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DISTRIBUTION, SEASONAL ABUNDANCE, AND ECOLOGY OF JUVENILE NORTHERN PINK SHRIMP, PENAEUS DUORARUM, IN THE FLORIDA BAY AREA

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
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ABSTRACT

The Florida Bay area of south Florida contains important nursery grounds used by juvenile northern pink shrimp, Penaeus duorarum, before their migration to the offshore Tortugas Grounds. Early juvenile shrimp were sampled in the bay area from 1965 to 1968; maximum concentrations of early juveniles were in the western bay; few occurred in the eastern bay. They occurred year-round and were most abundant from late summer to early winter, in seagrasses. Initial distribution of the early juveniles in the bay is effected by the flooding tide, which transports planktonic postlarval shrimp into the shallow nursery grounds where they settle as epibenthic postlarvae. The movement of postlarvae into the bay is apparently facilitated by the rise in sea level from about April to October. Variations in sea level control the areal extent of the shallow nursery grounds and may determine the abundance of early juveniles in the bay, and the subsequent commercial production of adult shrimp on the offshore Tortugas Grounds. The postlarvae probably actively select areas of shoal grass, Halodule wrightii, for initial benthic settling. The early juveniles are closely associated with shoal grass as the primary habitat and may depend upon this species for survival. Optimum habitat for early juveniles is characterized by 1) relatively open marine water circulation with daily tidal exchange, and 2) broad intertidal or subtidal beds of shoal grass with high blade densities. Shoal grass, often favored by environmental disturbances, may be a critical factor in recruitment success of pink shrimp.

INTRODUCTION

The northern pink shrimp, Penaeus duorarum,1/ of the Gulf of Mexico and Atlantic coast of the United States is the object of an important fishery on the Tortugas Grounds in the Gulf of Mexico off southwestern Florida (Figure 1). Migration studies of Tortugas pink shrimp show that juveniles of this stock spend several months in south Florida estuaries before movement to the offshore Tortugas Grounds (Costello and Allen 1966a). One extensive and important Tortugas shrimp nursery area is Florida Bay, located at the southern tip of the Florida Peninsula mostly within Everglades National Park. Environmental conditions in this estuary may control the abundance of shrimp on the Tortugas Grounds (National Marine Fisheries Service statistical zones 1,2, and 3). The Tortugas fishery produces about 4,142 t (tails) of pink shrimp annually; the ex-vessel value was about 22 million dollars in 1983.

1/ Penaeus duorarum is distinguished from the closely related southern pink shrimp, Penaeus notialis, of the Caribbean Sea and the Atlantic coasts of South America and West Africa (Perez Farfante 1978).

Planktonic pink shrimp postlarvae, the assumed progeny of Tortugas shrimp, enter the Florida Bay estuary from the Atlantic Ocean through channels breaching the Florida Keys (Allen et al. 1980). The postlarvae adopt a benthic mode of life in suitable shallow-water seagrass areas. Preliminary observations in Florida Bay indicated that, typically, the epibenthic early juvenile shrimp[2/] frequent shallower water than late juveniles and adults; the early juveniles and their habitats are more accessible for intensive study. From 1965 to 1968, primarily, the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) conducted research on the distribution, seasonal abundance and ecology of early juvenile pink shrimp that occupy the shoal waters of the Florida Bay area, before their movement to the deeper waters of the estuary and the offshore Tortugas Grounds. The results of these studies were partially reported by Costello and Allen (1965, 1966b, 1967, 1968, 1969, and 1970); Hudson et al. (1970); Allen and Hudson (1970); and Allen et al. (1980). In this paper we synthesize certain information contained in the above publications and provide additional data and analyses by which environmental conditions controlling distribution and abundance of early juvenile pink shrimp can be defined.

In Florida Bay, the chances for deleterious environmental modification have expanded with changes in freshwater runoff from the mainland, increased opportunities for pollution, particularly by oil and domestic sewage, and dredge-and-fill operations. Biological and ecological information collected in the mid-1960's can serve as a baseline against which contemporary and future fluctuations in the Florida Bay environment and pink shrimp abundance can be measured.

Perez Farfante (1969) and Costello and Allen (1970) summarized the considerable definitive research relating to pink shrimp that has been completed and published. The dependence of offshore shrimp production on environmental conditions in the estuarine habitat of the benthic juveniles has long been recognized, but information concerning pink shrimp during the early juvenile stage is sparse. Suitable shallow-water nursery grounds are necessary for the continued abundance of this species. The specific habitat needs to be identified and described.

The primary purposes of this study were to: 1) establish an index of abundance of early juvenile pink shrimp in the Florida Bay area; 2) describe the location and types of early juvenile habitat in the shallow-water nursery areas; 3) relate densities of shrimp to habitat types; and 4) develop a habitat quality index to evaluate each habitat type as a shrimp nursery unit.

ENVIRONMENTAL SETTING

Florida Bay (Figure 1), the principal study area, has been described by Ginsburg (1956); Tabb, Dubrow, and Manning (1962); Gorsline (1963); Craighead (1964); Scholl (1966); Price (1967); Hudson et al. (1970); Turney and Perkins

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2/ For the purposes of this paper, benthic shrimp < 46 mm total length (TL) are considered early juveniles. Total length is a straight line measurement from the tip of the rostrum to the tip of the telson.

(1972); Schmidt and Davis (1978); Schmidt (1979); and Enos and Perkins (1979). The bay is a vast, shallow, wedge-shaped lagoon located at the southern tip of the Florida Peninsula. The bay is bordered on the north by the Florida mainland, and on the east, southeast, and south by the curving chain of Florida Keys. The western portion of the bay opens into the Gulf of Mexico. If the western boundary of the bay is defined as a line running from east Cape Sable to Marathon (long. 81°05'W), then the area of the bay is 2,179 km^2 (841 mi^2) (Scholl, 1966).

Within the bay, carbonate mudbanks rise from the limestone floor. Many of the mudbanks are covered by < 60 cm of water and are exposed by low tide and wind effects. A network of mangrove keys and intersecting seagrass-covered mudbanks separates the Bay into semi-enclosed basins, or "lakes", 40 to 300 cm deep (Hudson et al. 1970). In the eastern part of the bay, the banks are narrow and form the peripheries of relatively large bodies of water. Proceeding to the west, these features gradually change, and in the western bay, the banks are extremely broad and surround relatively small basins. Many of the limestone basin floors, particularly in the eastern bay, are covered with only a few centimeters of sediment (Ginsburg 1956) and, therefore, seagrasses are sparse or lacking (Enos and Perkins 1979). In the western bay, however, some basin floors are covered with deep sediment, and luxuriant growths of seagrasses, primarily turtle grass, *Thalassia testudinum*, occur there. The shallowest basins are along the northern shore of the bay; maximum depths occur in basins adjacent to the Florida Keys and in the extreme western and southern bay. The basins are often joined by narrow, shallow channels through the seagrass-covered mudbanks and mangrove keys. A basin-mangrove key-mudbank complex is shown in Figure 2. The mangrove keys, associated with the banks, are scattered throughout the bay, but have a higher density (per unit area) in the eastern and central bay than in the western and southern bay.

Water circulation in the bay is restricted by the Florida Keys, seagrass-covered mudbanks, mangrove keys, and shallow depths, although there is exchange through narrow channels and over the mudbanks. Extensive penetration of tide water occurs only in the southern and western bay (McCallum and Stockman 1964). Here, salinity and temperature are similar to nearby oceanic water. The greatest salinity and temperature fluctuations occur along the northern border of the bay, in the mainland freshwater runoff zone. Annual and yearly fluctuations in salinity are produced by fluctuations in the amount of fresh water runoff from the mainland (McCallum and Stockman 1964). When hypersaline conditions occur in the eastern and central bay, they are primarily a reflection of reduced freshwater from the mainland, evaporation, and restricted water circulation. Based on Florida Bay subenvironments defined by Turney and Perkins (1972) from molluscan distribution, we have delineated the boundary between an Interior Zone characterized by restricted circulation, and a seaward Exterior Zone characterized by more open, marine circulation (Figure 1). We consider the boundary as only approximate, for use primarily to facilitate reference and discussion. The actual transition between open and restricted circulation is gradual and varies seasonally in response to wind direction and sea level.

In the Florida Bay area, sea level is lowest in the late winter and early spring and highest in the fall (Marmer 1954). Predicted tidal ranges in the bay area vary from < 15 cm in the eastern bay (Ginsburg 1956) to 52 cm on the east side of Big Pine Key (Kissling 1965) to 88 cm near Cape Sable (Scholl 1966). Wind speed and direction are important determinants of water level, particularly in the tide-restricted portions of the bay (Price 1967). Persistent strong winds lower water levels in up-wind areas and raise water levels in down-wind areas (Moore 1953).

For comparison, we extended our study area beyond Florida Bay, as defined, to the Florida Straits side of the adjacent Upper and Middle Keys and to the Lower Keys, southwest of Florida Bay. On the Florida Straits side of the Florida Keys, there is open water circulation (Ginsburg 1956). The Upper Keys are separated by only a few narrow channels; channels become more numerous and wider in the Middle Keys (Figure 1). Along the outer shoreline of the Upper and Middle Keys, substrates vary from exposed limestone bedrock to bedrock overlaid by a thin layer of carbonate sand or deep carbonate mud. Seagrasses are generally distributed along the keys in areas sheltered from excessive wave and current energy where sediment depths are adequate. The Lower Keys are separated by numerous tidal channels oriented in a northwest-southeast direction. North of most of the Lower Keys is an interior shelf lagoon that contains basins formed by seagrass-covered mudbanks and is separated from the Gulf of Mexico by an intertidal barrier belt (Jindrich 1969). Much of the land and water area in the Lower Keys rests on a foundation of eroded limestone rock. Particularly along shorelines, the rock is exposed or only thinly covered by sediment, restricting the growth of seagrasses. Water circulation in the Lower Keys is less restricted than in the Interior Zone of Florida Bay; salinities and temperatures are relatively stable due to marine influence from the Florida Straits and Gulf of Mexico.

PROCEDURE

Selection and Location of Sampling Stations

As noted by Eldred (1962), very small pink shrimp prefer protected, calm, shallow areas near shore where shoal grass, Halodule wrightii, occurs; larger juveniles are usually found in deeper water in turtle grass. Our sampling before December 1966 revealed that early juvenile pink shrimp occurred throughout most of the Florida Bay area, primarily in very shallow water bordering land, and that they rarely occurred on bottom that did not contain seagrasses or macroalgae. Late juveniles and adults generally frequent the deeper waters of the bay in basins and passes, based on sizes of shrimp caught by roller frame trawls and wing nets for use in mark-release studies (Costello and Allen 1966a; Allen and Costello 1966). However, the larger shrimp occasionally occur in shallow water, < 1 m in depth.

Our sampling of early juvenile shrimp was in three phases. Preliminary, semi-monthly sampling was conducted at several stations in the eastern, central, and southern portions of Florida Bay from April 1965 to November 1966 to determine early juvenile shrimp distribution, abundance, and zonation. These stations were located in shallow-water seagrass beds (turtle grass and shoal grass) on the peripheries of basins, either adjacent to mangrove keys or on mudbanks remote from keys. Stations were 12.5 x 12.5 m and were outlined by markers. The inner border of each station was established parallel to the shoreline or bank in about 10 cm of water. The depth of the outer border was controlled by the slope of the bottom and averaged about 60 cm. During the same time period, random sampling was conducted on bottoms devoid of vegetation.

Exploratory sampling was conducted from September 1 to November 10, 1966, by sampling once at each of 69 shallow-water stations, widely scattered throughout Florida Bay and the Upper, Middle, and Lower Keys (Figure 3). With two exceptions, all samples were from seagrass beds, primarily shoal grass and turtle grass. Stations were adjacent to the Florida Keys and to Florida Bay mangrove keys, on mudbanks, and in basins. The sites adjacent to keys and on banks were in depths from about 20 to 80 cm; those in basins were in depths from about 153 to 200 cm. The purpose of this quasi-synoptic survey was to determine the areal extent of early juvenile shrimp distribution and to select stations at which to sample shrimp monthly from January 1967 to January 1968.

During the period January 1967 to January 1968, extensive synoptic sampling (final) was conducted in Florida Bay and in the Middle and Lower Keys. We sampled at 22 stations, generally monthly, to establish indices of abundance of early juvenile shrimp, to determine spatial and seasonal distribution, and to relate shrimp abundance to various environmental conditions (Figure 4). Based on earlier observations, most sampling stations (18) were located in typical early juvenile shrimp habitat, i.e., in shallow water bordering land masses, which were generally mangrove keys (Figure 5), on bottoms containing growths of shoal grass, turtle grass, and manatee grass, Syringodium filiforme, or mixtures of these species. For comparative purposes, we also sampled at four atypical stations that were not near land but were on bottoms covered with seagrass. Two of these stations were on turtle grass-covered mudbanks which formed the rims of basins and two were in the centers of basins. Of the latter, one station was in a turtle grass bed and one in a shoal grass bed. Stations were spaced geographically throughout the large study area; the total number was determined by manpower and facilities available. Stations were 12 m x 12 m and were delineated by markers. For those stations bordering land, and those on mudbanks, the inner border of each station was established parallel to the shoreline or to the long axis of the mudbank in about 8-84 cm of water. Near land, the inner borders of the stations were positioned at the inshore edge of the seagrass beds. On seagrass-covered mudbanks, the inner borders were established at the shallowest portions of the banks. The depths of the outer borders, 12 m distant, were controlled by the slope of the bottom and ranged from about 31 to 99 cm in depth. There was no particular orientation of those stations in the centers of basins, which were about 122-184 cm deep.

Observations on Station Characteristics

Salinities were determined by station throughout the Florida Bay area from 1963 to 1969 (Appendix I). From April 1965 to November 1966, observations were made on seagrass species composition at several stations. From September 1 to November 10, 1966, we recorded topography, seagrass species, and blade density at 69 stations (Table 4). From January 1967 to January 1968 observations were made of the physical and biological characteristics of 22 stations (Tables 1 and 2) and were monthly with the exceptions noted. Depths were measured at the inner and outer borders of each station. Water samples for salinity, temperature, and turbidity were taken a few centimeters below the water surface, midway between the inner and outer borders. Turbidity was rated visually by comparing a vial of water collected at each station with a vial containing gin as a standard of clarity. Sediment samples were collected midway between the inner and outer borders in November 1967. Grain size was determined by wet-sieving through graduated sieves; material < 37 microns was divided into weight percent fractions by using established settling rates by grain sizes. Seagrass species composition, blade density, and blade length were determined by on-site inspection.

Shrimp Sampling Methodology

To accomplish our study objectives in the Florida Bay area, we required sampling equipment and methods to collect samples that could be quantified in terms of numbers of shrimp per unit area of bottom. Also, the equipment should operate with equal (or nearly equal) efficiency on various types of substrate. Conventional shrimp sampling equipment, such as a shrimp trawl, may be inadequate for quantitative sampling of juvenile pink shrimp. While there is evidence that pink shrimp < 55 mm TL are active in the daytime, the larger juveniles often remain buried in the substrate by day, and sometimes by night, and are thus unavailable to conventional sampling gear (Eldred et al. 1961; Perez Farfante 1969). The ideal sampling device is one that can remove all the shrimp, or a constant known percentage, from a unit area of substrate (Costello and Allen 1965).

After making observations of early juvenile pink shrimp habitats with respect to water depth, bottom types, and submerged vegetation, and conducting field tests, we selected two basic units of sampling equipment. For preliminary studies of shrimp distribution, abundance, and zonation at several stations from April 1965 to November 1966, we used the sled-mounted suction sampler, described by Allen and Hudson (1970). This vacuum device samples the epibenthos and infauna and is highly efficient at capturing most of the early juvenile pink shrimp, burrowed and unburrowed, over which it passes. The sled-mounted suction sampler, however, collects large quantities of sediment and seagrass with the shrimp and associated organisms, making sample sorting difficult and time-consuming. For sampling at a large number of stations from September 1966 to January 1968, we substituted the slednet (Figure 6). The slednet is a hand-towed frame trawl modified extensively from the marsh net described by Pullen et al. (1968). At the mouth of the "net" portion, we replaced the rigid bottom rods with a flexible leadline which tends the contour of the bottom closely and agitates burrowed shrimp to jump up or sideways. In addition, the metal frame of the "sled" portion was provided with screened overhead and side panels, effectively enclosing the disturbed, rapidly moving shrimp and guiding them into the trailing net and removable sample bag. There are several benefits in employing the slednet: 1) it is light, simple to operate, and requires minimum maintenance; 2) considerably more area of bottom can be covered in an equal time period, as compared with the suction sampler; and 3) the samples collected require less time to examine, since relatively little sediment is collected in the sample bag.

The daytime catch efficiencies of the sled-mounted suction sampler and the slednet were 80% and 48%, respectively, as compared to a standard that was assumed to be 100% efficient. The standard was a covered rectangular frame (inside dimensions 8.0 cm x 156.25 cm), which in shallow water could be forced quickly into the sediment to enclose all the shrimp within a 0.125 m^2 area. Then, the enclosed surface sediment, water, and shrimp were sucked into a sample bag by means of a suction dredge head (Allen and Hudson 1970) inserted through a hole in the sliding cover of the frame.

The slednet is primarily capable of capturing the epibenthos which includes those shrimp disturbed from the bottom by the leadline. Comparisons of the shrimp-catching efficiency of the slednet with the suction sampler show that the slednet is 60% as efficient as the suction sampler. Using this factor, we converted shrimp catch data obtained with the suction sampler to that obtained with the slednet to base all catch data on the same efficiency of effort.

Preliminary sampling with the sled-mounted suction sampler showed that early juvenile pink shrimp were usually abundant enough in water depths of $\leq$ 1 m to provide a density index (Allen and Hudson 1970). The density of early juveniles is often highest immediately adjacent to shore in depths < 20 cm (Costello and Allen 1966b). The early juveniles are concentrated near the low-tide mark in a zone parallel to the shoreline. The position of the narrow zone of concentration may vary in response to environmental factors; therefore, sampling gear is pulled perpendicular to shore to obtain the most representative measure of shrimp density (Allen and Hudson 1970).

We followed specific techniques when sampling in the daytime with the suction sampler and the slednet, which can be operated to sample discrete habitats of uniform area. Details of the sampling procedure for the suction sampler are given by Allen and Hudson (1970). Both sampling devices were drawn across the bottom at a standard speed (approximately 3.2 km/h) between and at right angles to the inner and outer borders of the stations. The suction sampler, which has an effective width of 8.0 cm, was pulled by a hand-operated winch a distance of 12.5 m to sample 1 m^2 of substrate. From April 1965 to November 1966, 2 m^2 areas were sampled every 2 wk by the suction sampler. The slednet, with an effective width of 0.5 m, was pulled by a 14-m towline a distance of 12 m to sample 6 m^2 of substrate. From September 1 to November 10, 1966, at each exploratory station, 6 m^2 was sampled once by slednet. From January 1967 to January 1968, most of the stations were sampled once each month by slednet. At each station, two 6 m^2 areas were sampled. The samples from the suction sampler and the slednet, contained in nylon mesh sample bags which were the removable cod ends of the sampling gear, were initially preserved in 10% formalin. Rose bengal was added to facilitate separation of shrimp from plant and substrate material.

In the laboratory, all _Penaeus_ shrimp were counted and measured and the information was recorded. The shrimp were stored in 10% formalin, which contained the additives hexamethylenetetramine as a buffer and white glycerine to prevent brittleness. The possible inclusion of closely related _Penaeus_ species in the samples was not considered to be a serious problem. _P. aztecus_ and _P. brasiliensis_ occur in the Florida Bay area at small sizes and are not easily distinguished from pink shrimp. However, pink shrimp is the dominant species (Allen et al. 1980) with _P. aztecus_ and _P. brasiliensis_ comprising less than 1%

of the catch (Saloman et al. 1968). The sizes of pink shrimp caught in our benthic samples ranged from 7.5 to 112 mm TL, and included postlarvae, juveniles, and adults (Eldred et al. 1961). However, about 80% were < 46 mm TL and were considered early juveniles. Our upper size limit for early juveniles is somewhat arbitrary but is related to behavioral and distributional changes associated with increased shrimp size. Although the majority caught were early juveniles, we refer to the entire size range in our samples as "pink shrimp" or "shrimp" except when a particular size group is being specified. Field tests showed that shrimp < 16 mm TL were capable of passing through the 3 mm mesh openings of the slednet, preventing a true measure of abundance of that size group. Therefore, for most analyses, we did not include shrimp < 16 mm TL.

In the following sections, the numbers of shrimp per unit area of bottom (m^2) represent the numbers caught by the slednet (or are adjusted to slednet efficiency) and are minimum density estimates. The true shrimp densities can be estimated using the efficiency factor we provide.

RESULTS AND DISCUSSION

General Distribution of Shrimp in the Florida Bay Area

Pink shrimp postlarvae entering Florida Bay at Whale Harbor Channel in the Upper Keys as plankton were most abundant from April to September; the planktonic postlarvae ranged from 5 to 10 mm TL in size (2 to 6 dorsal rostral spines) and the predominant size varied by season (Allen et al. 1980). The smallest shrimp caught at our shallow water stations in the Florida Bay area were 7.5 mm TL (3 dorsal rostral spines), indicating that postlarvae first become benthic at this size or a little larger. Based on studies of cultured pink shrimp by Tabb et al. (1972) and cultured *Penaeus* spp. by Yang (1975), the postlarvae become benthic at about 18 d after spawning; we estimate that newly-settled postlarvae of 10 mm TL (7 to 8 dorsal rostral spines) are about 21 d old. With growth, the young pink shrimp gradually move into deeper water (Iversen and Idyll 1960; Costello and Allen 1966a). A few late juvenile and adult shrimp from 66 to 112 mm TL were caught at our shallow water stations, but no specific attempt was made to sample this size range. From our random observations, and the catches of bait shrimpers, the larger shrimp generally occur in the deeper waters of the basins and passes throughout the bay. The monthly modes of pink shrimp caught in the 1951 bait fishery (frame trawl) in the bay were generally about 70-80 mm TL; few shrimp larger than 97 mm TL were taken, though recorded sizes ranged up to 120 mm TL in March (Iversen and Idyll 1960). Some shrimp remain in the bay until at least 170 mm TL, based on sizes of shrimp caught by a bait shrimper northwest of Bob Allen Key in March 1959 and measured by us. The shrimp spend from < 2 mo to at least 6 mo in the estuarine environment (Costello and Allen 1966a).

The late juveniles and adults move with the wind- and tide-driven currents through the natural drainages of the bay, often riding the surface waters at night (Mills [3/]). The inter-basin ridges that form the drainage divides are

3/ A.J. Mills, bait shrimper, Tavernier, FL 33070, pers. commun., March 1959.

oriented primarily in a north-south direction and extend from the mainland shore to the Florida Keys (Price 1967). The drainage divides serve to funnel the shrimp through the bay and toward the channels between the Florida Keys (Mills, see footnote 3). Shrimp pass through the keys channels into the Florida Straits on outgoing night tides, particularly in the late fall, winter and early spring in association with strong north or northwest winds (Higman 1952; Starck and Schroeder 1970). The occurrence of abundant late juvenile shrimp in the offing west of Sandy Key to Sprigger Bank during fall, winter, and spring (Still [4/]) indicates emigration in that direction also.

Spatial Distribution of Early Juvenile Shrimp

Preliminary sampling from April 1965 to November 1966 gave some indication of the spatial distribution of early juveniles in eastern, central, and southern Florida Bay. A comparison of abundances at three stations from June 1965 to June 1966 shows that shrimp were most abundant at Bob Allen Key (Station 5), in the central bay, where catches averaged 1.8 shrimp/m^2/mo. At Lignumvitae Key (southern bay), and near the entrance to Little Madeira Bay (eastern bay), catches averaged 0.8 and 0.2/m^2/mo, respectively.

The general order of spatial distribution and abundance of early juvenile pink shrimp in Florida Bay and in the Upper, Middle, and Lower Keys was determined from an exploratory survey conducted from September 1 to November 10, 1966 (Figure 3), when shrimp were expected to be seasonally abundant, based on our preliminary sampling begun in 1965. The shrimp, predominantly early juveniles, occurred at most of the sites sampled, but were in lowest densities in the eastern bay and Upper Keys, with densities increasing toward the west and southwest. Shrimp were relatively abundant in the southern bay and in the Middle Keys and eastern Lower Keys, but the highest densities were in the western bay. Sites in the Upper Keys and eastern bay yielded shrimp densities up to 1.2/m^2 of bottom; those in the southern bay, up to 8.2 shrimp; those in the Middle and Lower Keys, up to 10.0 shrimp; and those in the western bay, up to 21.8 shrimp. Where high shrimp densities occurred, they were usually at sites immediately adjacent to keys, where seagrass was dense. Shrimp densities were usually relatively low on banks remote from keys, in the centers of basins, or where seagrass was sparse.

Further confirmation of the distribution pattern observed previously was provided by samples of shrimp from the Florida Bay area from January 1967 to January 1968. Of 22 stations, 18 were sampled monthly from February 1967 to January 1968; the average monthly densities of shrimp/m^2 by station are shown in Figure 4. Similar to the results of the exploratory survey in the fall of 1966, sampling in 1967 and 1968 showed that densities of shrimp (predominantly early juveniles) were lowest in the eastern bay and increased towards the western and southern bay and Middle and Lower Keys. The highest densities were in the western bay. As observed during the 1966 exploratory survey, stations on banks or in the centers of basins (Stations 13, 14, and 16) usually had low densities of shrimp compared to stations situated directly adjacent to keys (Stations 11, 15, and 18). Percent abundance of shrimp at Station 15 in the western bay was 31% of the total yearly catch at 18 stations, followed by Station 11 in the

4/ Robert Still, bait shrimper, Islamorada, FL 33036, pers. commun., April 1981.

southern bay (24%), and Station 18 in the Middle Keys (17%) (Table 3). Therefore, the combined catch at Stations 15, 11, and 18 comprised 72% of the total catch. Shrimp were absent at Stations 2 and 3 in the eastern bay, and ranged from 0.2 to 4.8% of the total catch at the remaining 13 stations located throughout the bay and in the Lower Keys. Percent abundance of shrimp was high in all size categories at Stations 15, 11, and 18 (Table 3). Pink shrimp can reach 21 mm TL within about 2 wk after entering south Florida estuaries as planktonic postlarvae (Higman et. al. 1972). Furthermore, the peak abundances of planktonic postlarvae entering Florida Bay and benthic juveniles 16-25 mm TL relate closely in time (Allen et al. 1980). Therefore, the high percent abundance of shrimp 16-25 mm TL at Stations 15, 11, and 18 indicates that postlarval recruitment and/or survival is greater in the western and southern bay and Middle Keys than in other areas. No shrimp < 46 mm TL occurred at Stations 1,2, and 3 in the eastern bay. At these stations, shrimp of any size were few or absent.

Seasonal Abundance of Early Juvenile Shrimp

Shrimp were sampled at Bob Allen Key (Station 5) each month from April 1965 to January 1968. During this period, the numbers of shrimp/m^2/mo ranged from 0 to 3.0 (Figure 7). Shrimp were least abundant in the spring and early summer, increased in the mid- or late summer, and became most abundant in the fall and early winter.

Monthly sampling from February 1967 to January 1968 at 18 stations in the Florida Bay area showed a similar pattern of seasonal abundance on a 12-month basis (Figure 8). For all sizes caught (16-112 mm TL), shrimp were least abundant from March to July and most abundant from August to November. Abundance increased steadily from a seasonal low in May to a high in November. Based on the occurrence each month of shrimp 16-25 mm TL, recruitment of early juveniles was year-round, agreeing with the year-round entrance of planktonic postlarval shrimp into Florida Bay, reported by Allen et al. (1980). For shrimp 16-25 mm TL, abundance was lowest in April (0.5% of the annual catch) and highest in August (32.1% of the annual catch). The high abundance of 16-25 mm TL shrimp in August 1967 indicates a large influx of planktonic postlarvae into the Florida Bay area in July or August 1967. In fact, large influxes of postlarvae were documented in Buttonwood Canal in July 1967 (Roessler and Rehrer 1971), and at Whale Harbor Channel in the Upper Florida Keys in August 1967 (Allen et al. 1980). Furthermore, the numbers of early juveniles < 16 mm TL caught by us in August 1967 greatly exceeded those caught in any other month. Abundance of the 16-25 mm TL size group decreased in September but remained relatively high until December. Shrimp 26-45 mm TL were least abundant in May and most abundant from September to November, while shrimp 46-112 mm TL were least abundant in May and most abundant in October and November. The low abundance of shrimp 46-112 mm TL in May 1967 (1.2% of the annual catch) reflects 1) the movement of these larger shrimp into deeper water, and 2) the low influx of planktonic postlarvae in the winter and early spring, as shown by Allen et al. (1980) and further indicated by the low abundance of shrimp 16-25 mm TL from January to April 1967.

Seasonal abundances by size groups are shown for Stations 11,15, and 18, the three stations with highest shrimp densities on a 13-mo basis (Figures 9, 10, and 11). To simplify the following discussion, the size groups 16-25 and 26-45 mm TL are combined by station because growth, as estimated from increasing length, slows with increased size; the shrimp progress much more rapidly through the smaller size ranges than through the 46-112 mm TL range. At Station 11, shrimp 16-45 mm TL were abundant in February, declined sharply to a minimum in April and May, increased to a maximum in August, and remained abundant until December. Shrimp 46-112 mm TL occurred every month except January 1968; abundance of this size group was greatest in January 1967 but reached minimums in May, August, and December 1967 and January 1968. At Station 15, shrimp 16-45 mm TL declined to a minimum in April and May, after which there was a steady increase until a maximum was reached in November. Shrimp in this size category remained abundant until January 1968. Shrimp 46-112 mm TL occurred every month, with abundance greatest in January 1967 and least in May. At Station 18, shrimp 16-45 mm TL declined from moderate abundance in January and February 1967 to a minimum in May, and then increased to a peak in August, followed by moderate abundance until November. Shrimp 46-112 mm TL were absent in May and September, but reached moderate abundance in August and October. At the remaining stations, where shrimp densities were lower, similar seasonal abundance patterns were usually discernible, but were less distinct.

Evaluation of Early Juvenile Shrimp Habitat

Habitat for early juvenile pink shrimp in the Florida Bay area can be evaluated from our observations on environmental conditions associated with shrimp distribution and abundance.

Shrimp Distribution and Station Characteristics

Shrimp sampling stations were ranked with respect to shrimp densities for the periods September 1-November 10, 1966, and October 1967, when early juvenile shrimp were seasonally abundant. Shrimp densities could then be related to station location, water circulation, topography, and seagrass species and blade densities to determine optimum conditions (Tables 4 and 5).

Table 4 (1966, 69 stations) shows the following: 1) The highest ranking stations (ranked 1-10) supported shrimp densities ranging from 21.8 to 6.0/m^2. These stations were located in the western and southern bay and in the Middle Keys where water circulation was relatively open (Figure 3). High shrimp densities were associated with shoal grass that had high blade densities. The shoal grass was located adjacent to shorelines. 2) The second highest ranking stations (ranked 11-20) supported shrimp densities from 5.3 to 2.2/m^2. These stations were located in the western, southern, and central bay, and in the Middle and Lower Keys. Circulation was relatively open or marginally restricted. Shoal grass and turtle grass blade densities were high or medium with one exception; at the one site where seagrass blades were absent, the vegetative cover was macroalgae. The sampling sites were adjacent to shorelines or on mudbanks. 3) The lowest ranking stations (ranked 30) supported 0 shrimp/m^2. These stations were located in the western, southern, central, and eastern bay and in the Upper Keys and Barnes Sound. Circulation ranged from relatively open to restricted. Shoal grass blade densities were medium or low or blades were absent; turtle grass blade densities ranged from high to low or blades were absent. The sampling sites were adjacent to shorelines, on banks, or in basins.

Table 5 (1967, 22 stations) shows the following: (1) The highest ranking stations (ranked 1-4) supported shrimp densities ranging from 7.8 to 3.9/m^2. These stations were located in the western and southern bay and in the Middle Keys where circulation was relatively open (Figure 4). High shrimp densities were associated with shoal grass that had high blade densities. The shoal grass was located adjacent to shorelines or in a basin center. (2) The second highest ranking stations (ranked 5-10) supported shrimp densities from 1.7 to 0.5/m^2. These stations were located in the western, southern, and central bay and in the Lower Keys, Gulf of Mexico side. Circulation was relatively open to restricted. Shoal grass blade densities were low or blades were absent; turtle grass blade densities ranged from high to low. Sampling sites were adjacent to shorelines. (3) The lowest ranking stations (ranked 11-15) supported shrimp densities from 0.4 to 0/m^2. These stations were located in the western, central, and eastern bay and in the Lower Keys, Gulf of Mexico side. Circulation ranged from relatively open to restricted. Shoal grass blade densities were low; turtle grass blade densities ranged from high to low, and manatee grass blade densities were low. Sampling stations were adjacent to shorelines, on banks, or in basins.

Relationship of Shrimp Distribution to Abiotic and Biotic Factors

Both direct and circumstantial evidence is available to interpret the effects of environmental factors on shrimp distribution and abundance.

Hydrographic Features

Water circulation is an environmental factor of great importance in controlling the distribution and abundance of young penaeid shrimp in the estuarine nursery grounds (Kutkuhn 1966). Circulation in the Florida Bay area is determined by freshwater runoff from the mainland, tides, sea level, and wind (Ginsburg 1956; Gorsline 1963; McCallum and Stockman 1964; Price 1967). Oceanic water from the Florida Straits and Gulf of Mexico extends by tidal action into the Exterior Zone of Florida Bay, approaching the boundary of the Interior Zone (Figure 1); the location of the boundary varies with the factors that determine circulation (Ginsburg 1956). In the Interior Zone, north and east of the boundary, changes in water height and water circulation are strongly influenced seasonally by variations in freshwater runoff, evaporation, and wind, but only minimally by tides. In the bay, hydrographic regimes produced by varying degrees of circulation from open to restricted create an environmental gradient that supports distinctive populations of organisms (Hudson et al. 1970). Juvenile pink shrimp have an optimum band or zone along this gradient. The areal extent of favorable habitat can vary in response to fluctuations in hydrographic conditions (Browder and Moore 1981).

Currents are probably of major importance in controlling the distribution of planktonic pink shrimp postlarvae and, therefore, the distribution of early juveniles in the estuaries. The Florida Straits and Gulf of Mexico, adjacent to Florida Bay, are demonstrated sources of planktonic postlarval pink shrimp (Munro et al. 1968; Jones et al. 1970; Roessler and Rehrer 1971). The volume of influx of marine water from the Florida Straits and the Gulf of Mexico is of critical importance in transporting planktonic shrimp postlarvae from offshore to the Florida Keys and Florida Bay. The postlarvae are transported through the channels separating the Florida Keys by flooding tidal currents, at times aided by the wind, and facilitated seasonally by the annual rise in sea level (Allen et al. 1980). However, the channels through the Upper Florida Keys are extremely narrow and only capable of exchanging relatively small quantities of water between the Florida Straits and Florida Bay. Within the bay, mudbanks further restrict the flow of oceanic water and may limit the influx of postlarvae. Proceeding toward the southwest to the Middle Keys, and between the Middle and Lower Keys, the channels increase in size and provide for increased water exchange. For this section of the Florida Keys, and the adjacent southern and western Florida Bay, known as "The Sluiceway", currents from the Florida reef tract and Gulf of Mexico are adequate to transport large quantities of lime mud into the southern and western bay (Stockman et al. 1967). In addition, near the western margin of Florida Bay, we have observed strong tidal currents flowing north on the west side of Sandy Key, east in Joe Kemp Channel and Conchie Channel near Murray Key, and northeast in Man-of-War Channel. Furthermore, pink shrimp postlarvae are transported through Buttonwood Canal on a single flooding tide (Tabb, Dubrow and Jones 1962). These observations indicate that tidal currents are adequate to transport postlarvae into the margins of Florida Bay. Tidal current velocities decrease rapidly in the bay as depths lessen, and water movement in the interior basins is generally slow (Gorsline 1963). Therefore, most planktonic postlarvae probably do not penetrate the bay much beyond the boundary of the Interior Zone before settling to the bottom. Evidence of this postlarval distribution is shown in Figures 3 and 4 and Table 3, since the distribution of early juvenile shrimp is related to the distribution of recently settled postlarvae. The majority of early juvenile shrimp were found in the western and southern portions of the bay, in the Middle Keys, and to lesser extent, in the Lower Keys; relatively few occurred in the eastern bay, where there is little tidal influence.

In the Lower Keys, the flooding tide is from the Florida Straits on the south and from the Gulf of Mexico on the north (Jindrich 1969). Exchange of water through the Lower Keys is reduced by the land masses of the keys (Marszalek et al. 1977) and by the extensive shallows (Jindrich 1969). While currents in the interior shelf lagoon, a semi-enclosed depression to the north of the Lower Keys, are considered almost negligible by Jindrich 1969, the relatively stable salinities and temperatures (Table 2) suggest that circulation is less restricted there than in isolated sections of the Florida Bay Interior Zone. The effects of tidal current patterns in the Lower Keys on postlarval shrimp distribution are difficult to interpret. Although there is evidence that the postlarvae enter the Lower Keys shallows from the south (Florida Straits) side (Munro et al. 1968), it is possible that some postlarvae enter from the north (Gulf of Mexico) side (Jones et al. 1970). Early juvenile shrimp catches in the Lower Keys were higher than those in eastern Florida Bay, but relatively low when compared with catches in the western and southern bay and Middle Keys (Figures 3 and 4). Currents may be adequate to supply the Lower Keys with postlarvae; the limiting factor in respect to early juvenile shrimp abundance may be habitat quality. Close to shore, little or no sediment covers the rock floor, restricting the growth of shoal grass, which has been identified as a productive habitat for early juvenile pink shrimp.

Planktonic pink shrimp postlarvae are easily displaced by currents (Hughes 1969), although postlarvae of the genus Penaeus are capable of swimming (Cook and Lindner 1970). In south Florida waters, postlarval pink shrimp moving toward the estuaries respond to tidal currents, ascending into the flooding tide at night (Munro et al. 1968). The postlarvae are transported into the Florida Bay nursery area by the rapidly moving water of the flooding tide (Allen et al. 1980). On an ebbing tide, postlarval shrimp apparently descend to the bottom where they possibly cling to avoid displacement seaward (Jones et al. 1970). Several hypotheses have been advanced concerning the exact mechanism of current transport used by postlarval Penaeus (Hughes 1969; Staples 1980; Dall 1981) and the matter is unresolved.

The majority of planktonic postlarvae probably penetrate Florida Bay no further than the greatest incursion of the flooding tide, "settling out" as epibenthic postlarvae on suitable bottom habitat in the Exterior Zone. However, a few postlarvae may enter the Interior Zone by means of wind-driven currents. These currents, or wind tides, are capable of moving sediment (Price 1967) and, presumably, postlarval shrimp. Winds can force water across the bay (Ginsburg 1956); the resultant currents may account for the occurrence of limited numbers of early juveniles in the Interior Zone. Based on samples from April 1965 to January 1968, early juveniles < 16 mm TL were common in the Exterior Zone and a few shrimp of this size occurred several kilometers inside the boundary of the Interior Zone. Early juveniles, however, were rare or absent in the eastern bay, essentially a cul-de-sac, where keys and mudbanks severely restrict the influx of offshore water and associated planktonic postlarval shrimp. Only three Penaeus shrimp < 16 mm TL were found in the eastern bay. These shrimp were caught in the late fall and winter along the mainland shore, and due to their small size, were not identified to species, which may have been P. aztecus or P. brasiliensis rather than pink shrimp. We conclude that most pink shrimp > 15 mm TL occurring in the eastern bay initially settled in adjacent nursery grounds before migrating into the eastern bay.

For other areas of pink shrimp distribution, the extent of postlarval penetration of estuaries appears comparable to that in Florida Bay. In Whitewater Bay, immediately north of Florida Bay, a survey of juvenile pink shrimp indicated that initial settlement of postlarvae was in the western portion, near openings to the Gulf of Mexico (Idyll et al. 1970). In North Carolina estuaries, juvenile pink shrimp were most abundant at sites near inlets that are influenced by the marine environment (Weinstein 1979) and that have moderate tidal currents (Williams 1955).

Cyclic variations in sea level in South Florida were suggested by Allen et al. (1980) as being important to the distribution and abundance of early juvenile pink shrimp in the Florida Bay area. Sea level is low in the winter and early spring; the annual rise in sea level begins about April and reaches a maximum height by about October (Figure 12). The normal maximum annual range in the bay is suggested to be 53.5 cm (Ginsburg 1956). The prolonged rise in bay level apparently facilitates the transport of planktonic postlarval shrimp through the channels and across the mudbanks, allowing greater penetration of the bay between April and October. Sediments previously exposed to air are flooded, enlarging the shallow nursery areas. The limits of the intertidal zone change both annually and year-to-year as variations in sea level expand or contract the time and space in which coastal sediments are inundated (Provost 1973). In the Florida Bay area, the low beach slope angle common to mangrove shorelines allows a wide intertidal zone to be inundated and exposed in response to relatively small changes in water level. Since the newly settled epibenthic postlarval and early juvenile pink shrimp are primarily distributed in very shallow water, often in the intertidal zone, variations in sea level determine the extent of shrimp habitat. Therefore, variations in sea level, related to both astronomical and meteorological events, may influence the abundance of shrimp in Florida Bay and, subsequently, on the Tortugas Grounds.

Environmental factors linked to the intertidal zone, which is primarily located in the Exterior Zone, are considered important in determining the quantity and quality of early juvenile pink shrimp habitat. Water flow and changes in estuarine water level that occur on a regular basis enhance vegetative growth (Odum 1981). Furthermore, the extremely shallow water, close to shore, provides a refuge for early juvenile shrimp in that the shallow depth excludes certain shrimp predators (Kurata 1981), as does the stress of alternate drying and flooding. Shoal grass, which serves as habitat for early juvenile shrimp, is tolerant of the stress of the intertidal zone. An important determinant of shoal grass distribution and abundance in the intertidal zone is sea level (Strawn 1961). Shoal grass beds increase shoreward when sea level is high and provide increased areas of prime shallow water habitat in which postlarval shrimp can settle and develop. Early juvenile shrimp were most abundant in the second half of the year (Figures 7, 8, 9, 10, and 11), when maximum flooding occurs (Figure 12). In 1967, 81% of the annual total of early juveniles (16-25 mm TL) were caught from August to December (Figure 8). However, the relative importance of the individual variables related to sea level (i.e., water depth, shallow water area, alternate drying and flooding, and shoal grass) to early juvenile pink shrimp production has not been established; these factors may be at least partly interdependent.

Young pink shrimp have broad physiological tolerances for salinity and temperature (Perez Farfante 1969; Costello and Allen 1970). In south Florida, juveniles occur in salinities ranging from about 0 to 65 o/oo (Tabb et al. 1972), with greatest abundance from 30 to 50 o/oo (Tabb, D.C., cited in Costello and Allen 1970). Juveniles can tolerate water temperatures between 11° and 40°C, but temperatures below 18°C restrict pink shrimp feeding activity and shrimp are rare at temperatures approaching 36°C (Tabb et al. 1972). Preferably, salinity-temperature synergy should be considered when evaluating the effects of either factor on pink shrimp (Costello and Allen 1970). However, optimum osmoregulatory ranges for juvenile pink shrimp of specific sizes under controlled conditions of salinity and temperature have not been established, to our knowledge. In Florida Bay, from 1966 to 1968, during the seasons of highest abundance of early juveniles, salinities ranged from about 33 to 41 o/oo and water temperatures from about 22 to 32°C at the most productive stations. In interpretation of early juvenile pink shrimp distribution in Florida Bay, we assume that maximum recruitment and survival, not necessarily optimum osmoregulation, occurred within these ranges.

In Florida Bay, salinities and temperatures diverge widely from those associated with the maximum abundance of juvenile pink shrimp as reported above. From 1936 to 1976, salinities from about 0 to 70^{o}/oo and temperatures from about 12 to 40°C were recorded (Schmidt and Davis 1978). Based on our data from 1963 to 1969 (Appendix I) and data from 1973 to 1976 (Schmidt 1979), salinities in the eastern bay were highly variable, ranging from about 2 to 67^{o}/oo. Such salinity extremes may affect shrimp osmoregulation and have a direct effect on shrimp abundance. As compared with the eastern bay, salinities in the Lower Keys and western and southern bay, buffered by oceanic water from the Florida Straits and Gulf of Mexico, were relatively stable and ranged from about 32 to 45^{o}/oo, within the salinity range in which juvenile pink shrimp have been reported abundant. An exception to the lower limit of 32^{o}/oo occurs in the western bay close to the mainland shore, where salinities are sometimes reduced by freshwater runoff (Turney and Perkins 1972).

Salinity and water temperature ranges and means at our stations in the Florida Bay area from February 1967 to January 1968 are shown in Table 2. At these shallow-water stations, there were rapid changes in water temperature during a 24 h cycle, related primarily to air temperature variations. We were not equipped to collect constant or synoptic water temperature data; the temperatures are indicative only of gross differences between seasons and stations. For the 18 stations sampled monthly, salinities ranged from about 26 to 45^{o}/oo and temperatures from about 16 to 34°C. These salinity and temperature extremes are within the tolerance limits of juvenile pink shrimp, but extend beyond the ranges within which pink shrimp were reported most abundant.

Observations on salinities and juvenile pink shrimp abundance by geographic area and estuarine habitat suggest that within a broad salinity range, factors other than salinity per se control abundance of the euryhaline early juvenile pink shrimp. In the Florida Bay area, densities of early juveniles were highest at salinities from 33 to 41^{o}/oo. Yet, in a North Carolina estuary, juvenile pink shrimp were most abundant at salinities from 25 to 30^{o}/oo (Weinstein et al. 1980). In the Florida Bay area, salinities from 33 to 41^{o}/oo did not ensure high shrimp abundance in the absence of other suitable environmental factors. High densities of early juveniles occurred only in the western and southern bay and in the Middle Keys, almost exclusively in shoal grass beds (Tables 4 and 5). Within the same salinity range, high densities of juveniles did not occur elsewhere in the Florida Bay area where shoal grass was sparse or non-existent. Progressively lower shrimp densities occurred in turtle grass beds at shoreline sites in the Lower Keys, on banks or in basins in the western and southern bay, and at shoreline sites in the central and eastern bay. Other researchers have reached conclusions similar to ours concerning juvenile *Penaeus* and salinity. Hoese (1960) observed that salinity is not very important to juvenile pink shrimp if other environmental factors are ideal; and Dall (1981), from his studies of osmoregulation of early juvenile *Penaeus* spp., concluded that nursery ground selection is unlikely to be related to a salinity optimum determined by osmoregulatory ability.

Within relatively small areas of the bay, such as a basin complex (Figure 2), there can be large variations in early juvenile pink shrimp densities between different topographic sites such as shoreline, basin center, and bank (Tables 4 and 5). These variations suggest that shrimp distribution may be directly related to water depth or proximity to shore. However, seagrass species distribution is also related to depth and proximity to shore, which obscures an understanding of the relationship of shrimp distribution to topography per se. This subject will be discussed under Seagrasses.

Seagrasses

A direct relationship has been demonstrated between average annual yields of penaeid shrimp caught inshore, and the areal extent of estuarine vascular vegetation, which includes seagrasses, in the northeast Gulf of Mexico (Turner 1977). The dependence of juvenile pink shrimp on seagrasses is fairly well established (Costello and Allen 1970; Hudson et al. 1970); the decline of seagrasses is seen as a threat to the production of penaeid shrimp (Saloman 1965; Kirkman 1978). The role of seagrasses in providing habitat and food resources for organisms including pink shrimp was described by Thayer et al. (1979) and Zieman (1982).

Seagrasses provide necessary habitat for juvenile pink shrimp. In our extensive sampling for early juvenile pink shrimp in shallow waters of south Florida, few were caught on bottoms devoid of vegetation. Early juveniles usually occurred in seagrass beds where the vertical seagrass stems and blades form a 3-dimensional habitat, as opposed to the essentially 2-dimensional habitat of non-vegetated level bottom. Juvenile pink shrimp move from the sediment up onto the seagrass blades at night (Gore et al. 1981); the seagrass provides more living space for each shrimp. Therefore, as seagrass blade density increases, the amount of habitat per unit area of bottom increases, with expected increases in the density of associated shrimp.

In seagrass, early juvenile pink shrimp often are concentrated in very shallow water adjacent to shore, near the low-tide mark in a band parallel to the shoreline (Allen and Hudson 1970). Near shore, in intertidal areas of shoal grass, we caught pink shrimp among the grass blades while the blades were completely exposed at low tide. When intertidal shoal grass beds were covered by water (depth range 20-26 cm), no particular zonation of shrimp (12-50 mm TL) was observed. However, in intertidal and subtidal areas where shoal grass graded into turtle grass as the water deepened, the density of shrimp (12-40 mm TL) was highest ($13/m^2$) in the most shallow (shoreward) portion of the seagrass bed (depth range 15-20 cm). Shrimp density gradually decreased out to the deepest portion of the bed sampled (36 cm) where density was $0/m^2$. Similar observations were made by Kohout and Kolipinski (1967) who found juvenile pink shrimp to be most abundant near shore, in shoal grass. Proceeding seaward, as depth increased, shrimp numbers gradually declined as shoal grass first became mixed with and then replaced by turtle grass.

The relationship of juvenile pink shrimp with specific seagrasses has not been adequately defined, although Eldred (1962) reported that very small pink shrimp were associated with shoal grass and the larger juveniles with turtle grass. Costello and Allen (1969) observed that the newly-settled postlarval pink shrimp have an apparent preference for substrate vegetated by shoal grass. The highest density of early juvenile pink shrimp that we have observed (21.8/m^2) was in shoal grass (Table 4). According to Tabb et al. (1974), shoal grass beds are the preferred habitat for juvenile pink shrimp, and Yokel (1975) found that early juvenile pink shrimp were generally restricted to stations located in shoal grass.

Exploratory sampling in the Florida Bay area during a restricted time period (September 1 to November 10, 1966), and monthly sampling at established stations from January 1967 to January 1968, showed that early juvenile pink shrimp were much more abundant in shoal grass beds than in turtle grass beds (Tables 4 and 5). The only exceptions were when living shoal grass blades were sparse or had disappeared. In seagrass beds comprised predominately of turtle grass, early juveniles usually were more abundant near mangrove shorelines, decreasing away from shore in basin centers or on banks (Tables 4 and 5). In turtle grass beds at Stations 12 and 20 (shoreline), about 84-90% of the captured shrimp were 16-45 mm TL; while at Station 14 (basin center) and Station 16 (bank), only about 60-61% were 16-45 mm TL (Table 6). In shoal grass beds, the densities of early juveniles were high compared to densities in turtle grass. At Stations 11, 15, 18 (shoreline), about 74-82% of the captured shrimp were 16-45 mm TL (Table 6). Our limited observations in subtidal shoal grass beds indicate that early juveniles were as abundant in basin centers as near shore (Table 5). Shrimp 16-50 mm TL occurred in basin center shoal grass beds, but detailed size composition data were not obtained (Appendix II, Station 22).

In Florida Bay, most of our observations relating high densities of early juveniles to shoal grass were where the intertidal zone was relatively wide and shoal grass flourished out to at least 10 m from shore before being replaced by turtle grass. In the Exterior Zone, subjected to daily tides, a relatively wide intertidal zone enhances the development of shoal grass rather than turtle grass as the dominant seagrass adjacent to shore. In the Interior Zone the daily tide is greatly restricted. Here, a narrow intertidal zone often assures the dominance of subtidal turtle grass close to shore, although sparse shoal grass may exist as a narrow fringe between the turtle grass and shore. In the Exterior Zone, high densities of early juveniles also occurred in patches of subtidal shoal grass that were remote from shore and surrounded by turtle grass. The close relationship of early juvenile pink shrimp and shoal grass persisted whether the shoal grass was intertidal and adjacent to shore, or subtidal and several hundred meters from shore. The occurrence of abundant early juveniles in subtidal shoal grass was observed only in the Exterior Zone, where early juveniles were generally more abundant than in the Interior Zone, irrespective of seagrass species and topographic site.

To examine the relationship of pink shrimp to seagrass species apart from the geographic location and topography of the sample sites, we sampled shrimp at several shoreline sites where shrimp densities in beds of shoal grass and adjacent turtle grass could be compared. Based on 17 paired samples, shrimp were always more abundant in shoal grass, where the mean shrimp catch was 3.0/m^2, as compared with 0.6/m^2 shrimp in turtle grass (Table 7). The densities of shrimp in adjacent shoal grass and turtle grass beds varied with shrimp size; a higher proportion of the smaller shrimp were associated with shoal grass. Based on 13 paired samples collected monthly from January 1967 to January 1968 at adjacent Stations 11 and 12, 90.7% of the smallest shrimp (16-25 mm TL) were associated with shoal grass and 9.3% with turtle grass. For shrimp 26-45 mm TL, 85.8% were with shoal grass and 14.2% with turtle grass; and for shrimp 46-95 mm TL, 82.1% were with shoal grass and 17.9% with turtle grass, indicating that as shrimp size increases, there is successive movement from shoal grass to turtle grass (Table 8).

There were seasonal differences in the relationship of early juvenile shrimp to seagrass species. Successive waves of planktonic postlarvae ensured that early juveniles occupied shoal grass, the initial and primary nursery habitat, continuously throughout the year (Figures 9, 10, and 11). At Station 11 (shoal grass), shrimp 16-45 mm TL occurred every month from January 1967 to January 1968. However, at the adjacent Station 12 (turtle grass), shrimp 16-45 mm TL were absent from February to May 1967, in July 1967, and in January 1968 (Appendix II). These seasonal differences suggest that shoal grass is "preferred" by the early juveniles, and that, where shoal grass is available, turtle grass is used as habitat only at times of their highest seasonal abundance. Based on the size composition of shrimp (Figures 9, 10, and 11), and estimated growth from the initial size of 10 mm TL at settling to 35 mm TL in 4 wk (Higman et al. 1972), early juveniles were temporary residents of shoal grass, residing there < 2 mo before moving on, apparently to deeper water and/or turtle grass. Despite the relatively brief residence time of individuals, the continuous utilization of shoal grass by early juveniles is critical to the annual production of late juveniles.

Both intertidal and subtidal shoal grass beds are highly conducive to the settling of postlarvae and/or the survival of early juveniles. In Florida Bay along the shorelines, shoal grass is usually situated closer to shore than turtle grass, occurring in the intertidal and upper sub-tidal zones. The high densities of early juvenile pink shrimp associated with shoal grass located adjacent to shore might imply only that shrimp are less subject to predation at these shallow depths, or that shrimp and shoal grass are dependent upon the same ecological factors, inherent to the intertidal and upper subtidal zones, and perhaps related to the ecotone or habitat edge between water and land. The edge is highly productive and often supports large numbers of organisms (Odum 1976). However, proximity to shore may not be entirely the reason for high shrimp densities in shoal grass. Synoptic samples of shrimp collected in the western and southern bay and in the Middle Keys in October 1967, when shrimp were seasonally abundant (Figure 8), showed that Station 22, a completely subtidal shoal grass bed (depth 127 cm) in the center of a basin remote from shore, supported shrimp densities in about the same general order of magnitude (6.3 shrimp/m^2) as shoreline intertidal shoal grass beds, Station 11, 15, and 18 (3.9, 7.8, and 4.1 shrimp/m^2, respectively) (Table 9). Conversely, turtle grass beds at Station 12 (shoreline, adjacent to Station 11) and Station 14 (basin center, close to Station 15 and in a setting similar to Station 22, except for the seagrass species) produced only a few shrimp (0.5 and 0.4 shrimp/m^2, respectively). The occurrence of high densities of early juvenile pink shrimp in subtidal shoal grass beds has also been reported from other locations off the southwest coast of Florida. In Rookery Bay, early juveniles were abundant in subtidal seagrass beds comprised primarily of shoal grass (Yokel 1975). In Estero Bay, early juveniles were found to be much more abundant in subtidal shoal grass beds than in turtle grass beds.(Berkeley5/).

For Florida Bay area stations where shoal grass was the dominant seagrass, there was a positive relationship between blade densities and shrimp densities (Tables 4 and 5). At stations where shoal grass blades were dense, shrimp were abundant; where blades were absent or sparse, shrimp were absent or few in number. For example, at Murray Key (Station 17) in October 1966, shoal grass blades were dense and shrimp were exceptionally abundant (Figure 3, western bay, 20.5 shrimp/m^2). Coincident with the disappearance of most of the shoal grass blades at this station by January 1967, and all blades in subsequent months, shrimp disappeared and were absent or very few in number until the termination of sampling in January 1968 (Appendix II). At nearby Johnson Key (Station 15), shrimp associated with dense shoal grass were also exceptionally abundant in October 1966 (Figure 3, western bay, 21.8 shrimp/m^2). At this station, shoal grass blades did not disappear and shrimp remained relatively abundant throughout the sampling period (Appendix II). Heck and Orth (1980) reported that 1) a threshold density of seagrass is required to reduce the effectiveness of fish predation on seagrass-associated invertebrates, 2) increased seagrass density further reduces predator effectiveness, but 3) extremely dense seagrass may produce conditions unfavorable for the seagrass invertebrates. In our field work in south Florida, we did not recognize situations where shoal grass was dense enough to be unfavorable to early juvenile pink shrimp.

Based on our observations, the highest densities of early juvenile pink shrimp are associated with shoal grass rather than turtle grass, but the reasons for this relationship are uncertain. The possibilities include one or more of the following mechanisms.

1. Planktonic postlarval shrimp are transported by currents primarily to areas of shoal grass rather than turtle grass (hydrodynamic sorting).

2. Postlarval shrimp actively select shoal grass rather than turtle grass as a habitat for settling.

3. Early juvenile shrimp survive better in shoal grass habitat than in turtle grass, perhaps due to superior shelter and/or food resources provided by shoal grass.

4. Early juvenile shrimp and shoal grass are both dependent for survival upon local hydrographic and edaphic factors common to intertidal shorelines sites and subtidal sites remote from shore.

5/ Steven Berkeley, South Atlantic Fishery Management Council, Charleston, SC 29407, pers. commun., September 1981.

While no conclusive interpretation of the early juvenile pink shrimp/shoal grass relationship is provided by our data, the following observations provide partial understanding in respect to the suggested mechanisms.

1. We have no evidence that planktonic postlarval pink shrimp, at the time of settling, are distributed to areas of shoal grass rather than turtle grass by current sorting.

2. We strongly suspect that postlarval pink shrimp actively select shoal grass habitat for initial settling, based on a) the association of early juveniles with areas of shoreline and basin-center shoal grass, b) the continuous occurrence and higher densities of recently-settled early juveniles in areas of shoal grass rather than turtle grass, and c) the apparent movement of early juveniles from shoal grass to turtle grass as shrimp size increases. Many invertebrates are able to select substrates for settlement. Dall (1981) concluded that Australian *Penaeus* spp. postlarvae probably "select" marine plant types as habitat, and Zimmerman et al. (1984) concluded that juvenile *P. aztecus* may select for smooth cordgrass, *Spartina alterniflora*, habitat.

3. Seagrass beds provide food resources and shelter for pink shrimp (Thayer et al. 1979). However, in seagrass meadows, food probably is not a limiting resource for the inhabitants due to its apparent high abundance (Heck and Orth 1980). Considering the maximum density of early juvenile pink shrimp that we have observed ($21.8/m^2$, estimated to be $45/m^2$ at 100% sampling efficiency), food is not likely to be an important factor favoring higher densities of shrimp in shoal grass beds than in turtle grass beds. Dense blades of seagrass provide shelter from water currents (Hooks et al. 1976; and more protection from predators than sparse seagrass (Heck and Orth 1980). Minello and Zimmerman (1983) found that fish predation on juvenile *P. aztecus* was reduced by artificial vegetation. According to Heck and Orth (1980), cover from predators is probably the most important factor influencing the survival of seagrass animals. The habitat complexity of the sheltering seagrass controls predator effectiveness (Nelson 1979; Stoner 1980; Heck and Orth 1980). These authors related habitat complexity to grass blade surface area per biomass (unit weight) of blades, and to blade or shoot density per unit area of bottom. Increased habitat complexity can decrease predation on, and intraspecific competition among, macrocrustaceans including pink shrimp (Gore et al. 1981). For shoal grass and turtle grass, there are differences in blade surface area per unit weight of blades and in blade densities per unit area of bottom that lead to variations in structural complexity. Shoal grass blades are narrow and thin as compared with the broad, robust turtle grass blades. Therefore, shoal grass blades have a higher ratio of surface area per unit weight of blades than turtle grass blades (Stoner 1980). Shoal grass blades typically are more closely spaced on the bottom then turtle grass blades. In dense stands, the number of blades of shoal grass is about $38{,}750/m^2$

(Simmons 1957), and of turtle grass, 6,000/m^2 (Thorhaug 1976), or a ratio of about 6.5:1. Based on differences in blade densities, shoal grass might be expected to provide a better refuge for early juvenile pink shrimp than turtle grass. However, there is some evidence that this may not be so in respect to shelter from predation. In laboratory experiments, Stoner (1982) found that shoal grass provided less protection to amphipods than turtle grass from predation by juvenile pinfish, Lagodon rhomboides. This was despite the fact that earlier experiments (Stoner 1980) showed amphipods to select shoal grass over turtle grass and manatee grass as habitat. Stoner (1980) attributed this selection to habitat complexity, related to the high blade density and high ratio of blade surface area to unit weight of shoal grass blades as compared with turtle grass and manatee grass. As applied to the pink shrimp/shoal grass relationship, the paradox provided by Stoner (1982) may have several explanations, including the following: a) early juvenile pink shrimp may be more effective than amphipods at concealing themselves in shoal grass habitat as compared to turtle grass habitat; and b) shoal grass may provide less effective shelter than turtle grass for small predators that prey on early juvenile pink shrimp, so that in shoal grass, the small predators are removed by larger predators, allowing higher survival of shrimp.

4. Concerning the possible dependence of early juvenile pink shrimp and shoal grass on common environmental factors, shoal grass does serve as an indicator of early juvenile shrimp. The occurrence of shoal grass (either intertidal or subtidal) is indicative of recent or continuous environmental perturbation. Shoal grass is a pioneer that stabilizes denuded sediments, but only persists in a monospecific bed under conditions unfavorable to turtle grass succession (den Hartog 1967; Zieman 1982). At our stations, shrimp abundance varied with the stage of the successional gradient as indicated by bare sediment, shoal grass, and turtle grass. For example, a comparison of shrimp/m^2 at seven stations on the same day in October 1967 (Table 5) shows the following: Station 17, bare sediment, shoal grass blades absent, 0.8 shrimp; Station 11, dense shoal grass, 3.9 shrimp; Station 15, dense shoal grass, 7.8 shrimp; Station 22, dense shoal grass, 6.3 shrimp; Station 12, dense turtle grass, 0.5 shrimp; Station 14, dense turtle grass, 0.4 shrimp; and Station 16, dense turtle grass, 0.3 shrimp. All stations were located in the Exterior Zone where the degree of water circulation was relatively open; the high shrimp densities at Stations 11, 15, and 22 indicate that there was ample opportunity for recruitment of postlarvae to the nearby Stations 12, 14, 16, and 17. Yet, the latter four stations had low shrimp densities. These observations suggest that early juvenile shrimp can achieve relatively high densities in shoal grass habitat (Stations 11, 15, and 22), but are less abundant on bare sediment (Station 17), or in turtle grass habitat (Stations 12, 14, and 16). Our observation that, in turtle grass, early juvenile pink shrimp abundance generally declines with increased distance from shore may be explained by the increased environmental stability in turtle grass

beds with distance from shore as noted by Jackson (1972). From the above discussion it may be inferred that early juvenile pink shrimp are relatively tolerant of environments that have been physically disturbed, as indicated by their close association with shoal grass. Conversely, early juveniles possibly are less tolerant of the biological disturbance (predation and/or competition) that may be more intense in the more stable environments supporting turtle grass.

Identification of Optimum Shrimp Habitat

The optimum habitat for pink shrimp varies with shrimp size. In the Florida Bay area, the highest densities of early juvenile pink shrimp were located in the Exterior Zone, relatively close to the open Gulf of Mexico and Florida Straits. The high densities were primarily in the western and southern bay and Middle Keys. Proceeding into the Interior Zone the decline in shrimp densities was gradual, with shrimp numbers per unit substrate inversely proportional to distance inside the boundary in the central and eastern bay. The decreasing gradient of early juvenile shrimp abundance coincides with the decreasing gradient of marine circulation and increasing distance from the Tortugas spawning grounds (Figures 1, 3, and 4).

As compared with the Interior Zone, the Exterior Zone is characterized by the following environmental conditions:

1. increased circulation of marine water;
2. daily tidal exchange and associated flushing;
3. wider intertidal zone;
4. salinity ranges narrower and closer to that of oceanic water;
5. water temperature ranges generally narrower and having a higher minimum;
6. increased beds of shoal grass that have denser and longer blades; and
7. increased beds of turtle grass that have denser and longer blades.

The above conditions are related to marine influence, with some reflecting the buffering effect of marine water against the environmental extremes of the Interior Zone. The importance of marine influence in determining the differential distribution of early juveniles of several Australian *Penaeus* species was stressed by Young (1978) and Young and Wadley (1979).

Salinity and temperature per se were not considered to be factors directly limiting the distribution of early juvenile pink shrimp in the Florida Bay area during the study period. As noted previously, young pink shrimp have broad physiological tolerances for salinity and temperature. The salinities and temperatures encountered in the Florida Bay area from 1966 to 1968 were well within the tolerances of early juveniles and do not appear to have had a direct influence on their distribution. However, hydrographic regimes, related to water circulation patterns, differ between the Exterior and Interior Zones. As noted by Hudson et al. (1970), these different water masses with dissimilar ecological effects support distinctive populations of organisms. Hydrographic regimes, by controlling the general distribution of organisms in Florida Bay, control shrimp habitat, food resources, competitors, and predators and, therefore, the distribution of early juvenile pink shrimp.

Within wide salinity and temperature ranges, habitat for early juvenile pink shrimp can be evaluated from observations on marine water circulation, seagrass species and blade biomass, and topography. The optimum habitat is characterized by 1) relatively open marine circulation with daily tidal exchange, and 2) broad intertidal or subtidal beds of shoal grass with high blade densities.

SUMMARY AND CONCLUSIONS

1. In the Florida Bay area, maximum concentrations of early juvenile pink shrimp were in the western bay. Early juveniles were relatively abundant in the southern bay and in the Middle and Lower Keys; very few were found in the eastern bay.

2. Early juveniles occurred year-round and were least abundant in the spring and early summer, becoming most abundant in the late summer, fall, and early winter.

3. The initial, general distribution of early juveniles is governed primarily by marine water circulation, specifically the degree of penetration of the flooding tide. Tidal currents transport planktonic postlarval shrimp from the Florida Straits and Gulf of Mexico into the shallow nursery grounds of the Florida Bay area, where they settle as epibenthic postlarvae, primarily in the Exterior Zone.

4. There is no evidence that salinities and water temperatures encountered during the study period had a direct (physiological) effect on early juvenile distribution and abundance.

5. Early juveniles were most abundant in seagrass beds, particularly in shoal grass where blade densities were high. Although early juveniles occurred in turtle grass beds, shoal grass was the primary habitat whether located near mangrove shorelines (intertidal) or remote from shore in basin centers (subtidal). In turtle grass, the abundance of early juveniles usually decreased away from shore in basin centers or on banks. The high biomass of turtle grass in the bay area, therefore, does not necessarily ensure adequate habitat for early juveniles.

6. Early juveniles occupied shoal grass, the initial and primary habitat, continuously throughout the year, though most of the individual early juveniles were temporary residents for < 2 mo. The repeated utilization of shoal grass by early juveniles is apparently critical to the annual abundance of late juveniles.

7. It is probable that postlarval pink shrimp actively select shoal grass habitat in preference to turtle grass habitat for initial settling. The survival of early juveniles may be enhanced by the increased habitat complexity of shoal grass as compared to turtle grass.

8. There are strong indications that early juveniles are relatively tolerant of physical disturbances to the environment, as indicated by their close association with shoal grass. Early juveniles apparently are less tolerant of biological disturbances (competition and/or predation) associated with the more stable environment represented by turtle grass.

9. In the Florida Bay area, optimum habitat for early juveniles is located in the Exterior Zone, relatively close to the open Gulf of Mexico and Florida Straits. Optimum habitat is characterized by a) relatively open marine water circulation with daily tidal exchange, and b) broad intertidal or subtidal beds of shoal grass with high blade densities. Optimum habitat is most abundant in the western bay where the tidal range is greatest, producing the widest intertidal zone.

10. Annual and year-to-year variations in sea level may be important to the production of adult pink shrimp. The annual rise in sea level from about April to October apparently facilitates the movement of planktonic postlarval shrimp into the bay and enlarges the shallow nursery areas. Early juveniles are most abundant in the second half of the year, when maximum flooding occurs. Sea level is an important determinant of critical nursery habitat, including the spatial and temporal distribution of shoal grass. Therefore, sea level variations may determine the abundance of juveniles in the bay area and the subsequent abundance of adults on the offshore Tortugas Grounds. We suggest that historical records of sea level may provide a useful index of early juvenile habitat for comparison with yearly records of Tortugas Grounds pink shrimp production.

11. Under certain conditions, environmental disturbances may encourage the development of shoal grass, providing necessary habitat for early juvenile pink shrimp. Shoal grass is indicative of recent or continuous environmental perturbation, occurring under conditions unfavorable to turtle grass development. These perturbations may be the result of natural events or human activities. In south Florida, we observed that early juveniles often are associated with shoal grass in shallow-water spoil areas produced by dredge-and-fill operations. The colonization of spoil banks and other denuded areas by shoal grass may explain the persistence of pink shrimp in areas of habitat alteration. It is not inferred here that massive disturbances always enhance the development of shoal grass. For example, substrate suitable for shoal grass development must be at the correct elevation and consist of compatible sediment (Carangelo et al. 1979). However, in areas where shoal grass is relatively scarce as related to turtle grass, frequent, small perturbations may encourage the development of shoal grass and provide primary habitat for early juvenile pink shrimp.

12. In our studies, subtidal shoal grass beds were not sampled adequately to conclusively establish their relative importance as habitat for early juveniles. We recommend that future studies be designed to compare densities of early juveniles in subtidal shoal grass beds with shrimp densities in adjacent subtidal turtle grass beds and in nearby intertidal shoal grass beds.

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Table 1. — *Penaeus duorarum* sampling stations and characteristics, Florida Bay area, January 1967-January 1968. Location, depth, substrate, seagrass.

Station[1]				Depth[3]		
No.	Name	Sample site	Location[2]	Range (cm)	Carbonate sediment grain size	Seagrass[4]
1	Bob Key	E key, SE shore	A	31-89	very fine sand	T3B
2	Buttonwood Sound	S shore (Sunset Cove)	A	46-82	medium to coarse sand	T3C
3	Cowpens Anchorage	SW shore	A	69-97	very fine to coarse sand	T2A
4	Shell Key	N shore	D	79-92	medium fine sand	T3B; H1A
5	Bob Allen Key	SW key, S shore	B	43-82	silt to medium sand	T2B; H2A
6	Russell Key	W shore	B	28-51	silt to medium sand	T1A; H1A
7	Samphire Key	3rd key from S, W shore	B	48-51	silt to coarse sand	T2B
8	Dump Key	N key, N point	B	36-61	silt to mud	H1A[5]
9	Pelican Key	N key, W shore	C	53-61	silt to mud	H1B; T1B
10	Spy Key	W shore	B	43-81	silt to medium sand	T1A; H1A
11	Little Barnes Key (*Halodule*)	key NW of Barnes Key, NW point	D	46-71	silt to fine sand	H3B
12	Little Barnes Key (*Thalassia*)	key NW of Barnes Key, NW point	D	61-87	silt to coarse sand	T3B
13	Rabbit Key Bank	on bank, E end of pass	C	61-89	silt to medium coarse sand	T3C; H1B
14	Man-of-War Lake	1 n. mi. W of Johnson Key	C	184-184	silt to fine sand	T3C; S1B

See footnotes at end of table.

Table 1. — Continued.

Station				Depth	Carbonate sediment	
No.	Name	Sample site	Location	Range (cm)	grain size	Seagrass
15	Johnson Key	W shore	C	74-99	silt to coarse sand	H3C
16	Dildo Key Bank	0.5 n. mi. N of Johnson Key, edge of bank	C	76-89	silt to medium fine sand	T3C
17	Murray Key	S shore	C	56-79	silt to coarse sand	H1A 5/
18	Boot Key Bridge	E end of bridge	M	31-92	silt to medium sand	H3B
19	Costello Key	unnamed key, Kemp Channel S of Budd Keys, NE shore	L	79-97	silt to medium coarse sand	T2B
20	Raccoon Key	SW shore	L	36-59	silt to coarse sand	T2B
21	Riding Key	S shore	L	84-97	silt to medium coarse sand	T2C;S2C
22	Palm Key Lake	0.6 n. mi. SE of Palm Key	C	127-127	– 6/	H3B

1/ Not all stations were sampled in January 1967. Therefore, these data are based on monthly observations from February 1967 to January 1968 with the following exceptions: Stations 8, 9, and 17 were sampled in April, July, and October 1967, and in January 1968. However, at Station 17, no shrimp sample was collected in January 1968 because the station was dry. Station 22 was sampled only in October 1967. Stations were located near land masses, except for Stations 13 and 16, which were on seagrass-covered mudbanks, and 14 and 22, which were in the centers of basins.

2/ See Figure 4 for location in bay area. A = eastern bay, B = central bay, C = western bay, D = southern bay, M = Middle Keys, Florida Straits side, L = Lower Keys.

Table 1. — Continued.

3/ Depths in which shrimp samples were taken in October 1967. Sampling depths were generally less in the winter and early spring (sometimes as shallow as 8 cm) primarily due to seasonal variations in sea level.

4/ Species are in order of dominance and are indicated as follows: H = *Halodule wrightii*; S = *Syringodium filiforme*; T = *Thalassia testudinum*. Number indicates blade density as follows: 1 = low; 2 = medium; 3 = high. Letter indicates blade lengths as follows: A = short; B = medium; C = long. There were seasonal changes in seagrass species, blade densities, and blade lengths. The descriptions are of the "typical" situation at each station.

5/ Blades were absent during much of the sampling period.

6/ No data.

Table 2. — *Penaeus duorarum* sampling stations, additional characteristics, Florida Bay area, January 1967-January 1968. Salinity, water temperature, turbidity.[1]

Station No.[2]	Salinity (°/oo)[3]		Temperature (°C)		Turbidity (°/o)[4]	
	Range	Mean	Range	Mean	Clear	Turbid
1	26.0 - 38.4	31.2	16.6 - 30.0	25.7	42	58
2	29.5 - 39.3	34.5	19.2 - 33.7	28.5	92	8
3	35.2 - 41.3	38.0	15.7 - 30.5	25.4	92	8
4	35.7 - 41.6	38.3	21.0 - 32.2	27.7	92	8
5	29.0 - 41.7	36.7	17.6 - 31.5	27.2	67	33
6	27.8 - 38.5	33.0	15.9 - 30.2	26.2	25	75
7	30.9 - 40.7	35.3	16.1 - 31.0	26.5	67	33
8	31.1 - 36.5	34.1	17.2 - 30.0	25.3	0	100
9	33.5 - 42.4	36.5	16.2 - 30.4	25.1	50	50
10	32.8 - 42.5	37.8	17.1 - 31.5	27.2	42	58
11	33.5 - 42.5	38.4	20.2 - 32.1	27.1	42	58
12	33.5 - 42.5	38.4	20.2 - 32.1	27.1	42	58
13	35.0 - 44.8	38.7	17.9 - 31.4	26.2	58	42
14	33.8 - 42.9	37.8	18.0 - 31.7	26.1	83	17
15	33.6 - 43.0	37.7	19.9 - 31.3	26.5	83	17

See footnotes at end of table.

Table 2. — Continued.

Station No.	Salinity (o/oo) Range	Salinity (o/oo) Mean	Temperature (oC) Range	Temperature (oC) Mean	Turbidity (o/o) Clear	Turbidity (o/o) Turbid
16	34.1 - 43.0	37.9	19.7 - 32.5	26.4	83	17
17	35.4 - 38.2	36.3	21.3 - 30.5	26.4	0	100
18	35.1 - 39.4	37.2	19.8 - 32.0	26.5	100	0
19	35.8 - 40.0	37.7	20.0 - 30.5	25.7	100	0
20	36.2 - 39.3	37.9	20.0 - 31.0	26.3	100	0
21	36.8 - 39.1	37.8	20.0 - 30.3	25.8	83	17
22	- 5/	-	-	-	-	-

1/ Not all stations were sampled in January 1967. Therefore, these data are based on monthly observations from February 1967 to January 1968, except for Stations 8, 9, and 17, which are for April, July, and October 1967, and January 1968.

2/ See Table 1 and Figure 4 for specific sites and location in bay area.

3/ For monthly salinity records by station, see Appendix I.

4/ Percent of total number of observations.

5/ No data.

Table 3. — Abundance of *Penaeus duorarum* by station and size, Florida Bay area, February 1967-January 1968.[1]

Station		Percent by size groups [2/3/]			
No.	Name	16-25	26-45	46-112	16-112
1.	Bob Key	0	0	0.7	0.2
2.	Buttonwood Sound	0	0	0	0
3.	Cowpens Anchorage	0	0	0	0
4.	Shell Key	0.9	1.2	2.7	1.5
5.	Bob Allen Key	3.6	6.2	1.7	4.5
6.	Russell Key	0.4	0.6	2.4	0.9
7.	Samphire Key	1.3	1.8	3.4	2.0
10.	Spy Key	1.3	1.2	1.5	1.3
11.	Little Barnes Key (*Halodule*)	22.2	27.0	20.4	24.2
12.	Little Barnes Key (*Thalassia*)	2.3	4.4	2.7	3.4
13.	Rabbit Key Bank	0.6	0.3	0.2	0.4
14.	Man-of-War Lake	1.7	2.5	5.4	2.9
15.	Johnson Key	37.6	28.0	30.9	31.3
16.	Dildo Key Bank	0.4	1.3	2.2	1.3
18.	Boot Key Bridge	14.5	16.9	20.2	16.9
19.	Costello Key	2.8	1.5	0.7	1.7
20.	Raccoon Key	7.9	4.2	2.2	4.8
21.	Riding Key	2.6	2.8	2.7	2.7
	Total =	100.1	99.9	100.0	100.0
	N =	532	971	411	1,914

1/ For station locations, see Figure 4.

2/ Calculated for the 18 stations sampled monthly, based on 12 m^2 samples by slednet.

3/ Size ranges are in millimeters, total length. About 80% of the shrimp were 16-45 mm.

Table 4. — Relation of *Penaeus duorarum* densities to station characteristics, Florida Bay area, September 1-November 10, 1966.

Rank	Station location[1/]	Shrimp catch[2/]	Station characteristics: Degree of circulation[3/]	Seagrass[4/]	Topographic site[5/]
1	C	21.8	3	H3	Sh
2	C	20.5	3	H3	Sh
3	C	18.0	3	H3	Sh
4	C	14.6	3	H3	Sh
5	M	10.0	3	H3	Sh
5	M	10.0	3	H3	Sh
6	C	9.0	3	H3	Sh
7	C	8.8	3	H3	Sh
8	D	8.2	3	H3	Sh
9	D	8.0	3	H3	Sh
10	D	6.0	3	H3	Sh
11	L	5.3	3	H2	Sh
12	C	4.2	3	H3	Sh
12	C	4.2	3	T3	Bk
13	B	3.7	3	H3	Sh
13	C	3.7	3	T3	Bk
14	D	3.3	3	H2	Sh
15	C	3.2	3	H3	Sh
15	B	3.2	2	T2	Sh
16	L	3.0	3	H2	Sh
17	C	2.7	3	H3	Sh

See footnotes at end of table.

Table 4. —— Continued.

Rank	Station location	Shrimp catch	Station characteristics		
			Degree of circulation	Seagrass	Topographic site
17	D	2.7	3	H3	Sh
18	B	2.5	2	T2	Sh
18	C	2.5	3	T3	Bk
19	M	2.3	3	none[6]	Sh
20	B	2.2	2	H2	Sh
21	D	1.7	3	H2	Sh
22	B	1.5	3	T2	Sh
22	B	1.5	2	H1	Sh
23	B	1.3	3	T3	Bk
23	D	1.3	3	T3	Sh
24	D	1.2	3	T2	Sh
24	C	1.2	3	T2/H2	Bn
24	B	1.2	2	H2	Sh
24	A	1.2	1	T2	Sh
25	D	1.0	3	H2	Sh
25	B	1.0	2	T2	Sh
26	B	0.7	3	T2	Sh
26	U	0.7	3	H2	Sh
26	U	0.7	3	T2	Sh
27	B	0.5	2	T2	Sh
28	D	0.3	3	T3	Bk
28	BS	0.3	1	T2	Sh

Table 4. — Continued.

Rank	Station location	Shrimp catch	Station characteristics		
			Degree of circulation	Seagrass	Topographic site
28	L	0.3	3	H1	Sh
28	U	0.3	3	H1	Sh
29	A	0.2	1	H2	Sh
29	D	0.2	3	T3	Bk
29	B	0.2	2	T3	Bk
30	U	0	3	H1	Sh
30	D	0	3	T2	Bk
30	A	0	1	T1	Sh
30	A	0	1	T2	Sh
30	B	0	3	T3	Sh
30	D	0	3	T2	Bn
30	B	0	1	H2/T2	Sh
30	B	0	1	T2	Sh
30	B	0	1	T1	Sh
30	A	0	1	H2/T2/R2	Sh
30	A	0	1	H1	Sh
30	A	0	2	T2	Sh
30	U	0	3	H1	Sh
30	A	0	1	T3	Sh
30	D	0	3	T2	Bk
30	D	0	3	T3	Bk
30	C	0	3	T3	Bn
30	C	0	2	H0/T0	Sh

Table 4. — Continued.

Rank	Station location	Shrimp catch	Station characteristics: Degree of circulation	Seagrass	Topographic site
30	U	0	3	H1	Sh
30	U	0	3	T2	Sh
30	BS	0	1	H1	Sh

1/ See Figure 3 for location of stations. A = eastern bay; B = central bay; C = western bay; D = southern bay; U = Upper Keys, Florida Straits side; M = Middle Keys, Florida Straits side; L = Lower Keys, Florida Straits side; BS = Barnes Sound, western shore.

2/ Ranked in descending order of shrimp/m^2, reduced from 6 m^2 samples by slednet. Size range 16-94 mm total length, about 80% were 16-45 mm.

3/ Water circulation is: 1 = restricted; 2 = marginally restricted; 3 = relatively open.

4/ Dominant species are indicated as follows: H = *Halodule wrightii*; R = *Ruppia maritima*; T = *Thalassia testudinum*. When no species dominates, both or all are listed. Number indicates blade density as follows: 0 = roots only, blades absent; 1 = low; 2 = medium; 3 = high.

5/ Sh = shoreline; Bk = bank; Bn = basin.

6/ Macroalgae.

Table 5. — Relation of *Penaeus duorarum* densities to station characteristics, Florida Bay area, October 1967.

Rank	Station		Shrimp catch[2/]	Station characteristics		
	Number	Location[1/]		Degree of circulation[3/]	Seagrass[4/]	Topographic site[5/]
1	15	C	7.8	3	H3	Sh
2	22	C	6.3	3	H3	Bn
3	18	M	4.1	3	H3	Sh
4	11	D	3.9	3	H3	Sh
5	5	B	1.7	2	T2; H2	Sh
6	20	L	1.3	3	T2	Sh
7	9	C	1.2	3	H1; T1	Sh
8	17	C	0.8	3	H0	Sh
8	8	B	0.8	2	H1	Sh
8	4	D	0.8	3	T3; H1	Sh
9	21	L	0.7	3	T2; S2	Sh
9	7	B	0.7	1	T2	Sh
10	12	D	0.5	3	T3	Sh
11	14	C	0.4	3	T3; S1	Bn
12	16	C	0.3	3	T3	Bk
12	19	L	0.3	3	T2	Sh
13	6	B	0.2	1	T1; H1	Sh
13	1	A	0.2	1	T3	Sh
14	13	C	0.1	3	T3; H1	Bk
15	10	B	0	3	T1; H1	Sh
15	3	A	0	2	T2	Sh
15	2	A	0	1	T3	Sh

See footnotes at end of table.

Table 5. — Continued.

1/ See Figure 4 for location of stations. A = eastern bay; B = central bay; C = western bay; D = southern bay; U = Upper Keys, Florida Straits side; M = Middle Keys, Florida Straits side; L = Lower Keys.

2/ Ranked in descending order of shrimp/m^2, reduced from 12 m^2 samples by sled-net. Size range 16-112 mm total length, about 80% were 16-45 mm.

3/ Water circulation is: 1 = restricted; 2 = marginally restricted; 3 = relatively open.

4/ Species are listed in order of dominance and indicated as follows: H = Halodule wrightii; S = Syringodium filiforme; T = Thalassia testudinum. Number indicates blade density as follows: 0 = roots only, blades absent; 1 = low; 2 = medium, 3 = high.

5/ Sh = shoreline; Bk = bank; Bn = basin.

Table 6. — Relation of Penaeus duorarum densities and size composition to seagrasses and topography, Florida Bay area, February 1967-January 1968.

Station[1] Name	No.	Number and percent of P. duorarum[2] 16-45	46-112	16-112
Halodule wrightii[3]				
Little Barnes Key (shoreline)	11	31.7 (81.9)	7.0 (18.1)	38.7 (100.0)
Johnson Key (shoreline)	15	39.3 (78.8)	10.6 (21.2)	49.9 (100.0)
Boot Key Bridge (shoreline)	18	20.1 (74.4)	6.9 (25.6)	27.0 (100.0)
Thalassia testudinum[4]				
Little Barnes Key (shoreline)	12	4.6 (83.6)	0.9 (16.4)	5.5 (100.0)
Man-of-War Lake (basin center)	14	2.8 (60.9)	1.8 (39.1)	4.6 (100.0)
Dildo Key Bank (bank)	16	1.2 (60.0)	0.8 (40.0)	2.0 (100.0)
Raccoon Key (shoreline)	20	6.9 (89.6)	0.8 (10.4)	7.7 (100.0)

1/ For station locations, see Figure 4.

2/ Shrimp/m^2 (12 months' total), reduced from 12 m^2 samples by slednet. Size in millimeters total length.

3/ Sampling depths from 10 to 99 cm.

4/ Sampling depths from 20 to 184 cm.

Table 7. — Densities of Penaeus duorarum in adjacent shallow-water Halodule wrightii and Thalassia testudinum beds, Florida Bay, October 1966-January 1968.

Station[1] Name	No.	Date	Number of P. duorarum[2/3] H. wrightii	T. testudinum
		1966		
Lignumvitae Key	S8	Oct	3.3	1.2
Spy Key	10	Nov	3.7	1.5
		1967		
Shell Key	4	Aug	1.0	0.1
		Oct	1.7	0.8
Little Barnes Key	11,12	Jan	3.3	1.3
		Feb	6.5	0
		Mar	1.0	0
		Apr	0.5	0
		May	0.3	0.2
		Jun	1.2	0.1
		Jul	1.5	0.2
		Aug	6.7	1.0
		Sep	6.8	1.7
		Oct	3.9	0.5
		Nov	6.3	0.2
		Dec	3.0	1.7
		1968		
		Jan	1.0	0.1
		Total =	51.7	10.6
		$\bar{x}$ =	3.0	0.6
		Range =	0.3-6.8	0-1.7

1/ For station locations, see Figures 1 and 4.

2/ Shrimp/m^2, reduced from 12 m^2 samples by slednet in each species of seagrass. Size 16-95 mm total length, about 82% were 16-45 mm.

3/ Sampling depths from 13 to 71 cm (H. wrightii), and from 20 to 99 cm (T. testudinum).

Table 8. — Densities of *Penaeus duorarum* by size groups in adjacent shallow-water *Halodule wrightii* and *Thalassia testudinum* beds, Little Barnes Key (Stations 11 and 12), southern Florida Bay, January 1967-January 1968.[1]

P. duorarum size range	Number and percent of *P. duorarum*[2,3]		
mm total length	*H. wrightii*	*T. testudinum*	Total
16-25	9.8 (90.7)	1.0 (9.3)	10.8 (100.0)
26-45	23.5 (85.8)	3.9 (14.2)	27.4 (100.0)
46-95	8.7 (82.1)	1.9 (17.9)	10.6 (100.0)

1/ For station locations, see Figure 4.

2/ Shrimp/m^2 (13 months' total), reduced from 12 m^2 samples by slednet in each species of seagrass.

3/ Sampling depths from 20 to 71 cm (*H. wrightii*) and from 33 to 87 cm (*T. testudinum*).

Table 9. — Densities of *Penaeus duorarum* in shoreline and basin center *Halodule wrightii* and *Thalassia testudinum* beds, Florida Bay area, October 1967.

Station 1/ Name	No.	Number of *P. duorarum* 2/	Size range 3/
Shoreline: 4/			
H. wrightii			
Little Barnes Key	11	3.9	18-68
Johnson Key	15	7.8	16-61
Boot Key Bridge	18	4.1	19-75
T. testudinum			
Little Barnes Key	12	0.5	28-32
Basin Center: 5/			
H. wrightii			
Palm Key Lake	22	6.3	18-50
T. testudinum			
Man-of-War Lake	14	0.4	22-60

1/ For station locations, see Figure 4.

2/ Shrimp/m^2, reduced from 12 m^2 samples by slednet.

3/ In millimeters total length, based on 12 m^2 samples.

4/ Sampling depths from 31 to 99 cm.

5/ Sampling depths from 127 to 184 cm.

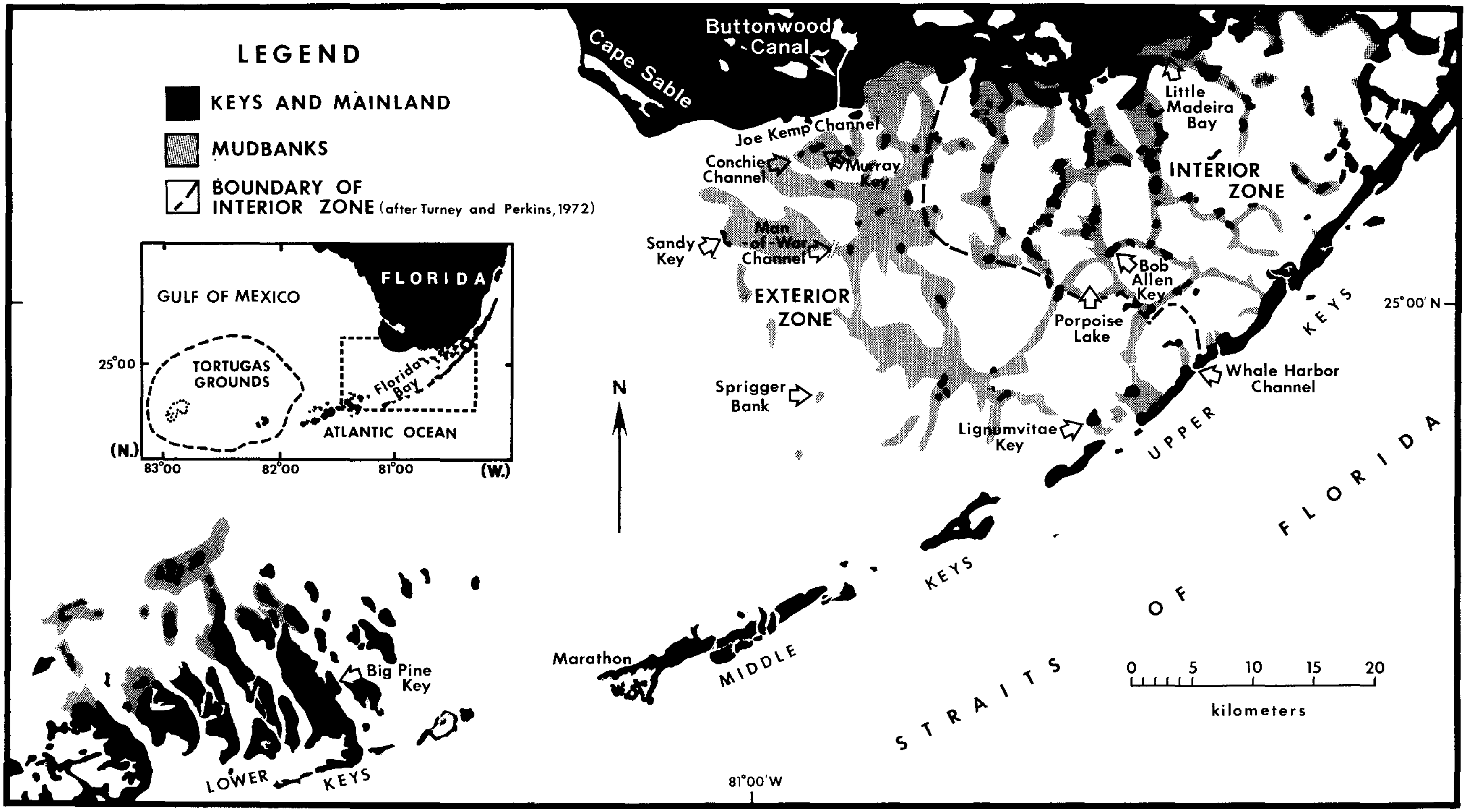
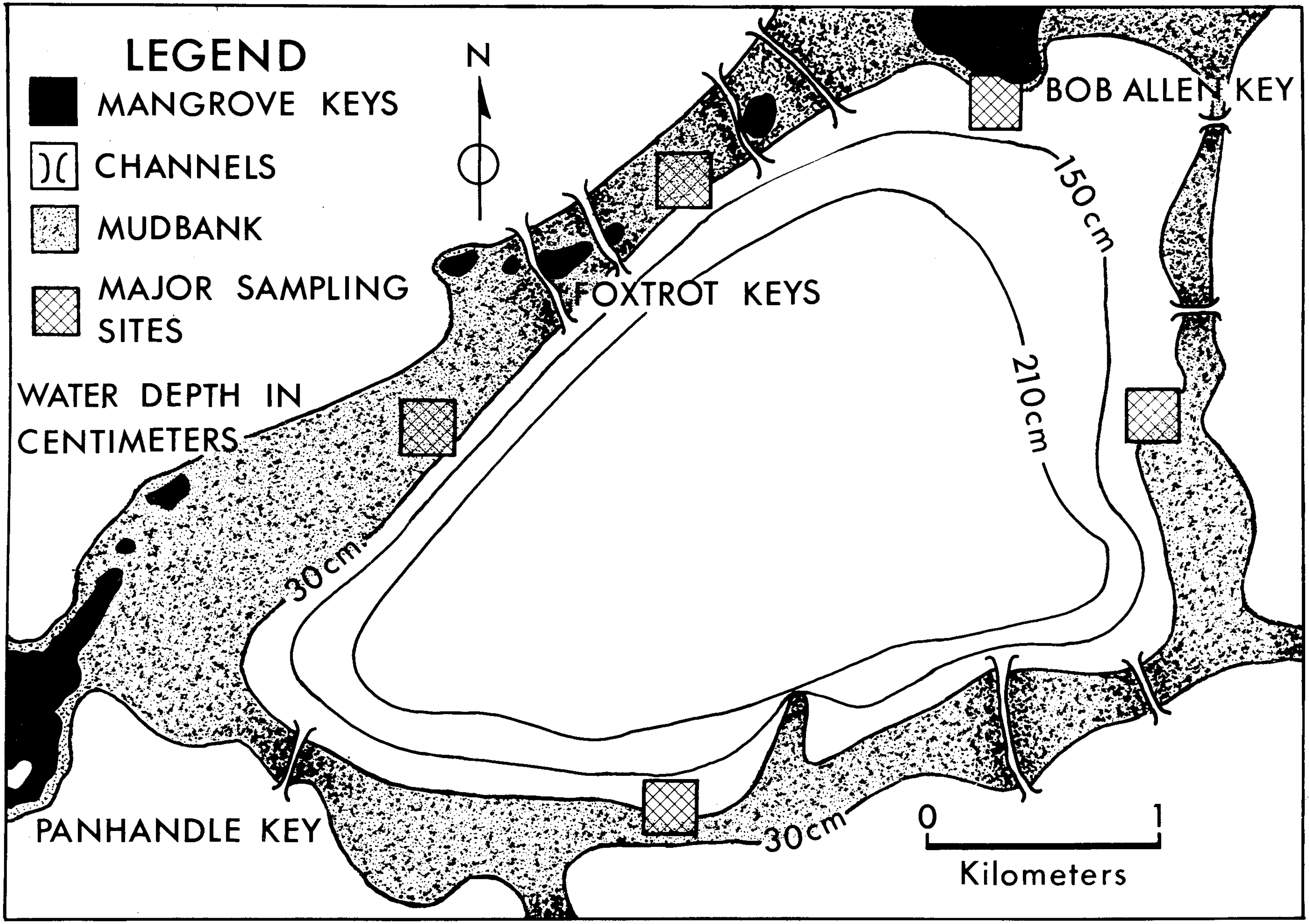


Figure 1. — Florida Bay-Tortugas Grounds area, with location of selected landmarks.



.Figure 2. — Porpoise Lake, a central Florida Bay basin or "lake" with associated mudbanks and mangrove keys (from Hudson et al. 1970). See Figure 1 for location in Florida Bay.

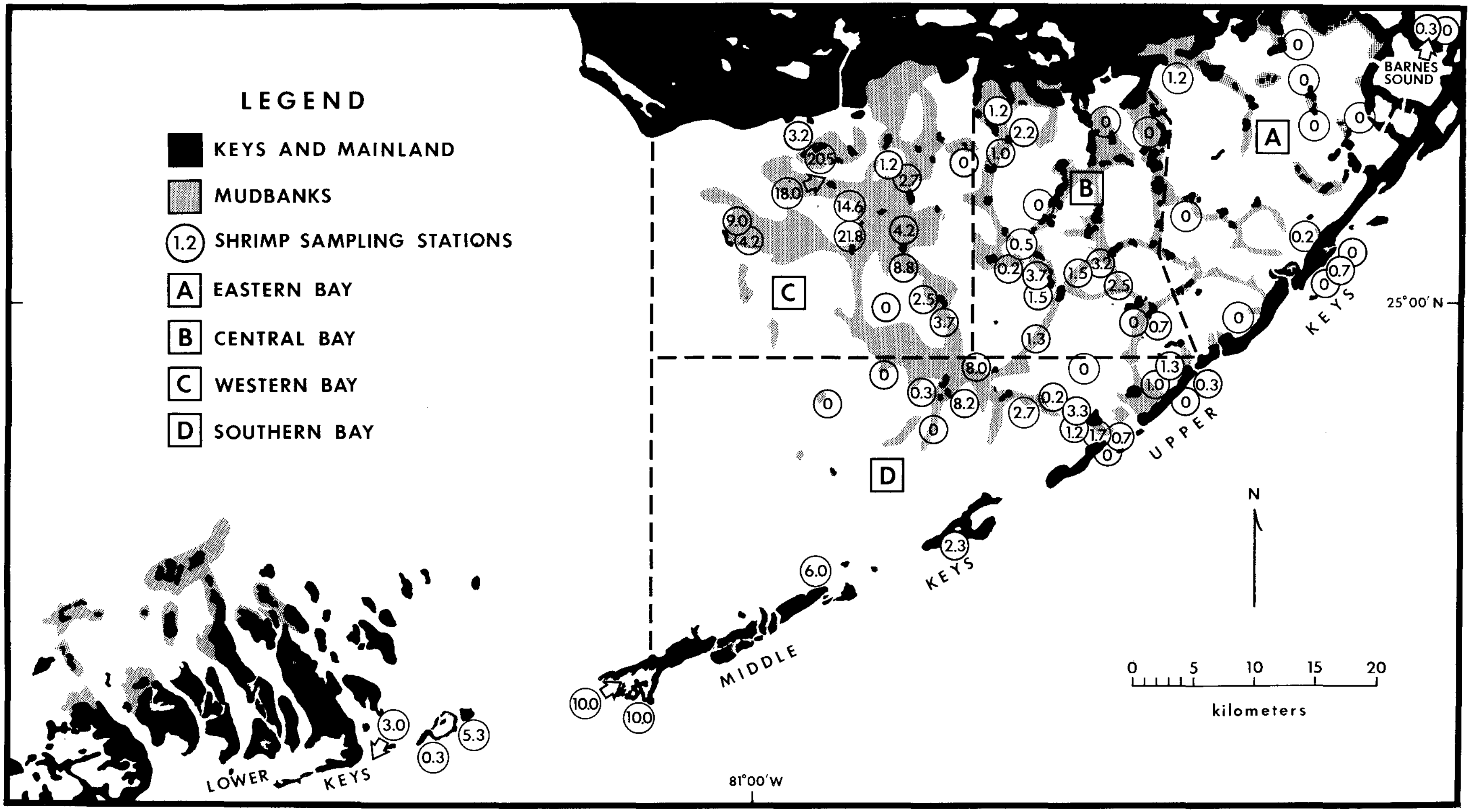


Figure 3. — Penaeus duorarum sampling stations (exploratory), Florida Bay area, September 1-November 10, 1966. Numbers in circles represent shrimp/m^2, reduced from 6 m^2 samples by slednet. Shrimp size 16-94 mm total length, about 80% were 16-45 mm.

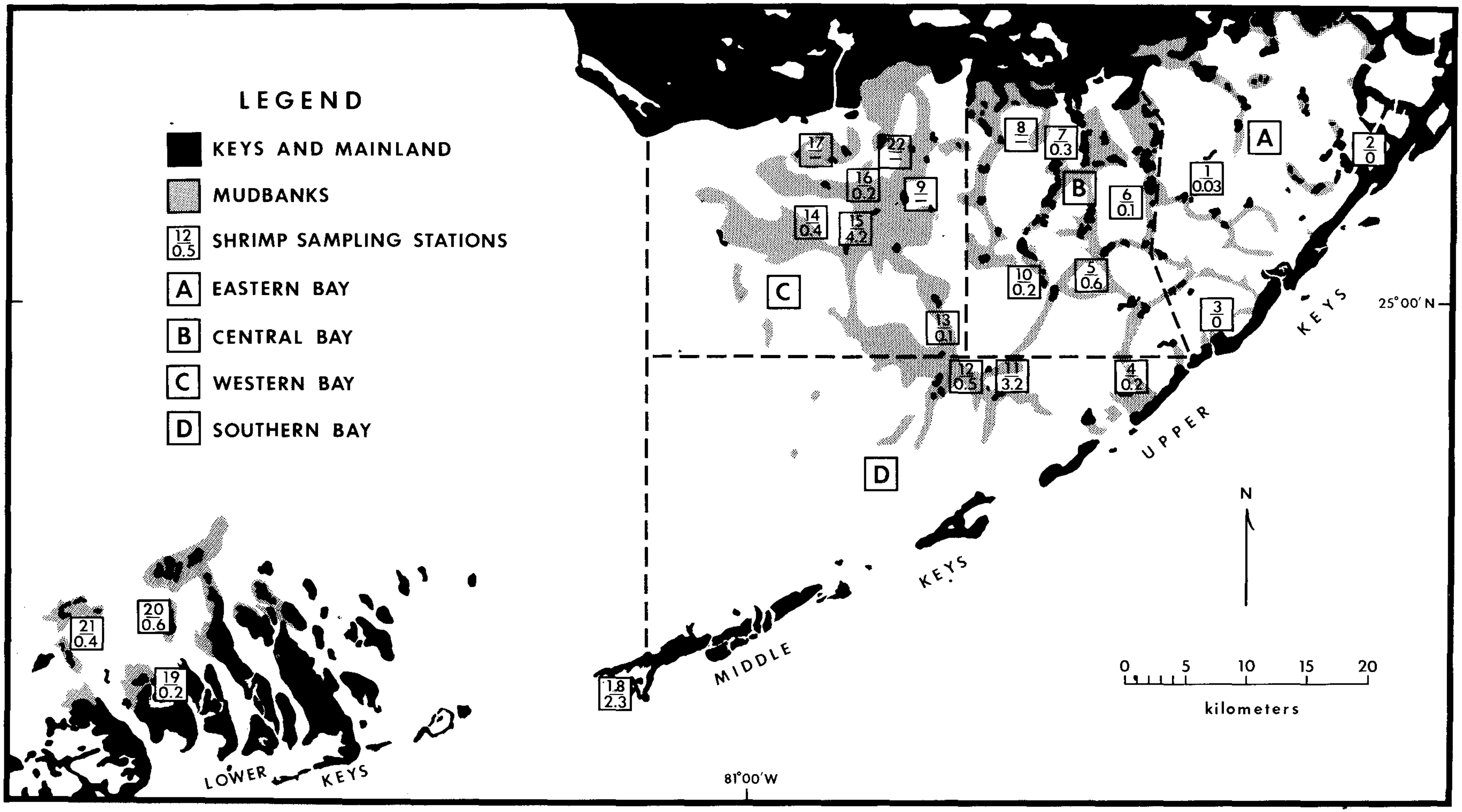


Figure 4. — Penaeus duorarum sampling stations (final), Florida Bay area, January 1967-January 1968. In rectangles, upper numbers indicate stations and lower numbers represent mean numbers of shrimp/m^2 for the 12 month period, February 1967-January 1968, reduced from 12 m^2 samples by slednet. Means were not calculated for four stations sampled < 12 months; the dash indicates no data. Shrimp size 16-112 mm total length, about 80% were 16-45 mm. See Tables 1 and 2 for station names, specific sites, and characteristics.

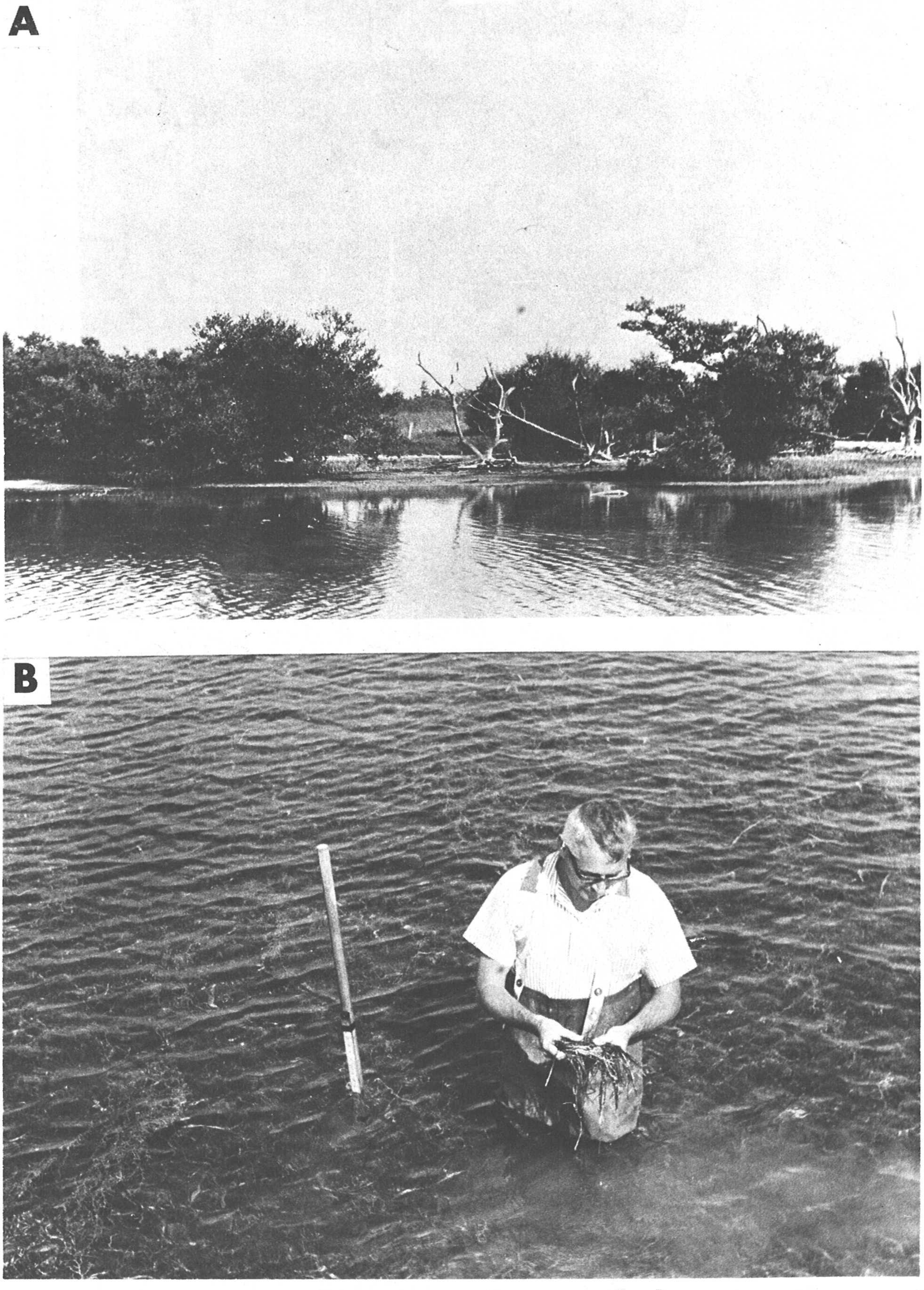


Figure 5. — Sampling station for early juvenile *Penaeus duorarum* on west side of Johnson Key (Station 15), western Florida Bay.
A. Shoreline of mangrove key.
B. Luxuriant bed of *Halodule wrightii*.

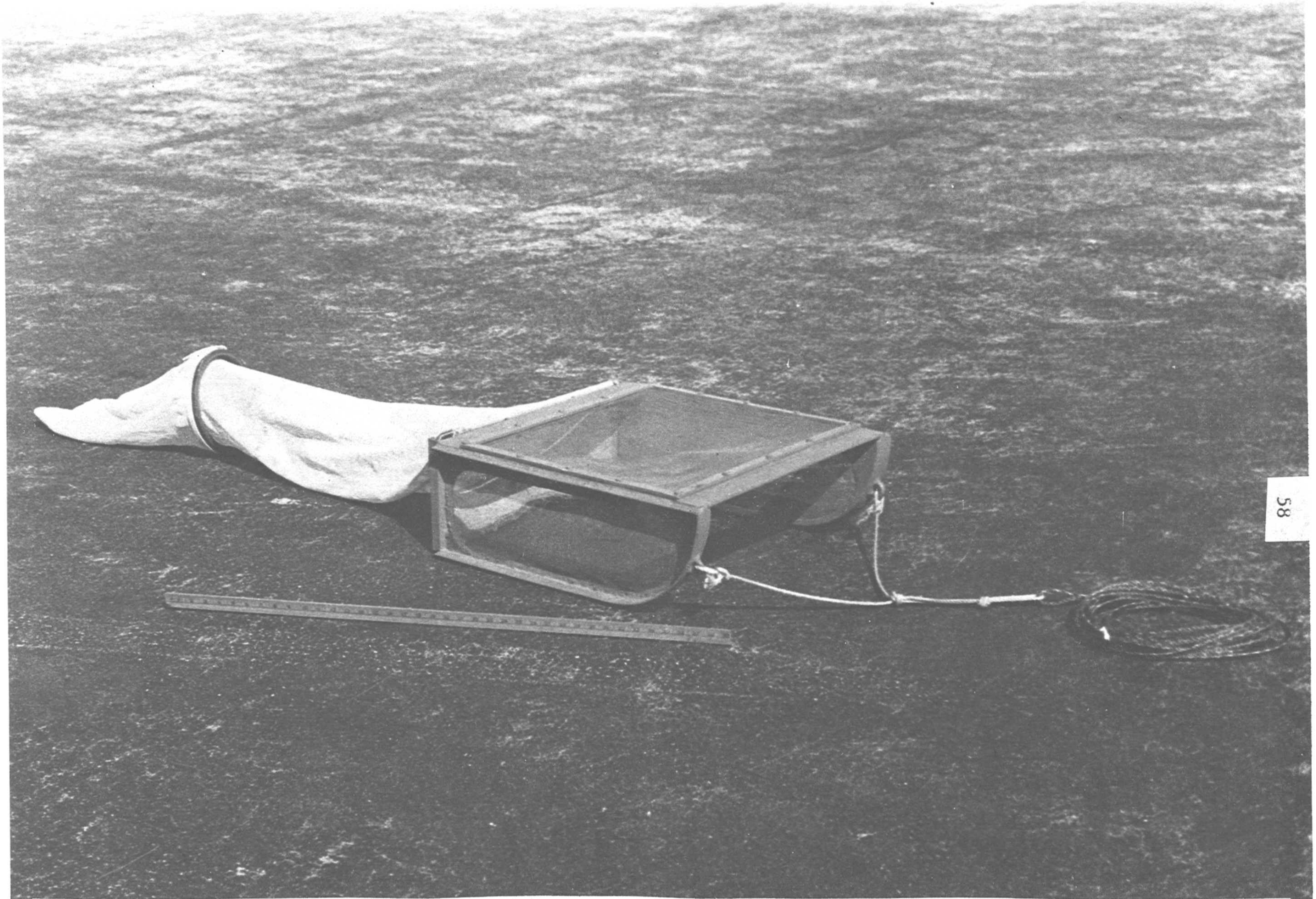


Figure 6. — The slednet, a hand-towed frame trawl for sampling Penaeus duorarum in shallow-water seagrass beds. The major components are as follows, from right to left: towline, sled, removable frame net with leadline at leading edge, and removable cod end sample bag. The sled opening has an inside diameter of 0.5 m. Therefore, when the slednet is pulled 12 m

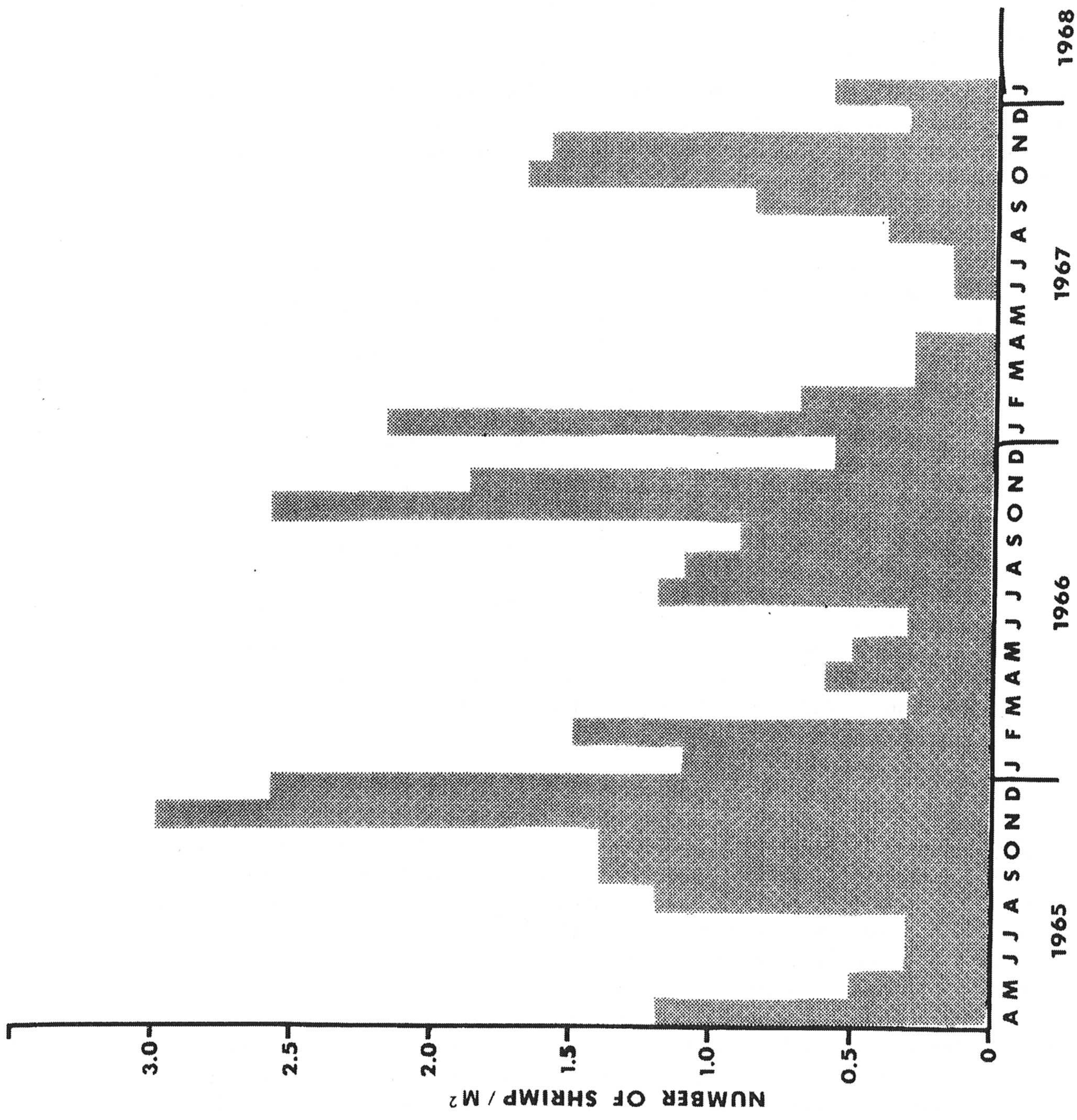


Figure 7. — Monthly abundance of Penaeus duorarum, Bob Allen Key (Station 5), central Florida Bay, April 1965–January 1968. Shrimp/m^2 reduced from 4 m^2 samples by sled-mounted suction sampler, April 1965–September 1966, and 12 m^2 samples by slednet, October 1966–January 1968. Shrimp size 16–87 mm total length, about 92% were 16–45 mm.

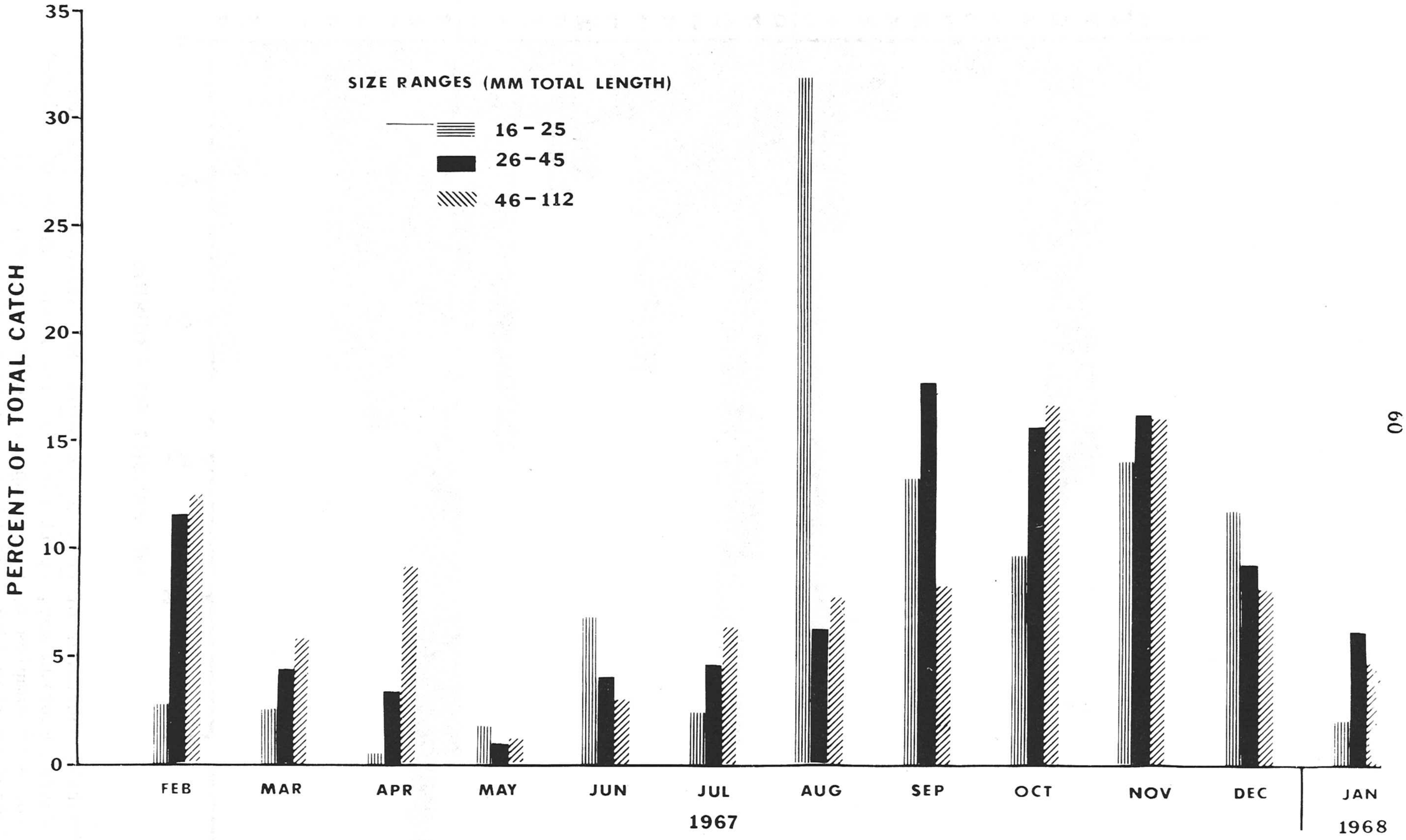


Figure 8. — Monthly abundance of Penaeus duorarum by size groups, Florida Bay area, February 1967-January 1968. Based on 12 m^2 samples by slednet from 18 stations sampled monthly; percent of total 12 months' catch. About 80% of the shrimp were 16-45 mm total length.

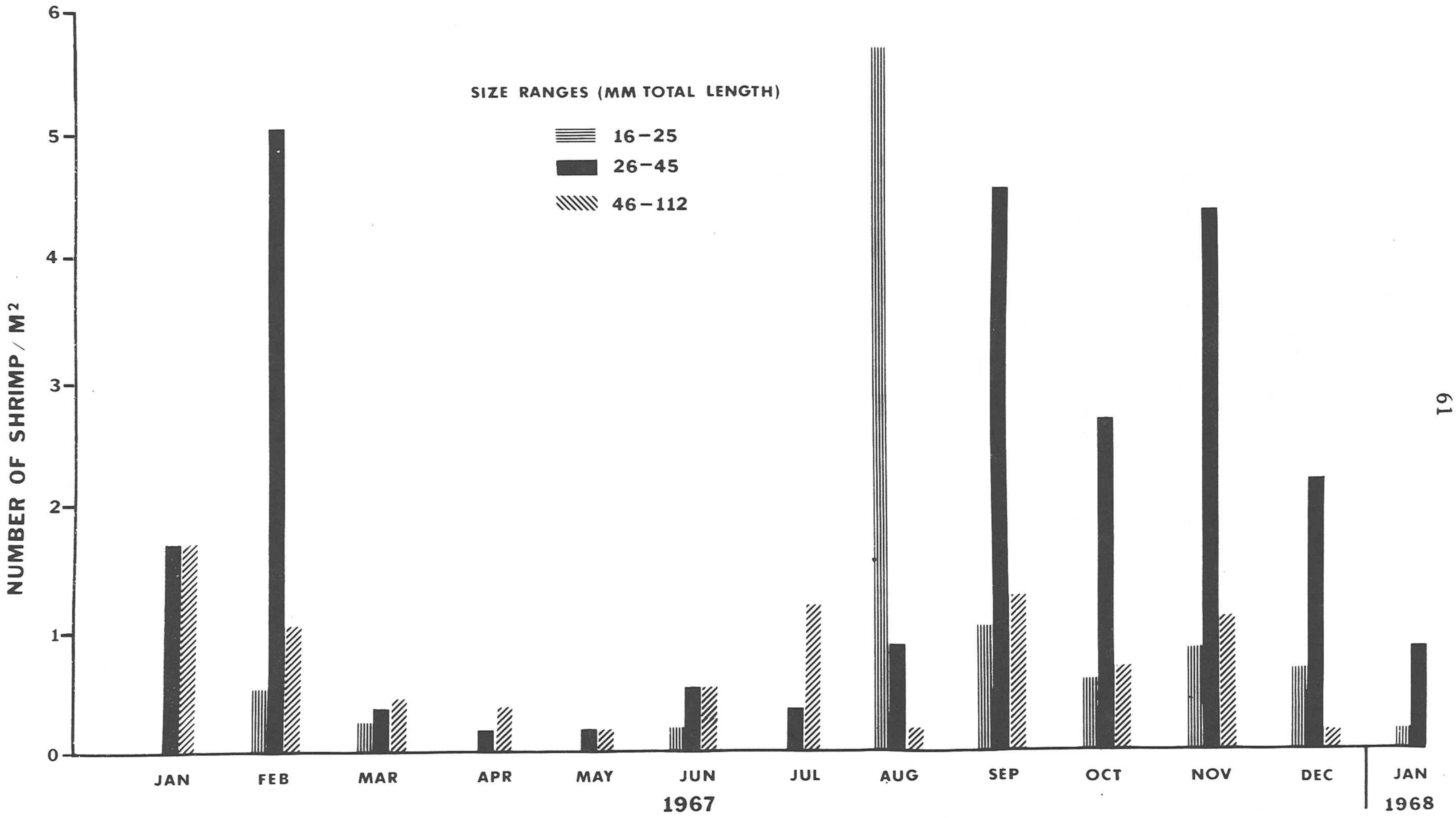


Figure 9. — Monthly abundance of Penaeus duorarum by size groups, Little Barnes Key (Halodule) (Station 11), southern Florida Bay, January 1967–January 1968. Shrimp/m^2, reduced from 12 m^2 samples by slednet. About 82% of the shrimp were 16-45 mm total length.

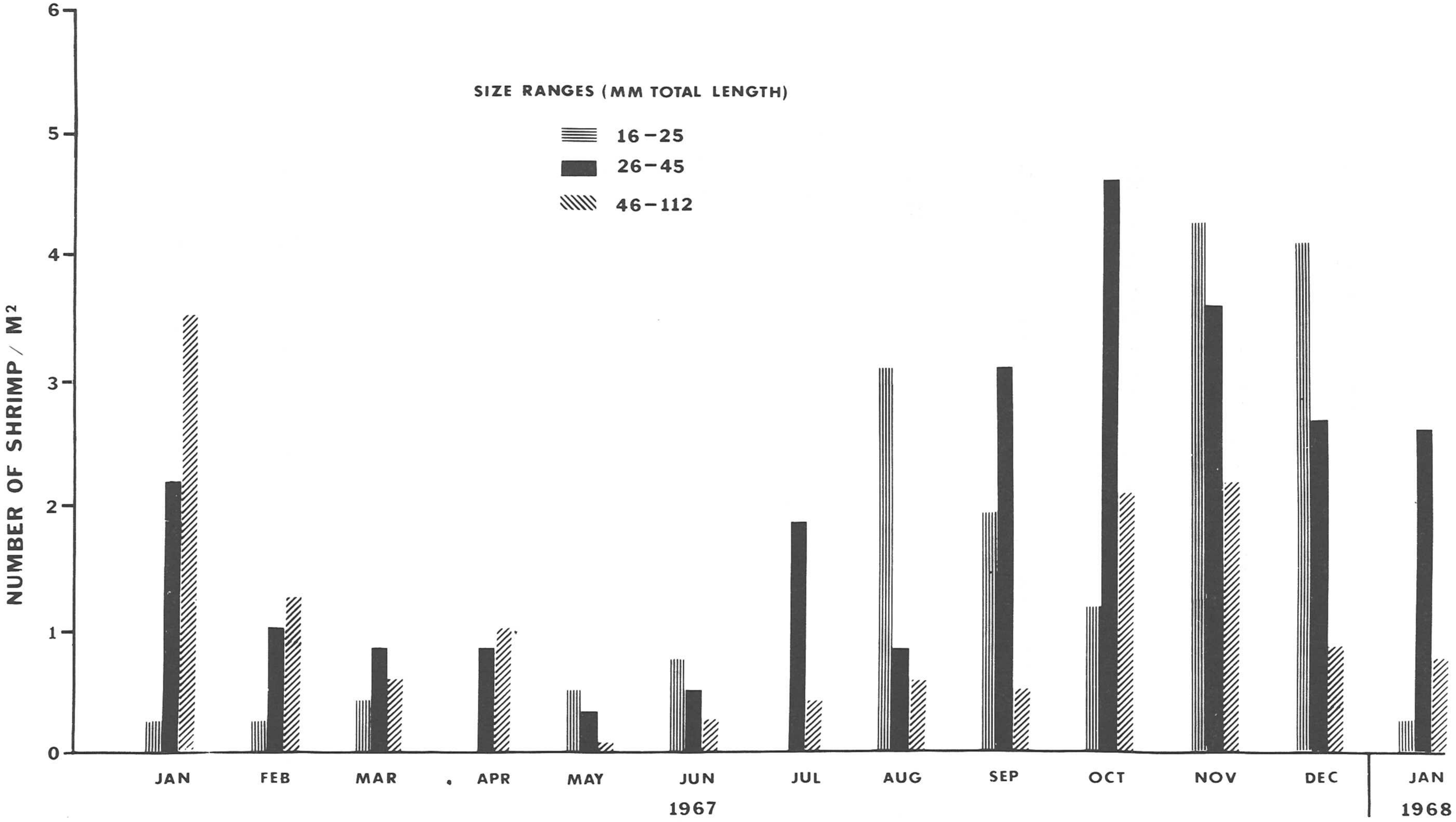


Figure 10. — Monthly abundance of Penaeus duorarum by size groups, Johnson Key, (Station 15), western Florida Bay, January 1967–January 1968. Shrimp/m^2, reduced from 12 m^2 samples by slednet. About 79% of the shrimp were 16-45 mm total length.

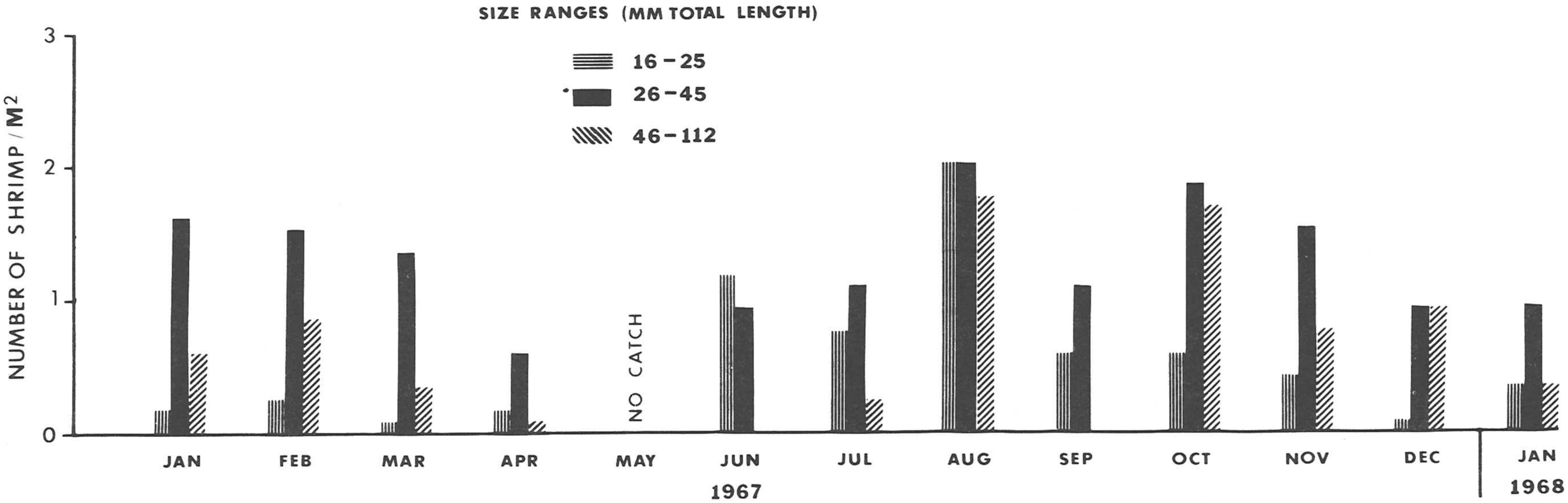


Figure 11. — Monthly abundance of Penaeus duorarum by size groups, Boot Key Bridge (Station 18), Middle Keys, Florida Bay area, January 1967–January 1968. Shrimp/m^2, reduced from 12 m^2 samples by slednet. About 74% of the shrimp were 16-45 mm total length.

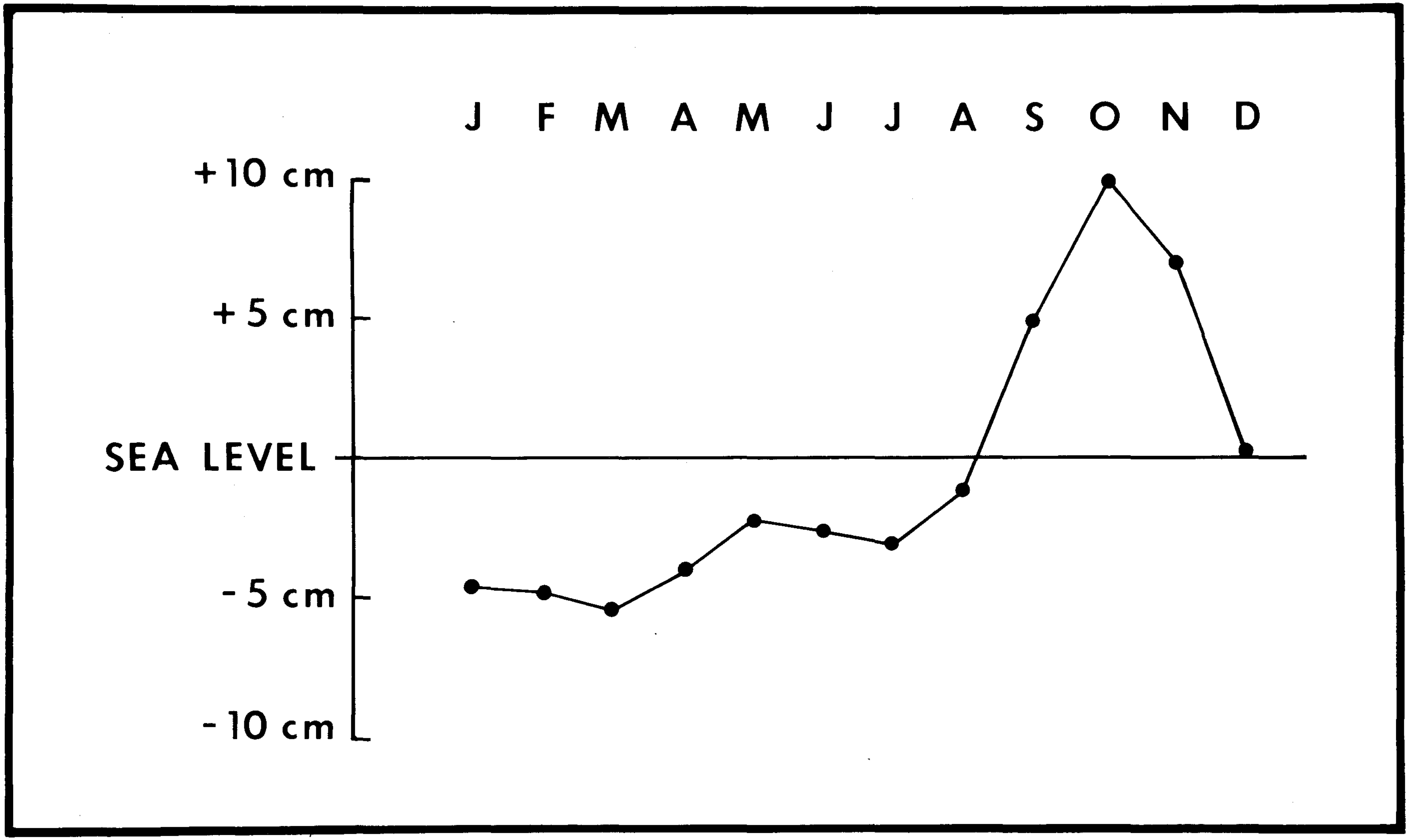


Figure 12. — Annual variation in sea level, south Florida (from Odum et al. 1982).

Appendix I. — Salinities (°/oo) by station and date, Florida Bay area, 1963 - 1969.

Location	Station [1] No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1963						
B	S1	Twin Keys, pass between keys	[2] -	-	-	-	-	-	-	[3] 29/44.0	-	-	-	-
								1964						
B	5	Bob Allen Key, SW key,	-	-	-	-	-	-	-	-	-	-	13/43.0	-
		SW shore	-	-	-	-	-	-	-	-	-	-	28/39.0	-
								1965						
A	S2	Little Madeira Bay,	-	-	-	-	-	23/51.0	7/52.4	5/56.0	1/55.0	13/35.0	10/26.6	-
		peninsula, 1 n.m. SW of mouth	-	-	-	-	-	-	21/54.2	17/57.6	15/46.8	29/32.9	-	-
A	S3	Little Madeira Bay,	-	-	-	-	-	-	-	-	-	-	10/29.4	9/29.9
		key, W end of mouth	-	-	-	-	-	-	-	-	-	-	24/29.3	23/34.2
A	S4	Black Betsy Key,	-	-	-	-	-	23/50.8	7/50.4	5/53.0	1/56.6	13/41.0	10/28.8	9/31.6
		largest key, E point	-	-	-	-	-	-	21/52.0	17/52.8	15/48.2	29/36.4	24/32.1	23/35.1
A	S5	Manatee Key, W key,	-	-	-	-	-	23/50.0	7/51.2	5/49.0	1/52.8	13/45.0	10/30.6	9/36.5
		W shore	-	-	-	-	-	-	21/48.0	17/50.6	15/50.4	29/40.2	24/36.8	23/36.7
U	S6	Whale Harbor Channel,	-	-	-	-	-	-	29/39.8	5/40.8	1/39.5	1/39.3	9/36.0	1/38.0
		bridge center	-	-	-	-	-	-	30/39.3	6/40.7	2/39.3	1/39.7	23/37.4	2/38.1
			-	-	-	-	-	-	-	11/40.6	22/38.3	7/39.2	-	8/38.4
			-	-	-	-	-	-	-	12/39.6	-	7/38.9	-	17/37.9
			-	-	-	-	-	-	-	17/39.5	-	8/39.8	-	22/38.5
			-	-	-	-	-	-	-	18/39.5	-	8/39.3	-	28/38.0

See footnotes at end of table.

Appendix I. —— Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1965						
U	S6	Whale Harbor Channel,	-	-	-	-	-	-	-	25/39.2	-	8/39.3	-	-
		bridge center (cont.)	-	-	-	-	-	-	-	26/38.8	-	12/38.9	-	-
			-	-	-	-	-	-	-	-	-	21/38.2	-	-
			-	-	-	-	-	-	-	-	-	28/39.3	-	-
D	4	Shell Key, N. shore	-	-	-	-	-	-	21/41.7	-	-	-	-	-
B	5	Bob Allen Key, SW key,	-	-	4/40.0	20/41.3	13/45.8	9/44.3	7/47.4	5/46.3	1/48.6	13/44.4	10/41.3	9/40.3
		SW shore	-	-	-	-	-	24/45.7	21/49.6	17/45.3	15/47.2	29/42.4	24/41.5	23/40.6
B	S7	Bob Allen Key, SW key, enclosed "pond"	-	-	-	-	-	-	-	-	1/77.6	-	-	-
B	S1	Twin Keys, pass between keys	-	-	-	-	-	-	-	-	22/43.2	-	-	-
D	S8	Lignumvitae Key,	-	-	-	-	14/40.0	10/40.2	8/39.9	5/43.5	1/40.9	8/39.3	10/36.4	9/39.2
		W shore	-	-	-	-	-	24/40.0	21/40.5	17/40.7	15/39.9	29/40.7	24/37.7	23/40.6
U	S9	Channel Two, bridge	-	-	-	-	-	-	-	-	-	28/40.5	-	-
M	S10	Channel Five, bridge	-	-	-	-	-	-	-	-	-	21/39.8	-	-
D	S11	Lower Arsenicker Key key off SE point of large key, E shore	-	-	-	-	-	10/42.3	-	-	-	-	-	-
M	S12	Long Key Viaduct, bridge	-	-	-	-	-	-	-	-	-	-	9/37.6	-

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1966						
A	S3	Little Madeira Bay, key, W end of mouth	12/32.3 19/35.2	3/30.9 24/33.5	10/33.2 23/35.3	7/38.7 21/38.5	5/39.0 24/37.9	7/26.8 21/15.7	10/11.8 20/13.8	10/9.4 17/8.4	10/12.0 21/10.3	10/12.3 23/14.3	1/17.7 9/19.5	10/22.2 26/21.4
A	S13	Little Madeira Bay, 1 n. m. S of mouth	–	–	–	–	–	21/21.9	–	–	–	–	–	–
A	S14	Trout Creek, mouth	–	–	–	–	–	–	–	–	–	19/19.9	–	–
A	S4	Black Betsy Key, largest key, E point	12/33.4 19/34.0 –	3/35.6 24/35.0 –	10/37.0 23/36.5 –	7/38.4 21/39.8 –	5/38.4 24/39.8 –	7/36.0 21/28.3 –	10/18.9 20/18.8 31/20.5	10/18.7 17/15.5 24/14.7	10/18.1 21/20.5 30/16.3	10/15.3 23/19.2 –	1/18.6 9/19.0 26/20.8	10/21.1 26/25.0 –
A	S5	Manatee Key, W key, W shore	12/36.1 19/35.8 –	3/36.1 24/36.8 –	10/36.2 23/37.4 –	7/40.4 21/40.0 –	5/39.2 24/41.3 –	7/37.4 21/34.9 –	10/24.6 20/27.1 31/25.7	10/23.6 17/22.0 24/26.0	10/27.6 21/25.8 30/23.4	10/17.5 – –	1/23.7 9/23.4 26/25.0	10/28.4 26/26.7 –
A	S15	Little Buttonwood Sound, point of W peninsula	–	–	–	–	–	–	–	–	–	19/29.0	–	–
A	S16	Pigeon Key (NE bay), SE point	–	–	–	–	–	–	–	–	–	19/28.8	–	–
A	3	Cowpens Anchorage, SW shore	–	–	–	–	–	–	–	–	–	19/37.3	–	–
D	S17	Cotton Key, 1.5 n. m. S	–	–	–	–	–	–	–	–	–	19/36.4	–	–
D	S6	Whale Harbor Channel, bridge center	6/37.1 19/37.5 –	2/37.6 23/37.7 –	9/38.8 22/38.7 –	6/39.4 21/39.3 29/38.9	5/39.3 10/38.3 23/38.9	6/36.0 20/36.5 –	6/36.0 19/36.5 –	1/36.9 16/37.5 –	1/37.6 16/36.4 29/36.0	13/34.2 – –	12/33.6 – –	11/33.8 – –

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
										1966				
B	S18	Umbrella Key, SE point	-	-	-	-	-	-	-	-	-	-	10/20.4	-
B	8	Dump Key, N key, N point	-	-	-	-	-	-	-	-	-	10/21.8	-	
B	S19	Roscoe Key, SE point	-	-	-	-	-	-	-	-	-	-	10/24.7	-
B	S20	Triplet Keys, basin SW of keys	-	-	-	-	-	-	-	-	-	19/20.4	-	-
B	S21	Black Betsy Key, basin on W side	-	-	-	-	-	-	-	-	-	19/21.7	-	-
B	S22	Coon Key, basin on E side	-	-	-	-	-	-	-	-	-	20/28.2	-	-
B	S23	Corinne Key, basin on W side	-	-	-	-	-	-	-	-	-	20/30.2	-	-
B	5	Bob Allen Key, SW key, SW shore	12/39.8 19/39.4	3/40.0 24/39.4	10/40.8 23/40.3	7/43.1 21/41.8	5/41.4 24/41.2	7/36.2 21/38.0	7/34.1 20/33.1	2/31.5 17/32.4	2/31.7 30/27.8	19/28.7 -	1/29.0 30/32.4	15/30.0 -
B	10	Spy Key, W shore	-	-	-	-	-	-	-	-	-	-	1/31.8	-
B	S24	Twin Keys, 1.5 n. m. SW, on bank at pass	-	-	-	-	-	-	-	-	-	-	1/32.1	-

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1966						
D	S25	Shell Key, basin on W side	-	-	-	-	-	-	-	-	-	-	30/36.8	-
D	11	Little Barnes Key, key NW of Barnes Key, NW point	-	-	-	-	-	-	-	-	-	-	1/32.7	-
D	S26	Peterson Keys, middle key, SW shore	-	-	-	-	-	-	-	-	-	20/33.4	-	-
D	S8	Lignumvitae Key, W shore	12/36.8 19/37.7	3/38.6 24/37.8	10/38.3 23/38.6	7/40.6 21/38.7	4/38.5 23/39.2	7/36.4 21/37.6	- -	- -	- -	- -	- -	- -
C	S27	Bradley Key, SW shore	-	-	-	-	-	-	-	-	-	26/33.8	-	-
C	17	Murray Key, S shore	-	-	-	-	-	-	-	-	-	26/35.8	-	-
C	28	Palm Key, SE point	-	-	-	-	-	-	-	-	-	-	10/34.9	-
C	S29	Camp Key, N point	-	-	-	-	-	-	-	-	-	-	10/25.8	-
C	9	Pelican Key, N key, W shore	-	-	-	-	-	-	-	-	-	-	10/36.1	-
C	S30	Clive Key, N shore	-	-	-	-	-	-	-	-	-	26/35.7	-	-
C	S31	Sandy Key, N end, E shore	-	-	-	-	-	-	-	2/36.5	-	26/36.6	-	-
C	15	Johnson Key, W shore	-	-	-	-	-	-	-	-	-	26/36.0	-	-

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1966						
C	S32	Cluett Key, S shore	-	-	-	-	-	-	-	-	-	-	2/37.0	-
C	S33	Rabbit Key, N key, NE point	-	-	-	-	-	-	-	-	-	-	30/33.7	-
D	S11	Lower Arsenicker Keys, key off SE point of large key, E shore	-	-	-	-	-	-	-	-	-	-	2/36.8	-
								1967						
A	S3	Little Madeira Bay, key, W end of mouth	10/23.2 28/19.1	11/22.7 28/22.8	11/25.4 25/26.3	9/31.3 22/36.0	18/39.1 -	21/25.4 -	8/23.8 22/18.2	7/21.3 21/25.4	11/27.0 23/28.6	7/17/.8 23/11.5	12/18.8 20/20.5	5/19.6 26/20.4
A	S4	Black Betsy Key, largest key, E point	10/23.3 28/23.6	11/25.3 28/24.0	11/25.9 25/27.6	9/29.7 22/34.8	18/38.2 -	21/33.5 -	8/28.0 22/24.4	7/27.3 21/28.8	11/34.9 23/35.0	7/26.0 23/22.0	12/20.3 20/22.3	5/23.5 26/22.4
A	1	Bob Key, E key, SE shore	19/25.4	15/26.4	22/29.4	18/33.1	18/38.4	28/34.7	10/36.1	17/35.3	20/35.0	17/26.9	28/26.0	20/26.7
A	2	Buttonwood Sound, S shore (Sunset Cove)	19/28.9	14/29.5	14/33.2	18/36.6	17/39.3	28/34.4	19/36.8	16/37.9	19/38.6	16/32.7	15/30.1	19/32.0
A	S5	Manatee Key, W key, W shore	10/28.3 28/25.4	11/27.5 28/27.1	11/26.7 25/29.2	9/30.5 22/34.8	18/38.2 -	21/34.9 -	8/35.0 22/32.6	7/34.8 21/33.4	11/37.6 23.37.5	7/30.9 23/27.6	12/27.3 20/26.9	5/27.1 26/27.3
A	S34	Low Key, NE shore	19/27.4	-	-	-	-	-	-	-	-	-	-	-
A	S16	Pigeon Key (NE bay) SE point	19/27.9	-	-	-	-	-	-	-	-	-	-	-

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1967						
A	3	Cowpens Anchorage, SW shore	-	15/35.3	22/37.0	18/39.4	18/41.3	28/37.1	20/39.6	17/40.3	20/39.7	17/36.6	28/36.5	20/36.1
U	S6	Whale Harbor Channel bridge center	10/34.5 -	9/34.8 -	10/35.6 -	9/34.3 -	9/35.6 -	8/36.4 -	7/35.3 -	5/35.7 -	4/36.1 -	3/34.1 -	2/34.5 6/36.4	1/35.2 29/34.8
D	4	Shell Key, N shore	-	2/36.0	22/37.9	18/38.7	18/41.6	28/38.7	20/40.0	17/40.4	20/39.0	18/35.7	29/37.2	20/36.7
B	8	Dump Key, N key, N point	-	-	-	12/36.5	-	-	20/34.2	-	-	17/31.1	-	-
B	7	Samphire Key, 3rd key from S, W shore	-	16/30.9	22/37.0	18/33.7	18/40.0	28/36.0	20/38.7	17/41.2	20/38.4	17/32.4	28/31.9	20/32.0
B	6	Russell Key, W shore	24/25.4	15/27.8	22/30.0	18/33.5	18/38.5	28/36.2	20/35.5	17/36.8	20/38.2	17/31.6	28/30.8	20/29.3
B	10	Spy Key, W shore	11/33.6	2/32.8	22/37.1	18/39.4	18/42.5	28/37.4	20/39.4	17/40.0	20/42.0	18/35.5	28/35.7	20/35.8
B	S35	Panhandle Key, E shore	25/28.6	-	-	-	-	-	-	-	-	-	-	-
B	S36	Foxtrot Key, S shore	25/28.5	-	-	-	-	-	-	-	-	-	-	-
B	5	Bob Allen Key, SW key S shore	11/31.9 25/27.9	2/29.0 -	22/35.2 -	18/37.3 -	18/41.7 -	28/39.4 -	20/39.9 -	17/41.3 -	20/41.0 -	10/35.2 -	28/34.2 -	20/32.4 -
D	11	Little Barnes Key, key NW of Barnes Key, NW point	11/33.8	2/33.5	22/39.0	19/39.6	18/42.5	28/36.2	21/38.7	17/40.7	20/41.3	10/38.1	28/37.0	21/37.7
D	S8	Lignumvitae Key W shore	-	-	-	-	-	28/38.8	-	-	-	-	-	-

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1967						
C	17	Murray Key, S shore	18/34.4	-	-	12/38.3	-	-	21/38.2	-	-	17/35.9	-	-
C	9	Pelican Key, N key, W shore	-	-	-	12/42.4	-	-	20/35.1	-	-	17/33.5	-	-
C	16	Dildo Key Bank, 0.5 naut. miles N of Johnson Key, edge of bank	-	16/36.9	23/38.4	19/42.3	19/43.0	29/35.8	21/37.0	18/40.6	21/41.0	17/35.0	29/35.2	21/34.1
C	15	Johnson Key, W shore	18/34.5	16/36.9	23/38.1	19/41.8	19/43.0	29/35.5	21/37.0	18/40.1	21/40.9	17/35.1	29/35.4	21/33.6
C	14	Man-of-War Lake, 1 n. m. W of Johnson Key	-	16/36.9	23/37.4	19/41.8	19/42.9	29/37.3	21/37.5	18/39.8	21/40.3	17/36.2	29/34.1	21/33.8
C	S37	Rabbit Key Basin, 3 n. m. W of Rabbit Key	-	-	-	19/40.3	-	-	-	-	-	-	-	-
C	13	Rabbit Key Bank, on bank, E end of pass	-	2/35.0	22/39.1	19/39.3	19/44.8	29/36.8	21/37.6	17/40.1	21/43.0	17/37.1	29/37.7	21/36.0
M	18	Boot Key Bridge, E end of bridge	5/36.3 -	1/37.3 -	8/37.1 -	5/37.6 -	4/39.4 -	20/35.7 -	12/38.7 -	9/37.6 -	6/38.9 13/39.0	12/35.1 -	14/36.2 -	13/36.3 -
L	S38	Ohio-Missouri Channel, bridge	-	1/37.3	-	-	-	-	-	-	-	-	-	-
L	21	Riding Key, S shore	-	1/36.9	9/37.3	6/37.3	4/38.5	21/37.0	13/38.1	15/39.1	14/37.6	12/37.6	14/38.4	14/36.8
L	20	Raccoon Key, SW shore	-	1/37.6	9/37.5	6/38.2	4/39.3	21/37.0	13/38.8	15/38.2	14/38.7	12/36.9	14/38.4	14/36.7

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1967						
L	19	Costello Key, Kemp Channel S of Budd Keys, unnamed key, NE shore	12/36.7	1/37.3	9/37.3	6/37.3	4/40.0	21/36.2	13/37.8	15/38.3	14/38.3	12/35.8	14/39.0	14/37.1
L	S39	Knockemdown Key, E shore	12/36.8	1/37.8	-	-	-	-	-	-	-	-	-	-
								1968						
A	S3	Little Madeira Bay, key, W end of mouth	7/21.1 22/22.5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
A	S4	Black Betsy Key, largest key, E point	7/23.3 22/23.3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
A	1	Bob Key, E key, SE shore	17/26.4	-	-	-	-	-	-	-	-	-	-	-
A	2	Buttonwood Sound, S shore (Sunset Cove)	16/32.4	-	-	-	-	-	-	-	-	-	-	-
A	S5	Manatee Key, W key W shore	7/25.0 22/27.6	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
A	3	Cowpens Anchorage, SW shore	17/36.7	-	-	-	-	-	-	-	-	-	-	-
U	S6	Whale Harbor Channel, bridge center	29/33.7	28/32.3	29/35.3	27/35.2	27/33.5	25/29.4	25/34.8	23/36.9	-	-	-	-

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1968						
D	4	Shell Key, N shore	18/38.0	-	-	-	-	-	-	-	-	-	-	-
B	8	Dump Key, N key, N point	17/34.6	-	-	-	-	-	-	-	-	-	-	-
B	S40	Crocodile Dragover, in pass	-	-	-	-	23/31.4	-	-	-	-	-	-	-
B	7	Samphire Key, 3rd key from S, W shore	17/32.1	-	-	-	-	-	-	-	-	-	-	-
B	6	Russell Key, W shore	17/27.8	-	-	-	-	-	-	-	-	-	-	-
B	S41	Whipray Channel, in pass	-	-	-	-	23/35.3	-	-	-	-	-	-	-
B	10	Spy Key, W shore	18/36.2	-	-	-	-	-	-	-	-	-	-	-
B	5	Bob Allen Key, SW key, SW shore	18/33.7	-	-	-	-	-	-	-	-	-	-	-
D	11	Little Barnes Key, key NW of Barnes Key, NW point	18/36.6	-	-	-	-	-	-	-	-	-	-	-
C	17	Murray Key, S shore	18/35.4	-	-	-	-	-	-	-	-	-	-	-
C	9	Pelican Key, N key, W shore	17/35.0	-	-	-	-	-	-	-	-	-	-	-

Appendix I. — Continued.

Location	Station No.	Name, Sample Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
								1968						
C	16	Dildo Key Bank, 0.5 n. mi. N of Johnson Key, edge of bank	18/35.4	-	-	-	-	-	-	-	-	-	-	-
C	15	Johnson Key, W shore	18/35.4	-	-	-	-	-	-	-	-	-	-	-
C	14	Man-of-War Lake, 1 n. mi. W of Johnson Key	18/35.6	-	-	-	-	-	-	-	-	-	-	-
C	13	Rabbit Key Bank, on bank, E end of pass	18/35.9	-	-	-	-	-	-	-	-	-	-	-
M	18	Boot Key Bridge, E end of bridge	11/37.2	-	-	-	-	-	-	-	-	-	-	-
L	21	Riding Key, S shore	11/38.0	-	-	-	-	-	-	-	-	-	-	-
L	20	Raccoon Key, SW shore	11/38.4	-	-	-	-	-	-	-	-	-	-	-
L	19	Costello Key, Kemp Channel S of Budd Keys, unnamed key, NE shore	11/38.4	-	-	-	-	-	-	-	-	-	-	-
								1969						
B	S42	Coon Key, N key, W shore	-	6/24.0	-	-	-	-	-	-	-	-	-	-

1/ Station locations: A = eastern bay; B = central bay; C = western bay; D = southern bay; U = Upper Keys, Florida Straits side; M = Middle Keys, Florida Straits side; L = Lower Keys. Station numbers preceded by "S" represent stations other than those which were sampled regularly for *Penaeus duorarum* from January 1967 to January 1968, which have no prefix. For locations of "S" stations, see Appendix III; for stations with no "S", see Figure 4.

2/ No data.

3/ 29/44.0 indicates day of month/salinity.

Appendix II. — Catches[1/] of Penaeus duorarum by station, size, and month, Florida Bay area, January 1967-1968. For station locations, see Table 1 and Figure 4.

Station Name	Station No.	Shrimp sizes mm [2/]	Number of P. duorarum: Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
Bob Key	1	16-25	0	0	0	0	0	0	0	0	0	0	0	0	0
		26-45	0	0	0	0	0	0	0	0	0	0	0	0	0
		46-112	0	0	0	0	0	0	0	0	0	0.2	0	0	0.1
	Total	16-112	0	0	0	0	0	0	0	0	0	0.2	0	0	0.1
Buttonwood Sound	2	16-25	0	0	0	0	0	0	0	0	0	0	0	0	0
		26-45	0	0	0	0	0	0	0	0	0	0	0	0	0
		46-112	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	16-112	0	0	0	0	0	0	0	0	0	0	0	0	0
Cowpens Anchorage	3	16-25	[3/]-	0	0	0	0	0	0	0	0	0	0	0	0
		26-45	-	0	0	0	0	0	0	0	0	0	0	0	0
		46-112	-	0	0	0	0	0	0	0	0	0	0	0	0
	Total	16-112	-	0	0	0	0	0	0	0	0	0	0	0	0

See footnotes at end of table.

Appendix II. — Continued.

Station Name	No.	Shrimp sizes mm	Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
			Number of *P. duorarum*												
Shell Key	4	16-25	-	0.1	0	0	0	1	0	0	0.1	0.2	0	0	0
		26-45	-	0	0	0	0.1	0.1	0	0.1	0.6	0.2	0	0	0
		46-112	-	0.1	0	0	0	0	0	0	0.3	0.4	0	0.1	
	Total	16-112	-	0.2	0	0	0.1	0.2	0	0.1	1.0	0.8	0	0.1	0
Bob Allen Key	5	16-25	0.2	0	0.1	0	0	0	0	0.3	0.2	0.7	0.3	0.2	0
		26-45	1.3	0.5	0.3	0.1	0	0.2	0.1	0.2	0.8	1.0	1.3	0.2	0.5
		46-112	0.5	0.2	0	0.3	0	0	0.1	0	0	0	0	0	0.1
	Total	16-112	2.2	0.7	0.3	0.3	0	0.2	0.2	0.4	0.9	1.7	1.6	0.3	0.6
Russell Key	6	16-25	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0
		26-45	0	0	0	0	0	0	0.1	0	0.3	0	0.2	0	0
		46-112	0	0	0.2	0	0	0	0	0	0.1	0.1	0.4	0.1	0
	Total	16-112	0	0	0.2	0	0	0	0.1	0	0.4	0.2	0.6	0.1	0

Appendix II. — Continued.

Station Name	Station No.	Shrimp sizes mm	Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
			Number of *P. duorarum*												
Samphire Key	7	16-25	-	0	0	0	0	0	0	0	0.2	0.1	0	0.2	0.2
		26-45	-	0	0	0	0	0	0	0	0.5	0.3	0.6	0	0
		46-112	-	0.3	0.2	0.2	0	0	0	0	0.1	0.3	0.2	0.2	0.2
	Total	16-112	-	0.3	0.2	0.2	0	0	0	0	0.8	0.7	0.7	0.3	0.3
Dump Key	8	16-25	-	-	-	0	-	-	0	-	-	0	-	-	0.1
		26-45	-	-	-	0	-	-	0	-	-	0.4	-	-	0
		46-112	-	-	-	0	-	-	0	-	-	0.3	-	-	0
	Total	16-112	-	-	-	0	-	-	0	-	-	0.8	-	-	0.1
Pelican Key	9	16-25	-	-	-	0	-	-	0	-	-	0.2	-	-	0.7
		26-45	-	-	-	0.3	-	-	0.7	-	-	0.7	-	-	1.4
		46-112	-	-	-	0.6	-	-	1.3	-	-	0.3	-	-	0.4
		16-112	-	-	-	0.9	-	-	2.0	-	-	1.2	-	-	2.5

Appendix II. — Continued.

Station Name	No.	Shrimp sizes mm	Number of *P. duorarum* Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
Spy Key	10	16-25	0	0	0.1	0	0	0	0	0.3	0	0	0.2	0	0.1
		26-45	0.1	0.1	0.3	0.2	0	0	0	0	0	0	0.3	0.1	0.2
		46-112	0.1	0.1	0.1	0.1	0	0	0.1	0	0	0	0.2	0	0
	Total	16-112	0.2	0.2	0.4	0.3	0	0	0.1	0.3	0	0	0.6	0.1	0.3
Little Barnes Key (*Halodule*)	11	16-25	0	0.5	0.3	0	0	0.2	0	5.7	1.0	0.6	0.8	0.7	0.2
		26-45	1.7	5.0	0.3	0.2	0.2	0.5	0.3	0.8	4.5	2.7	4.3	2.2	0.8
		46-112	1.7	1.0	0.4	0.3	0.2	0.5	1.2	0.2	1.3	0.7	1.1	0.2	0
	Total	16-112	3.3	6.5	1.0	0.5	0.3	1.4	1.5	6.7	6.8	3.9	6.3	3.0	1.0
Little Barnes Key (*Thalassia*)	12	16-25	0	0	0	0	0	0	0	0.8	0.2	0	0	0	0
		26-45	0.3	0	0	0	0	0.1	0	0.2	1.5	0.5	0.2	1.2	0
		46-112	1.0	0	0	0	0.2	0	0.2	0	0	0	0	0.5	0.1
	Total	16-112	1.3	0	0	0	0.2	0.1	0.2	1.0	1.7	0.5	0.2	1.7	0.1

Appendix II. — Continued.

Station Name	No.	Shrimp sizes mm	Number of *P. duorarum* Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
Rabbit Key Bank	13	16-25	-	0	0	0	0	0	0	0.1	0.2	0	0	0	0
		26-45	-	0	0	0	0	0	0	0	0.1	0	0	0.2	0
		46-112	-	0	0	0	0	0	0	0	0	0.1	0	0	0
	Total	16-112	-	0	0	0	0	0	0	0.1	0.3	0.1	0	0.2	0
Man-of-War Lake	14	16-25	0	0	0	0	0	0	0	0.2	0.1	0.1	0.3	0.1	0
		26-45	0	0.3	0.3	0.1	0	0.1	0	0	0.3	0.2	0.8	0	0
		46-112	0.2	0.2	0	0.8	0	0	0	0	0	0.2	0.7	0.1	0
	Total	16-112	0.2	0.5	0.3	0.8	0	0.1	0	0.2	0.3	0.4	1.8	0.2	0
Johnson Key	15	16-25	0.3	0.3	0.4	0	0.5	0.8	0	3.1	1.9	1.2	4.3	4.1	0.3
		26-45	2.3	1.0	0.8	0.8	0.3	0.5	1.8	0.8	3.1	4.6	3.6	2.7	2.6
		46-112	3.5	1.3	0.6	1.0	0.1	0.3	0.4	0.6	0.5	2.1	2.2	0.8	0.8
	Total	16-112	6.1	2.6	1.8	1.8	0.9	1.5	2.3	4.5	5.5	7.8	10.0	7.6	3.6

Appendix II. — Continued.

Station Name	Station No.	Shrimp sizes mm	Number of *P. duorarum* Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
Dildo Key Bank	16	16-25	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0
		26-45	0	0	0	0.5	0	0	0	0	0.4	0.2	0	0	0
		46-112	0	0	0	0.3	0	0.1	0	0	0	0.2	0	0.1	0.1
	Total	16-112	0	0	0	0.8	0	0.1	0	0.1	0.5	0.3	0	0.1	0.1
Murray Key	17	16-25	0	-	-	0	-	-	0.7	-	-	0.1	-	-	[4] +
		26-45	0	-	-	0	-	-	0.1	-	-	0.7	-	-	+
		46-112	0	-	-	0	-	-	0	-	-	0	-	-	+
	Total	16-112	0	-	-	0	-	-	0.8	-	-	0.8	-	-	+
Boot Key Bridge	18	16-25	0.2	0.3	0.1	0.2	0	1.2	0.8	2.0	0.6	0.6	0.4	0.1	0.3
		26-45	1.6	1.5	1.3	0.6	0	0.9	1.1	2.0	1.1	1.8	1.5	0.9	0.9
		46-112	0.6	0.8	0.3	0.1	0	0	0.3	1.8	0	1.7	0.8	0.9	0.3
	Total	16-112	2.3	2.6	1.8	0.8	0	2.1	2.1	5.8	1.7	4.1	2.7	1.9	1.6

Appendix II. — Continued.

Station Name	No.	Shrimp sizes mm	Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
			Number of *P. duorarum*												
Costello Key	19	16-25	0.1	0.1	0	0	0	0	0.2	0.7	0.3	0	0.1	0	0
		26-45	0.2	0.1	0	0	0	0.3	0	0.3	0.2	0.3	0.1	0	0
		46-112	0	0	0	0	0	0.1	0.1	0	0	0.1	0	0	0
	Total	16-112	0.3	0.2	0	0	0	0.4	0.3	1.0	0.4	0.3	0.2	0	0
Raccoon Key	20	16-25	-	0.1	0.2	0	0.2	0.3	0	1.2	0.8	0.7	0.1	0.1	0
		26-45	-	0.2	0.2	0	0	0.5	0.2	0.7	0.6	0.6	0.4	0.2	0
		46-112	-	0	0.2	0	0	0.1	0	0.2	0.3	0	0	0	0
	Total	16-112	-	0.3	0.5	0	0.2	0.9	0.2	2.0	1.7	1.3	0.5	0.3	0
Riding Key	21	16-25	-	0.1	0	0	0.1	0.2	0	0.2	0.4	0.3	0	0	0
		26-45	-	0.3	0.2	0.3	0	0.3	0	0	0.8	0.4	0	0.1	0
		46-112	-	0.3	0	0.2	0	0.1	0	0	0.2	0	0.2	0.1	0
	Total	16-112	-	0.6	0.2	0.4	0.1	0.6	0	0.2	1.3	0.7	0.2	0.2	0

Appendix II. — Continued.

Station Name	Station No.	Shrimp sizes mm	Jan 1967	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1968
			Number of *P. duorarum*												
Palm Key Lake	22	16-25	-	-	-	-	-	-	-	-	-	5/x	-	-	-
		26-45	-	-	-	-	-	-	-	-	-	x	-	-	-
		46-112	-	-	-	-	-	-	-	-	-	x	-	-	-
	Total	16-112	-	-	-	-	-	-	-	-	-	6.3	-	-	-

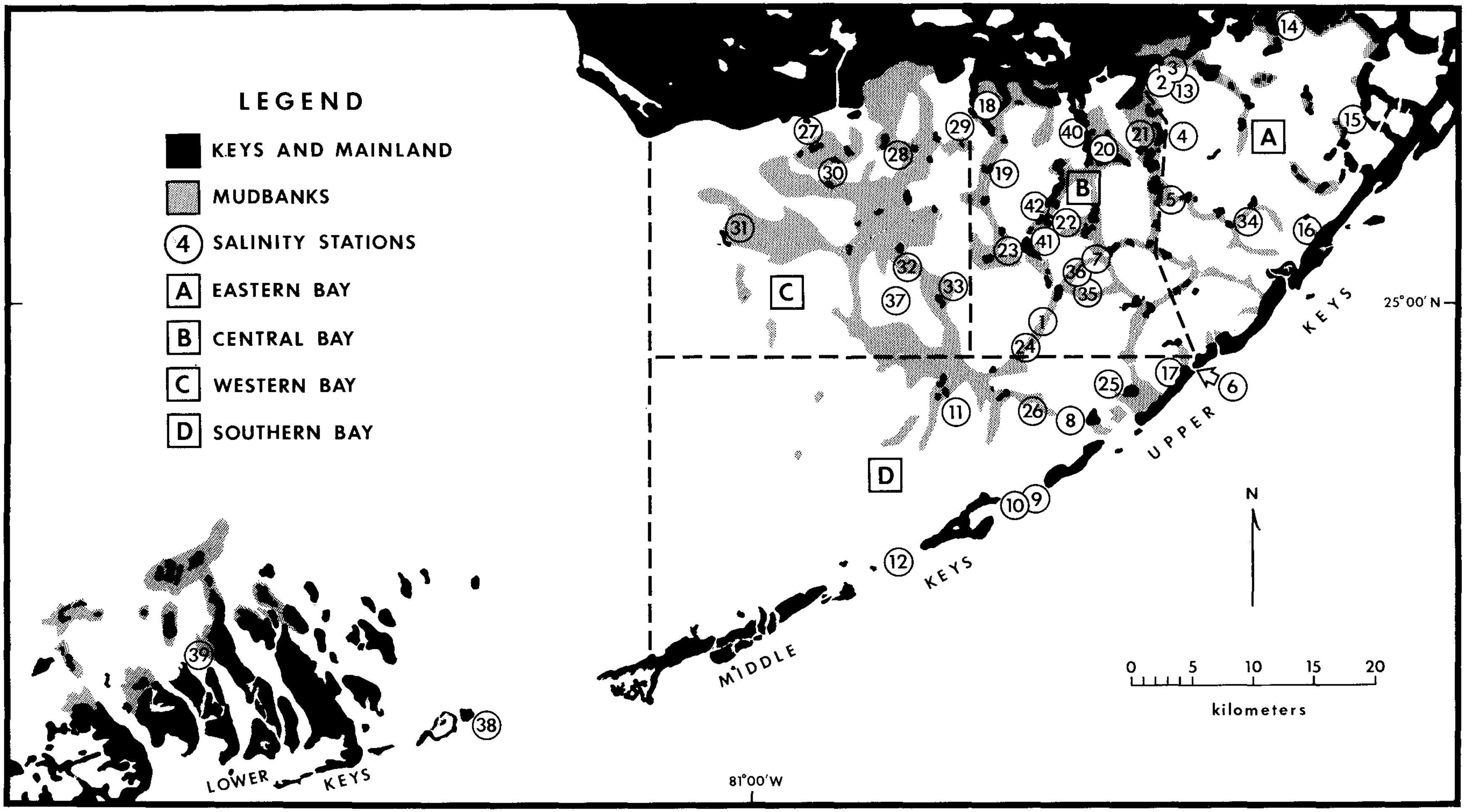
1/ Shrimp/m^2, reduced from 12 m^2 samples by slednet. Catches of shrimp less than 16 mm total length not included because this size group is not retained by slednet mesh in proportion to abundance. Monthly columns may not add up to totals due to rounding.

2/ Total length.

3/ No samples scheduled.

4/ No sample taken, station was dry.

5/ No breakdown by size groups available, size was 16-50 mm.



Appendix III.— Approximate location of salinity stations, Florida Bay area, 1963-69. For specific sites, see Appendix I, station numbers with "S" prefix.