undeveloped (U) stage oocytes from a 12 mm CL female (x92.3).



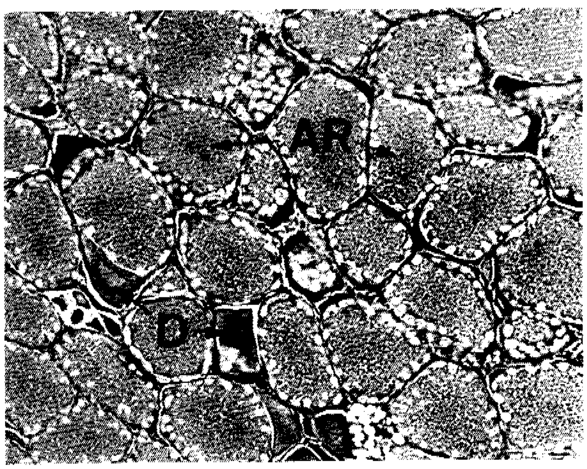
b. Developing (D) stage oocytes from a 31 mm CL female (x92.3)



c. Nearly ripe (NR) stage oocytes from a 28 mm CL female (x92.3)

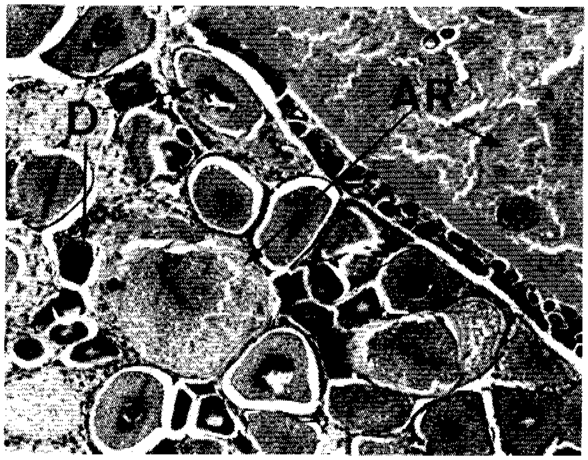


d. Ripe (R) stage oocytes from a 28 mm CL female (x92.3)

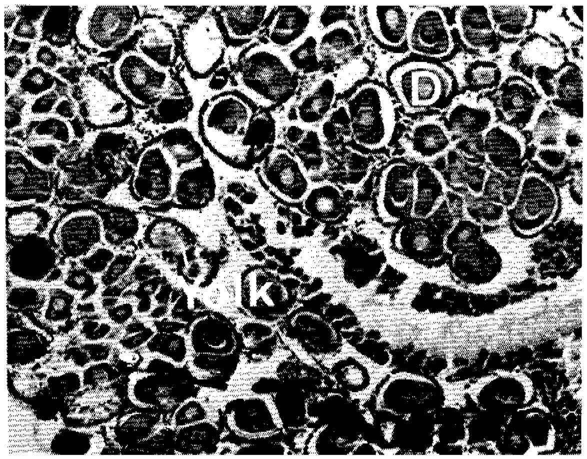


e. Advanced ripe (AR) stage oocytes from a 24 mm CL female (x92.3)

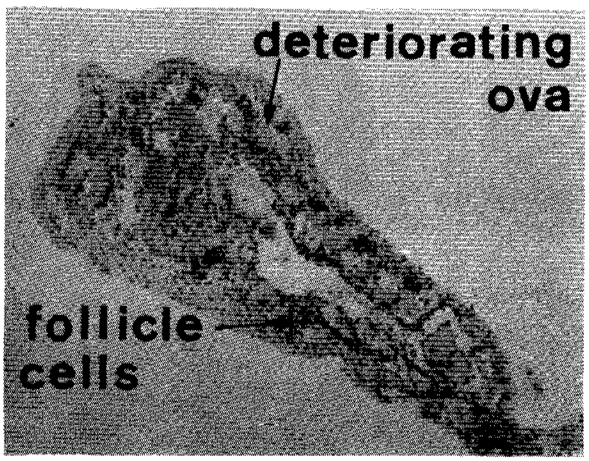
Figure 8. Photomicrographs of *S. brevirostris* ovarian sections.



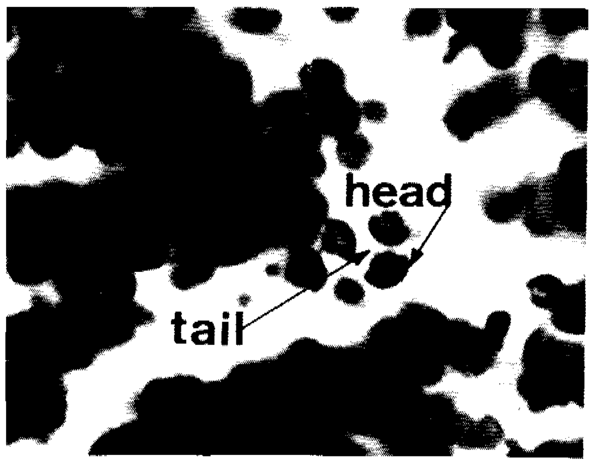
a. Spawned but viable (-S) ovary with viable D-stage oocytes, and deteriorating AR-stage oocytes from a 28 mm CL female (x92.3)



b. Possibly spawned but viable (-S?) ovary with viable D-stage oocytes and free yolk globules from a 22 mm CL female (x92.3)



c. Terminally spent (TS) ovary from a 26 mm CL female (x92.3)



d. Spermatazoa in the testes of a 26 mm CL male (x2000)

Figure 9. Photomicrographs of sections through the ovaries and testes of *S. brevirostris*.

TABLE 4. DISTRIBUTION OF OVARIAN STAGES IN RELATION TO CARAPACE LENGTH.

	Ovarian Stage													
Size (mm CL)	U	D	D-S?	D-S	NR	NR-S?	NR-S	R	R-S?	R-S	AR	AR-S?	TS	Total
< 5	1													1
5	5													5
6	10													10
7	12													12
8	16													16
9	37													37
10	33													33
11	35	2												37
12	37	1												38
13	25	6												31
14	32	8												40
15	22	10												32
16	19	22												41
17	16	22	1											39
18	8	35	4		1				1					49
19	4	36	6	3	2	2	1	1	1	1				57
20	4	30	10	4	3	3	2		2	1	1		1	61
21	1	40	16	6	7	4	1	4	5					84
22	4	34	24	6	4	9	1	4	4		1		1	92
23		32	16	10	12	9		8	7	1	2		2	99
24		25	17	19	12	13	4	11	6	1	1	1	2	112
25		24	36	11	15	12	4	11	7	1	1		3	125
26		33	29	15	19	14	1	5	7		2		3	128
27		27	24	17	12	11	5	12	4	1			4	117
28		16	31	7	23	9	3	14	3	1	2		7	116
29		9	21	16	13	5	2	9	12	1	2		8	98
30		10	20	16	12	5	2	8	3		1		11	88
31		7	16	14	9	2	2	5	4				4	63
32		7	11	5	8	8	3	3	2				5	52
33		3	10	4	6	2		2	5				5	37
34			6	2	3	2	1	1					6	21
35			3	3	1			1	2				4	14
36						1							2	3
37							1							1
38													1	1

stage females were included since most had spawned previously.

The first mature female was 17 mm CL. The percentage of mature females increased rapidly between 17 mm and 24 mm CL as more females reached maturity for the first time. Seventy-nine pecent maturity was reached at 24 mm CL, but because some D-stage ovaries most likely showed no evidence of prior spawning, all females were probably sexually mature by this size.

Inspection of data in Table 4 shows that numbers of each reproductively mature stage, except TS, varied slightly at three to four mm CL intervals. These variations suggest multiple spawning of the same individuals. In addition, nearly all D-S stage ovaries contained two separate groups of D-stage ova, indicating at least three spawns, provided that the two remaining groups matured separately. Multiple spawning in Florida penaeids has been reported for *Penaeus setiferus* (King, 1949; Lindner and Anderson, 1956; Perez-Farfante, 1969), *P. d. duorarum* (Cummings, 1961; Eldred et al., 1961; Perez-Farfante, 1969; Martosubroto, 1974), and *P. a. aztecus* (Perez-Farfante, 1969). Most report two possible lifetime spawns, although Lindner and Anderson (1956) suggested four.

Approximate contribution to total reproduction in relation to size class was estimated using the percentage of all mature females, except TS, in each size class and female size class distribution for all samples collected (Figure 10). Nearly 80% of all potential spawners were 26 mm CL or smaller, while 60% were between 23 mm and 26 mm CL. These estimates do not include the effect of fecundity, which is known to increase with size in other penaeids (Perez-Farfante, 1969; Martosubroto, 1974).

One hundred and forty-seven males were examined to determine the size at which maturity

TABLE 5. FREQUENCY OF THREE OVARIAN DEVELOPMENTAL STAGES IN RELATION TO SIZE (CL).

	Undeveloped		Developing		Reproductively Mature		
CL (mm)	n	%	n	%	n	%	N
< 5	1	100.0					1
5	5	100.0					5
6	10	100.0					10
7	12	100.0					12
8	16	100.0					16
9	37	100.0					37
10	33	100.0					33
11	35	94.6	2	5.4			37
12	32	97.1	1	2.9			33
13	22	78.6	6	21.4			28
14	25	75.8	8	24.2			33
15	17	63.0	10	37.0			27
16	16	42.1	22	57.9			38
17	13	36.1	22	61.1	1	2.8	36
18	8	16.3	35	71.4	6	12.2	49
19	3	5.4	36	64.3	17	30.4	56
20	2	3.4	29	50.0	27	46.6	58
21	0	0	39	47.6	43	52.4	82
22	2	2.3	32	36.4	54	61.3	88
23			28	29.5	67	70.5	95
24			23	20.9	87	79.1	110
25			20	17.2	101	82.8	121
26			28	24.0	95	76.0	123
27			24	21.1	90	78.9	114
28			14	12.3	100	87.7	114
29			8	8.2	89	91.8	97
30			10	11.4	78	88.6	88
31			6	9.7	56	90.3	62
32			5	10.0	45	90.0	50
33			3	8.1	34	91.9	37
34					21	100.0	21
35					14	100.0	14
36					3	100.0	3
37					1	100.0	1
38							

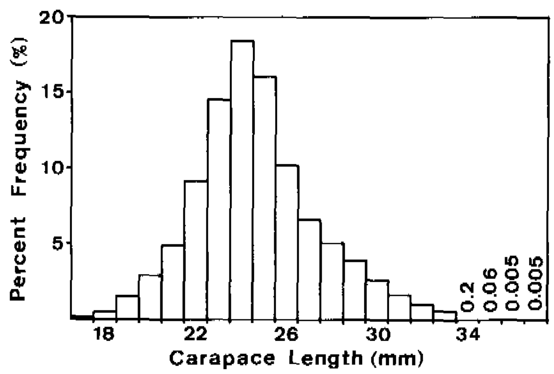


Figure 10. Contribution to total reproduction in relation to size.

is reached and to detect seasonal variation in quantity of mature males (Table 6). Both the presence of petasmal fusion and spermatozoa were used as an indication of maturity (Figure 9, d).

Petasmal fusion was first evident in approximately 14% of the 10 mm CL size class. All males 14 mm CL or larger showed fusion. Spermatozoa were first observed in 18% of the 11 mm CL size class. All males 18 mm CL or larger had spermatozoa. Specimens 18 mm CL or larger were selected with particular emphasis on equal representation from all four seasons. There was no seasonal variation in numbers of mature males; all had spermatozoa, and seemed capable of impregnating females throughout the year.

Spawning

Seasonal spawning aspects were determined by percentages of mature females in each month's sample, all areas combined. Mature females were those having NR, R, AR, and D-S stage ovaries. Ovarian stages U, D, D-S?, and TS were treated separately. Stages transitional between U and D or D and NR were not included.

TABLE 6. MALE SEXUAL DEVELOPMENT IN RELATION TO SIZE.

Carapace Length (mm)	NON FUSED PETASMA		FUSED PETASMA			GERMINAL EPITHELIUM		SPERMATOGONIA		SECONDARY SPERMATOCYTE		SPERMATID		SPERMATOZOA		
	n	%	n	%	N	n	%	n	%	n	%	n	%	n	%	N
7	3	100	0	0	3	3	100									3
8	7	100	0	0	7	6	100									6
9	11	100	0	0	11	7	70	3	30							10
10	6	85.7	1	14.2	7	1	14.2	6	85.7							7
11	6	54.5	5	45.4	11	2	18.1	6	54.5	—		1	9.0	2	18.1	11
12	4	40.0	6	60.0	10	2	20.0	4	40.0	1	10.0	2	20.0	1	10.0	10
13	5	45.4	6	54.5	11	—		4	40.0	2	20.0	4	40.0	—		10
14	0	——	9	100	9	—		1	11.1	2	22.2	6	66.6	—		9
15	—		11	100	11	—		2	18.1	1	9.0	6	54.5	2	18.1	11
16	—		11	100	11			—		—		6	54.5	5	45.4	11
17	—		10	100	10	—		—		—		4	40.0	6	60.0	10
18			3	100	3							—		3	100	3
19			1	100	1									1	100	1
20			7	100	7									7	100	7
21			5	100	5									5	100	5
22			5	100	5									5	100	5
23			9	100	9									9	100	9
24			6	100	6									6	100	6
25			3	100	3									3	100	3
26			3	100	3									3	100	3
27																
28																
29			3	100	3									3	100	3
30																
31																
32																
33			1	100	1									1	100	1
Total	42	41.6	59	58.4	147	21	14.3	30	20.4	5	34.0	29	19.7	62	42.2	144

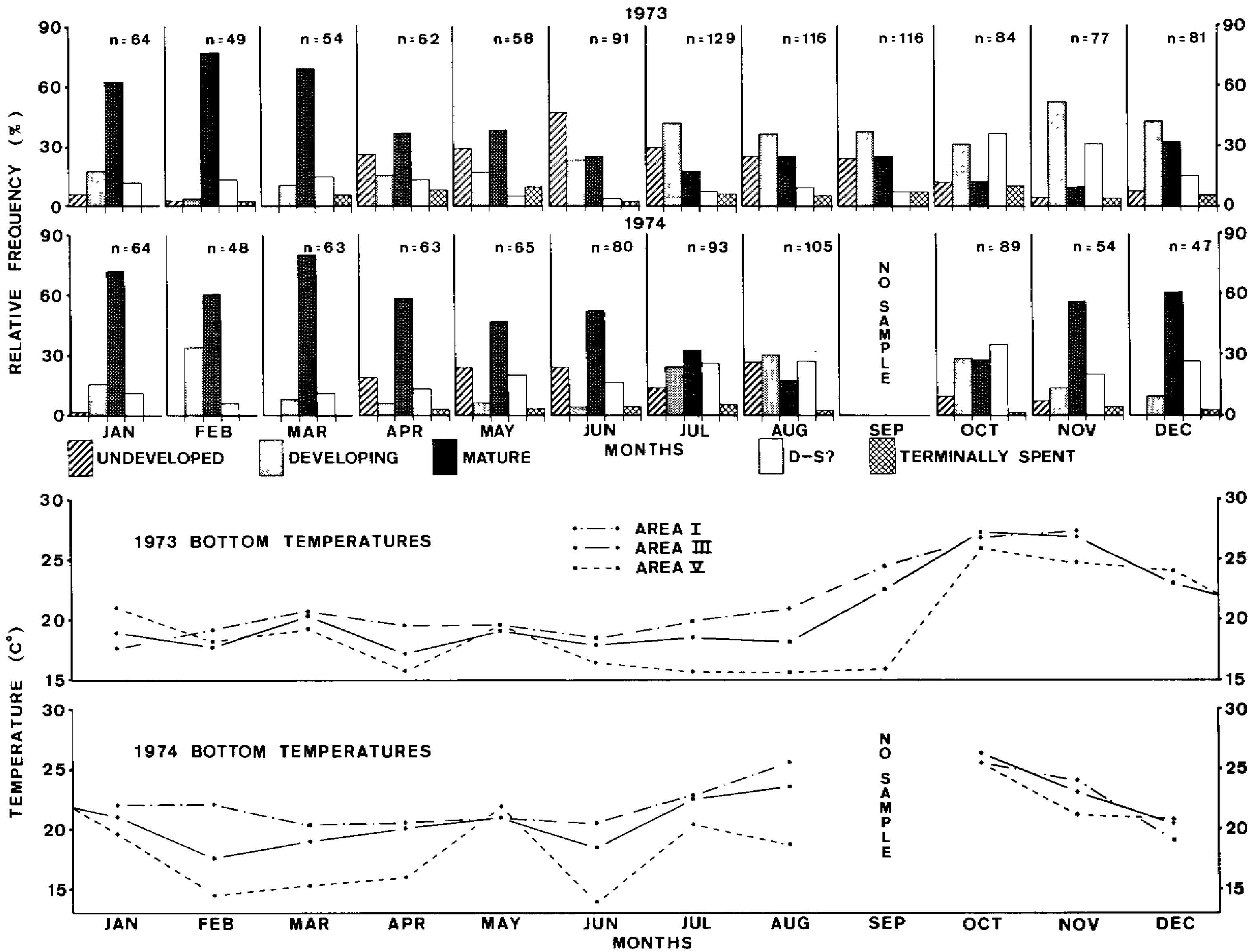


Figure 11. Monthly frequency distribution of ovarian stages and comparisons to monthly bottom temperatures; n is the number of gonads examined each month.

Sampling was conducted during one complete spawning season (1973-1974) and parts of two others (1972-1973, 1974-1975) (Figure 11). The 1973-1974 spawning season began in December 1973, reached maximum from January through March, and then declined through August. The 1972-1973 season exhibited similar maximum spawning, but a slightly more rapid spring decline. The 1974-1975 spawning season began in October 1974, two months earlier than the previous season.

Percentages of U-stage females increased directly with recruitment of juveniles from April through August 1973 and 1974. The first clear indication of D-stage ovaries in these recruits was found in June 1973 and July 1974. Most D-stage females occurring before this were from the previous year class. In 1973-1974, maximum percentages of D-stage females occurred in November 1973; thereafter, maturation proceeded rapidly as the spawning season approached. Ovarian development from U-stage to D-stage took approximately five months and from D-stage to mature approximately four months. Ovarian development in 1974-1975 year class females was not well defined; but apparently as little as six or seven months were required for complete development.

Temperature, salinity, and photoperiod were evaluated as causes of seasonal spawning. Photoperiod is inversely related to observed spawning periodicity and reportedly influences spawning behavior of some animals (Moe, 1969). Rock shrimp spawning, however, was not rigidly set to the same months each year so photoperiod cannot be the only controlling factor.

Bottom salinities ranged between 32.0 ‰ and 36.75 ‰. Since they did not fluctuate seasonally, they probably had minimal effect on spawning.

Bottom temperatures in areas I, III, and V were compared to seasonal spawning (Figure 11). Instead of directly initiating spawning activity, increasing temperatures apparently triggered development from D-stage to mature ovaries. In area III, where most adults occurred, temperatures increased from 18.1 to 27.3°C between August and October, 1973. Three months after initial temperature increases, percentage of mature females began to increase. Likewise, temperatures in 1974 began to increase between June and July, followed three months later by increases in mature females. Spawning continued beyond the time when minimum bottom temperatures were recorded during 1973 and 1974.

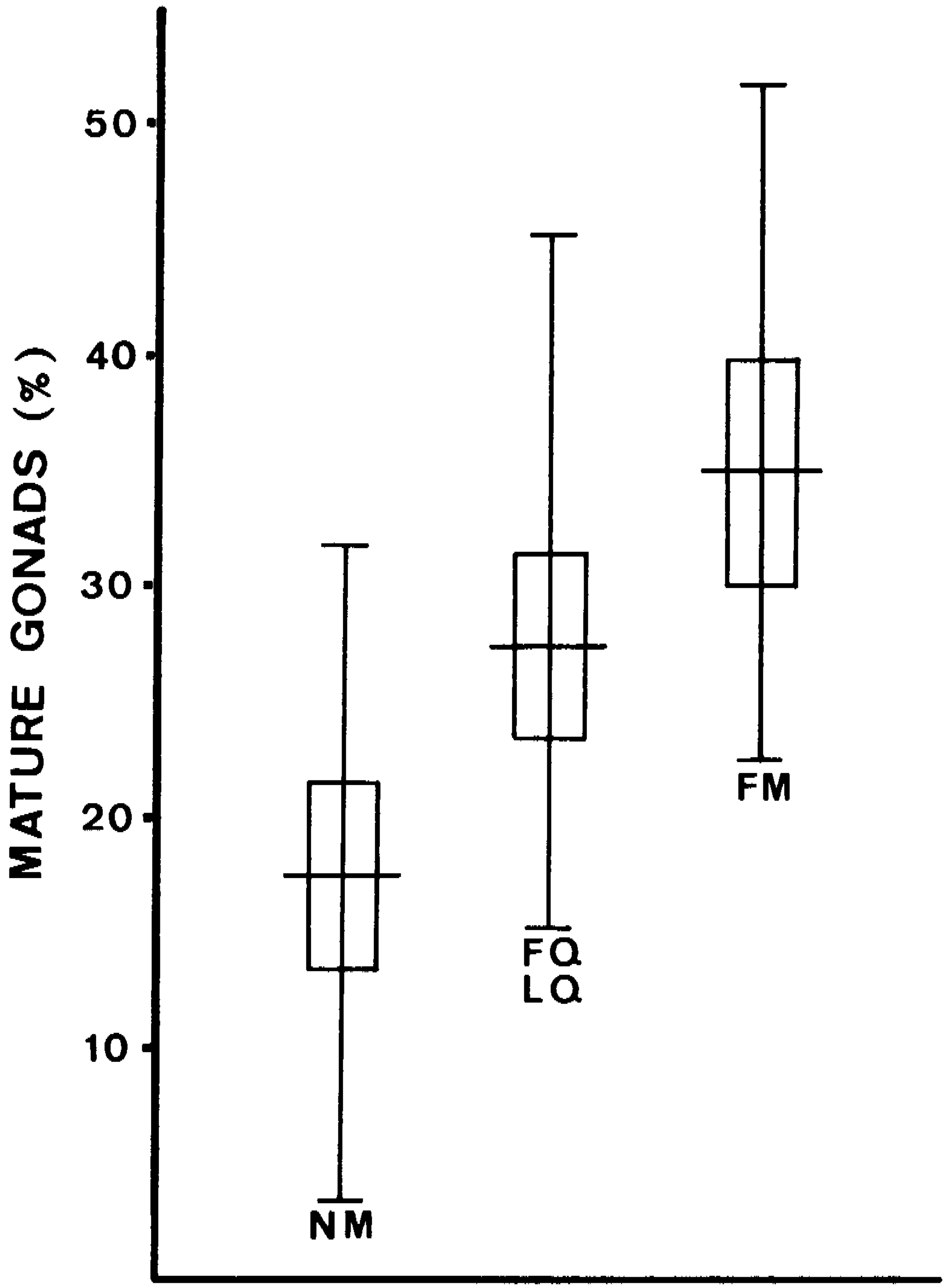
Intramonthly spawning in relation to lunar influence was evaluated using females very near spawning or recently spawned (AR and D-S) as a ratio of each month's mature females. These percentages were initially grouped into three month intervals without respect to lunar phases and tested by completely random design (CRD) ANOVA for seasonal influences. No significance was found (P=0.05), allowing other factors to be independently evaluated for effects on spawning. All monthly percentages occurring within one lunar quarter were averaged. For example, the new moon quarter extended from three days before mid-phase to three days after. Averages grouped in this way represented too few ratios to permit dependable evaluation of lunar periodicity. First and last lunar quarter percentages were then combined to examine the effect of lunar light intensity on spawning (Figure 12). Mean percentage were compared using a CRD ANOVA and Tukey's *w*-procedure. Full moon showed significantly higher percentages (P=0.05) of near-spawning and recently-spawned females than new moon, indicating that high lunar light intensity apparently stimulated intra-monthly spawning. Lunar periodicity in spawning has been reported for *P. duorarum* (Munro et al., 1968) and other organisms (Korringa, 1957).

Larval Dynamics

All *Sicyonia* larvae were assumed to be *S. brevirostris*. This assumption, supported by adult catch data, was required since no adequate identification keys to *Sicyonia* larvae exist. Only one adult *Sicyonia* taken at life history survey stations and only two *Sicyonia* taken during our fishery survey were not *S. brevirostris*. Joyce (1965) reported that of the few *Sicyonia* caught in his nearshore survey (depths ⩽ 13 m) from St. Mary's Inlet to Cape Canaveral, virtually all were *S. brevirostris*.

Using the STP test, no significant differences (P=0.05) in larval catches were found between life history survey areas (Table 7). A large number of early stage larvae did appear initially in area I during the 1973 major spawn; but for the other months of the study, larvae were distributed irregularly throughout the entire area. Major transport mechanisms affecting planktonic larvae are shelf current systems near Cape Canaveral described by Milliman (1972) and Bumpus (1973). These systems keep larvae on the Florida Shelf, and may transport them inshore during spring.

Station larval catch data were pooled each month and plotted for the two-year period (Figure 13). It was apparent that spawning occurred throughout the year. Monthly differences were evident, but no annual seasonal cycle emerged. Extreme patchiness and large between-tow variations probably contributed greatly to monthly fluctuations. Although major spawns occurred during late winter and early spring, these were reflected in larval abundance only in February, 1973. Summer larval peaks present in both years were neither followed by an eventual appearance



SOURCE	df	SS	MS	F
TREATMENT	2	980.39	490.19	3.98 *
ERROR	18	2217.5	123.19	
TOTAL	20	3197.89		

Figure 12. Mean percentages, standard error of means and ranges of females near spawning or recently spawned relative to lunar light intensity. ANOVA results provided.

TABLE 7. STP TEST FOR BETWEEN STATION DIFFERENCES IN MEAN LARVAL ABUNDANCE.

	001-01A	003	004	005
001-01A	XXXXX	312	238.5	307.5
003		XXXXX	279.5	248.5
004			XXXXX	263.5
005				XXXXX

$U_{0.05}$ [4,22] = 351.4 is significant

of juveniles nor predictable from previous gonadal analyses. Since no regular seasonal cycle was recognizable, relationships between larval catches and seasonal parameters such as temperature and hours of daylight were not discernible (Figure 14). Salinity was relatively constant over the year and larval numbers fluctuated greatly, no relationship was evident.

Ages of protozoea were calculated to establish dates of spawning. Laboratory growth studies by Cook and Murphy (1965) showed: protozoea I to be 3-5 days old; protozoea II, 6-9 days old; and protozoea III, 10-11 days old. Protozoea I were back-dated 4 days; protozoea II, 8 days; and protozoea III, 10 days. Percentage of protozoea represented in each nightly catch was averaged by halves of the lunar cycle (NM-FQ and FM-LQ) and by lunar light intensity (NM, FQ-LQ, FM). For example, the first lunar half extended from three days before new moon mid-phase to three days before full moon mid-phase. Data grouped in this way were tested by ANOVA for differences in relative abundance; no significant differences (P=0.05) were observed in either test (Figure 15). Tests using only protozoea I relative abundance produced similar results. Lunar light influence on spawning was supported by gonadal evidence but not by larval results.

Unfortunately, since our sampling program was not specifically designed for intramonthly analyses, lunar effects on larval abundance could not be adequately examined. Patchiness of larval concentrations and large between-tow variations probably masked any fluctuations in larval abundance caused by lunar influences or seasonal parameters. Because non-parametric statistics were used, the extent to which each of these factors varied could not be determined.

POSTLARVAL DEVELOPMENT

Morphometrics

Carapace length (CL) and weight (W) relationships were analyzed using 241 males and 278 females, randomly selected. Least squares regression was computed for pairs of $\log_e$ transformed variates for females, but predicted weights deviated severely from the empirical. Back-calculated weights for larger animals were as much as ten grams heavier than empirical weights for the same carapace length. Empirical length-weight relationships in larger animals appeared linear so the data was partitioned by the following method.

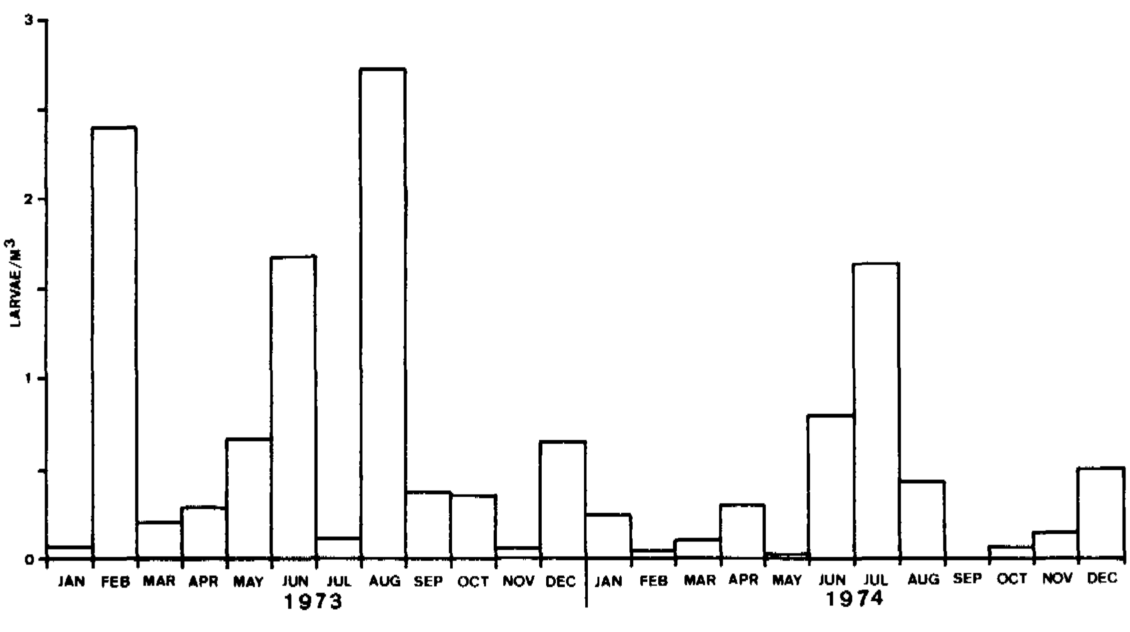


Figure 13. Monthly abundance of combined *Sicyonia* larval stages.

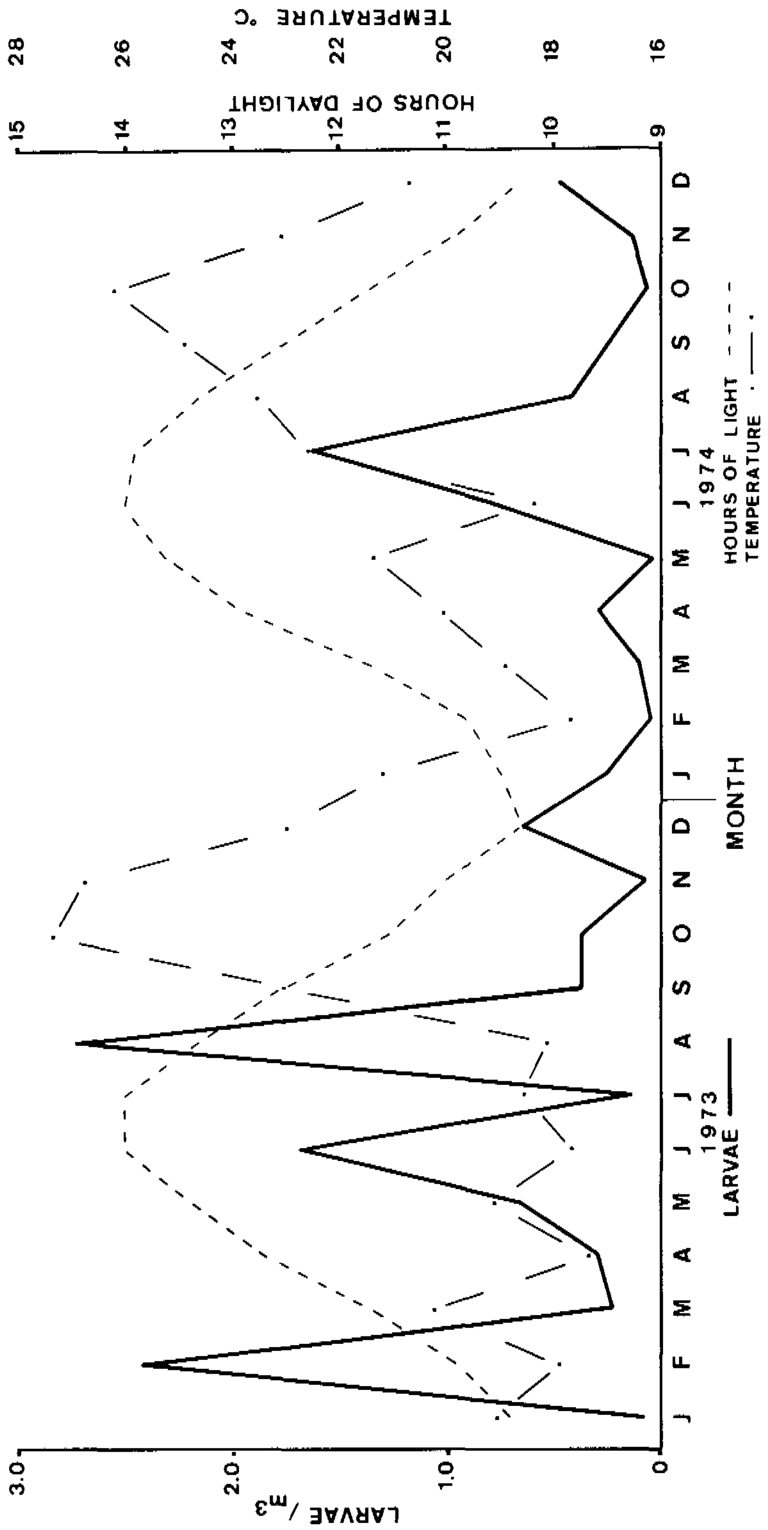
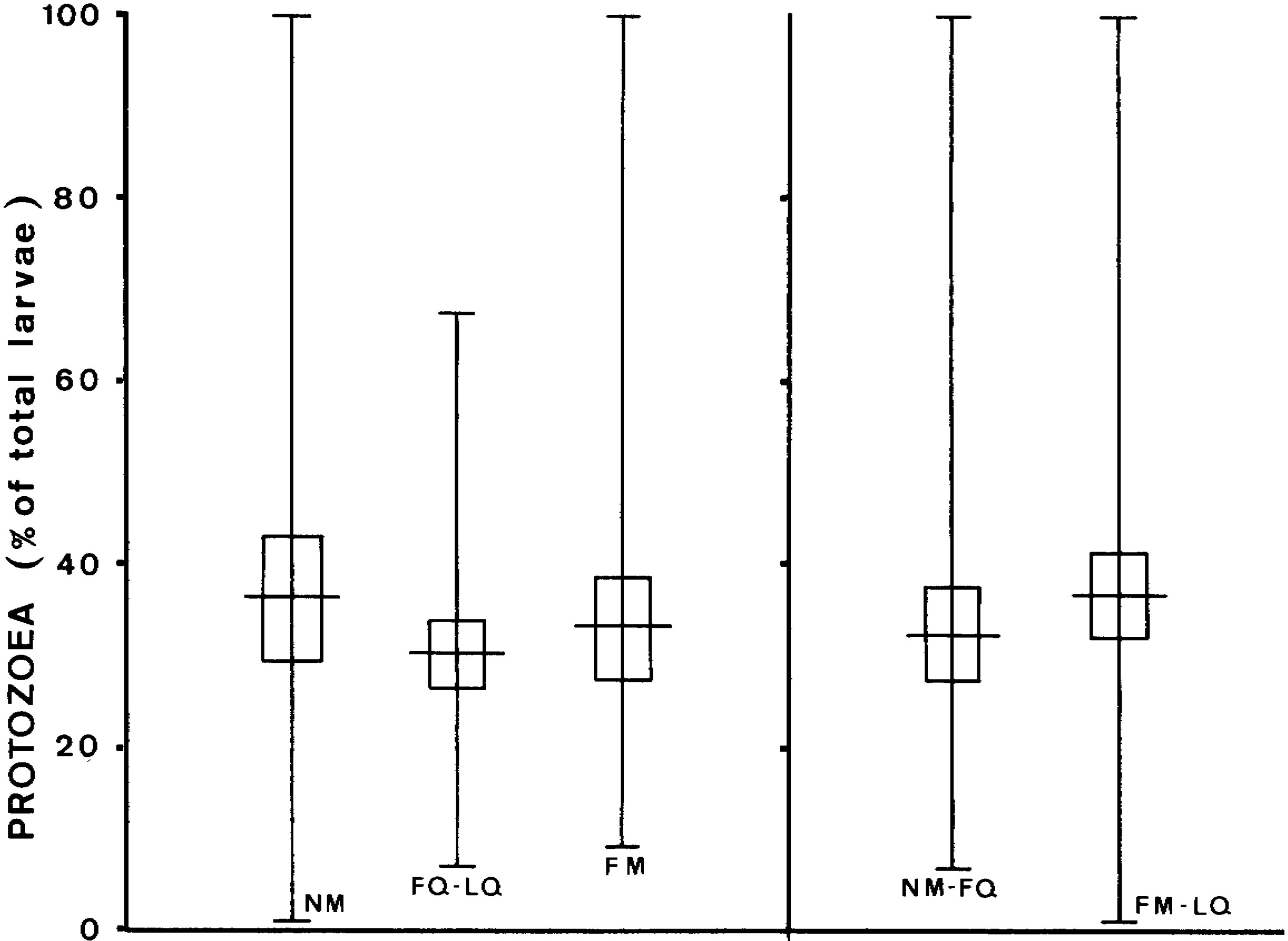


Figure 14. Comparison of monthly larval abundance with physical parameters.



	MOONLIGHT INTENSITY				LUNAR HALVES			
SOURCE	df	SS	MS	F	df	SS	MS	F
TREATMENT	2	397.40	198.70	0.316	1	321.00	321.00	0.471
ERROR	62	38954.14	628.29	NS	63	42962.94	681.95	NS
TOTAL	64	39351.54			64	43283.94		

Figure 15. Mean percentages, standard error of means, and ranges of protozoea abundance relative to lunar halves and light intensity. ANOVA results provided.

The criterion for choosing a dividing point between power curve and linear relationships was based on an equation for average deviation or residuals developed by the authors as a modification of average deviation described by Sokal and Rohlf (1969). The average deviation (D_A) of the empirical values from those predicted was expressed by:

$$D_A = \frac{\Sigma \left| \hat{W}_i - \bar{W}_i \right|}{N}$$

where $\hat{W}_i$= back-calculated weight at a particular mean CL; $\bar{W}_i$= mean empirical weight at the same mean CL; and N = number of comparisons. The maximum deviation (D_{MAX}) was the greatest single difference between empirical and predicted weights. Average and maximum deviations were computed using carapace lengths from 20-24 mm CL as division points (Table 8). Maximum deviations for lines derived from divided data were considerably less than that calculated for a logarithmic line based on data not so treated. Lowest average deviations resulted from use of division points from 21-23 mm CL. Division at 23 mm CL, where D_{MAX} was minimum, was chosen to increase accuracy of the length-weight regression equation for larger females (Figure 16). Male length-weight regression equations were computed for the same size ranges (Figure 17). Average deviation for this pair of equations was 0.167 g and D_{MAX} was 1.591 g.

TABLE 8. COMPARISONS OF DEVIATIONS FROM CL-W EQUATIONS FOR FEMALES BASED UPON DIFFERENT POINTS OF DATA DIVISION.

Point of Division	D_A	D_{MAX}
24 mm CL	.220g	1.478g
23	.184	0.898
22	.178	1.006
21	.168	1.275
20	.188	1.082

Analysis of covariance compared male and female length-weight relationships for both size ranges (Table 9). Residual mean square for females was significantly larger (P=0.05) than that for males in the smaller size category. Growth function plots for males had significantly greater elevation but not slope for both size categories. Female's weights were more variable for a given size smaller than 23 mm CL than were weights for males at the same sizes. Males gained weight slightly faster than females at all sizes.

Carapace length (CL) and total length (TL) relationships were examined using the same animals. By inspection, the plot of empirical data for females curved slightly while that for males did not. To facilitate male-female comparisons, the data were divided into two size categories and separate linear regressions computed for each. The pairs of variates for females were divided at 20 mm CL based on the smallest average deviation and the resulting equations plotted (Table 10; Figure 18). Data for males were also divided at 20 mm CL and regression equations computed for each category (Figure 19). The average deviation for males at 20 mm CL was 0.716 mm with a maximum deviation of 1.480 mm.

Analysis of covariance showed no significant differences in residual mean squares, slopes, or elevations (P=0.05) between sexes in the smaller size range (Table 11). Slopes and elevations were significantly different (P=0.01) for the larger range. Total lengths for males and females change at the same rate until 20 mm CL. The rate of increase in total length for females slowed after this size. Morphological changes in females between 20 mm and 23 mm CL were probably caused by the onset of sexual maturity and spawning which clearly began in the majority of the female population in this size range.

Growth and Mortality

Three generations of shrimp were observed during part or all of their life cycle: the G_1 generation from January through November 1973; the G_2 generation from April 1973 through November 1974; and the G_3 generation from April through December 1974. Monthly mean carapace lengths for each generation from Areas I and III combined were calculated (Figure 20).

Monthly changes in mean carapace lengths as an estimate of growth rate showed rapid growth in young shrimp from May through August 1973 (G_2 generation) and from May through September 1974 (G_3 generation). Average growth rates for G_2 and G_3 male juveniles from May through August were 2.3 and 3.2 mm CL per 30-day month respectively, and rates for females were 2.9 and 3.3 mm CL per month, respectively. A maximum monthly increase of 5 mm CL was observed for G_2 male and female juveniles between June and July 1973. Similar growth rates were reported for *Penaeus duorarum* by Costello and Allen (1960) and Tabb et al. (1962).

Sex size differentiation in smallest animals was observed in April and May 1973 and 1974. This could have been a result of misinterpretation

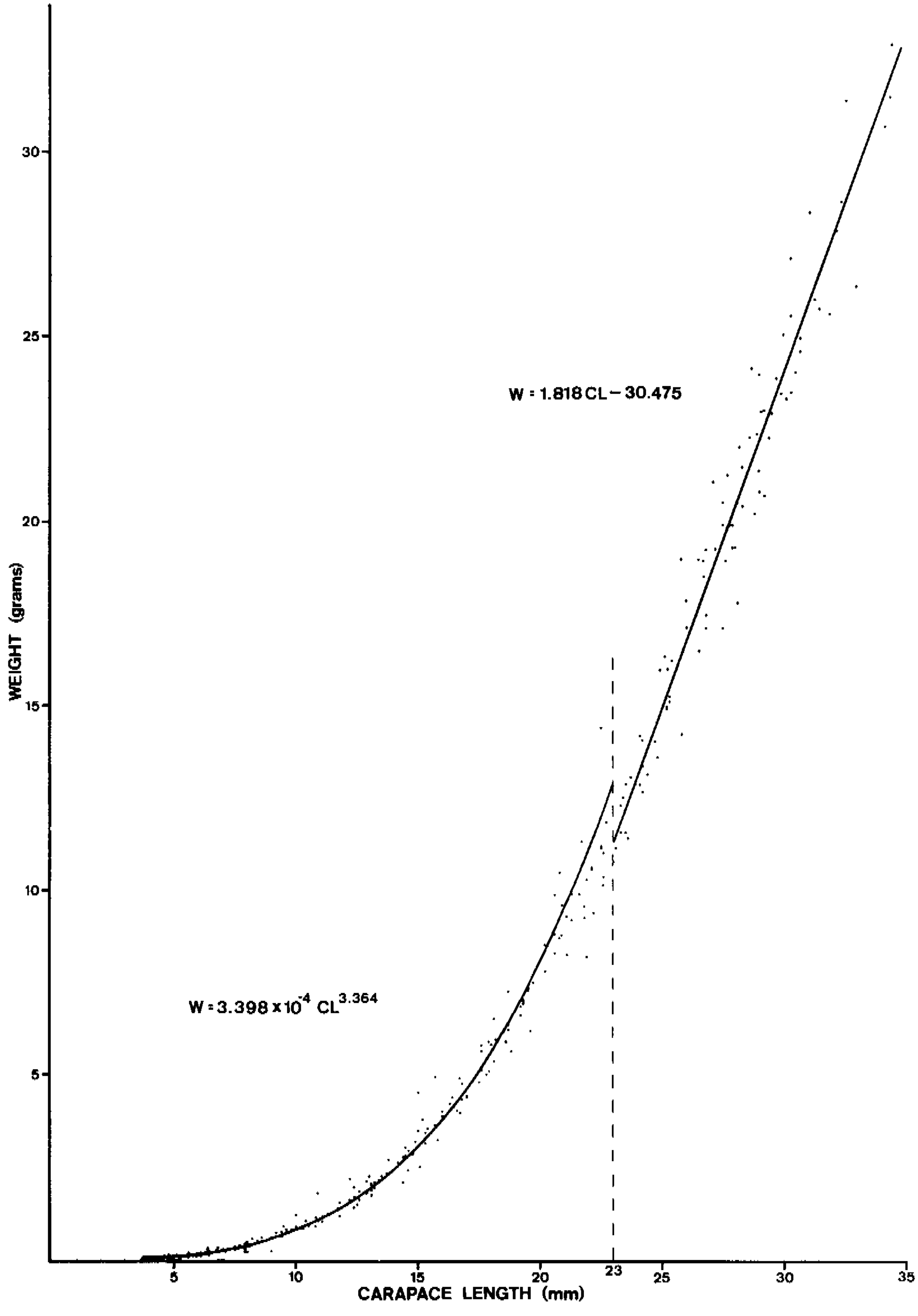


Figure 16. Relationship of carapace length to weight of 278 females.

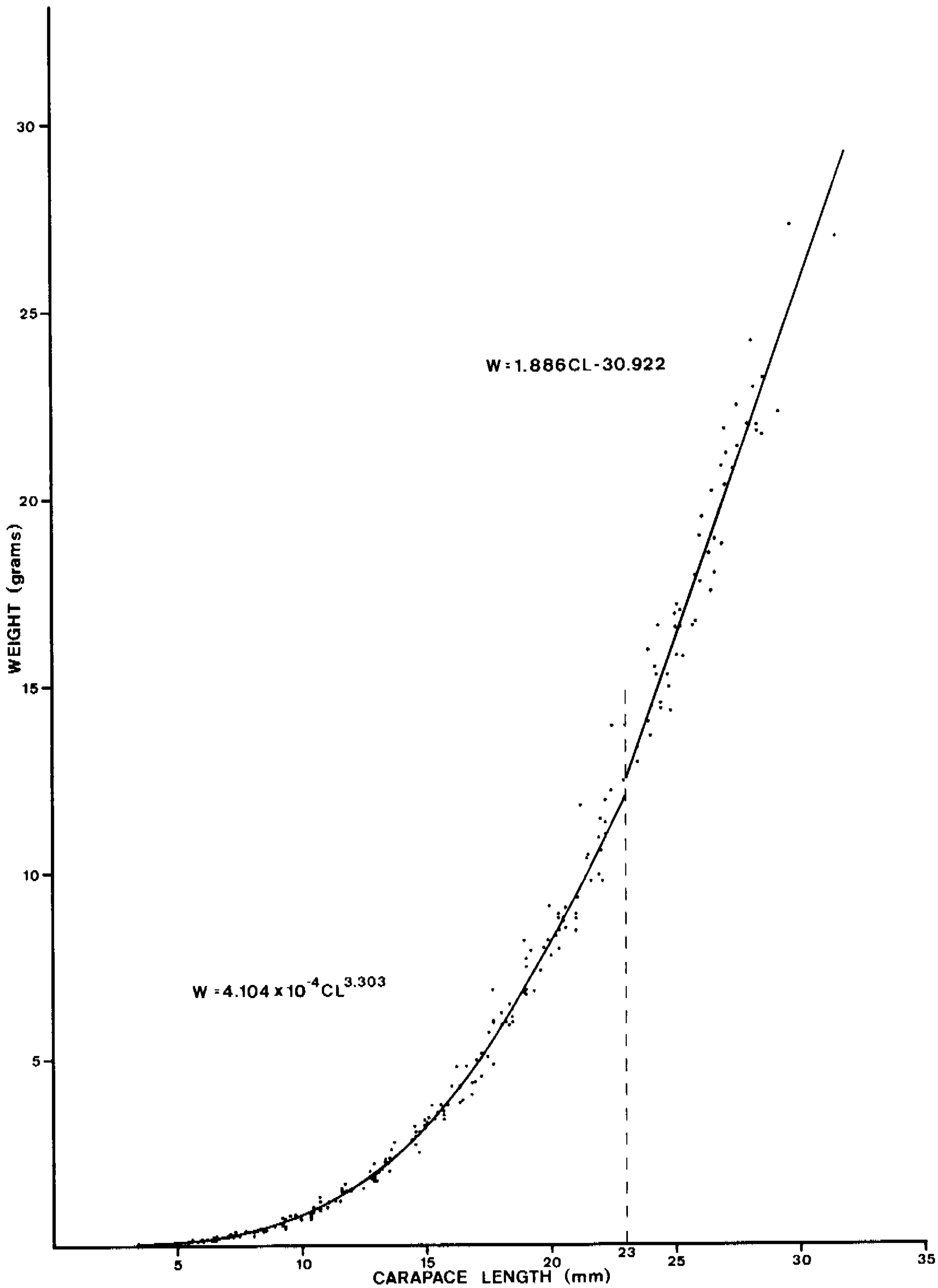


Figure 17. Relationship of carapace length to weight of 241 males.

TABLE 9. REGRESSION EQUATIONS AND ANALYSES OF COVARIANCE FOR *S. BREVIROSTRIS* BASED ON WEIGHT AND CARAPACE LENGTH.

CL	Sex	df (n−1)	Σx^2	Σxy	Σy^2		%V
<23	Female	186	39.870	134.107	457.696	$W = 3.398 \times 10^{-4} CL^{3.364}$	98.5
<23	Male	184	37.401	123.537	410.401	$W = 4.10 \times 10^{-4} CL^{3.303}$	99.4
<23	Total	371	77.281	257.714	868.569		
⩾23	Female	90	777.845	1414.360	2700.323	$W = 1.818CL - 30.475$	95.2
⩾23	Male	55	194.711	367.187	745.946	$W = 1.886CL - 30.922$	92.8
⩾23	Total	146	1083.936	1903.372	3579.514		

Analysis of Covariance

<23 $F_{(variance)} = 2.780$**; $F_{(slope)} = 2.905$ns; $F_{(Y\ intercept)} = 4.826$*

⩾23 $F_{(variance)} = 1.458$ns; $F_{(slope)} = 0.557$ns; $F_{(Y\ intercept)} = 42.877$**

TABLE 10. COMPARISON OF DEVIATIONS FROM CL-TL EQUATIONS FOR FEMALES BASED UPON DIFFERENT POINTS OF DATA DIVISION.

Point of Division	D_A (mm)	D_{MAX} (mm)
22 mm CL	.799	3.365
21	.796	3.546
20	.793	3.604
19	.807	3.803
18	.947	3.893
17	.877	4.130
16	.904	4.227
15	.942	4.320

of young males in which the petasma, used as the sole sex indicator, was not yet developed. This effect would be magnified when dealing with small sample size and a narrow size range, both prevalent in April and to a lesser extent in May. For these reasons, male and female juveniles were probably similar in size when first recruited. Both sample size and range were larger by June, and G_2 male and female mean sizes were similar. Females were definitely growing faster in August; female mean size was 19 mm CL, while male mean size was 18.4 mm CL.

Growth of G_1 adults from January through November 1973 and G_2 adult growth from October 1973 through November 1974 were examined by linear regression analysis. Regression of mean carapace length on elapsed time in days was computed for each sex and each generation (Table 12). Largest mean sizes for each generation (October and November) were not included due to small sample sizes and difficulties in accurately separating generations. The G_1 shrimp in January 1973 averaged slightly larger than G_2 shrimp in January 1974. This disparity, which continued throughout the remainder of their life spans, was possibly caused by age differences. Slopes of the equations were daily carapace length increases multiplied by 30 for average monthly growth rates. Females grew slightly faster than males in both generations, and G_2 animals grew slightly faster than G_1 animals. Females were clearly larger within generations.

Growth was also examined using instantaneous rates as described by Ricker (1958) so that seasonal differences in growth could be examined. Instantaneous rates were computed for each monthly change in carapace length, starting in January, 1973 for G_1 adults and October, 1973 for G_2 adults. Continued recruitment precluded examination of G_2 or G_3 juvenile instantaneous growth rates.

Mean carapace lengths for each generation and elapsed time (Δt) in days were used to compute instantaneous rates of growth (g) per day, then multiplied by 30 for comparison (Table 13). Instantaneous growth rates for G_2 shrimp indicate that growth was slower from October to February than from February to August. Growth patterns in G_1 shrimp were not as clear; however, by averaging rates, overall growth from January to April was slower than from April to August. Between sexes, no clear pattern of growth emerged for either generation.

Survival rates (s) of G_1 and G_2 shrimp and instantaneous rates of mortality (i) were calculated

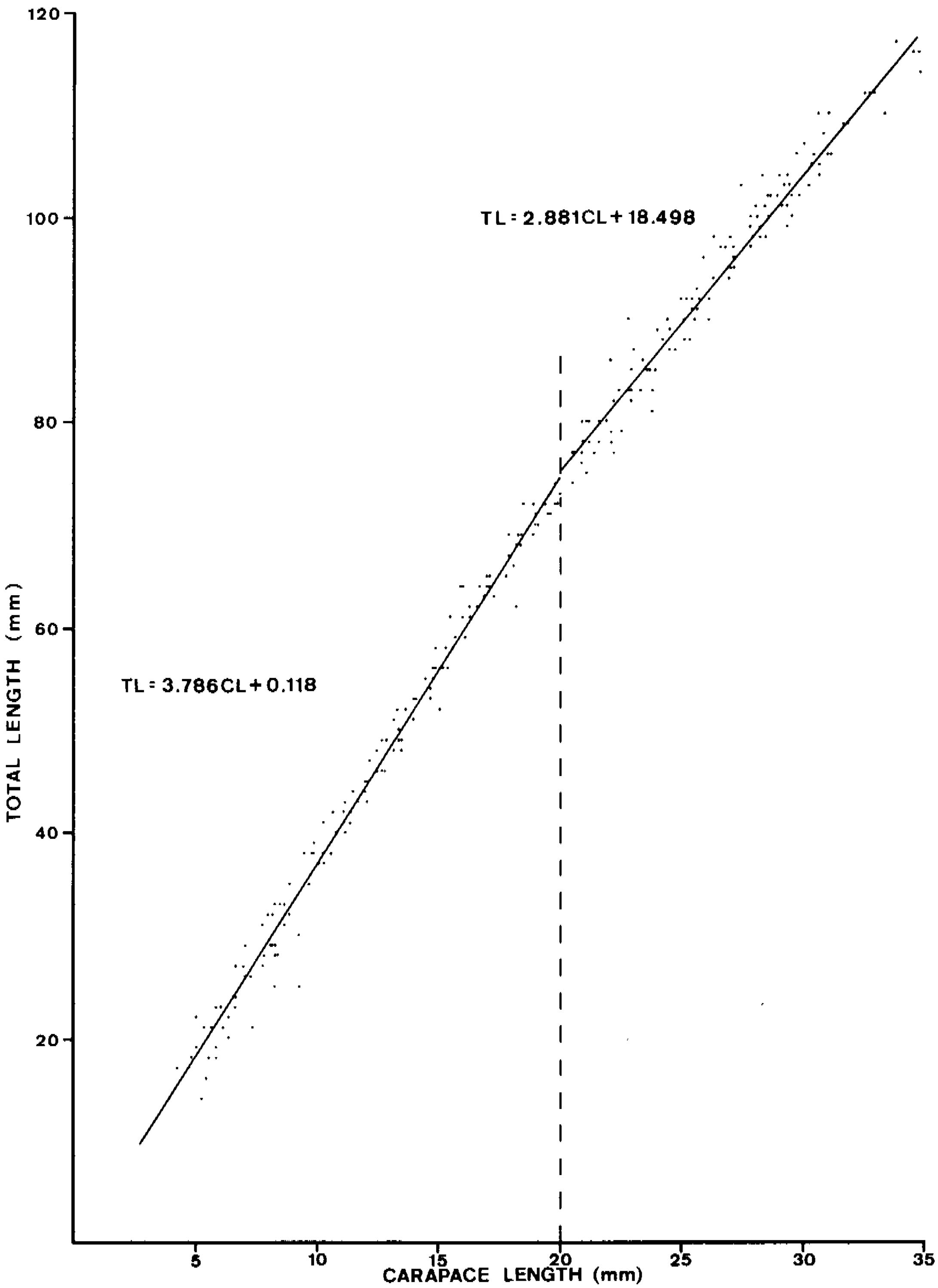


Figure 18. Relationship of carapace length to total length of 278 females.

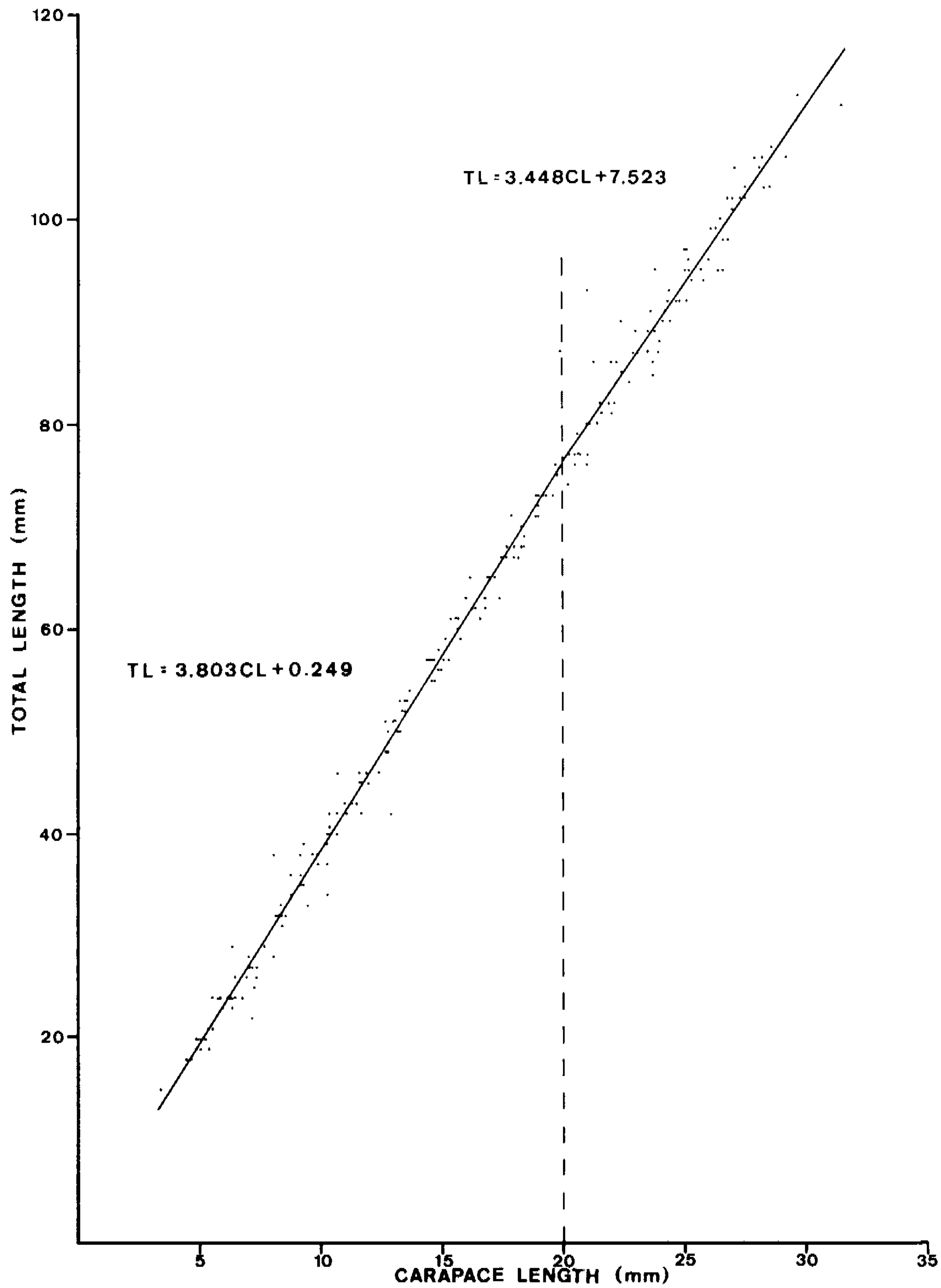


Figure 19. Relationship of carapace length to total length of 241 males.

TABLE 11. REGRESSION EQUATIONS AND ANALYSES OF COVARIANCE FOR *S. BREVIROSTRIS* BASED ON TOTAL LENGTH AND CARAPACE LENGTH.

CL	Sex	df $(n-1)$	Σx^2	Σxy	Σy^2		%V
< 20	Female	156	3267.384	12371.039	47386.191	TL = 3.786CL+0.118	98.8
< 20	Male	154	3136.767	11927.949	45948.994	TL = 3.803CL+0.249	98.8
< 20	Total	311	6405.063	24305.233	93377.920		
⩾ 20	Female	120	1644.337	4737.288	14477.835	TL = 2.881CL+18.498	94.3
⩾ 20	Male	85	611.912	2109.923	7903.302	TL = 3.448CL+ 7.523	92.0
⩾ 20	Total	206	2427.342	7080.392	22698.937		

Analysis of Covariance

< 20 $F_{(variance)} = 1.096$ ns; $F_{(slope)} = 0.117$ ns; $F_{(elevation)} = 2.299$ ns

$\geqslant 20$ $F_{(variance)} = 1.072$ ns; $F_{(slope)} = 19.970$**; $F_{(elevation)} = 56.628$**

from catch per unit effort data for Areas I and III combined (Table 14). The largest G_2 CPUE was obtained in October, 1973, but since maximum CPUE might have occurred after October's sampling date, instantaneous mortality between October and November could not be computed reliably. Instantaneous rates were computed over several months in cases where CPUE's were less than 100 in order to reduce sample variability. High mortality coincided with large relative abundance when only one generation was present. Once a new generation entered in large quantity (June or July), mortality rates increased again, probably caused by increased competition for available space and food. Natural mortality was lower in females than in males within a generation.

Natural logarithms of G_2 CPUE (N) from October, 1973 to October, 1974 were regressed on elapsed time in days (D) to obtain the following relationships:

$$\ln N = 8.974 - 0.0142 D \quad \text{(males)}$$
$$\ln N = 8.383 - 0.0117 D \quad \text{(females)}$$

Variations in CPUE attributable to time were 95.1% for males and 93.1% for females. Percent variations indicate that empirical catch values follow an exponential relationship with time as assumed when computing instantaneous rates.

Instantaneous rates of growth and mortality for G_2 combined sexes were used to indicate changes in CPUE biomass ($g - i$) from November 1973 through August 1974 (Table 15). Mean carapace lengths per month were converted to average weights by the geometric mean regression equation:

$$W = 1.817 \text{ CL} - 29.951$$

for average lengths 23 mm CL or larger. Instantaneous rates of change in CPUE biomass were all negative, indicating that catch biomass was continually decreasing. Maximum catch biomass occurred before November 1973 and decreased rapidly until December. Thereafter, biomass decreased at 15-20% per month until July when new recruits entered the population in quantity.

Life Span

Rock shrimp life span can be estimated by following the 1973 year class from its appearance in May 1973 until it disappears in November, 1974 (Figures 5, 6, 20). This period covers 17 months for males and 18 months for females. With approximately one month required for development from egg to first postlarvae (Cook and Murphy, 1965) and two to three months estimated for development from first postlarvae to the smallest mode of recruits, maximum life span for *S. brevirostris* is 20-22 months. Life spans of 12-16 months for *Penaeus setiferus* (Lindner and Anderson, 1956) and possibly as long as two years for *P. d. duorarum* (Eldred et al., 1961) have been reported.

Sex ratio

The male-female ratio was examined relative to size and season for all station samples combined (Figure 21). Males were more abundant than females in all size classes from 15 to 23 mm CL and in all months from September through December 1973. This trend was reversed in size classes 24 mm CL or larger, and from January to August 1973 and during 1974. The sex ratio was approximately equal between 11 mm and 15 mm CL.

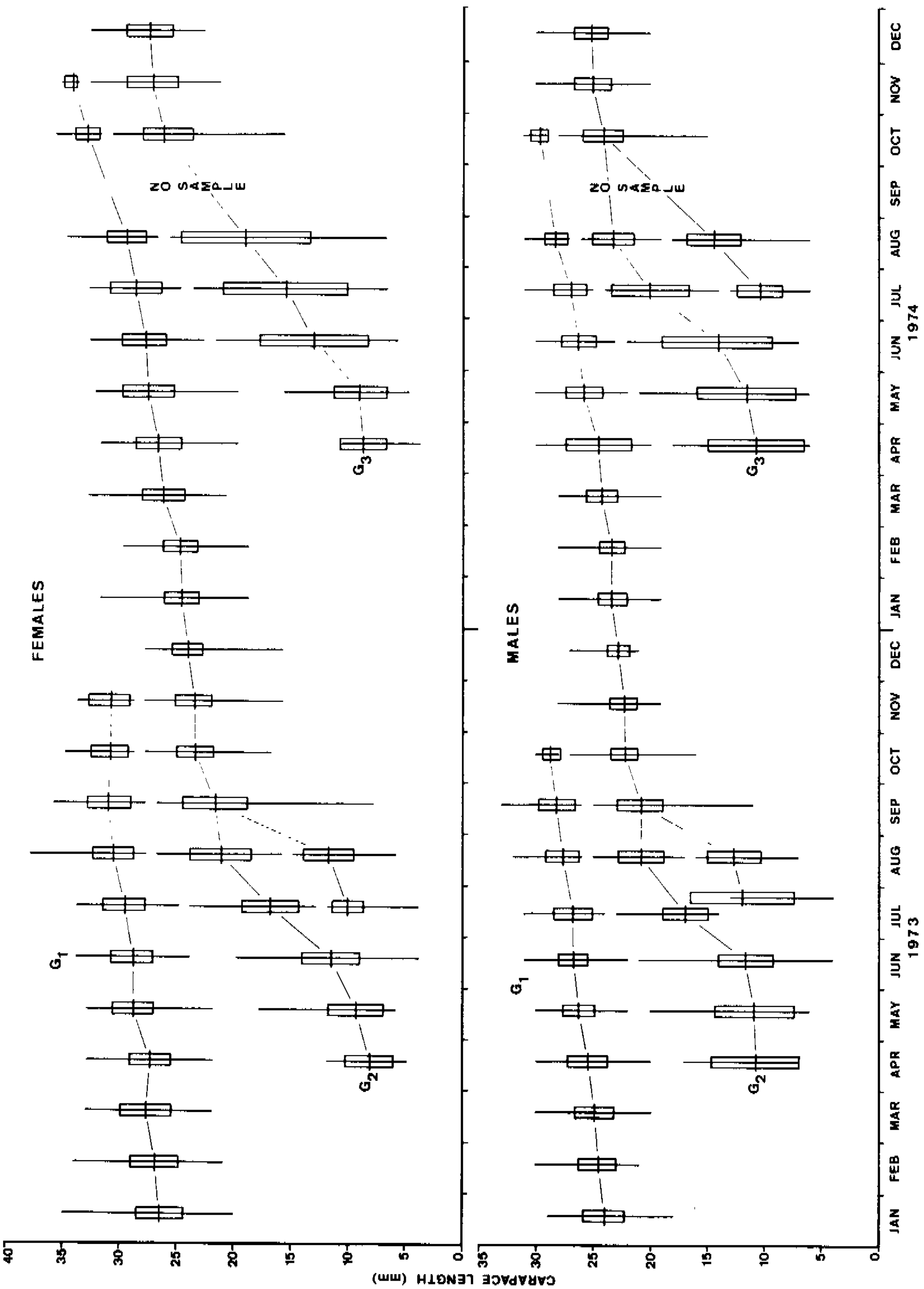


Figure 20. Monthly mean carapace lengths, standard deviations, and ranges for shrimp generations.

TABLE 12. RELATIONSHIPS BETWEEN MEAN CARAPACE LENGTH AND ELAPSED TIME IN DAYS FOR EACH SEX AND EACH GENERATION.

		Correlation Coefficient	30-day Growth (mm CL)
January - September 1973			
G_1 males	CL = 0.0170D + 24.179	.994	0.51
G_1 females	CL = 0.0198D + 26.514	.985	0.60
October, 1973 - August, 1974			
G_2 males	CL = 0.0190D + 21.736	.979	0.57
G_2 females	CL = 0.0209D + 23.295	.992	0.63
D = days			

TABLE 13. INSTANTANEOUS RATES OF GROWTH (g) BY CHANGES IN CARAPACE LENGTH FOR MALE AND FEMALE *S. BREVIROSTRIS*.

G_1 generation				*G_2 generation*			
Month	Δt	*g*(♀)	*g*(♂)	Month	Δt	*g*(♀)	*g*(♂)
				1973 October			
					18	.007	.015
				November			
					33	.019	.016
				December			
					42	.017	.015
1973 January				1974 January			
	21	.027	.029		16	.008	.000
February				February			
	28	.031	.031		33	.053	.034
March				March			
	33	−.010	.022		39	.012	.009
April				April			
	28	.057	.033		31	.035	.050
May				May			
	26	.004	.017		20	.016	.029
June				June			
	31	.023	.004		44	.019	.015
July				July			
	43	.023	.023		27	.030	.050
August				August			

TABLE 14. SURVIVAL RATES (s) AND INSTANTANEOUS RATES OF MORTALITY (i) FOR MALE AND FEMALE *S. BREVIROSTRIS*.

		G_1♀			G_1♂		
Month	Δt	N	*s*	*i*	N	*s*	*i*
1973							
January		43			30		
	21		.685	.378		.642	.443
February		33			22		
	61		.837	.178		.801	.222
April		23			14		
	85		.984	.016		.856	.156
July		22			9		
	43		.766	.267		.839	.175
August		15			7		
	53		.650	.431		.585	.535
October		7			1		

		G_2♀			G_2♂		
Month	Δt	N	*s*	*i*	N	*s*	*i*
1973							
November		427			530		
	33		.500	.694		.457	.783
December		199			224		
	42		.860	.151		.804	.218
1974							
January		161			165		
	16		.739	.303		.612	.491
February		137			127		
	72		.799	.224		.711	.341
April		80			56		
	95		.790	.235		.794	.230
July		38			27		
	27		.684	.380		.369	.998
August		27			11		
	62		.397	.924		.438	.825
October		4			2		

TABLE 15. INSTANTANEOUS RATES OF GROWTH IN WEIGHT AND INSTANTANEOUS RATES OF MORTALITY FOR *S. BREVIROSTRIS* G_2 COMBINED SEXES.

Month	Δt	$\overline{CL}$	$\overline{W}$	*g*	N	*s*	*i*	(*g*–*i*)
November		23.02	11.876		957			
	33			.066		.476	.742	–.676
December		23.51	12.767		423			
	58			.048		.784	.244	–.196
February		24.19	14.002		264			
	72			.091		.761	.273	–.182
April		26.04	17.436		137			
	95			.068		.790	.235	–.167
July		28.37	21.597		65			
	27			.089		.551	.596	–.507
August		29.36	23.396		38			

Females were more abundant in size classes less than 11 mm CL. The sex ratio for all rock shrimp over the two years was 0.93. A 1:1 ratio has been reported for *Penaeus d. duorarum*, *P. setiferus*, and *P. a. aztecus* (Perez-Farfante, 1969).

Males and females probably entered the population in equal numbers. Some deviations from unity in size classes less than 11 mm CL could have been due to misidentification of males as discussed previously (see page 23). The sex ratio did not diverge from unity until about 18 mm CL, when a growth rate disparity became evident; females were larger. Male mortality rates were higher from approximately 23 mm CL, so females became more numerous at lengths greater than 23 mm CL.

Monthly sex ratios were compared to the sex ratio of that month's major size classes. When large sizes predominated, females were more abundant than males. When modal size ranged between 20 and 23 mm CL, males were more abundant. Although a sex ratio near unity would be expected when large numbers of recruits were present (June-August), previous year class adults, mostly large females, maintained the sex ratio in favor of

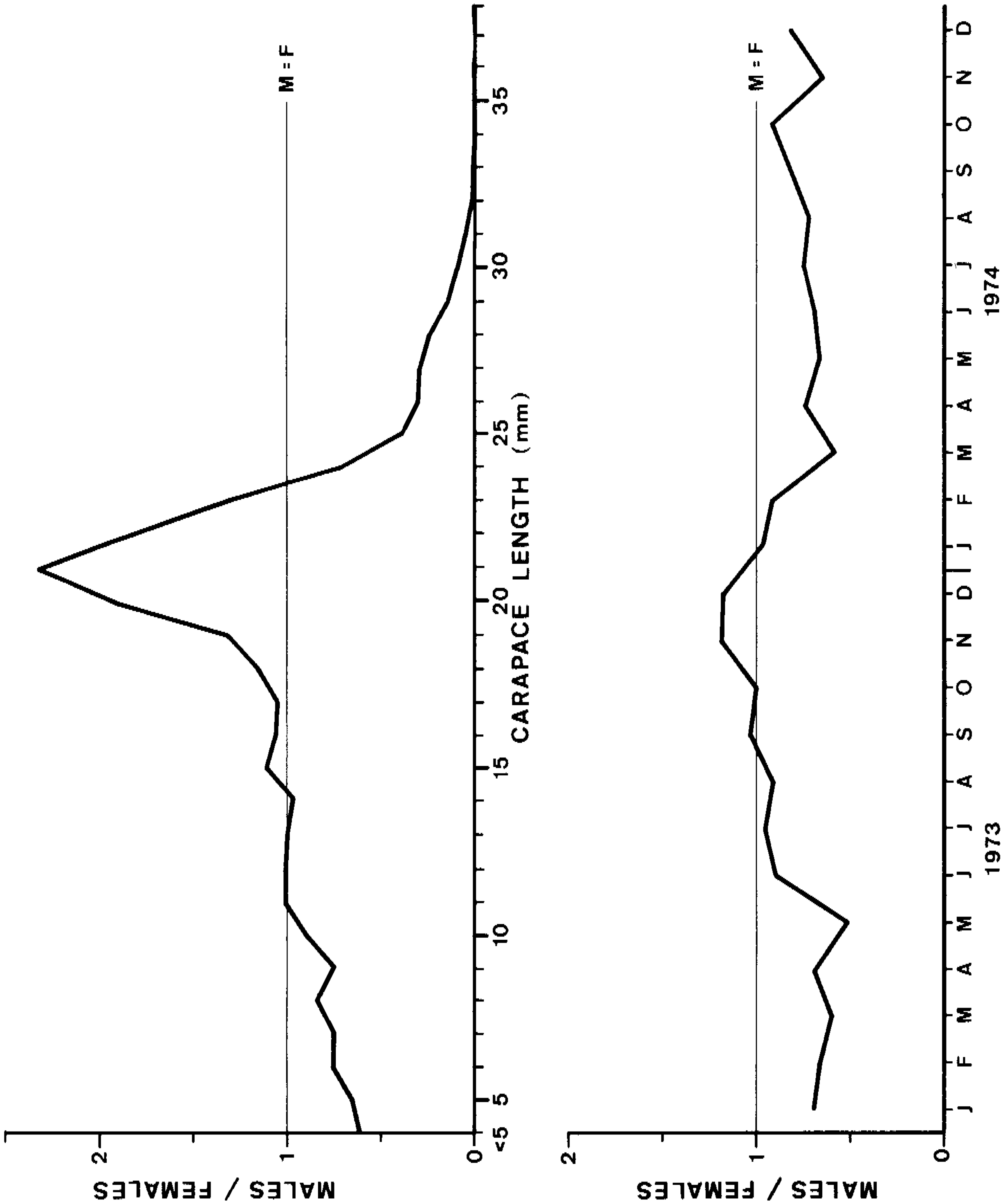


Figure 21. Sex ratio trends by size class (upper) and by season (lower).

females. Without the massive influx of juveniles in 1974, that year's sex ratio was determined primarily by abundance of 1973 year class females.

DIET

Analysis of *S. brevirostris* diet was based upon examination of 412 stomachs, of which 14 were empty. The percentage of food-bearing stomachs in which each taxon occurred as predominant or residual was calculated and ranked (Table 16). Mollusks, crustaceans, and polychaetes were major food items, both as predominant and residual. Since mollusks and crustaceans were more prevalent, these groups were selected for further examination.

TABLE 16. RELATIVE DISTRIBUTION OF TAXA IN DIET OF *S. BREVIROSTRIS*.

Food Items	Predominant	Residual
Algae		+
Foraminifera	+	++++
Porifera		++
Bryozoa		+
Nematoda	+	+++
Hydroidea		++
Nemertea		+
Polychaeta	++	+++
Mollusca	++++	++++
Mollusca, unidentified	+++	+++
Bivalvia	++	+++
Gastropoda	++	++++
Scaphopoda		++
Pteropoda		+
Crustacea	+++	++++
Pycnogonida	+	+++
Echinodermata, unidentified		+++
Echinoidea	+	+++
Ophuroidea	+	++
Pisces-eggs		++

+ = 0.1 - 0.9%
++ = 1.0 - 9.9%
+++ = 10.0 - 49.9%
++++ = 50.0 - 99.9%

Crustaceans and mollusks from benthic samples were identified to class or order, then to genus or species when possible. These data provided an estimate of the various crustaceans and mollusks in the area and their availability as food items, and aided in identification of crustacean and molluscan fragments in stomachs. Classification of most numerically important groups yielded 7 isopod, 2 tanaidacean, 2 cumacean, 18 decapod, 40 bivalve, 90 gastropod, 1 polyplacophoran, and 2 scaphopod genera, together with 22 groups of amphipods (Appendix III).

Stomachs from 214 shrimp taken concurrent with benthic samples were re-examined for identification of crustaceans. Due to disintegration of food and similarities of characteristics within orders, identification to species was extremely difficult. Cumacean fragments were most easily identified, while amphipod, tanaidacean, and isopod fragments were very similar. With exception of a few whole organisms, most identifications were based upon observations of pleonal and carapace segments and gnathopod chelae, with a large portion of fragments remaining unidentified.

Relative occurrence of a particular crustacean order in stomachs was proportionate to its availability in the benthic fauna (Table 17). Amphipods appeared more frequently in stomachs than any other order, probably a result of their high availability as indicated by benthic samples. Availability of tanaidaceans was also high, but the proportion with which they occurred in stomachs in relation to benthic samples was lowest. No clear reason for this phenomenon is known.

TABLE 17. RELATIVE OCCURENCES OF CRUSTACEAN ORDERS IN *S. BREVIROSTRIS* STOMACHS AND BENTHIC SAMPLES.

	Stomach with Crustaceans	Benthic Samples with Crustaceans
Amphipoda	++++	++++
Isopoda	+	++
Cumacea	++	++
Tanaidacea	+	++
Copepoda	+	+
Ostracoda	++	+
Decapoda	+++	+++

+ = 0.1 - 9.9%
++ = 10.0 - 19.9%
+++ = 20.0 - 49.9%
++++ = 50.0 - 99.9%

Identification of mollusks from stomachs was based on postembryonic shell fragments and opercula. Some were identified to species; however, all comparisons with mollusks in benthic samples were made between genera. Relative occurrences of live mollusks in stomachs generally corresponded to their availability in benthic samples (Table 18), but there were several exceptions. *Argopecten*, *Cyclopecten*, *Anachis*, *Nassarius*, *Odostomia*, and *Turbonilla* occurred very frequently in stomachs, but were rarely found alive in benthic samples. *Cyma-*

TABLE 18. RELATIVE OCCURRENCES OF LIVE MOLLUSCA IN ROCK SHRIMP STOMACHS AND IN BENTHIC SAMPLES.

	Stomach	Benthic
Class Bivalvia	++	++
Solemya	A	+
Nucula	+++	+++
Nuculana	+	A
Anadara	++	+
Barbatia	A	+
Noetia	A	+
Glycymeris	+	+
Amygdalum	A	+
Crenella	++	+
Chlamys	A	+
Argopecten	++++	+
Cyclopecten	++++	+
Limaria	+	+
Crassinella	+++	++++
Pleuromeris	+	+
Astarte	A	+
Lucina	++	++
Arcinella	A	+
Laevicardium	+	+
Trachycardium	+	A
Chione	+++	+++
Gouldia	++++	++
Pitar	+	+
Dosinia	+	+
Ervilia	+++	+++
Tellina	++	++++
Abra	+++	+++
Semele	++	++
Corbula	+	+
Varicorbula	++++	++++
Pandora	+	A
Lysonsia	+	+
Verticordia	+	A
Class Gastropoda	++	+
Solariella	+	+
Arene	++	+
Tricolia	+	+
Circulus	A	+
Episcynia	A	+
Architectonica	+	A
Heliacus	A	+
Turritella	+	+
Caecum	+++	++++
Finella	+	A
Cerithiopsis	+	A
Seila	+	A
Epitonium	++	+
Opalia	+	A
Balcis	+	A
Niso	+	+
Macromphalina	A	+
Calyptraea	+	+
Natica	++	++
Polinices	A	+
Sigatica	A	+
Eupleura	A	+
Anachis	++++	+
Mitrella	++	A
Nassarina	++	+

TABLE 18. RELATIVE OCCURRENCES OF LIVE MOLLUSCA IN ROCK SHRIMP STOMACHS AND IN BENTHIC SAMPLES (Continued).

	Stomach	Benthic
Class Gastropoda (Continued)		
Nassarius	++++	+
Olivella	++	A
Marginella	+	+
Prunum	+	+
Agatrix	+	A
Terebra	A	+
Brachycythara	+	A
Cerodrillia	++	+
Kurtziella	+++	++
Nannodiella	+	A
Rubellatoma	A	+
Vitricythara	+	A
Eulimastoma	++	A
Odostomia	+++	A
Turbonilla	+++	A
Acteon	+	A
Acteocina	++	+
Cylichnella	+	A
Pyrunculus	+	+
Retusa	+	A

A = Absent
+ = 0.1 - 4.9%
++ = 5.0 - 9.9%
+++ = 10.0 - 19.9%
++++ = 20.0 - 39.9%

tium was found in one stomach, but did not occur alive or dead in benthic samples. Specialized habitat needs of these genera and the discontinuous distribution of their habitats might have caused these exceptions (W. G. Lyons, FDNR, personal communication). No distinction could be made between relative occurrences of bivalvia and gastropoda in the stomachs. Occurrence of food items in stomachs appeared to depend mainly upon availability. Rock shrimp diet included a large variety of other items indicating opportunistic feeding.

FISHERY SURVEY

This section of the work was used to describe the Florida Continental Shelf distribution and dynamics of the rock shrimp population and fishery stocks. Results were derived from 172 fishery survey stations and four life history survey stations (Figure 4). Weather and logistical restraints prevented sampling of the entire study area within a seasonal cycle. Seasonal population trends developed from life history survey data were therefore used to describe seasonal trends in the fishery survey area. Mesh sizes of otter trawls differed for the two surveys; but through testing, their effectiveness appeared to be equivalent both in quantity and sizes caught.

DISTRIBUTION

Rock shrimp were found in all regions sampled; and their distribution was aggregate (Figure 22). For this study, an aggregation was defined as an area yielding 25 or more shrimp per 15 min tow, the lowest monthly mean catch taken in life history survey area III. Catches of 100 or more shrimp were considered indicators of large aggregations.

Three geographical regions were defined based on contours plotted in Figure 22. The Ft. Pierce region from St. Lucie Inlet to Melbourne was sampled from April through June 1973 and in November, 1974, mainly during times of adult abundance; several small aggregations of shrimp were found. The Cape Canaveral region from Melbourne to Matanzas Inlet was sampled from June through November 1973 and in March 1974, primarily during periods of recruitment; one large aggregation of shrimp was located. The Jacksonville region from Matanzas Inlet to Amelia Island was sampled in February 1974 and May through August 1974, primarily during times of recruitment, and another large aggregation was observed.

The general bathymetric range of *S. brevirostris* for the east coast of Florida has been reported as 18 m to 73 m (Anderson, 1956). Similar results were given by Bullis and Rathjen (1959) for the southeast U. S. Continental Shelf, by Lunz (1957) off South Carolina, and by Brusher et al. (1972) for the Texas-Louisiana coastal area. Joyce (1965) in a nearshore survey of the northeast Florida shelf reported few rock shrimp inside 13 m.

The bathymetric range of our stations, based upon literature reports, was between 18 m and 73 m, but no absolute limit to the population was apparent at these boundaries. Best average adult catches were found between 34 m and 55 m in the Cape Canaveral and Jacksonville regions (Table 19). Average adult catches progressively decreased both inshore and offshore from the 34 to 55 m zone. Decreased catches in shallower areas were further evidenced by subdividing Area I depths sampled; fewest shrimp (CPUE) were taken at shallowest stations (Table 19). Anderson (1956) and Bullis and Rathjen (1959) obtained their best catches between 36 m and 46 m off the Florida east coast.

Depth segregation of juveniles and adults was very evident during recruitment periods. Five complete transects in the Cape Canaveral region taken between May 22 and July 1, 1973, were

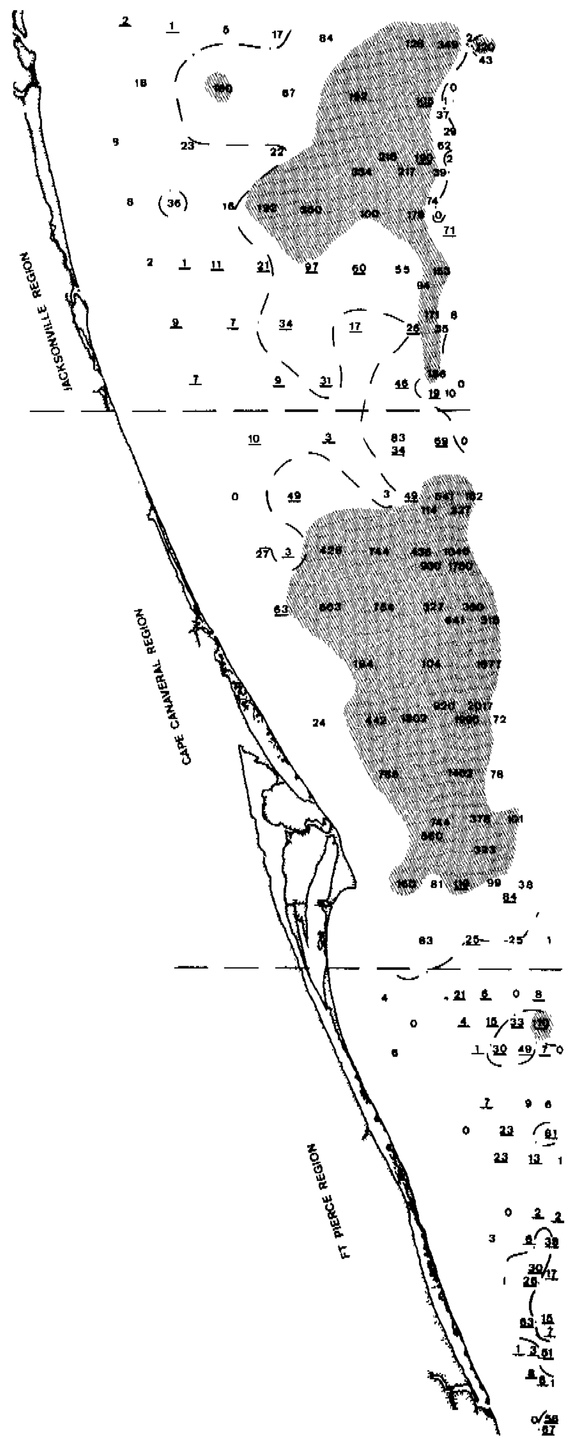


Figure 22. *S. brevirostris* distribution by region on the Florida Atlantic Shelf based on catch per 15 minute tow. The 25 and 100 shrimp per tow contour lines are presented.

TABLE 19. BATHYMETRIC COMPARISON OF ADULT CPUE PER 15 MIN TOW FOR THE ENTIRE SURVEY AREA AND SELECTED REGIONS.

AREA	Ia	Ib	I	III	V
DEPTH(m)	*18-20*	*21-33*	*18-33*	*34-55*	*56-74*
Jacksonville Region (May-Aug. 1974)	3	8	6	34	12
Cape Canaveral Region (Jun.- Nov., 1973)	10	44	23	103	30
Entire Area (Apr., 1973-Nov., 1974)	6	19	14	52	14

pooled by depth zones for examination of size frequency distribution (Figure 23). Juveniles were found in all depth zones; however, previous year class adults were absent from 18 to 20 m, were barely represented in 22-33 m, but comprised a major part of the population in 34-55 m and at 64 m. Joyce (1965) found no rock shrimp larger than 20 mm CL in depths of 13 m or less along Florida's northeast coast.

Bottom temperatures and salinities were examined for effects on bathymetric distribution of rock shrimp (Table 20). Temperatures and salinities were similar to those obtained for the life history survey stations. Minor variations between temperatures recorded during the life history survey and fishery survey were attributed to the expanded depth range included in the latter. Salinity does not appear to be limiting to bathymetric distribution of rock shrimp. The decreasing average temperature gradient correlated to increasing depth, and may have influenced bathymetric distribution. Tolerable temperature ranges reported for *Penaeus setiferus* (?-36°), *P. d. duorarum* (6-35.5°C), and *P. a. aztecus* (9-35°C) (Perez-Farfante, 1969) are considerably broader than the range of temperatures measured in our fishery survey area.

The deep water limit to large rock shrimp aggregations was due more likely to decrease of suitable bottom habitat than to other physical parameters discussed. Rock shrimp abundance decreased sharply from 55 m to 73 m (Table 19). On the southeast U. S. Atlantic Continental Shelf, algal ridges occur near the shelf break, in the middle of the shelf from 20 to 40 m, and on the Florida-Hatteras Slope at depths of 80 m (Uchupi, 1970). Bullis and Rathjen (1959) reported rugged coral formations in depths from 37 to 180 m between St. Augustine and Cape Canaveral. Our sampling was aborted at nine of eighteen stations near the shelf break (73 m) due to rugged bottom topography. Other tows at 64 m and 73 m snagged on the bottom or brought up coral and other reef animals. Stations as shallow as 55 m had to be relocated due to bottom topography.

Factors limiting inshore expansion of large aggregations of rock shrimp were not so obvious. *Sicyonia brevirostris* have been found most frequently on terrigenous and biogenic sand substrates and only sporadically on mud bottoms (Cobb et al., 1973). Hildebrand (1955) reported that *S. brevirostris* was scarce on mud bottoms in brown shrimp grounds and suggested that the few shrimp collected were strays from areas of hard sand. Other investigators have reported specific substrate preferences for other western Atlantic penaeids (Hildebrand, 1954, 1955; Williams, 1955, 1958; Perez-Farfante, 1969). During the life history survey, the main population was found in area III; but all areas had the same fine to medium-grained sand substrate. Along the Florida Atlantic coast, the predominant substrate inside 200 m depth was a fine to medium sand with small patches of silt-clay (Milliman, 1972). Within the 18 m (10 fm) contour, the substrate is primarily a hard sand (U. S. Department of Commerce, 1971a, 1971b). Observed aggregations of rock shrimp were not restricted by the nature of the substrate which was relatively uniform over the entire area. None of these factors individually accounted for the decrease and eventual disappearance of the rock shrimp inshore. Interactions between these factors and others, such as competition with other decapods inshore for space and food, may have determined the observed distribution.

SEASONAL DYNAMICS

Seasonal fluctuations in CPUE were examined for each depth zone (Figure 24). Biannual distributions of fishery survey CPUE for each bathymetric area were made by compositing average monthly values from different regions. Average monthly values were adjusted to projected catch per 30 min

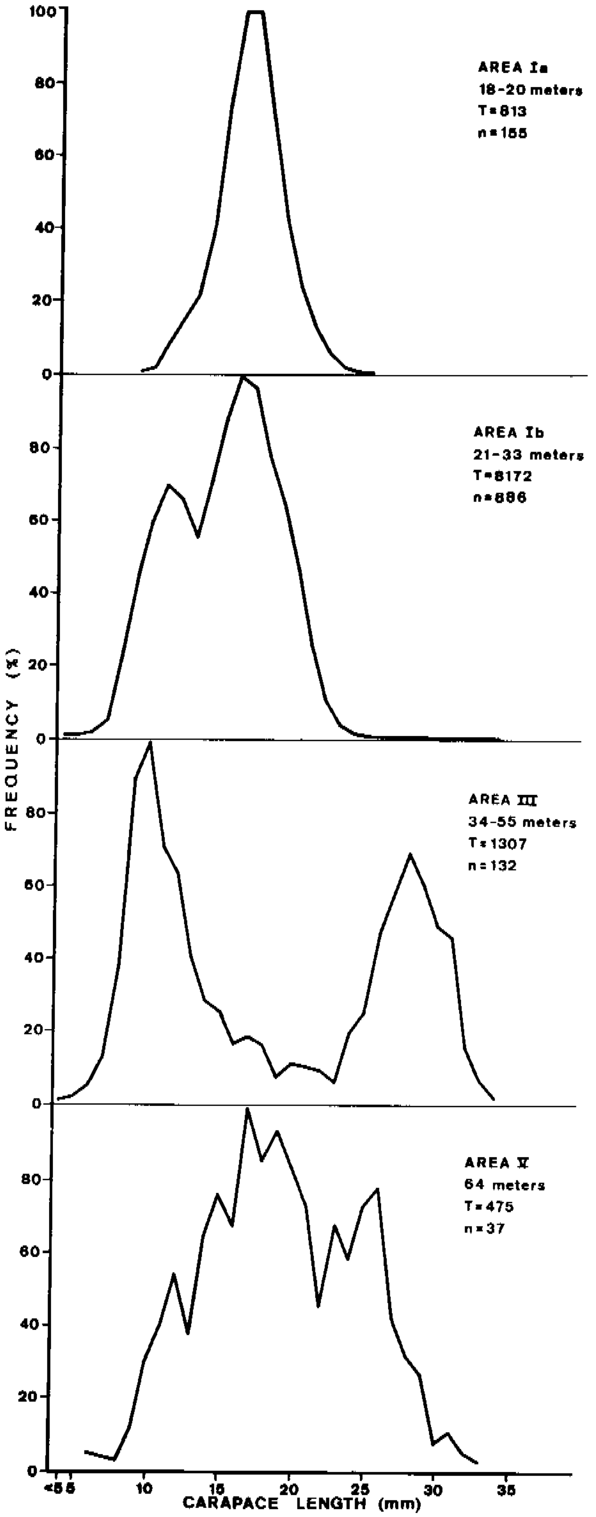


Figure 23. Comparisons of length frequency distributions by bathymetric zones. T is total number of shrimp, n is the number of shrimp in the largest modal size class.

tow so comparisons to life history survey data could be made. April through June 1973 and November 1974 values were from the Fort Pierce region; July through November 1973 and March 1974 values were from the Cape Canaveral region; February 1974 and May through August 1974 values were from the Jacksonville region.

The northern part of the Fort Pierce region was sampled during only the first month of heavy recruitment. Fort Pierce juvenile abundance was considerably lower in all depths compared to the life history survey area at that time. Data were insufficient to allow discussion of overall seasonal recruitment in this region.

Recruitment in the Cape Canaveral region followed the same abundance and size class structure trends as in the life history survey area during 1973. This was expected since the life history survey area was within the Cape Canaveral region.

Juveniles were observed in the Jacksonville region during 1974 when recruitment was occurring in the life history survey area, but were as much as 10 mm CL larger than life history survey juveniles (Figure 25). Growth rate information developed from life history data indicate that recruitment in the Jacksonville region may have begun three to four months prior to our May sampling, two to three months before recruitment began in the life history survey area. Information developed from life history data indicated that spawning could have begun in the Jacksonville region as early as late September or October 1973, but did not begin in the life history survey area before December 1973.

Juvenile CPUE of 650 in the Jacksonville region during 1974 was much higher than comparable life history survey CPUE, but was only seventy per cent of the life history survey CPUE achieved during a comparable period in 1973. Jacksonville region values for May 1974 were compared to September life history survey values for 1974 and 1973 since the Jacksonville region juveniles were three to four months older than life history survey juveniles.

Adult abundance trends from July through November 1973 and March 1974 were obtained from the Cape Canaveral region. CPUE values were similar to those from the life history survey except during November when the extreme northern edge of the Canaveral region was sampled. This part of the Canaveral region, and the southern extreme of the Jacksonville region, had fewer shrimp than might have been expected based on life history survey results, particularly in depths less than 30 m.

From May through August 1974, Jacksonville adult CPUE and life history survey adult CPUE were similar; but Jacksonville recruits were months older with many reaching adult size. When G_2

TABLE 20. TEMPERATURE AND SALINITIES FOR CORRESPONDING LIFE HISTORY AND FISHERY SURVEY DEPTH AREAS.

	Area I		Area III		Area V	
	TEMPERATURE °C					
Fishery Survey	Range	Avg.	Range	Avg.	Range	Avg.
Warm Water (Aug.-Jan.)	21.8 - 27.8	25.4	17.9 - 26.2	23.8	15.5 - 25.4	20.3
Cold Water (Feb.-July)	17.5 - 27.1	21.4	14.8 - 25.9	19.5	13.2 - 22.2	17.5
Life History Survey						
Warm Water (Aug.-Jan.)	17.8 - 27.2	23.3	17.3 - 27.6	22.8	15.6 - 25.8	19.4
Cold Water (Feb.-July)	18.4 - 22.9	20.4	16.5 - 22.6	19.1	13.8 - 22.0	17.2
	SALINITY ‰					
Fishery Survey	33.80-37.12	35.66	31.90-36.43	35.58	33.90-36.43	35.56
Life History Survey	34.00-36.57	35.72	32.00-36.57	35.56	34.00-36.75	35.65

I 18-33 m (fishery survey)
26-33 m (Life history survey), stations 001, 01A

III 34-55 m (fishery survey)
40 m (life history survey), stations 003, 004

V 56-74 m (fishery survey)
64 m (life history survey), station 005

adults of the previous year class were separated from new G_3 adults and compared to life history survey G_2 adults, their sizes were similar; but the Jacksonville catches were two to four times lower. Based on expected mortality rates, the Jacksonville region did not contain as large a concentration of shrimp as the Canaveral region in 1973. However, from observed abundance levels in 1974 the situation is reversed; a larger concentration of adults occurred in the Jacksonville region than in the Canaveral region.

The small aggregations of adult populations from the Fort Pierce region were generally comparable to the life history survey area both in abundance and size structure. Distribution of adults in this region was very patchy.

Seasonal dynamics may also be examined using standard measures (count size and catch weight) applied by the industry. The equation for combined sexes, W =1.817 CL − 29.951, converted carapace length (CL) to whole weight (W) for shrimp 23 mm CL or larger. Whole weights of smaller shrimp were calculated from empirical data. Carapace length (CL) was converted to total length (TL) by the equation: TL = 3.058 CL + 15.170. Heads-on counts (number per pound) were derived from summed weights divided by the number of shrimp included in the summed weight. These values were converted to heads-off counts based on 40% weight loss reported by Kutkuhn (1962) and Cobb et al. (1973). A nomograph of these relationships is presented (Figure 26).

Combined monthly catches from life history survey areas I and III were converted to counts by summing weights of the largest shrimp and progressively including smaller shrimp until the selected average counts were reached. The numbers of shrimp required to obtain these average counts were converted to percentages of total catch. Shrimp 21 mm CL or greater were used since only shrimp of those sizes are currently processable by the industry. The weight of shrimp used to

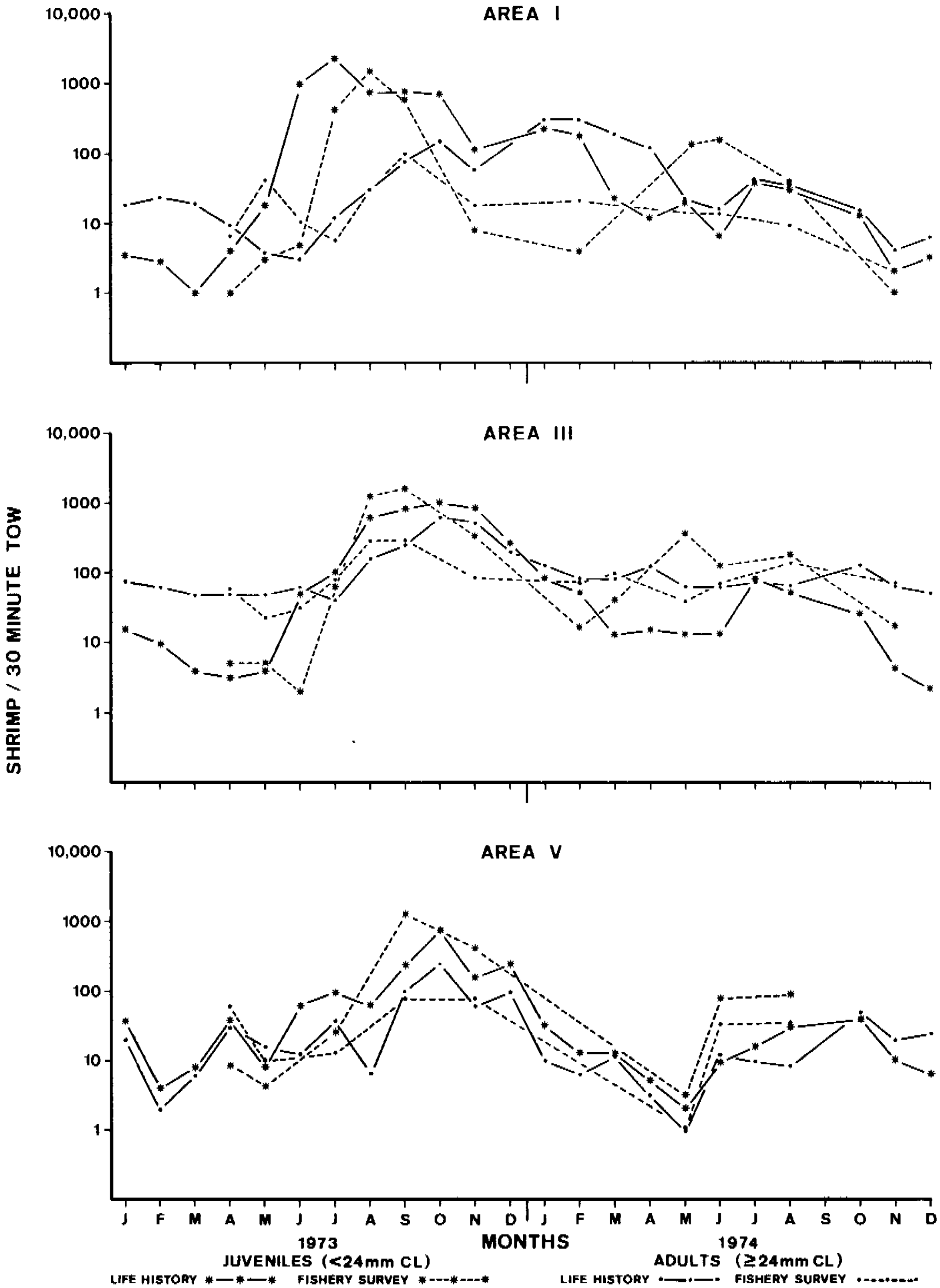


Figure 24. Seasonal abundance in life history and fishery survey areas. Point to point interpolation has been used where average fishery survey values were absent.

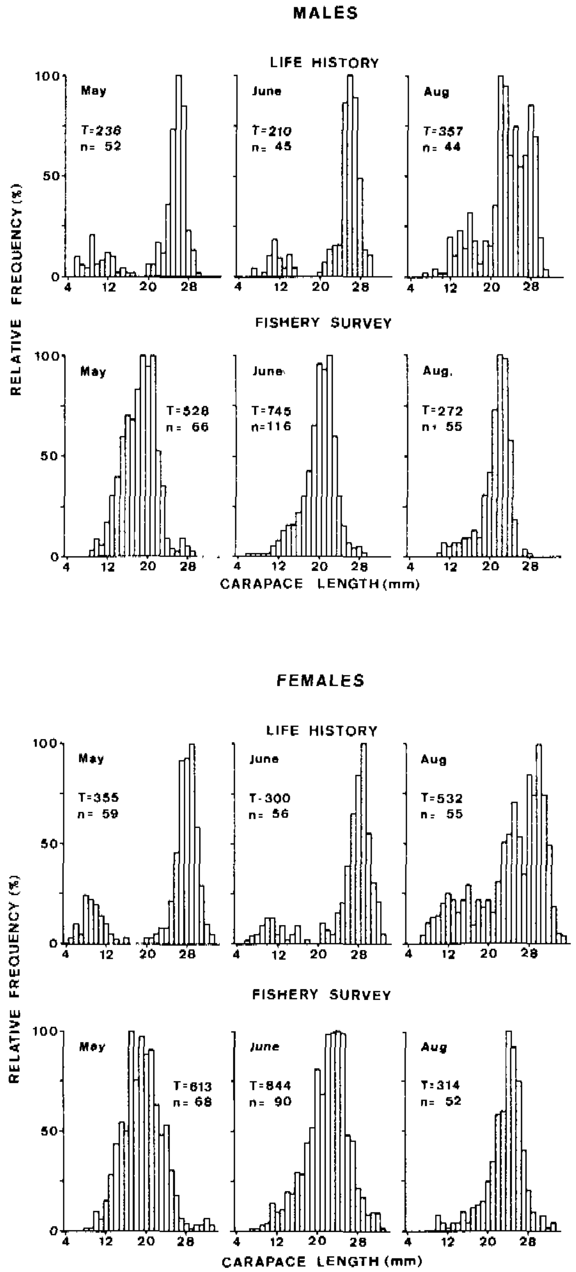


Figure 25. Length frequency distribution for the Jacksonville region (fishery survey) and the Cape Canaveral region (life history survey) during late spring and summer of 1974. T is total shrimp and n is the number of shrimp in the largest modal size class.

calculate the average counts is also presented (Figure 27). Counts and weights of processable sized shrimp per fishery survey station are included in Appendix II.

Effects of recruitment, growth and mortality on count size, abundance and weight during a season are best exemplified by examination of the 1973-1974 season. Two months after the beginning of large-scale recruitment in June, some juveniles started to enter the fishable count sizes, first dramatically increasing the 50 count shrimp percentage, then each larger size in succession. Maximum catch weight of shrimp of processable size coincided with maximum abundance of all shrimp in October, but only a small proportion of the total catch by numbers was 40 or 45 count. The processable portion of the total catch, averaging 40 count, consisted of a small number of shrimp averaging 26-30 count and a very large number of shrimp averaging slightly above 40 count. A month later, 40 count portion of the catch consisted of only 36-40 count shrimp. High mortality caused catch weight to decrease rapidly from October to November. The combined effect of mortality and growth eventually stabilized the 40 and 45 count weights. A second increase in weight occurred near the season's end as the processable portion of the catch gained weight more rapidly than weight was lost through mortality. The 1973-1974 season was an example of a cycle in which very high recruitment occurred.

Recruitment in 1974 was considerably lower than in 1973; and our estimates indicate that recruitment in 1972 was also low. Intensity of seasonal fluctuations was moderated by the effects of lower recruitment. Based on composite results from the partial seasons, catch weights were not as high, declined less rapidly; and the season's end peak was absent. The processable catch became 40 count or better earlier in seasons in which fewer juveniles were recruited, even though individual growth did not change appreciably from year to year.

FISHERY RECOMMENDATIONS

Industry and management require answers to specific biological, economic and sociological questions for the most efficient use of the natural resource. We have attempted in this study to provide many of the necessary biological answers. Based on this data and the implications thereof, some useful suggestions can be offered.

Potential fishing grounds have been well delineated. The most productive areas for fishable stocks (adults) are located in 18 to 30 fathoms on hard sand bottom. Rock shrimp distribution can fluctuate annually so the actual location of each year's stock or stocks must be determined by inspection. Once large stocks of juveniles are found during fall, fishable stocks will probably occur in those same areas or slightly offshore after allowing time for growth. We suggest that short exploratory fishing (inspection trips) be made to the most likely areas offshore from Jacksonville, Cape Canaveral and Melbourne during late fall in order to find the most concentrated stocks of juveniles.

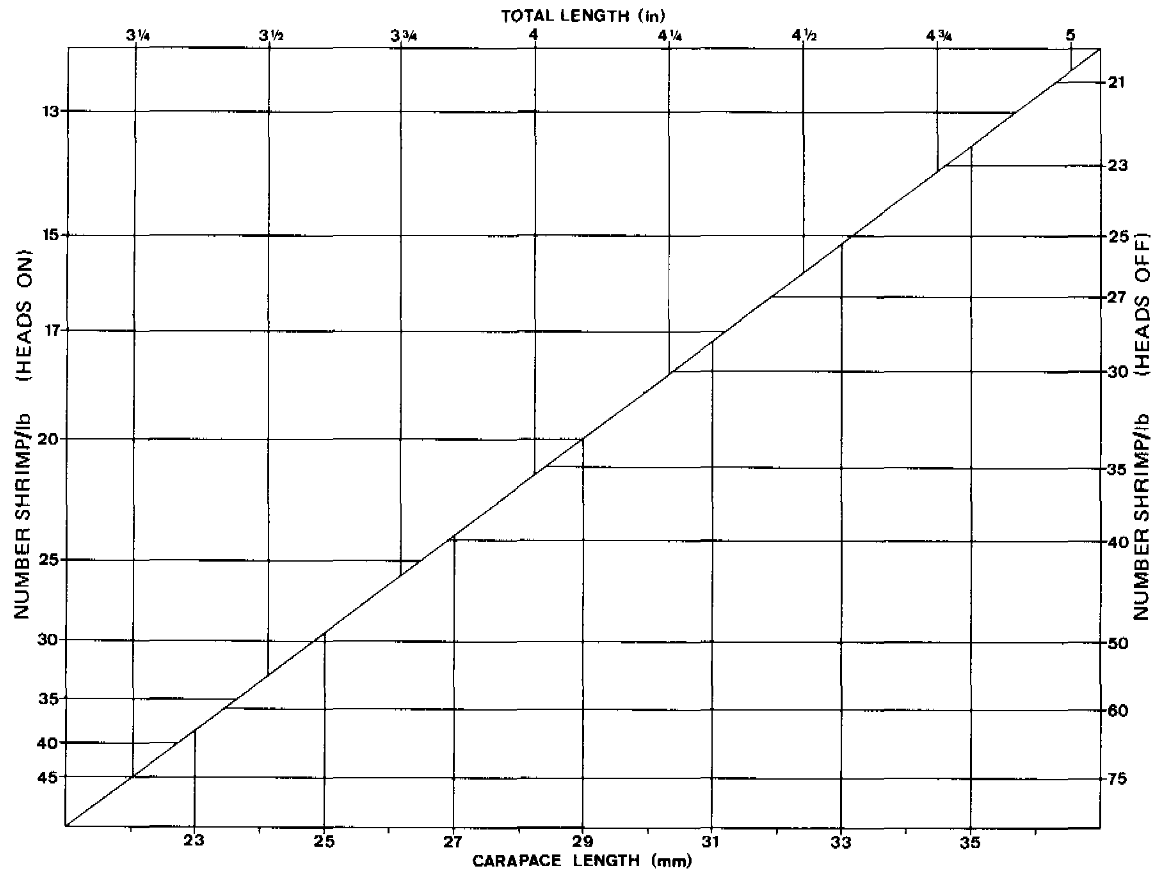


Figure 26. Nomograph for conversion of lengths and counts of *S. brevirostris*.

These stocks of shrimp can increase as much as five count sizes per month (i.e. 56-60 to 51-55 count). Therefore, the start of the fishing season can be roughly calculated depending on the current marketable sizes.

The yield of fishable stocks is determined by natural mortality, fishing mortality and growth rates which in turn are affected by environmental conditions. Given a set of conditions similar to those during our study, mortality moderated by the effects of growth could cause a 50% reduction in total catch weight in each of two months after peak abundance and a decrease of 20% per month thereafter. These observations provide the basis for predicting the potential yield just prior to the start of fishing using juvenile abundance and size collected during the exploratory trips. The fifty percent mortality occurred during very high juvenile abundance and only just after peak abundance so the above prediction will probably provide a minimum yield for the beginning of the fishing season.

In addition to predicting overall catch weight at the beginning of the season, it is also important to describe the counts and discard ratios during this same time for potential economic benefit. Shrimp sizes were diverse at peak abundance, averaging 56-60 count, currently an unacceptable market size. In 1973, when a large juvenile stock occurred, the catch contained marketable sizes (40 count) in acceptable quantities (about three and one half pounds per sample), but a ten to one discard ratio was required to harvest these sizes. A three to one discard ratio could have been achieved by assumming the marketable size to be 45 count instead of 40 count, thereby producing a 100 percent increase in marketable catch weight. If more smaller sizes could have been marketed, the total seasonal catch could have been increased as well. With advances in shrimp graders and splitter-deveiners, the early season catch could be processed with as much as half the dockside weight being 40 count or better, the rest being 41-45 count. If these sizes could be marketed, we suggest that fishing could start several months earlier than presently possible. The advantages should be an increase in total seasonal catch weight and possibly in total catch of large shrimp over the season.

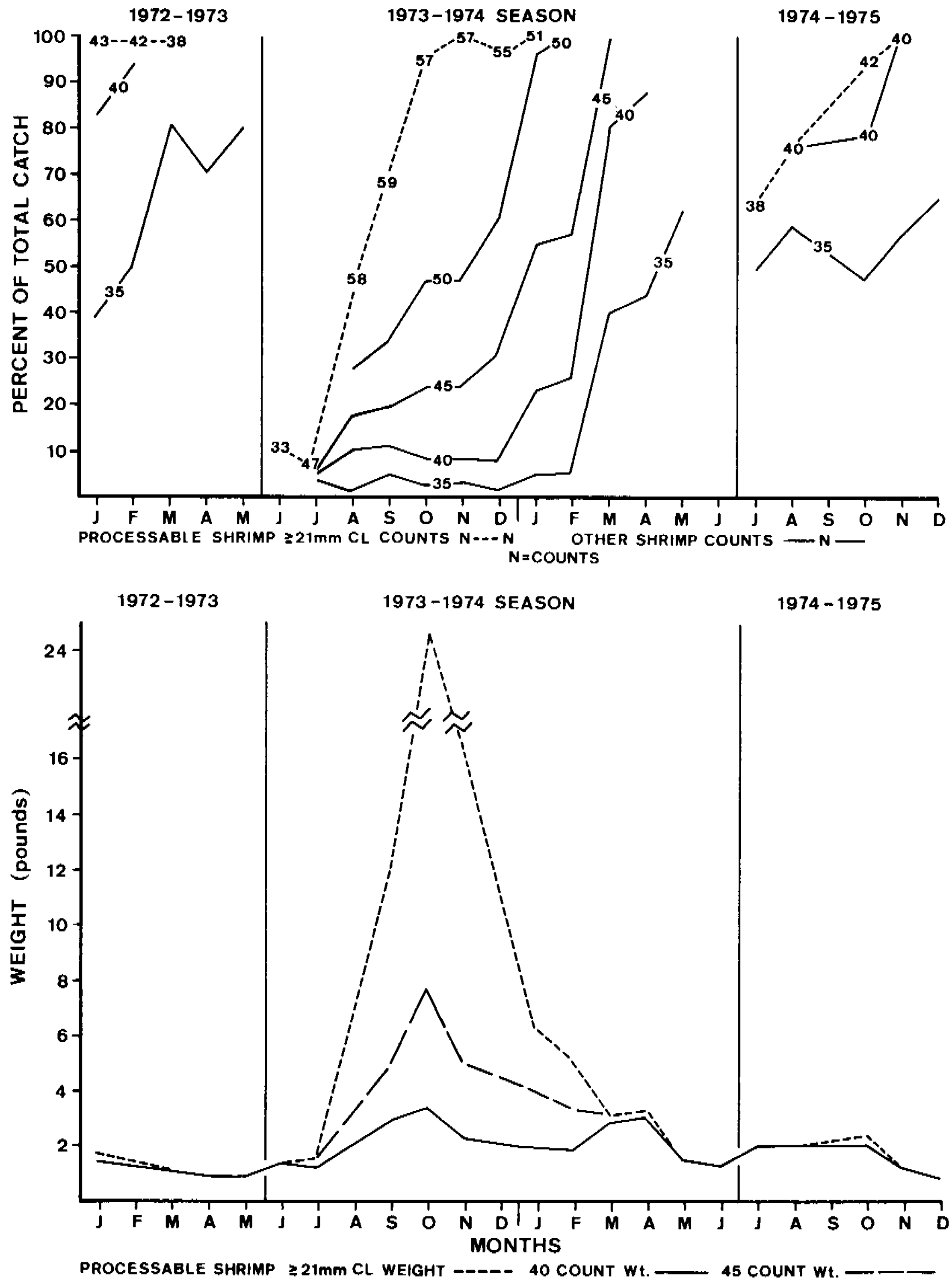


Figure 27. Monthly trends of selected average heads-off counts expressed as percentages of total catch (upper) and as total weight of heads-off shrimp (lower).

SUMMARY

1. Rock shrimp have recently become a viable Florida fishery. Little information has been available until now upon which to base sound management decisions. The Florida Department of Natural Resources initiated a project to develop information of the population dynamics of rock shrimp to facilitate fisheries management. This project was partially funded through Public Law 88-309 administered through the Fisheries Management Division, U. S. Department of Commerce.
2. The sampling program consisted of life history and fishery surveys conducted along Florida's Atlantic Continental Shelf from January 1973 through December 1974. Four life history survey stations between 26 m and 64 m depths were sampled monthly. Fishery survey sampling included the life history survey stations and single samplings of 163 stations located along 31 east-west loran transects from 18 m to 73 m depths.
3. Rock shrimp distribution fluctuated throughout the life history survey area, with major concentrations of adult shrimp in 40 m. Mean catches of adults were significantly lower at 26 m and 64 m.
4. Major population recruitment began in 26 m or less and then spread throughout the survey area. Some recruitment continued all year. All life history survey areas had major recruitment from late spring through summer. Maximum abundance occurred in fall and then declined until the next year class appeared the following spring.
5. Five ovarian developmental stages were found and described as undeveloped, developing, nearly ripe, ripe, and advanced ripe. Three modified stages were found and designated as spawned but viable, possibly spawned but viable, and terminally spent.
6. Females can mature as small as 17 mm CL. Nearly all are mature when they reach 24 mm CL. Individual females may spawn three or more times within one season.
7. All males are mature by 18 mm CL and are able to impregnate females throughout the rest of their life.
8. Peak spawning occurs for about three months starting in November, December, or January. Increasing temperatures apparently influence spawning by triggering gonadal maturation. Increased lunar light intensity apparently stimulated intramonthly spawning.
9. *Sicyonia* larvae were present all year, but no trends were found relating abundance to depth, temperature, salinity, day length or lunar influence.
10. The morphometric relationship between weight and carapace length for males and females changed from non-linear to linear between 20 mm and 24 mm CL. Males gained weight slightly faster and in proportion to females at all carapace lengths. Total lengths change at the same rate for males and females until 20 mm CL. The rate of increase in total length for females slows after this size, most likely in response to sexual maturity and subsequent spawning.
11. Growth was 2 - 3 mm CL per month in juveniles and 0.5 - 0.6 mm CL per month in adults. Females grow slightly faster than males. Both sexes apparently grow more slowly in winter. Natural mortality coincided with abundance. Natural mortality in females was slightly lower than that of males within generations.
12. Maximum life span for *S. brevirostris* is 20-22 months.
13. The sex ratio for rock shrimp in this study was 0.93; females were more abundant. Sex ratio fluctuations in relation to size and season were caused by growth rate differentials between sexes and by slightly greater female longevity.
14. The diet of rock shrimp consists primarily of crustaceans and mollusks, although numerous other organisms are consumed. Occurrence of food items in stomachs depends mainly upon availability; however, there were some exceptions.
15. In the fishery survey, rock shrimp were found in all depths from 18 m to 73 m, but best average adult catches were between 34 m and 55 m. Substantial rock shrimp aggregations were located off Jacksonville, Cape Canaveral, and to a lesser extent off Fort Pierce. Depth segregation of adults was indicated by their absence from the shallowest zone. Factors limiting inshore expansion of large rock shrimp aggregations were not obvious. Lack of available sand habitat in offshore reef zones appears to be a major factor limiting abundance of rock shrimp there.
16. Seasonal trends of change in all life history functions were similar between years within both survey areas.

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APPENDIX I — HYDROGRAPHIC, METEOROLOGICAL, AND CATCH DATA FROM LIFE HISTORY SURVEY.

KEY

+ — Benthic sample
♦ — Back-up hydrographic gear
* — Values based on 30 Minute tows. Fishable stock = animals 24 mm CL or larger. Stations 003 and 004 are combined.
** — Adult = 24 mm CL or larger.
P-M-J — Protozoea-Mysis-Postlarvae (Juvenile)
a — Aliquot taken. Adults estimated. Fishable animals, weight, and counts from aliquot only.

APPENDIX I

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (℃)	Bottom Salinity ($^0/oo$)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals / Adults**	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex Ratio ♂/♀	Larvae/m^3 P-M-J
001	1-15-73+	28 34.8N 80 14.8W	33	◆17.80	◆35.0	8 ft seas	NNW 20-30	Cloudy	78 67	22 437	38	.95	0-0-0
	2-7-73+			◆19.20	◆34.0	2 ft seas	WNW 8	Clear	77 69	23 443	38	1.03	14.6-0-0
	3-6-73+			20.86	36.41	2-4 ft seas 8-12 ft swell	SE 6-10	Cloudy	66 62	21 421	37	.47	.1-0-0
01A	4-9-73	28 35.9N 80 18.6W	26	19.46	35.56	1 ft seas 4 ft swell	W 8-20	P/C	45 33	11 207	40	1.25	1.0-.1-0
	5-6-73+			◆19.5	◆36.0	1 ft seas 4-6 ft swell	SE 8	Clear	70 14	5 98	38	.63	1.4-.1-0
	5-31-73			18.37	35.99	2-3 ft seas	SE 4	P/C	3293 9	3 58	38	.96	5.4-.1-0
	7-2-73+			19.84	35.70	1 ft seas	NNE 3-5	Clear	8096 34	11 191	45	1.00	0-0-0
	8-14-73			20.79	35.82	2-3 ft seas	SE 8	P/C	2565 94	31 482	48	1.10	.8-.5-0
	9-10-73+			24.30	35.88	2-3 ft seas	NW 8-10	P/C-Cloudy	2750 220	73 1123	50	1.04	0-.2-0
	10-15-73			◆26.8	◆34.0	1 ft seas 2-4 ft swell	E 5	Clear-P/C	2816 507	169 2607	48	1.07	.2-0-0
	11-4-73+			◆27.2	◆34.6	Calm 1 ft swell	NW 3	Clear	548 183	61 1148	30	.98	.3-0-0
	1-17-74+			22.13	36.23	1-2 ft seas	N 4	Clear	1677 911a	206 3334	47	1.41	.3-.1-0
	2-1-74			22.15	36.14	Calm	WSW 8-10	P/C	1592 1006a	187 3106	45	.99	0-0-0
	3-6-74+			20.44	36.20	1-2 ft seas 2-4 ft swell	ESE 4	Clear-P/C	641 568	189 3567	38	.60	0-.2-0
	4-20-74			20.77	36.12	1-2 ft seas	NE 7	Clear-P/C	394 356	119 2302	37	.94	.2-1.2-0
	5-16-74+			21.11	35.94	1 ft seas 3-5 ft swell	E 6	P/C-Cloudy	115 57	16 386	35	.98	.1-0-0

APPENDIX I (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (‰)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals / Adults**	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex Ratio ♂/♀	Larvae/m³ P-M-J
01A	6-4-74	28 35.9N 80 18.6W	26	◆20.6	◆36.50	1 ft seas	SE 4	Cloudy	71 52	17 348	35	.78	0-.8-0
	7-18-74+			◆22.89	◆34.97	Calm 1 ft swell	SE 5	Clear-P/C	248 118	39 695	43	.82	1.5-.6-0
	8-14-74			◆25.56	◆36.57	2-3 ft seas	E 5-8	Clear	185 91	30 532	43	.89	.1-0-0
	10-16-74			25.44	35.98	Calm 3-5 ft. swell	SE 7-10	Clear	74 36	12 210	43	.95	0-0-0
	11-5-74+			23.99	36.20	Calm 1 ft swell	SE 12-16	P/C-Cloudy	19 12	4 68	43	1.11	.4-.1-0
	12-6-74			19.25	35.99	Calm 1-2 ft swell	NE 4-8	P/C	26 16	5 97	42	1.89	.1-0-0
003	1-16-73+	28 37.0N 80 11.2W	40	◆17.3	◆32.0	6-8 ft seas	NE-ENE 15	Cloudy	219 173	79 1464	40	.81	.04-0-0
	2-5-73+			◆18.5	◆34.0	Calm	SSW 2	Clear	164 150	63 1199	40	.56	0-0-0
	3-4-73+			20.30	36.06	1-2 ft seas 10 ft swell	S 10-14	P/C	203 186	51 1041	37	.47	0-0-0
	4-9-73			16.54	35.84	4-6 ft seas 8-10 ft swell	W 14-24	Cloudy	151 147	47 946	37	.62	.2-0-0
	5-6-73+			19.29	35.99	1 ft seas 3-5 ft swell	SE 7-10	Clear	147 137	47 1053	35	.55	.7-0-0
	6-1-73			18.09	35.90	Calm	SE 5	P/C	317 165	65 1453	33	.71	.2-0-0
	6-30-73+			18.39	35.95	1-2 ft seas 3-6 ft swell	W 10	Clear	326 134	43 1026	32	.68	.1-.3-0
	8-15-73			18.73	35.93	2-4 ft seas 5 ft swell	SE 8-10	P/C	3086 660	163 2856	43	.76	1.4-2.9-.2
	9-10-73+			22.46	36.05	1-3 ft seas	NNW 6-8	P/C	3397 1006	278 4744	43	.92	.3-.1-0
	10-16-73			◆27.0	◆33.6	Calm 2-3 ft swell	E 2	P/C	4736 1809	698 11,145	48	1.05	.3-.3-0

APPENDIX I (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (℃)	Bottom Salinity (⁰/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals / Adults**	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex Ratio ♂/♀	Larvae/m³ P-M-J
003	11-2-73+	28 37.0N 80 11.2W	40	♦26.8	♦34.2	Calm	S 3	Clear-P/C	4687 1519a	129 2040	48	1.42	0-0-0
	1-18-74+			20.56	35.90	Calm 1-3 ft swell	N-NW 2-6	Clear	803 538	136 2243	45	.64	0-0-0
	2-1-74			18.85	36.01	1 ft seas	N 2	Clear-Hazy	357 238	84 1384	35	.74	0-0-0
	3-7-74+			20.63	36.14	1-2 ft seas	SE 8	Clear-P/C	186 156	82 1472	38	.52	0-0-0
	4-10-74			20.06	36.09	3-6 ft seas 5-8 ft swell	NE 10	P/C	441 394	124 2315	40	.54	.1-0-0
	5-17-74+			22.23	36.07	1-2 ft seas 3-5 ft swell	SE 8	Cloudy	231 173	65 1347	37	.63	0-0-0
	6-4-74			♦18.5	♦36.04	1 ft seas	NE 4-8	Cloudy Storms	220 180	59 1258	35	.67	0-.1-0
	7-18-74+			♦22.38	♦36.22	1 ft seas	SE 2	Clear-P/C	410 202	76 1702	33	.72	.5-.2-0
	8-14-74			♦24.11	♦36.57	1 ft seas 4-5 ft swell	E 8	P/C	279 144	72 1599	33	.64	.1-.2-0
	10-14-74			25.74	35.82	1-2 ft seas 5-7 ft swell	E 12	Clear	441 356	115 2222	38	1.01	0-0-0
	11-5-74+			22.92	36.17	1 ft seas 2-3 ft swell	SE 8-12	Clear	239 221	62 1238	38	.72	.2-0-0
	12-6-74			19.74	36.19	1 ft seas 2-3 ft swell	NE 8-12	Clear-P/C	211 206	49 966	38	.82	.4-0-0
004	1-18-73+	28 32.5N 80 10.3W	40	♦20.6	♦33.0	2-3 ft swell	SE 4-8	P/C	356 300	79 1464	40	.58	.05-0-0
	2-6-73+			♦17.2	♦34.0	1-2 ft seas	W 12	Clear	264 229	63 1199	40	.66	.1-.1-0
	3-5-73+			20.32	36.16	1-2 ft seas 8 ft swell	SE 6-9	P/C	127 118	51 1041	37	.87	.8-0-0
	4-8-73			17.82	34.39	Calm 3-4 ft swell	0	Clear	150 135	47 946	37	.52	0-0-0

APPENDIX I (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (⁰/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals / Adults**	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex Ratio ♂/♀	Larvae/m^3 P-M-J
004	5-7-73+	28 32.5N 80 10.3W	40	18.91	35.92	1-2 ft seas 4-6 ft swell	SE 10-14	P/C	159 148	47 1053	35	.47	.5-0-0
	6-1-73			17.25	35.83	Calm	0	Clear	357 223	65 1453	33	.49	.1-0-0
	7-1-73+			18.72	35.67	Calm 1-2 ft swell	W 10	Clear	529 125	43 1026	32	.64	0-0-0
	8-13-73			17.50	35.88	2-3 ft seas 4-6 ft swell	SE 10-12	P/C	1792 321	163 2856	43	.91	1.7-.8-0
	9-11-73+			29.91	35.91	1-3 ft seas	NNW 4-6	P/C	3497 664	278 4744	43	1.22	.2-.4-0
	10-16-73			◆27.6	◆33.9	Calm 2-3 ft swell	E 4-6	Clear-P/C	5822 2376	698 11,145	48	.86	.2-.2-0
	11-2-73+			◆26.8	◆34.1	Calm 1 ft swell	S-SW 3-10	Clear-P/C	3406 1199a	129 2040	48	1.08	0-0-0
	12-10-73			23.02	36.10	1-3 ft seas 3+ ft swell	NW 10-35	Clear	1270 588a	47 1484	48	1.14	.1-.9-0
	1-16-74+			21.61	36.22	Calm	S 2	Clear	459 279	136 2243	45	.71	0-.6-0
	2-2-74			16.52	35.73	1 ft seas	S 4-6	P/C-Hazy	428 265	84 1384	35	.87	0-0-0
	3-8-74+			◆17.5	◆35.0	2-4 ft seas 6-8 ft swell	E 10-12	Clear	388 333	82 1472	38	.51	0-0-0
	4-11-74			19.98	36.06	3-6 ft seas 5-8 ft swell	E 12-15	P/C-Cloudy	410 347	124 2315	40	.76	.2-0-0
	5-15-74+			20.45	35.97	3-5 ft seas	N 6-10	P/C	247 216	65 1347	37	.59	0-0-0
	6-5-74			◆18.45	◆36.20	Calm	SE 2	Cloudy	219 177	59 1258	35	.71	0-1.6-0
	7-17-74+			◆22.65	◆36.43	Calm	W 4	Clear-P/C	493 251	76 1702	33	.70	.5-.2-0
	8-15-74			◆22.89	◆36.57	1 ft seas 4-5 ft swell	E 8-10	P/C	425 287	72 1599	33	.61	.5-.7-0

APPENDIX I (Continued)

Sta-tion	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (^{0}/00)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals / Adults**	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex Ratio ♂/♀	Larvae/m^3 P-M-J
004	10-15-74	28 32.5N 80 10.3W	40	26.63	35.99	Calm 3-5 ft swell	SE 8	Clear	409 336	115 2222	38	.79	0-0-0
	11-4-74+			23.29	36.14	1-3 ft seas 3-5 ft swell	ESE 8-12	Clear	158 148	62 1238	38	.42	0-0-0
	12-6-74			21.23	36.27	Calm	E 6-8	P/C	98 88	49 966	38	.72	.5-.1-0
005	1-18-73+	28 37.1N 80 04.8W	64	♦21.0	♦34.0	6-8 ft seas	ESE 10-15	P/C	125 46	15 263	43	.91	.1-.05-0
	2-6-73+			♦18.2	♦36.0	Calm	SW 6	Clear	18 6	2 32	47	.38	.1-0-0
	3-5-73+			19.22	36.00	1-2 ft seas 8 ft swell	S 15	P/C	44 20	7 119	42	.69	0-0-0
	4-8-73			15.66	34.21	Calm 2-3 ft swell	NNE 7	Clear	228 92	31 509	45	.75	0-0-0
	5-5-73+			♦19.5	♦34.1	2-3 ft seas 5-8 ft swell	N 10-12	Clear	73 50	17 310	40	.52	0-0-0
	6-1-73			16.33	36.01	Calm	SE 6	P/C-Storm	74 12	12 203	47	1.18	.1-0-0
	7-1-73+			15.72	35.72	1 ft seas	NE 10	Clear	436 113	38 703	40	.88	0-.1-0
	8-14-73			15.64	35.76	2-4 ft seas 8 ft swell	SE 10-12	Clear	235 19	6 116	42	1.10	1.8-1.3 -0
	9-9-73+			15.82	35.97	Glass	SE 2	P/C	1150 320	107 1851	43	.82	.3 -0-0
	10-17-73			♦25.8	♦35.0	Calm 1-3 ft swell	S 4	Clear	3332 726	242 3816	28	1.14	.3 -0-0
	11-3-73+			♦24.6	♦34.4	Calm 1 ft swell	WSW 7-10	Clear-P/C	434 127	64 1029	47	1.14	0-0-0
	12-2-73			♦24.0	♦35.0	3-5 ft seas	E 12	P/C	371 97	97 1568	47	1.22	.3 -0-0
	1-17-74+			19.60	35.99	Calm	S 2	Clear	132 31	10 171	32	1.28	0-.1-0

APPENDIX I (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (‰)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals / Adults**	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex Ratio ♂/♀	Larvae/m³ P-M-J
005	1-31-74	28 37.1N 80 04.8W	64	14.53	35.63	Calm	S-SW 2-4	Cloudy	55 18	6 99	33	1.62	.1-0-.1
	3-7-74+			15.25	36.75	2-4 ft seas 4-6 ft swell	E 8-10	Clear	75 37	12 207	37	1.08	.1-0-.1
	4-19-74			15.91	35.75	1-2 ft seas	N 5	Clear-P/C	24 10	3 62	35	.85	0-0-0
	5-16-74+			21.96	36.08	1-3 ft seas	SE 6-10	P/C	9 4	1 22	38	.13	0-0-0
	6-3-74			♦13.8	♦35.90	1-2 ft seas 2 ft swell	SE 4	Cloudy	65 38	13 225	35	.48	.4-.4-0
	7-19-74+			♦20.3	♦36.43	Calm	SE 1-4	Clear	88 33	11 217	38	.66	1.6-1.1-0
	8-13-74			♦18.61	♦36.57	1-2 ft seas 4-5 ft swell	ESE 6-8	P/C	117 23	8 135	43	1.21	0-.1-0
	10-15-74			25.35	36.21	2-4 ft seas 5-7 ft swell	SE 12-15	Clear	197 114	57 1036	42	.97	0-.1-0
	11-5-74+			21.16	36.32	1-3 ft seas 3-6 ft swell	S 10-14	P/C	99 67	22 442	40	.80	0-0-0
	12-5-74			20.84	36.25	1-2 ft seas 3-5 ft swell	NNE 10-12	P/C	92 71	24 452	40	.92	.5-.2-0

APPENDIX II — HYDROGRAPHIC, METEOROLOGICAL, AND CATCH DATA FROM FISHERY SURVEY

KEY

N.S. — Station occupied but not sampled due to bottom topography.
♦ — Back-up hydrographic gear.
* — Fishable stock is 24 mm CL or larger.
✓ — Stations sampled but data not included in analysis.
Δ — ♂ is all male animals in tow.
♀ is all female animals in tow.

APPENDIX II

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (℃)	Bottom Salinity ($^0/oo$)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
15	8-27-74	30 33.2N 81 09.5W	18	◆27.2	◆35.63	2 ft. seas	SE 5	clear	2	2 32	47	♂
16		30 32.5N 81 01.5W	22	◆27.2	◆35.85				1	1 18	42	♀
17	8-28-74	30 31.8N 80 50.0W	24	◆27.3	◆35.85				5	1 22	35	1.50
18		30 31.0N 80 44.0W	27	◆26.9	◆35.49				17	1 14	53	1.43
19		30 30.5N 80 37.5W	31	◆26.8	◆35.85				84	19 291	53	1.05
20		30 30.0N 80 22.2N	37	◆23.4	◆35.85	2-3 ft. seas	SE 5-6		128	36 607	48	.88
21		29 29.6N 80 15.3W	46	◆20.1	◆36.35		SE 8-10		349	168 2919	47	.81
22		29 29.5N 80 12.4W	55	◆19.2	◆35.99		SE 10-12		2	1 16	52	1.00
23		29 29.5N 80 11.8W	64	◆16.6	◆34.14				43	14 231	50	1.39
24	8-29-74	29 29.4N 80 11.0W	73	◆15.5	◆35.85				120	42 722	48	1.79
35	6-20-74	30 24.2N 81 07.0W	18	◆27.1	◆37.12	1-2 ft. seas	SE 7		18	7 127	47	1.00
36	6-21-74	30 23.3N 80 54.0W	27	◆26.5	◆35.85	1 ft. seas	SE 6		160	16 280	48	1.00
37		30 22.5N 80 42.4W	32	◆25.9	◆36.07		SE 4		67	14 228	50	.86
38	6-21-74	30 21.9N 80 31.5W	33	◆24.0	◆36.36	1 ft. seas	SE 4		192	9 130	57	.86
39		30 21.3N 80 19.5W	37	◆23.2	◆36.07		SE 2	clear squalls	193	105 1884	45	1.01
40		30 21.3N 80 17.5W	37	◆22.8	◆36.43			clear	37	12 245	38	.68

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (⁰/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
41	6-21-74	30 21.3N 80 15.0W	49	◆22.8	◆36.07	1-2 ft. seas	S 10	clear	1	0 0		♂
42		30 21.3N 80 14.4W	55	◆22.2	◆36.15		S 12		0	—	—	—
49	9-29-74	30 17.1N 80 17.4W	55	◆19.7	◆35.85	2-3 ft. seas	S 10		N.S.	—	—	—
50		30 17.1N 80 16.4W	64	◆16.9	◆35.85				62	0 —	—	1.30
51		30 17.1N 80 15.0W	73	◆15.7	◆36.06				29	16 280	43	1.64
52	5-24-74	30 15.8N 81 11.2W	18	24.47	36.25	1-3 ft. seas	W 4	P/C	8	1 18	42	.33
53	5-25-74	30 15.0N 80 59.0W	27	◆24.2	◆34.7		W 6		23	2 31	50	1.30
54		30 14.4N 80 44.5W	27	◆24.0	◆35.0		W 6-10		22	0	—	1.20
55		30 13.7N 80 31.1W	34	◆23.2	◆34.8		W 8-10		360	6 123	43	1.02
56		30 13.5N 80 26.0W	37	◆22.8	◆34.5		W 7		216	27 487	42	.76
57	6-22-74	30 13.0N 80 21.8W	38	◆20.6	◆36.15	1-3 ft. seas 2-4 ft. swell	S 4-6	clear	217	82 1415	43	.58
58		30 13.0N 80 18.9W	38	◆20.2	◆36.15	1-3 ft. seas	S 4		190	97 1791	42	.62
59		30 13.0N 80 16.1N	47	◆19.4	◆36.43	1-2 ft. seas	S 4-6		39	10 176	43	1.67
60		30 13.0N 80 15.8W	61	◆21.8	◆36.22		S 8		2	0 —	—	♀
71	6-23-74	30 07.1N 81 09.2W	18	◆26.8	◆36.07	1 ft. seas	SW 10		8	1 14	52	1.67
72		30 06.8N 81 00.0W	24	◆24.1	◆36.15	1-3 ft. seas	W 6-10		36	4 61	50	1.25

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (℃)	Bottom Salinity ($^0/_{00}$)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
73	6-24-74	30 06.5N 80 52.6W	27	◆21.9	◆36.29	2-4 ft. seas	NW 6-12	clear	16	2 38	40	1.67
74		30 06.2N 80 46.7W	31	◆20.3	◆36.29	3-6 ft. seas	W 8-15		192	4 61	50	1.11
75	5-23-74	30 05.8N 80 39.0W	31	23.23	36.21	1-3 ft. seas 3-7 ft. swell	S-SW 15	P/C	260	25 418	45	1.03
76		30 05.4N 80 29.5W	37	22.78	36.07		SE 12		100	21 416	38	.92
77	5-22-74	30 05.0N 80 20.0W	46	21.58	36.07		E-SE 10		178	29 525	42	0.68
78	6-22-74	30 05.0N 80 20.0W	46	◆17.6	◆36.07	1 ft. seas	S 10	clear	74	27 472	38	.85
79		30 05.0N 80 18.0W	61	◆15.4	◆36.29				0	—	—	—
80	6-23-74	30 05.0N 80 16.6W	73	◆15.2	◆36.43		S 10		71	35 637	38	.58
91	2-14-74	29 58.4N 81 05.8W	18	18.27	36.05	1 ft. seas 2-4 ft. swell	W 12-14		2	0 —	—	♀
92		29 58.2N 81 00.4W	22	19.39	36.21	1 ft. seas 1-3 ft. swell	W 10		1	1 27	28	♂
93		29 58.0N 80 54.3W	26	19.55	36.20		S 8		11	11 266	32	.83
94		29 57.7N 80 47.3W	27	19.74	36.23	1 ft. seas 2-4 ft. swell	S 12		21	20 448	33	.31
95		29 57.4N 80 39.3W	36	20.18	36.18	1-2 ft. seas 2-4 ft. swell	SE 10		97	78 1395	45	1.06
96		29 57.2N 80 31.0W	38	18.96	35.85	1-2 ft. seas 2-5 ft. swell	SE 13		60	50 890	38	.82
97	6-23-74	29 57.0N 80 24.2W	37	◆17.8	◆36.07	1-3 ft. seas	S 12		55	4 59	52	1.04
98		29 56.8N 80 19.8W	48	◆16.7	◆36.43		S 10		94	3 53	43	1.19

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (⁰/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
99	6-23-74	29 56.8N 80 17.4W	64	♦15.9	♦36.43	1-2 ft. seas	S 10	clear	153	30 502	45	.88
100		29 56.8N 80 16.5W	73	—	—				N.S.	—	—	—
111	2-14-74	29 49.6N 81 01.7W	20	19.16	36.18	1 ft. seas 2-3 ft. swell	W 10-14		9	7 121	44	8.00
112		29 49.4N 80 52.3W	25	19.61	36.19	1-2 ft. seas 2-4 ft. swell	W 15-18		7	6 135	33	.40
113		29 49.2N 80 43.7W	27	20.23	36.24	1 ft. seas 1-2 ft. swell	W 6-8		34	27 574	37	.42
114	2-13-74	29 49.0N 80 32.0W	34	20.55	36.10	calm	SW 5-12		17	15 326	45	.42
115		29 48.8N 80 21.2W	45	17.17	35.80	calm swell	WNW 4		26	19 325	45	.86
116	5-22-74	29 48.7N 80 19.0W	55	22.03	36.00	1-2 ft. seas 3-6 ft. swell	E 6-8	clear-P/C	171	5 93	40	.94
117		29 48.7N 80 18.2W	64	22.14	35.92	2-3 ft. seas 3-6 ft. swell	SE 8-10	P/C	35	1 16	47	1.19
118		29 48.7N 80 17.4W	73	21.63	36.07	2-3 ft. seas 3-5 ft. swell			8	0 —	—	1.00
128	2-13-74	29 41.2N 80 58.4W	18	18.96	36.16	1 ft. seas 1-3 ft. swell	W 6	clear	7	5 114	33	2.50
129		29 41.1N 80 44.5W	27	20.16	36.26	1.2 ft. seas 1-4 ft. swell	W 10-12		9	8 187	33	.80
130		29 41.0N 80 37.0W	27	20.82	36.13	1 ft. seas 1-3 ft. swell	SW 8		31	27 535	38	1.21
131		29 40.7N 80 24.0W	37	17.88	35.92		SE 5		46	42 819	38	.64
132	2-12-74	29 40.6N 80 19.6W	46	16.08	35.89	calm	SW 6		19	15 304	37	.36
133	5-22-74	29 40.5N 80 19.2W	55	21.12	35.91	2-3 ft. seas 3-5 ft. swell	SE 8	P/C	156	22 362	47	1.67

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (‰)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
134	5-22-74	29 40.5N 80 18.5W	64	21.07	35.89	1-3 ft. swell	SE 8-10	P/C	10	1 16	47	1.00
135	5-21-74	29 40.5N 80 14.2W	73	21.03	36.02	1-2 ft. seas 3-5 ft. swell	SE 8		10	0 —	—	2.50
144	11-9-73	29 32.6N 80 48.3W	18	◆24.8	◆34.4	1 ft. seas 1-3 ft. swell	W 7	P/C-Hazy	10	6 100	45	2.50
145		29 32.5N 80 36.8W	22	◆26.2	◆34.2	1-2 ft. seas 1-4 ft. swell	W 12	cloudy	3	2 38	40	♀
146		29 32.4N 80 25.2W	37	◆26.2	◆33.8	2 ft. seas 4-6 ft. swell	W-NW 18-20		83	17 283	45	.76
146	2-12-74	29 32.4N 80 25.2W	37	20.54	36.04	calm 1-3 ft. swell	0	clear	34	25 452	42	1.12
147	3-12-74	29 32.3N 80 17.0W	55	◆15.8	◆34.0	1-2 ft. seas 3-4 ft. swell	W 10		69	48 856	43	.64
148		29 32.2N 80 14.0W	73	◆15.2	◆33.9	1-2 ft. seas 3-5 ft. swell	SW 10-14		0	—	—	—
157	11-9-73	29 24.4N 89 51.8W	18	◆24.0	◆33.8	1 ft. seas 1-3 ft. swell	SW 10-12		0	—	—	—
158		29 24.4N 80 46.8W	24	◆26.2	◆34.4	1 ft. seas 2-4 ft. swell	SW 10		49	38 634	45	.48
159	11-8-73	29 24.4N 80 25.4W	38	◆25.5	◆34.3	calm	SW 7		3	0 —	—	♂
160		29 24.4N 80 23.4W	37	◆25.0	◆34.4	calm 1-3 ft. swell	SSW 8		49	31 537	43	.88
161		29 24.1N 89 19.3W	46	◆25.4	◆34.2		SW 5		114	49 786	47	.87
162		29 24.1N 89 17.1W	55	◆25.4	◆34.7		VAR.		541	61 965	48	1.09
163	10-18-73	29 24.1N 80 15.5W	64	◆25.4	◆34.4	calm	VAR. 3		327	60 962	47	.76
164		29 24.1N 80 13.0W	73	◆24.8	◆34.6	calm 2-5 ft. swell	VAR. 2		162	18 286	48	1.89

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (‰)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex∆ Ratio ♂/♀
173	9-21-73	29 16.0N 80 47.3W	18	♦27.8	♦35.1	1-2 ft. seas 3-6 ft. swell	E 12	P/C	27	13 212	47	.59
174		29 16.0N 89 43.6W	23	♦27.8	♦35.6	1-2 ft. seas 4-6 ft. swell	SE 16-20		3	2 31	50	2.00
175		29 16.0N 80 36.6W	27	♦26.8	♦35.9	1 ft. seas 2-4 ft. swell	E 5		428	80 1231	48	1.08
176		29 16.0N 80 28.4W	27	♦26.2	♦35.6	1-2 ft. seas	E 4-6		744	159 2482	48	1.02
177		29 16.0N 80 21.2W	37	♦25.0	♦36.4	1-2 ft. seas 3-4 ft. swell	E 5		436	152 2518	45	.78
178	9-18-73	29 16.0N 80 18.0W	46	♦23.6	♦35.8	1-2 ft. seas 3-4 ft. swell	NNE 4-5	clear-P/C	944	96 1617	45	1.98
179	9-17-73	29 16.0N 80 15.4W	55	♦23.4	♦36.0	1-2 ft. seas 3-5 ft. swell	NNE 6-10	clear	1046	63 1092	43	1.40
180		29 15.8N 80 13.9W	64	♦22.6	♦36.2	1-3 ft. seas 5-7 ft. swell	NNE 10-12	clear-P/C	1780	60 1002	45	1.10
181		29 15.8N 80 12.7W	73	—	—	—	—		N.S.	—	—	—
190	9-20-73	29 07.7N 80 44.3W	18	♦26.8	♦34.6	1-3 ft. seas 3-5 ft. swell	E 8-12	clear	63	30 530	43	.85
191	9-21-73	29 07.8N 80 37.0W	24	♦27.2	♦35.8		E 4	P/C-storms	603	69 1040	50	1.05
192	9-17-73	29 07.9N 80 28.4W	27	♦23.6	♦35.8	1-3 ft. seas 2-5 ft. swell	ESE 6-8	clear	754	38 587	48	.92
193		29 07.8N 80 19.5W	37	♦24.6	♦35.6	1-3 ft. seas 4-5 ft. swell	NE 3-5	clear-P/C	327	122 1986	47	.97
194		29 07.8N 80 15.7W	46	♦24.0	♦35.9	1-3 ft. seas	NE 6	P/C	641	60 968	47	1.18
195		29 07.8N 80 12.8W	55	♦23.8	♦35.6	2-4 ft. seas 4-8 ft. swell	N.S.		360	80 1343	45	.93
196		29 07.7N 80 09.7W	64	♦23.6	♦36.0	1-3 ft. seas 2-4 ft. swell	NE 4-6		318	54 851	48	1.04

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (°/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
197	9-17-73	29 07.7N 80 08.4W	73	—	—	—	—	—	N.S.	—	—	
205	9-16-73	28 59.6N 80 30.6W	18	◆23.8	◆34.2	1-2 ft. seas	E 6	clear	184	30 451	50	1.56
206	9-13-73	28 59.6N 80 30.6W	37	◆24.8	◆35.8		S 9	P/C	104	3 47	48	.78
207		28 59.6N 80 10.0W	55	◆22.0	◆35.3	calm	S 8		1877	290 4387	50	.93
208		28 59.5N 80 07.0W	64	—	—	—	—	—	N.S.	—	—	—
216	8-24-73	28 51.1N 80 37.9W	18	◆23.8	◆34.9	3-6 ft. seas	SSE 8-10	clear-P/C	24	3 60	38	.85
217		28 51.4N 80 29.0W	19	◆23.4	◆34.2	4-6 ft. seas	S 10	P/C	442	11 227	37	.88
218		28 51.5N 80 21.3W	27	◆21.8	◆34.5	5-8 ft. seas	SSE 8-10		1802	39 606	48	.88
219	9-12-73	28 51.5N 80 17.6W	37	◆24.8	◆34.2	calm	SW 6-8	cloudy	920	44 709	47	.97
220		28 51.5N 80 13.5W	46	◆23.0	◆35.6		SE 6		1995	300 4871	47	.99
221	9-13-73	28 51.5N 80 11.4W	55	◆21.8	◆35.5		SE 7		2017	435 7026	47	.98
222		28 51.5N 80 08.7W	64	◆22.2	◆35.2		SSW 8		72	9 137	50	.67
223		28 51.5N 80 05.4W	73	—	—	—	—		N.S.	—	—	—
231	8-24-73	28 43.4N 80 26.3W	18	◆23.4	◆35.2	3-6 ft. seas	N.S.	clear-P/C scattered cloud	766	10 148	52	.87
232	8-23-73	28 43.4N 80 15.0W	37	◆20.2	◆31.9		S 5	clear	1462	258 4242	47	.98
233	8-21-73	28 43.1N 80 09.0W	55	17.87	35.87	calm	SW		78	28 477	47	.95

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (⁰/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex∆ Ratio ♂/♀
234	8-21-73	28 43.1N 80 04.0W	73	—	—	calm	SW 2-5 25 GUST	clear	N.S.	—	—	—
241	6-28-73	28 35.3N 80 19.7W	19	22.20	34.98	calm	S 12	P/C	560	1 14	53	.96
242		28 35.1N 80 03.9W	73	—	—	—	—	—	N.S.	—	—	—
246	6-27-73	28 27.4N 80 23.7W	19	21.97	35.63	calm 1-2 ft. swell	N.S.	P/C	159	0 —	—	.81
247		28 27.4N 80 18.0W	27	19.52	35.84	1 ft. seas 2-3 ft. swell	SSE 4		81	9 215	32	.88
248	6-27-73	28 27.4N 80 13.6W	37	17.59	35.89	1 ft. seas 2-3 ft. swell	SSE 4		119	73 1617	35	.68
249		28 27.4N 80 08.5W	46	15.75	35.70	1 ft. seas 2-4 ft. swell	S 5-7		98	18 368	37	.63
250	6-26-73	28 27.4N 80 05.9W	55	15.29	35.78		NNE 3-5		84	71 1454	37	.83
251		28 27.2N 80 02.9W	64	13.22	35.44				38	13 245	40	.90
252		28 27.2N 80 00.8W	73	—	—	—	—	—	N.S.	—	—	—
260	6-20-73	28 19.0N 80 20.8W	18	17.51	35.50	1 ft. seas	calm	cloudy	83	1 16	47	1.02
261		28 19.2N 80 11.9W	37	17.24	35.50		N.S.		25	22 505	33	.19
262	6-19-73	28 19.0N 80 04.5W	55	15.82	35.44		SW 5		25	2 40	38	.92
263		28 18.9N 79 59.1W	73	14.80	35.68	1-2 ft. seas			1	0 —	—	♀
271	5-24-73	28 10.7N 80 26.6W	18	23.02	36.04	2-4 ft. seas 6 ft. swell	SW 10	clear	4	0 —	—	1.00
272		28 11.3N 80 13.8W	27	20.89	35.54		SW 12-13		21	21 469	33	.75

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (℃)	Bottom Salinity ($^0/00$)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex∆ Ratio ♂/♀
273	5-23-73	28 11.3N 80 10.1W	37	20.24	35.44	2-4 ft. seas	SSW 9-10	clear	6	5 99	38	1.00
274		28 11.1N 80 05.0W	46	19.25	34.76		S 10		0	—	—	—
275		28 11.0N 80 01.0W	55	17.70	34.27	2-3 ft. seas	SSE 10-12		8	6 131	35	.60
276		28 10.9N 79 59.3W	73	—	—	—	—		N.S.	—	—	—
278	11-20-74	28 06.7N 80 22.8W	20	23.92	36.26	calm	SE 6		0	—	—	—
279		28 07.0N 80 13.4W	27	25.07	36.27	calm 1-3 ft. swell			4	3 51	45	1.00
280		28 07.0N 80 08.9W	37	24.49	36.31	calm			15	9 181	37	1.50
281		28 06.9N 80 04.0W	46	24.73	36.29	calm 1-3 ft. swell	SE 6-8		33	30 552	42	.44
282	11-19-74	28 06.8N 80 02.6W	55	24.49	36.31				110	86 1528	43	.86
285	5-23-73	28 02.4N 80 25.6W	18	23.05	36.11	1 ft. seas 2-3 ft. swell	SE 6-8		6	0 —	—	1.00
286		28 03.1N 80 11.2W	27	21.49	35.70		SW 4-8		1	1 24	48	♂
287		28 03.1N 80 07.4W	37	17.95	34.83	1 ft. seas 3-4 ft. swell	SSW 10-12		30	30 625	37	.43
288		28 03.0N 80 03.5W	46	14.76	34.50	1-2 ft. seas 3-5 ft. swell	SSW 10-15	P/C	49	48 944	38	.26
289		28 02.9N 80 00.0W	55	14.21	34.17	1-2 ft. seas 4-5 ft. swell	SSW 8-12		7	6 113	40	.40
290	5-22-73	28 02.8N 79 58.0W	73	15.45	35.44	1 ft. seas 2-3 ft. swell	S 6	cloudy	0	—	—	—
295	5-14-73	27 54.8N 80 09.8W	27	19.66	35.71	2-3 ft. seas	SW 6-8	P/C-clear	7	7 149	35	.75

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity ($^{0}/oo$)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
296	5-14-73	27 54.8N 80 02.9W	46	17.49	35.63	2-3 ft. seas	S 4-6	P/C-clear	9	2 38	40	1.25
297		27 54.6N 79 59.7W	64	16.84	35.26	1-3 ft. seas	SW 6		6	0 —	—	5.00
298	11-19-74	27 50.9N 80 13.2W	18	25.43	36.29	calm 1-3 ft. swell	SE 6-8	clear	0	—	—	—
299		27 50.8N 80 06.4W	37	24.78	36.30		NE 6-8		23	22 427	38	.53
300		27 50.6N 79 59.0W	55	24.51	36.26		ENE 6-8		81	62 1187	40	.56
302	5-14-73	27 47.0N 80 07.6W	27	18.89	35.59	1 ft. seas 3-4 ft. swell	ESE 2	P/C-hazy	23	23 499	35	.35
303		27 46.6N 80 01.6W	46	18.40	35.64	2-4 ft. seas 6 ft. swell	S 10	P/C	13	12 234	38	.62
304		27 46.4N 79 57.4W	64	16.87	35.22	1-3 ft. seas 6-7 ft. swell			1	0 —	—	♀
309	5-13-73	27 38.7N 80 06.2W	27	19.26	35.70	4-6 ft. seas 8 ft. swell	SE 10-15		0	—	—	—
310		27 38.5N 80 00.8W	46	18.12	35.59	2-4 ft. seas 6-7 ft. swell	S 12-14	clear	2	2 46	33	♀
311		27 38.2N 79 57.8W	64	16.76	35.10		ESE 6		2	2 33	47	1.00
312	11-19-74	27 34.7N 80 09.0W	18	24.83	36.27	calm	0		3	1 20	37	2.00
313		27 34.5N 80 02.6W	37	24.82	36.26				6	5 106	37	.50
314		27 34.0N 80 00.0W	55	24.09	36.14				38	30 519	43	.73
316	5-13-73	27 30.5N 80 03.7W	27	19.80	35.02	calm 1-2 ft. swell	S 8-10		26	24 489	37	.62
317		27 30.2N 80 01.5W	46	18.34	35.59	calm 1-4 ft. swell	SSW 11-13		30	27 526	38	.43

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (°C)	Bottom Salinity (°/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex△ Ratio ♂/♀
318	5-13-73	27 30.1N 75 59.9W	64	16.60	34.78	calm 1-3 ft. swell	S 11-12	clear	17	14 256	42	.89
323	5-12-73	27 22.1N 80 02.6W	27	19.31	35.47		SE 10-14		63	58 1130	38	.85
324		27 21.9N 80 00.4W	46	17.49	35.61		E-SE 6		15	13 240	42	1.50
325		27 21.6N 79 59.0W	64	16.11	35.87		SE 12-15		7	6 130	35	.40
326	11-19-74	27 18.3N 80 04.5W	18	24.74	36.17	calm	0		1	1 14	52	♂
327		27 17.9N 80 02.0W	37	24.86	36.22	calm 1-2 ft. swell	S-SE 2		3	3 66	35	♀
328	11-18-74	27 17.6N 80 00.0W	55	23.92	36.12		S 2		51	39 707	42	.64
330	4-14-73	27 14.7N 80 02.3W	27	22.41	35.34	calm	NE 5		8	7 127	42	.33
331		27 13.8N 80 01.5W	35	—	—	1 ft. seas	NE 6-8		8	7 126	42	.60
332		27 13.1N 79 58.7W	64	19.79	35.70		NE 8		1	0 —	—	♂
337	4-13-73	27 07.5N 80 01.5W	27	23.72	35.81		NE 8		0	—	—	—
338		27 07.3N 80 00.4W	45	20.93	35.43				58	54 971	42	.76
339		27 06.7N 79 59.3W	64	20.61	35.65				66	59 1032	43	1.13
330✓	1-24-73	27 14.7N 80 02.3W	28	—	—	2-3 ft. seas	N 15-20	P/C-rain	1	1 15	50	♀
331✓		27 13.4N 79 59.4W	35	—	—	—	—	—	N.S.	—	—	—
332✓		27 13.1N 79 58.7W	64	—	—	3-4 ft. seas	NE 8-10	P/C-rain	3	1 15	50	2.00

APPENDIX II (Continued)

Station	Date M-D-Y	Location Lat. Long.	Depth (m)	Bottom Temp. (℃)	Bottom Salinity (⁰/oo)	Sea Conditions	Wind Dir. Vel. (kt)	Weather	Total No. Animals	Fishable* No. Animals / wt (g)	Count* (heads) (off)	Sex∆ Ratio ♂/♀
337✓	1-24-73	27 07.5N 80 01.5W	28	—	—	2-3 ft. seas	E 10-12	P/C	9	8 132	45	♀
338✓		27 07.4N 80 00.8W	46	—	—		NE 10-12		36	15 305	37	.59
339✓	1-23-73	27 07.0N 79 59.6W	65	—	—	calm 1-2 ft. swell	N 6-8		12	5 88	43	3.00

APPENDIX III. CRUSTACEAN AND MOLLUSCAN TAXA IN BENTHIC SAMPLES.

Class Crustacea
Order Isopoda
Apanthura sp.
Astacilla sp.
Cyanthura burbancki
Colanthura tenuis
Eurydice littoralis
Ptilanthura tricarina
Xenanthura sp.

Tanaidacea
Apseudes sp.
Leptochelia sp.

Cumaceana
Cyclaspis varians
Oxyurostylis smithi

Mysidacea
1 Phenotype

Decapoda
Alpheidae sp.
Carpoporus papulosus
Euceramus praelongus
Hypoconcha arcuata
Hypoconcha sp.
Leptochela sp.
Micropanope sp.
Paguroidea sp.
Parthenope fraterculus
Pilumnus sp.
Pinnixa floridana
Pinnixa sp.
Portunus gibbesii
Processa sp.
Ranilia muricata
Solenocerinae sp.
Synalpheus sp.
Xanthidae sp.

Amphipoda
22 Phenotypes

Class Pelecypoda
Family Solemyidae
Solemya sp.
Nuculidae
Nucula proxima
Nuculanidae
Nuculana sp.
Arcidae
Anadara transversa
Barbatia sp.
Noetia ponderosa
Glycymerididae
Glycymeris pectinata
Glycymeris spectralis
Mytilidae
Amygdalum sagitatum
Crenella divaricata
Musculus lateralis
Pectinidae
Argopecten gibbus
Chlamys benedicti
Cyclopecten sp.
Limidae
Limaria sp.
Anomiidae
Anomia simplex
Crassatellidae
Crassinella dupliniana
Crassinella lunulata
Crassinella sp.
Carditidae
Pleuromeris tridentata
Astartidae
Astarte nana
Condylocardiidae
Carditopsis smithi
Lucinidae
Lucina blanda
Lucina multilineata
Lucina sp.
Leptonidae
Montacuta sp.
Chamidae
Arcinella sp.
Chama sp.
Cardiidae
Trachycardium egmontianum
Trachycardium muricatum
Laevicardium sp.
Veneridae
Chione grus
Chione intapurpurea
Chione latilirata
Gouldia cerina
Dosinia sp.
Pitar fulminata
Pitar sp.
Mesodesmatidae
Ervilia concentrica
Tellinidae
Macoma spp.
Tellina cristata
Tellina spp.
Semelidae
Abra spp.
Semele bellastriata
Semele nuculoides
Semele spp.

APPENDIX III (Continued)

Class Pelecypoda (Cont.)
Family Corbulidae
Corbula barrattiana
Corbula sp.
Varicorbula operculata
Hiatellidae
Hiatella sp.
Pandoridae
Pandora sp.
Lyonsiidae
Lyonsia hyalina
Verticordiidae
Verticordia ornata

Class Gastropoda
Family Trochidae
Calliostoma yucatecanum
Calliostoma spp.
Solariella lacunella
Skeneidae
Skenea sp.
Liotiidae
Arene tricarinata
Arene variabilis
Turbinidae
Turbo castanea
Phasianellidae
Tricolia affinis
Rissoidae
Alvania auberiana
Alvania sp.
Zebina browniana
Rissoinidae
Rissoina sp.
Vitrinellidae
Anticlimax sp.
Aorotrema sp.
Circulus sp.
Cyclostremiscus spp.
Episcynia inornata
Parviturboides interruptus
Teinostoma goniogyrus
Teinostoma spp.
Vitrinella spp.
Architectonicidae
Architectonica sp.
Heliacus bisulcatus
Turritellidae
Turritella acropora
Turritella exoleta
Vermicularia sp.
Caecidae
Caecum cooperi
Caecum pulchellum
Caecum spp.
Cerithiidae
Alaba incerta
Cerithiopsis taeniolata
Cerithiopsis spp.
Cerithium sp.
Diastoma varium
Finella spp.
Seila adamsi
Triphora spp.
Epitoniidae
Amaea retifera
Depressicala nautlae
Epitonium spp.
Opalia sp.

Class Gastropoda (Cont.)
Family Eulimidae
Balcis spp.
Niso aeglees
Niso sp.
Aclididae
Henrya sp.
Fossaridae
Fossarus spp.
Macromphalina floridana
Macromphalina palmalitoris
Calyptraeidae
Calyptraea centralis
Crepidula fornicata
Naticidae
Natica pusilla
Natica sp.
Polinices duplicatus
Polinices lacteus
Sigatica carolinensis
Cassidae
Phalium sp. (juv.)
Eratoidae
Erato maugeriae
Tonnidae
Tonna sp.
Cymatiidae
Distortio sp.
Muricidae
Eupleura caudata
Murex sp. (juv.)
Columbellidae
Aesopus stearnsi
Anachis lafresnayi
Anachis iontha
Anachis obesa
Mitrella lunata
Nassarina glypta
Nassarina sp.
Melongenidae
Busycon contrarium
Nassariidae
Nassarius spp.
Olividae
Oliva sp.
Olivella spp.
Mitridae
Costellaria wandoensis
Vexillum sp.
Cancellariidae
Agatrix smithii
Marginellidae
Granulina ovuliformis
Marginella eburneola
Prunum roscidum
Prunum sp.
Volvarina sp.
Terebridae
Terebra concava
Terebra protexta
Turridae
Bellaspira pentagonalis
Brachycythara barbarae
Cerodrillia sp.
Cerodrillia sp.
Cochlespira radiata
Crassispira sp.
Ithycythara sp.
Kurtziella spp.

APPENDIX III (Continued)

Class	Gastropoda (Cont.)	Class	Gastropoda (Cont.)
Family	Turridae (Cont.)	Family	Cylichnidae
	Nannodiella spp.		*Cylichna verrillii*
	Pyrgocythara coxi		*Cylichnella bidentata*
	Rubellatoma rubella		Philinidae
	Rubellatoma sp.		*Philine sagra*
	Vitricythara sp.		Haminoeidae
	Pyramidellidae		*Atys riiseana*
	Cingulina babylonia		Retusidae
	Eulimastoma spp.		*Pyrunculus caelatus*
	Odostomia dianthophila		*Retusa sulcata*
	Odostomia dux		*Volvulella* spp.
	Odostomia gibbosa		
	Odostomia seminuda	Class	Polyplacophora
	Odostomia spp.	Family	Ischnochitonidae
	Turbonilla spp.		*Chaetopleura apiculata*
	Acteonidae		
	Acteon spp.	Class	Scaphopoda
	Ringiculidae	Family	Dentaliidae
	Ringicula semistriata		*Cadulus* spp.
	Acteocinidae		*Dentalium americanum*
	Acteocina candei		*Dentalium* spp.
	Acteocina sp.		