PRC -2OG Wie. Wo Gre Some Prapeets of the Eamreer OL Aye eres WATER stems IN the UPPER ESPIRITU BROTD Rwee Ar ex verte, PE Toney UiLRqeiL Av RG. CLEMENT ---Page Break--- SOME ASPECTS OF THE ECOLOGY OF THE FRESHWATER CURDS IN THE UPPER ESPIRITU BAJO RIVER: AND EL VERDE, PUERTO RICO Johnny Villani and Richard G. Clement2 Terrestrial Ecology Division PUERTO RICO NUCLEAR CENTER Operated By UNIVERSITY OF PUERTO RICO For the U.S. ENERGY RESEARCH (AND) DEVELOPMENT ADMINISTRATION ---Page Break--- A direct survey was performed in the upper Espiritu to collect, identify, and trace the distribution of the shrimp fauna. The species encountered were Atya lanipes, Xiphocaris elongata, Macrobrachium heterochirus, and Atya innocous. Selected physical and chemical characteristics of the stream were measured to describe the habitat of each species and their effect on the distribution. The physical parameters which affected habitat selection and distribution were water flow, substrate type, and elevation. No apparent relationship was found between the chemical characteristics and the distribution. The ecology of the species encountered was described. Intraspecific differences in habitat selection were observed in Atya lanipes. Preference for sunlit areas in low-flow conditions and gravel substrate were observed for Xiphocaris elongata. Macrobrachium heterochirus was observed in shaded areas, residing under rocks and low-flow conditions. Selected anatomical characteristics were measured for Atya lanipes and Xiphocaris elongata. Size differences were found between sexes in Atya lanipes and Xiphocaris elongata. The division of the genus Xiphocaris into three species using a criterion of length of rostrum was found to be related to development. ---Page Break--- TABLE OF CONTENTS Part Research The Study Area ~ 5 Objectives of the Project ~ 9 Methods Zonification of the River ~ 9 Field and Laboratory Techniques RESULTS AND DISCUSSION Introduction Species Found in the Study Area Distribution Ecology of the

Species Found ~ Selected Physical Characteristics of the Species Physical Characteristics of the Study Area ~ Chemical Characteristics of the Study Area ~ SUMMARY ~ LITERATURE CITED ---Page Break--- Table 6 LIST OF TABLES AND FIGURES Both Particle Size Classification - Location, Elevation, and Site Description of the Survey Stations at the Upper Espiritu Santo ~ 25 Zonal Distribution of the Species Number of Individuals Captured in the Collecting Average Size of the Individuals Captured Each Collecting Site Subject: Amount of Particulate Matter in the Five Zones of the River Espiritu Santo ~ Chemical Data of the Sampling Stations ~ Espiritu Santo Drainage Basin ~ Study Area ~ Bones at the Upper Espiritu Santo Diagrammatic Sketch of a Typical Pool showing the Zonation Used in the Survey Collecting Stations - 16 Patterns of Water Flow and Substrate Distribution in a Typical Pool and Their Relationship to Atys Janipes Habitat Selection ~ Species Zonation at the Espiritu Santo Atya lanipes Histogram Atya lanipes Population Histogram Divided by Sex ~ 39 ---Page Break--- Cont. List of Tables and Figures - 1. Xiphocaris elongata Histogram No. Xiphocaris elongata Population Histogram Divided by Sex IP. Carapace vs. Rostrum, Xiphocaris elongata Appendix Page No. Scatter diagram showing correlation of the proportionate length of the rostrum with growth in specimens of X. elongata IG = Table 1, Family Atyidae, Key to Species abi X. Atya Macrobrachium, Key to Meet Traian ---Page Break--- Introduction Although palaemonid and atyid shrimp are common in both fresh and brackish waters in Puerto Rico, little is known of their biology. Gundlach (1887) was the first to report some of the species of shrimp in Puerto Rico. He concentrated on the identification of many species as possible comparing them to collections from Cuba. Species identified by Gundlach included Xiphocaris elongata, Atya lanipes, Macrobrachium carcinus, and others. In 1935, Schmidt in the Scientific Survey of Puerto Rico and the Virgin Islands reported the presence of

Macrobrachium schmitti, M. carcinus (as M. jamaicensis), E. faustinum (as M. olfersii), Xiphocaris elongata, Atya scabra, A. innocous (as A. occidentalis), and Micratya poeyi. In addition to the species reported by Gundlach (1887) and Schmidt (1935), Chace and Hobbs (1969) reported the presence in Puerto Rico of Macrobrachium heterochirus. The work by Chace and Hobbs (1969) has become the standard reference for decapods in the West Indies. Prior knowledge suggested that these animals formed an important but little-studied element of the rainforest ecosystem. Much of the work on the biology of shrimps has been limited to the genus Macrobrachium, because of its commercial potential. The life cycle of Macrobrachium carcinus has been studied by Lewis et al. (1966). Gravid females were obtained between May and October, larval development appears to take place normally in brackish water. Artificial cultivation of M. acanthurus cannot be kept for long periods of time in small aerated aquaria, because of their cannibalistic nature which leads them to attack the newly molted individuals. Molting, under artificial conditions, took place about every two weeks in young, rapidly growing animals. Although M. acanthurus appears to be tolerant of relatively high temperatures, it is sensitive to cold. As temperature approaches 50°F, the shrimp appear sluggish and become debilitated, and below 50°F, death occurs in one to three days. Culture studies on Macrobrachium acanthurus and M. carcinus have been done by Dungen and Franks (1972). Macrobrachium larvae were reared in gradually increasing salinities and in constant salinities of 14, 16, and 20 ppt. In both species, the best survival (36%) was achieved when salinity reached 16 ppt. Feeding studies have been made by Sickle et al. (1973). Several experiments revealed that ingestion rates of penaeid juveniles are indirectly proportional to both size (on a unit weight basis) and the length of exposure to the same food, directly proportional to light intensity, and

independent of the percentage of fed biomass. Information on the reproductive cycle of the decapods is very meager. Erdman (1972) reported the presence of gravid females of Macrobrachium carcinus in the Maricao River and in the Yunque River in northeastern Puerto Rico, in the period from May to November. Little is known about the biology of atyid shrimps. Most of the work done to date has dealt with the description and distribution of the species in the Caribbean area. Hart (1961) studied the freshwater shrimps of Jamaica and Chace and Hobbs (1969) reported on the West Indies species with special reference to Dominica. The presence of some atyid species in Puerto Rico was reported by Gundlach (1887) and further described by Schmidt (1939) and Erdman (1972). One of the few works on the biology of the Atyidae shrimps was made by Hunte (1975). Hunte worked with Atya lanipes in Jamaica including in his work taxonomic notes and a description of the first larval stage. Hunte describes the habitat of Atya lanipes as living in freshwater where the rate of water flow was high and a stony bottom substrate. Chace and Hobbs (1969) reported the presence of A. lanipes from Puerto Rico in the collections of the U.S. National Museum and stated that the Puerto Rican materials "agreed well" with the type description except for a variation in the amount of pubescence on the last three pereiopods. However, more recently, Chace (1972, as cited by Hunte, 1975) confirmed that some of the Puerto Rican specimens did indeed show marked differences from the type description. It must be appreciated that either A. lanipes is an unusually variable species or represents a complex of races or subspecies affected by different environmental factors. The limnological studies conducted in Jamaica and Puerto Rico by Hart (1964) showed that the total hardness of the water in the El Yunque area was low compared with that of Jamaica. This difference resulted in carapaces that were extremely thin and fragile when compared with

those of Jamaica. This can make a difference in the biology of the species of Puerto Rico related to those of Jamaica. Clutter and Cole (1970) of the University of West Florida studied certain aspects of the biology and distribution of freshwater decapods in the streams of the Caribbean National

Forest near El Verde, Puerto Rico. Their major goals were to make exploratory surveys of the decapod crustaceans of the El Verde area, to correlate their distribution with various ecological factors, and to determine the major stresses imposed by the environment. The species of shrimps Atya lanipes, A. scabra, Micratya poeyi, Xiphocaris elongata, and Macrobrachium carcinus were studied. Their survey took place on the Sonadora and Espiritu Santo Rivers. The species found in the area were Atya innocous, A. lanipes. The distribution of Atya innocous in the study area indicates that the animals tend to favor the slower-flowing streams. Eggleton (1939) emphasized that one of the most far-reaching environmental factors, indeed the most characteristic and powerful one, in lotic communities is water flow. Either directly or indirectly, it profoundly affects the biotic assemblages of the streams. Atya lanipes was found in every stream where shrimp were present. It appears to be the dominant aquatic crustacean fauna and is probably the single most important species for the recycling of detritus. Atya lanipes is interesting because they are found where apparently A. innocous and nutrients washed into the streams. The distribution of cannot live. ---Page Break--- Atya scabra appears to be the most ecologically restricted and most specialized member of the crustacean fauna of the area. The females were collected only from rocky riffles and the males only from crevices between rocks over which a fast current was flowing. Micratya poeyi is the smallest decapod found in the streams. Possession of tufted pereiopods indicates filter feeding. Xiphocaris elongata was ubiquitous in the Gifford and Cole study area. It was never more numerous than Atya lanipes, but contributed significantly to the

Biomass of the aquatic habitat. Preference to unit areas was noticed which made the animal visible during the day. Its feeding habits were not observed; since the feeding tufts are not present on the first pair of pereopods, a particle-picking mode of feeding is implicated. S. brachium carcinus were collected by trap from the larger streams. Their apparent feeding pattern seems to lie in wait for their food to pass. To date, the work of Gifford and Cole (1972) is the most important work that has been done on the ecology of the freshwater shrimps of Puerto Rico and provides some information on the distribution and physiological adaptations of the shrimps.

The Study Area

The study area is the forested component of the Espiritu Santo Drainage basin (see Fig. 1). It is approximately 1200 acres in extent. The area contains the headwaters of the upper Espiritu Santo River and many feeder brooks that drain into the main river channel (see Fig. 2). The drainage pattern is dendritic. The geological material underlying this forested area has been described by Seiders (1961) and consists of three principal geologic formations. These are the Quartz Diorite and Diorite, the Hato Puerto, and the Tabanico. The Quartz Diorite and Diorite formation is of Paleocene origin and the residual soil formed is sandy. This geologic base is restricted to the upper headwater region of the river (750 meters and above approximately). The Hato Puerto formation is of upper Cretaceous origin and consists of massive tuffs and volcanic breccias. The dominant geologic formation consists of dark grey mudstones and volcanic sandstones of the lower Cretaceous period. The north branch of the headwater originates in this formation. The Tabanico formation is composed of dark grey mudstones and volcanic sandstones of the lower Cretaceous. Three forest associations of the area have been described for the area; namely, Dwarf, Palm breaks, and Palo colorado (Wadsworth, 1952). The Dart

Forest association is restricted to the ridges above the 750 meters of elevation. The Palm break association is found on extremely steep slopes and along banks of the headwater system and some feeder brooks. The Palo Colorado association is the dominant vegetation type throughout the study area.

The annual rainfall in the study area ranges from 75 inches to 150 inches (Odum, 1970). The objectives of the study were: 1. To identify and determine the distribution of the shrimps in the upper Espiritu Santo River. 2. To study the relationship between the distribution of each species and various physical chemical factors. 3. To determine and describe the habitat of each species. 4. To measure, describe and compare selected physical 'attributes' of individuals within and among species.

Methods: The upper Espiritu Santo river was divided into five zones (fig. 3) according to differences in topography and preliminary field observations. Preliminary surveys suggested that because of high stream velocities in the rapids, none of the decapods were present. Therefore, pools were selected to study the distribution of shrimps in the river system. A typical pool can be subdivided into three areas based on water flow rates. These areas are 1) low flow, 2) high flow, and 3) riffle (See Fig. 4). On this basis, three representative pools were selected in each zone to study the species present, to measure selected physical and chemical variables and describe the habitat. The only variation to the schema presented in Figure 4 occurred in zone 1 in which riffles were kept in the water for about 24 hours. Each pool was surveyed

by skin diving to record observations on the species present, behavior, and habitat preference of the shrimps. The captured individuals were taken to the laboratory at El Verde Experimental Field Station for identification, according to the key of

Chace and Hobbs (1969). Habitat description was based upon the measurement of selected physical and chemical variables. Chemical variables measured included in situ measurements of dissolved oxygen, temperature, pH, and free carbon dioxide. Water samples were taken at each collecting site and stored in polyethylene bottles for subsequent measurements of iron, carbonate, phosphate, sulfate, salinity, sodium, magnesium, calcium, and potassium. The physical variables included elevation, water flow, substrate analysis, visibility, water depth, and the amount of particles drifting in the water. All measurements and samples were taken only once at each station and under base flow conditions. The following methods and/or instruments were used for the determination of the parameters mentioned above. Chloride and pH measurement were determined using an Orion Specific Ion meter Model Yok with the appropriate electrodes. Chloride measurements were converted to salinity values by multiplying chloride concentration by 1.65 according to the procedure given in Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971. Temperature and dissolved oxygen were determined in situ using a YSI Dissolved Oxygen Meter. Free carbon dioxide was determined by the titrimetric method given in Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971. A Hach spectrometer, model DR/2, was used for the determination of carbonate, iron, phosphate, and sulfate. Concentrations of calcium, magnesium, sodium, and potassium were determined by atomic absorption methods. Water flow was measured with a General Oceanics Digital Flow Meter model O1WK9. The amount of drifting particles in the water was measured with the use of a plankton net (size 25) and the flow meter on the five zones. Visibility was measured with a Secchi disk of 19 cm in diameter, and water depth was measured with a nylon string with a lead weight, divided in meters. A substrate analysis was performed for each river.

one. This analysis was conducted according to the procedures set forth in Biological field and laboratory methods for measuring the quality of surface waters by the FFA (1973), using U.S.

standard sieves number 10, 35, 120 and 230. The soil particle size classification was as established in Table 1.

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Table 1. Soil Particle Size Classification
Particle Size Name Size (mm) Sieve Series #
Boulder 256+
Cobble 64-256
Coarse gravel 32-64
Medium gravel 8-32
Fine gravel 2-8
Coarse sand 0.5-2
Medium sand 0.25-0.5
Fine sand 0.125-0.25
Very fine sand 0.0625-0.125
Silt 0.0039-0.0625
Centrifuge (750 rpm)
Clay 0-0.0039
Evaporate and weigh residue

Results and Discussion

The study area was divided into five zones based upon differences in topography and preliminary field observations. A brief description of each zone is given in the following paragraphs and some of the important characteristics are summarized in Table 2.

Zone 1: This zone comprises the headwaters region of the Espiritu Santo River (see Fig. 5). It consists of a complex network of

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approximately 20 feeder brooks that join together on an upland plain at 750 meters of elevation to form the Espiritu Santo River. The Palm break association is dominant throughout the area and especially near the drainage ways. The residual soils grade from sandy loams to sands. The pools of this zone are very shallow with an average depth of 0.33 meters (see Table 2). The average flow rate under base flow conditions varies from about 5 cm/sec to 10-15 cm/sec in areas of higher currents. In the feeder brooks, the flow rates are hardly detectable (less than 5 cm/sec). The results of the substrate analysis showed that the bottoms of the two pools sampled are dominated by sand fractions; 84.5 and 91 percent (see Table 7). Zone

2. The area set aside as zone 2 is that area embracing what has been identified as the North Fork of the headwaters (see Figure). The stream originates in a cave at 820 m elevation. Above this elevation, the stream apparently flows underground and drains the west slopes of Mount Britton and El Yunque. Unlike zone 1, Palo Colorado association is the dominant vegetation of the area. The stream bed consists of boulders and rubble. The substrate analysis of two pools in this zone (see Table 1) showed that the gravel fraction comprised 50 percent or more of the bottom. The pools in this zone are generally shallow and do not exceed 1 meter in depth. Flow rates were found

essentially the same as those in zone 1 (see Table 2).

Zone 3. The upper limits of this zone begin at the confluence of two streams emanating from zones 1 and 2 (elev. 750 m) and extend downstream to an elevation of 700 m (see Fig. 5). The Palo Colorado association dominates the gentle slopes of this area. The stream bed is composed mainly of large boulders. The substrate analysis of two pools in this zone showed that 70-80 percent of the bottom sediment is gravel size (see Table 7). The largest pools encountered in the study area are found in this zone with depths ranging from 1 to 3 meters (see Table 2). In the more quiet areas of the pools studied, flow rates of 10 cm/sec were recorded increasing to 20 cm/sec in high flow areas. The flow rates in the riffle areas were the highest recorded in association with the pools studied and varied between 80-85 cm/sec (Table 2).

Zone 4. The area between an elevation of 700 meters and 550 meters comprises zone 4 (see Figure 5). It is an area of steep slopes which produce high stream velocities thus reducing the amount of fine sediments in the stream bed. However, the substrate analysis (Table 7) suggests that the pools studied in this zone are similar to those of Zone 3. The deepest pools are found in this area with depths ranging from 2 to 5 meters (Table 7). Water flow rates in the

Slow-moving areas of the pools were approximately one-half of the values for the same areas in the pools of Zone 3, while flow rates in the high flow areas were similar. Flow rates in the area of riffles were about one-fifth of those in Zone 3. The Palo Colorado Zone 5 (see Fig. 5) begins at an elevation of 550 meters and extends downstream to the Forest Service Road (elevation 500m). The vegetation cover of the zone is the Palo Colorado association. While large pools characterize the zones, the depths are shallow, ranging from 0.3 to 1 meter. Large boulders are common throughout the streambed. The gravel fraction is dominant in the sediments (see Table 7). Water flow rates in the high flow areas of the pools (20 cm/sec) were similar to those found in Zones 3 and 4. In the area of riffles, average flow rates of 60 cm/sec were intermediate to those found in Zones 3 and 4 (see Table 2). The selection of sampling sites had to be modified in some cases because the pools available did not contain areas of low flow, high flow, and riffle. Under these circumstances, the sampling site was established either upstream or downstream from the pool. The deviations from the typical pool schema (see Fig. 4) occurred in Zones 1 and 2. The locations and identification of the collecting sites are presented in Figure 5. The individuals identified were collected during the period of early October to mid-December. All the species present in the upper Espíritu Santo River were collected, and a labeled reference collection was established at El Verde Field Station. The species identities were: Order Decapoda Suborder: Natantia Section: Caridea Family: Atyidae 1. Atya lanipes 2. Atya innocous 3. Xiphocaris elongata Family: Palaemonidae 4. Macrobrachium heterochirus Each captured individual was identified using Chace and Hobbs' key for family Atyidae and genus Macrobrachium (See Appendix 1 and 2). After being properly identified, the individuals were classified by sex.

and measured. The explanation of measurements: The carapace and rostrum length of Xiphocaris elongata was made according to the procedures used by Chace and Hobbs (1969). Carapace length was measured from the posterior-most margin of an orbital directly down the dorsal midline to the posterior-most edge of the carapace. Rostrum length was measured from the posterior-most part of the orbitals anteriorly to the tip of the rostrum. Atya lanipes, Atya innocous, and Macrobrachium heterochirus overall length were measured from the posterior-most margin of the orbital to the posterior-most part of the telson. This is an arbitrary measurement utilized to have uniformity of measuring techniques for all the species mentioned above. The usual method as described by Chace and Hobbs (1969) does not include the measurement to the telson; for the purpose of this study, the length to the telson was included.

The diagnosis of each species, the material examined, and occurrence are presented in the following paragraphs. The diagnosis is taken directly from Chace and Hobbs (1969).

Family Atyidae
Atya lanipes Holthuis, 1963
Type locality - Saint Thomas
Distribution - Puerto Rico and Saint Thomas; freshwater streams.
Diagnosis: "Orbital margin unarmed. Rostrum unarmed dorsally, lateral lobes represented only by very slight broadening of proximal half of rostrum, ventral margin armed with two or three teeth, not regularly serrate. Ventral margin of abdominal pleura unarmed. Basal segment of antennular peduncle without dorsal spines proximal to series bounding distal margin. Pereiopods bearing tufts of long hair, Carpus of second pereiopod broader than long. Last three pereiopods without the scales or tubercles. Merus, carpus, and propodus of third pereiopods not swollen, only slightly more robust than those of fourth pereiopod. Appendix masculina on second pleopod of male forming broad lobe bordered with slender curved spines. A moderately large species, maximum postorbital carapace length at least 28 mm!" Material

examined: A total of 73 individuals were examined. The total included 38 non-gravid females, 1 gravid female, and 34 males. Postorbital telson length for the non-gravid females ranged from 30.15 mm to 62.90 mm with an average of 41.18 mm. The length for the males ranged from 50.25 mm to 74.55 mm with an average of 61.87 mm. The gravid females measured 34.25 mm. Occurrence: Atya lanipes was found in all the areas studied with the exception of Zone 2 low flow B, Zone 3 low flow A, Zone 5 low flow A. Xiphocaris elongata (Guérin-Méneville), Hippolyte elongatus, Guérin-Méneville, 1855, Oplophorus americanus, De Saussure, 1858, Xiphocaris elongata, Von Martens, 1872, Xiphocaris gladiator, Pocock, 1889, Xiphocaris gladiator var. intermedi, Xiphocaris brevirostris, Pocock, 1889, Oplophorus elongatus, Sharp, 1893, Xiphocaris elongate, Chace and Hobbs, 1969. Type locality - Habana, Cuba. Distribution - Confined to the West Indian Islands; freshwater streams. Diagnosis: "Rostrum armed dorsally and ventrally, the former consisting of a series of small, subequal, closely-set teeth, while the latter comprised a fine serration. Ventral edges of abdominal pleura unarmed. Basal segment of antennular peduncle without dorsal spines proximal to those bordering distal margin. Exopods well-developed and present on all pereiopods. First and second pereiopods without terminal tufts of setae. Last three pereiopods without horny scales of tubercles or spines. Ambulatories all of approximately equal size and rather slender. Appendix masculina subcylindrical, armed distally with a row of moderately long spines, and shorter than appendix interna. Medium-sized species, maximum postorbital carapace length measured was 14.9 mm." Material examined: A total of 227 specimens were examined. This total included 117 non-gravid females and 95 males. Carapace length for the non-gravid females ranged from 9.50 mm to 15.90 mm with an average of 13.18 mm. The length for gravid females ranged from 10.55 mm to 25.40 mm.

Males carapace length ranged from 7.25 mm to 12.30 mm with an average of 10.73 mm. Occurrence: Kiphocaris elongata was encountered in almost all sampling sites with the exception of Zone 1 low flow A, B; high flow a, Zone 2 riffle 2, Zone 3, riffle 1, 2, 3, Zone 4 high flow b and riffle 2, 3; and Zone 5 riffle 1, 3. Family Palaemoninae Macrobrachium heterochirus Wiegmann, 1836 Palaemon heterochirus Wiegmann, 1836 Macrobrachium heterochirus Chace and Hobbs, 1969

Type locality - East coast of Mexico Distribution - Estado de Puebla, Mexico, and the West Indies to Estado de Sao Paulo, Brazil; fresh water. Diagnosis: Carapace with antennal and hepatic spines, without branchiostegal spine. Rostrum reaching anteriorly nearly or just as far as end of antennular peduncle. Dorsal margin sinuous, tip slightly upturned; armed with 10 to 13 dorsal and 2 to ventral teeth; posterior 5 to 6 teeth of dorsal series placed on carapace behind level of orbital margin, posterior 3 to 4 erect and more widely spaced than others. Eyes large, cornea well pigmented. Second pereiopods of adult male similar in form but unequal in length; fingers about two thirds as long as palm, meeting throughout their length without noticeably large teeth on opposable margins, each finger bearing numerous scattered spinules on exterior surfaces and short pubescence along cutting edges; palm only slightly compressed, three or more times as long as wide, provided with scattered spinules protruding from short pubescence, but without spiny crest along margin continuing from fingers; carpus about three-fourths as long as palm and as long as or longer than merus. Third pereiopod with propodus two or three times as long as dactyl. Color pattern characterized by dark transverse bands on abdominal tergites and dark borders on pleura. A medium-sized species, maximum postorbital carapace length about 3 cm Material examined: A total of 4 specimens were obtained, two

female (carapace lengths 30 mm - 45 mm) and two males (carapace lengths 38 mm - 59 mm) Occurrence: Zone 3 low flow A, B. Zone high flow A, Zone 5 downflow C. Atya innocous Herbst, 1792 Cancer (Astacus) innocous Herbst, 1792 Atya innocous Chace and Hobbs, 1969 Type locality - Martinique Distribution - Nicaragua to Panama and the West Indies fresh water streams. Diagnosis: flat junction of rostrum and carapace. If equidistant lines are drawn from the lateral most edge of the shoulders and the tip of the rostrum, when viewed dorsally, the angle at the intersection of these lines is obtuse. Ventral margins of abdominal pleura bear a row of small, sharp denticles, excepting the second segment which is unarmed. Basal segment of antennular peduncle without dorsal spines proximal to those bordering distal margin. No exopods present on any of the pereiopods. First and second pereiopods terminating in thick, wooly brushes of long setae. All ambulatory noticeably heavy and rough in appearance, bearing depressed horny scales. Appendix masculina of male (located on second pleopod) a broad, spinose lobe, extending to three quarters of the podites. Pre-anal carina shaped like a wide-bladed sickle, hooking toward anus, and pointing sharply pointed bluff in bend of hook. Two color phases, green and brown (for detailed description of these phases see Chace and Hobbs, 1969). Material examined: Only one specimen was obtained (carapace length 20 mm). The smallest size at which sex can be determined for females is around 4.5 mm carapace length, for males around 5.0 mm carapace length (Gifford and Cole, 1972). Note: Chace & Hobbs, (1969) found that the appendix masculina at this size is occasionally subequal in length to the appendix interna. This condition may persist until a carapace length of 6.2 mm is reached. The male appendage is a key diagnostic character for this species. Occurrence: Zone 5 riffle 2. Distribution of Species The distribution of the species captured and identified throughout

The study area is summarized in Table 3. The presence or absence of the species in a collecting site was confirmed by direct observations of the area by skin diving (and by trapping). Atya lanipes were found to be ubiquitous throughout the study area. (See Table 3). This species does not appear to be restricted by any physical and chemical parameters measured. The distribution of Xiphocaris elongata was found to be restricted by current and substrate. In Zone 1 (See Table 3) Xiphocaris were not found in most of the collecting sites because of the substrate composition. The effects of the substrate composition on the distribution of Xiphocaris will be discussed further. In riffles 1, 2, and 3 of Zone 3, there was a total absence of Xiphocaris. Their presence in this riffle was affected by high flow conditions. The average water flow of this riffle was 80 cm/sec. (See Table 2). In addition to water flow and substrate type, elevation appears to be a limiting factor in the distribution of species. Macrobrachium heterochirus and Atya innocous distribution appear to be restricted to lower elevations during the collecting period or are restricted to lower elevations all year round. The captured Macrobrachium were found to be restricted to low-flow areas in the low elevation zones of the study area (See Table 3). Ecology of the Species. The ecology of each species found in the upper Espiritu Santo will be discussed separately in the following paragraphs. Atya lanipes is the dominant element in the aquatic crustacean fauna because of

Its member and relative size compared to the majority of the decapod fauna is probably the single most important species for the recycling of detritus and nutrients washed into the stream (Gittoré and Cole, 1972). In a pool approximately 100 square feet, a minimum of 26 individuals were counted by Gittoré and Cole. Through skin-diving, an average of 25 individuals per square meter were counted over large boulders in riffle areas in the study area, filtering from the current. Atya lanipes individuals were present throughout the study area and no limiting factors for their distribution were observed. Intraspecific differences in the selection of habitat were observed. Sex exclusion in habitat preference was observed throughout the study area. These differences are based on the selection of water flow and substrate type conditions. Figure 6 represents a generalized schema of water-flow patterns, substrate conditions, and habitat preference of a typical pool in the study area. The distribution and/or deposition of materials is directly related to particle size and water velocity. Upon entry into a pool, the velocity is reduced and the larger particles settle first while the finer sediments settle in the areas of low velocities. Thus, Figure 6 illustrates areas of fast and slow current encountered in such a pool not only in the surface waters but also with depth (Fig. 6, b and e). These current patterns lead to a segregation and deposition of sediments as shown in Fig. 6, a and d. Based on the above, the individuals captured and observations made by skin diving, the habitat preferences of the males and females can be delineated. A. lanipes males were found to prefer high-flow and boulder substrate conditions in the pool (see Fig. 6, c and f). They are established on the sides of the pools, especially near the bank, sharing

habitat with Xiphocaris elongata, Macrobrachium heterochirus and fish, Sicydium plumieri. Filter feeding was observed for A. lanip. The method of feeding is to face into the current, preferably immediately below a riffle rest, then spread the bristles surrounding the fingers of the chelae of the first and second pereiopods. The presence of either conspecific or congeneric individuals does not seem to disturb this process. Also, it was observed that individuals feed by direct grazing on the algae covering the boulders. Xiphocaris elongata, the most important factors affecting the distribution and habitat preference of Xiphocaris are substrate type and water-flow. Xiphocaris were encountered in pools where the dominant substrate was gravel. In areas where the substrate is composed of more than 50% sand, Xiphocaris were not found. Preference for low-flow areas was noticed throughout the collecting sites. In fast-moving waters, more than 70 cm/sec, Xiphocaris were not found. Water depth does not appear to be a restriction to their vertical distribution in the water column. Individuals have been observed swimming in the deepest pools of the study area at some (see Table 2). Preference for sunlit areas was noticed in the majority of the stations where they were captured. The only feeding habit observed for Xiphocaris was particle picking using the first pair of pereiopods. The feeding habits were directly observed in each surveyed pool by skin diving. Gravid females of Xiphocaris elongata were encountered throughout the period of May to November. Also, Xiphocaris females that have released their larvae have been found throughout the study area. Macrobrachium heterochirus, the individuals were captured in high-flow pools and pools very near riffles. These pools were deep (approx. 4-5 feet) and in shaded areas, and spaces under rocks or in small

caves. Chace and Hobbs (1969) found that heterochirus are restricted to riffle and low cascades, sharing the habitat with Atya scabra. The shrimp is a rapid swimmer, speeding either up or downstream. The shrimp was not captured or observed above the 650 m in the study area. Chace and Hobbs (1969) did not find the shrimp at elevations higher than 800 meters in Dominica, perhaps due to lack of water in the dry season. The individuals observed in this study were captured during the rainy season, and it appears that this is the highest altitude limit for the species (800 m). The species had not been reported for the Luquillo National Forest before this study. Other surveys should be done at other times during the year, to know if the M. heterochirus can be found at higher elevations. Atya innocous, Gifford and Cole (1972) found, the distribution of Atya innocous in their study area indicates the animals tend to favor the slower ---Page Break--- ---Page Break--- Table 4. Number of Individuals Captured in the Collecting Site, copy 7, Tit — low-flow a 20 : . - low-flow 8 : : : outflow 6 : 2 5 2 low-flow (a) ay : : low-flow (3) 3 : : low-flow (2) 2° : : tone 2 low-flow a 6 - a - low-flow 18 . 3 : low-flow 6 * 2 : low-flow (a) 6 : ‘ - low-flow (3) a : & : low-flow (e) 9 : ; : high 1 : 5 - high 2 a high : high 5 é : : low 2 r - % 1 low 6 : 2 3 low-flow 4 18 : % : low-flow (a) a5 - y : low-flow (3) af : al : low 6 : 5 : low 2 » . - - low 2 6 : : low 5 é : : : 4 . 20 - 5 : low : 3 :) low : low high-flow (3) 6 : a : high-flow (6) 6 : 2% : high 2 as - 8 - low 2 a : : low 3 % : : : tone 5 low : : 2 : low-flow 3 8 : B : low : 2 a a low-flow (a) uw - a - low-flow (3) 2 : 8 : low-flow (2) 3 : 6 : low 2 6 - . . low 2 8 i : low 3 % p. £ : ---Page Break--- Table 5. Average size of the individuals examined at each collecting site.

oun on BF St ay ase Do: ee as DE SB es Re one as w RE oBe BS Ko BS RS B eT c 22.05 Aovks, ol 58. 2 RB Se Ri Bees BE Me ake B ; ma 8} x20 18 sarees xa ay TorTlow k 12.89 : < sess EB: eteriew (e) wee me na oe ‘ Wigh-few (a) 10.00 ume he ¢ ---Page Break--- Slowing stress. No specimens were captured from the Sonadora or Espiritu Santo Rivers. But the captured individual was from a small rill on the Espiritu Santo. Chace and Hobbs (1969) found that it seems to be equally at home in the cascading reaches of mountain rivulets, in quiet upland pools and in low-lying brooks. Its feeding habits are similar to those described for Atya lanipes. The position of Atya innocuous in the crustacean fauna in the study area did not appear to be dominant as observed from the results of Gifford and Cole (1972) and our observations. From the habitat preferences of the species, a zonation pattern for a typical pool can be drawn (see Fig. 7). Atya lanipes males are found over large boulders in high-flow areas. Xiphocaris elongata, Macrobrachium heterochirus and females of Atya lanipes are found in areas of low flow in substrate type of small rocks. By means of the number of captured individuals (see Table 4) and direct observation, it was noticed that as the elevation increases, the size of the shrimp populations decreases. The largest amount of captured and observed individuals was in the low elevation zones (see Table 1). An average of 200 individuals per zone were captured in zones 4 and 5. In Zone 3, 208 individuals were captured. In Zone 2, 139 individuals were captured. In Zone 1, 64 individuals were captured. (See Table 4). Whether the migration of shrimps affects the population size and distribution is not known. Groups of Xiphocaris elongata have been observed at low elevations migrating upstream, probably orienting against the current (pers. com, with José A. Colón). ---Page Break--- The individuals who reach high elevation areas in the streams are on average larger in size and fewer than those of low elevation areas (see

Table 5). The individuals encountered in the upper portion of the Espiritu Santo headwaters are adults according to Chace and Hobbs (1969) carapace length range for adults. Possibly, the low amount of individuals in high elevation areas and the relatively larger size of the individuals in high elevation areas could be due to migration. It can be summarized that fewer individuals reach high elevation zones (see Table 5) but their average size is larger than those at lower elevations (see Table 5). Since a marine phase of the life cycle of shrimps has been postulated, the question of whether the females migrate down to the estuary to release their larvae and migrate upstream is still not settled. It could be postulated that during the larvae releasing period for each species, the larvae move in a planktonic form until conditions are met for further development, i.e., contact with brackish water. Xiphocaris elongata juveniles are known to live in salinities of 90% sea water to fresh water (pers. comm. with W. Bhajan). Also, Atya innocous zoea are known to live in 19% of sea water (pers. comm. with M. Canals). Xiphocaris elongata females that have released their larvae have been found throughout the study area. The failure to capture or encounter juveniles of any of the species present in the study area tends to support the marine phase theory. Additional research is required to answer this question.

Selected physical characteristics of some species collected will be discussed in the following paragraphs. Only physical characteristics of Atya lanipes and Xiphocaris will be presented. The carapace length of Xiphocaris elongata and the overall length of A. lanipes are summarized in Table 5. A plot of the overall length of A. lanipes in the form of a histogram revealed a bimodal distribution (see Fig. 8). When the measurements were separated by sex and re-plotted, the data showed that the bimodal was due to sex differences (see Figure 9). In general, male A. lanipes are

Larger than females (61.87 mm vs. 28 mm). This larger length of A. lanipes may explain why they are better adapted to cope with high-flow conditions. On the other hand, A. lanipes females are smaller and live over gravel and rubble substrate where they can hold between the rocks to filter their food from the water. Holthuis (1963) described Atya lanipes, the description being based on two specimens from St. Thomas, Virgin Islands, preserved in the Rijksmuseum van Natuurlijke Historie, Leiden, Holland. He described the last three pereiopods being densely clothed in hair, dense enough to conceal the underlying surface. Chace and Hobbs (1969) reported the presence of A. lanipes from Puerto Rico in the collections of the U.S. National Museum and stated that the Puerto Rican material "agreed well" with the type description except for a variation in the amount of pubescence on the last three pereiopods. More recently, Chace (1972, per. comm. with M. Munter) confirmed that some of the Puerto Rican specimens did indeed show quite strong differences from the type description. All of the Atya lanipes captured in the study area are completely devoid of hair on these surfaces. The only ovigerous female was captured during November. During the months of December to February, a large number of ovigerous females were observed and captured at low elevations in other forested areas of the Espiritu Santo River basin (pers. com. with M. Canals). It appears that the breeding season of Atya lanipes is from the months of November to March, and probably releasing their larvae during February to March. Xiphocaris elongata: In the captured individuals of Xiphocaris elongata, differences in size were found. A histogram of the size distribution of the carapace in the Xiphocaris captured in the study area is represented in Figure 10. Differences in sizes are present in the individuals captured in the area. On a histogram of the carapace length measured in males and females (see

Fig. 22) It is noticed that the differences are due to differences in the size of individuals of each sex. Females were found to have a larger body size than the males. No effects on behavior or habitat selection were observed by reason of this difference. Pocock (1869) was led by the variation in length of the rostrum in this species to split Xiphocaris elongata into three different species. These species were X. gladiator, X. longirostris, and X. brevirostris. ---Page Break--- Fig. elongata misTOCRAM DO eum TOCRAM, DIVIDED BY SEX ---Page Break--- Chace and Hobbs (1969) disagree with this proposal, stating that the rostrum increases rapidly in relative length in the youngest juveniles, then gradually decreases in proportion as the body lengthens and broadens. To illustrate this, they calculated the rostrum-carapace ratio for a range of animals. The smallest specimens (carapace length 2 mm) had a ratio range of 1.0 to 1.3, and the range from 0.8 to 1.3 was set for the mature animals (cl. 8-12 mm). From their 1964 collections, they described a lower limit of 0.8 rostrum-carapace ratio for adults (cl. 12-15 mm). See appendix figure 1 for the scatter diagram showing correlation of the proportionate length of the rostrum with growth in specimens of Xiphocaris elongata, from Chace and Hobbs (1969). Gifford and Cole (1972) reported ratios from 0.27 to 0.54 for shrimps length ranging from 8-15 mm. Measurement of three shrimps (carapace length 9.5 - 10.9, all males) caught in 1967 by Gifford and Cole yielded ratios from 0.40 - 0.54. They concluded that their data tended to support Pocock's taxonomy, in Puerto Rican Xiphocaris. Measurement of carapace length and rostrum were taken from all the captured Xiphocaris. A histogram showing the frequency of the carapace length was plotted (see Fig. 10). Chace and Hobbs (1969) state that the carapace length of adult Xiphocaris ranges from 6 mm to 2 cm. Based on this criterion, all of the specimens measured from the Espiritu Santo river are adults. Xiphocaris juveniles were not encountered in

The studied area. Chace and Hobbs (1969) also suggested a correlation between rostrum length and carapace length. This was done by making a scatter diagram of Rostrum length vs Carapace length (see Fig. 12) and the data subjected to a correlated regression analysis. No correlation was found (R= 0.014). The lack of correlation in this study can be ascribed to the fact that only the adult population encountered in the study area was examined, whereas in the study of Chace and Hobbs the sample included adults and juveniles. In addition, the pattern of the scatter points in Fig. 12 agreed with those of Chace and Hobbs (appendix Fig. 21) in the range of adult carapace length. In view of these results, we can state that Pocock's taxonomy does not apply, since there seems to be a correlation between rostrum length and growth (in terms of carapace length) and not three different species according to differences in rostrum length. Physical-Chemical Characteristics of the Studied Area The physical and chemical characteristics and their effects on the distribution of the species encountered will be discussed separately in the following section. Physical characteristics The two most important physical parameters encountered in the study, which affect the distribution of shrimps, are the water-flow or current and the type of substrate on the riverbed. Eggleton (1939) states that one of the most far-reaching environmental factors, indeed an

Eo ee wre wer br "3 023 ¥ Too 2 Suez wre or 9 ie 2 Wie 78 06. szoyunres: @ oo" e BS is jee Bat “O61 saqmepean y 00d tuo a] aS RE Bas eR — rans wr ouiy fan Sug ems sew “aung = “(T orga 998) setrmuy oyeszeans -) aren 45 ---Page Break--- The most characteristic and powerful one, in lotic communities is the current. Either directly or indirectly it profoundly affects the biotic assemblages of streams. In the riffles of Zone 3 Xiphocaris elongata were not found (see Table 6) presumably due to the high stream velocities (80 cm/sec., see Table 2). Substrate analysis for the river bed was performed according to the procedures set forth in Table 1 and the results are summarized in Table 7. The river bed in Zone 1 has more sand in its composition in pools A and B than the river bed in the pools in other zones. The percentages of sand in the bed of pools A and B were 81.5% and 91.56% respectively. The river bed in pools in other zones yielded higher percentages of gravel composition and less than 50% of the bed consisted of sand. Where the bottom is composed of shifting sands and silts, most bottom fauna cannot maintain a foothold especially under high flow conditions. Thus benthic communities cannot be considered stable and the community composition may fluctuate widely. The detritus carrying capacity of the river bed could determine the distribution of "particle picker" shrimp. Personal observations made on Zone 1 suggest that the river bed does not accumulate detritus as much as do pools in other zones. The sandy composition of the river bed does not provide enough space between particles to maintain large quantities of detritus such as could be imagined in a gravel river bed substrate. This could be one of the reasons why in Zone 1 Xiphocaris elongata was not found in two of the pools (see Table 3). ---Page Break--- In sharp contrast to sandy stream beds, stream beds characterized by boulders or rock ledges permit development of a large and heterogeneous fauna community. The data in Table 3 illustrate this most

Clearly, this condition in Zone II probably accounts for the observation of three different species, Xiphocaris elongata, Atya lanipes, and Macrobrachium heterochirus (see Table 3). Water depth does not appear to be a restriction in the vertical distribution in the water column. Indeed, both Xiphocaris and Atya lanipes have been observed swimming at depths of the order of meters (in pools of Zone II, see Table 2). This behavior in deep water for other species has yet to be described. The amount of particulate matter per unit volume of water was estimated by filtering 10 gallons of water through a number 25 plankton net, measured once at five locations. Table 4 shows the amount of particulate matter measured near a riffle area in pools for the five zones of the upper Espiritu Santo. The amount of particulate matter drifting in the water will largely determine the food available for the filter-feeding shrimps. The water flow and the amount of particulate matter per cubic meter of water will determine the time an individual must spend facing the current in order to fulfill its nutritional requirements. A rough estimate of the amount of food material available to a shrimp of the Atya type can be made on the basis of the above data, assuming an effective brush filtering area having a diameter of (2.54 cm).

Table 6. Amount of Particulate Matter in the Five Zones of the Upper Espiritu Santo, Arena

Water Flow Front of Particulate cubic in cubic matter in Zone/Station meters meters/sec. Zone 1 Riffle 2 0.2919 34.37 Zone 2 Riffle 2 0.1907 33.84 Zone 2 Riffle 1 2.4809 439.30 Zone Riffle 1 0.0001 0.00 Zone Riffle 2 0.0807 7.086

The amount of particulate matter available in Zone 2 is 0.12519 grams/cubic meter of water (see Table 6). The above-mentioned shrimp filter, a core of 2.5 cm in diameter by 100 cm long, will filter approximately 0.02006 grams/hour. Conclusions

Reached on the basis of physical measurements are as follows. High stream velocity is a limiting factor for the distribution of amphipod diversity in a given area. The amount of particulate "longata. Substrate composition affects the species matter available in a given zone of a stream will affect the duration of feeding time of the filter-feeding shrimps. Chemical Characteristics ‘The chemical characteristics believed to be most important in the life cycle of the stream water in the study area are presented in Table 8. They included pH, dissolved oxygen, free CO_2, water hardness, sulfate, phosphorus, salinity, Na, Ca, Mg, Cu, K, Fe. The pH values ranged from 6.1 to 7.1 with a modal value of 6.6. The habitat preference of the shrimps encountered in the study area is not apparently affected by any particular pH in the range of pH's measured. Atya lanipes and Xiphocaris elongata were found in pools in which the pH varied from 6.1 to 7.1 (see Table 6). This suggests that pH is not a limiting factor for these two species during the time studied. Water hardness measured as the concentration of $CaCO_3$ could affect the amount of calcium available in the water for deposition in the shrimp exoskeleton (Clark, 1961). Water hardness in the study area ranged from 4 meq/L to 8 meq/L $CaCO_3$, with a mean value of 7.62 meq/L $CaCO_3$. The USGS Water Resources data for Puerto Rico from the period 1960 to date (USGS Report, 1972 Part 2A) in the Espiritu Santo River at an elevation of 50 m showed a mean water hardness value of 28.6 mg/L. Jars (1964) found in some streams of Jamaica a mean water hardness that was considerably higher than that observed for the Espiritu Santo River. In the Luquillo National Forest, Rio Ta Mine; a 49

STE ARE eee aaa eee E88 RAR ERE BRE | | wu wt ssc ase | j ---Page Break--- stream draining an area geographically similar to that drained by the Espiritu Santo River, the mean value of water hardness was 36.33 mg/l. Mart (1961) found that the carapace of the shrimp of La Mina river was extremely thin and fragile compared with the carapace of the same species collected from the Jamaican streams, possibly reflecting the low values of water hardness in La Mina stream compared with the water hardness for Jamaica. Free carbon dioxide (CO■), when present in all surface waters, amounts to generally less than 10 mg/l (APIA, 1971). The range of free carbon dioxide values measured during this study was considerably lower, ranging from 2.30 mg/l to 2.60 mg/l in the selected area, with a mean value of 2.45 mg/l. Dissolved oxygen (DO) concentrations were found to be at or near saturation levels in the study area. The mean dissolved oxygen concentration was 8.46 mg/l with a range from 7.0 mg/l to 8.7 mg/l. Water temperature during daytime ranged from 17°C to 21°C. Maximum dissolved oxygen concentration for this temperature range varies from 9.7 mg/l at 17°C to 9.0 mg/l at 21°C. These near-saturation values of DO could be a result of the effects of temperature and/or aeration brought about by turbulent mixing with the air layer over the surface of the water due to rapid flow through steep gradients. Thus, dissolved oxygen does not appear to be a limiting factor for the distribution of the shrimps in the study area. The concentration of sulfate, orthophosphate, and iron is fairly constant through the stream. Here again, low concentrations of these ---Page Break--- three micronutrients could not be considered critical for the distribution of the shrimps. The mean concentration of sulfate was 0.12 mg/l with a range of measured values from 0.1 mg/l to 0.5 mg/l. Phosphorus concentration is commonly expressed in three different ways depending on the method used to detect it. In this case, the concentrations of orthophosphate (PO■) were

measured. The mean concentration of orthophosphate in the study area was 0.13 mg/l to 0.15 mg/l. Iron is normally present in the oxidized ferric form (Fe). The mean concentration of iron in the study area was 0.17 mg/l, ranging from 0.25 mg/l to 0.20 mg/l. Salinity, expressed as sodium chloride (NaCl) equivalents, was found to be fairly constant, ranging from 22.8 mg/l to 20.0 mg/l, with a mean value of 23.3 mg/l. The distribution of the shrimps in the study area was not affected by these concentration variations. However, salinity values could affect the distribution of juvenile shrimp in the area or the development of the larvae, which may depend on higher salinity values for embryonic development and survival after hatching. The concentrations of sodium, magnesium, potassium, and calcium measured in the studied area were found to be constant throughout the study area. The mean concentration of sodium was 5.0 ppm with a range of values from 3.8 ppm to 5.5 ppm. Magnesium was found to have a mean concentration of 1.2 ppm with a range of values from 1.0 ppm to 1.5 ppm. The mean concentration of potassium was found to be 1.1 ppm with a range of measured values from 0.2 ppm to 0.6 ppm. Low calcium concentrations were found in the studied area, the mean concentration was 0.64 ppm ranging from 0.53 ppm to 0.67 ppm. Although the low calcium concentration does not appear to affect the distribution, it seems to affect the quality of the exoskeleton of the decapods in the area. In general, the low concentrations found for the above elements are not considered to be a limiting factor in the distribution of shrimp in the study area. The conclusions derived from chemical measurements are as follows: The selection of habitat of the species encountered in the forested reaches of the Espiritu Santo appears not to be affected by the water chemistry. This conclusion is not surprising in that little change in chemical properties of the water throughout the Espiritu Santo River basin had been found previously.

Cuevas (1975)

Reported that water quality parameters, namely Dissolved Oxygen, pH, free carbon dioxide, salinity, sodium, potassium, calcium, magnesium, and chloride of the Espiritu Santo basin in the forested areas are fairly constant. Summary: A survey was carried out between October 15 to December 15 in the upper portion of the Espiritu Santo River to collect, identify and describe the distribution of the shrimps. The species encountered in the study area were Atya lanipes, Xiphocaris elongata, Macrobrachium heterochirus, and Atya innocuous. Selected physical and chemical parameters of the stream were measured to characterize the habitat of each species and to describe possible effects upon species distribution. Physical parameters included water flow or current, visibility, water depth, substrate particle size analysis, and quantity of particulate matter in the water. The chemical parameters measured included dissolved oxygen (DO), free carbon dioxide (CO■), pH, water hardness, iron, orthophosphate, sulfate, salinity, sodium (Na), calcium (Ca), potassium (K), and magnesium (Mg). The physical parameters that affect the distribution are water-flow, type of substrate, and elevation. Chemical characteristics were found to be constant throughout the study area having little apparent effect on the distribution. The results agreed with those of Cuevas (1975) who demonstrated constancy in chemical concentrations over time in the forested area of the Espiritu Santo River basin. Atya lanipes showed intraspecific differences in habitat selection. Males were found in high-flow areas in which the substrate was largely boulders. Atya lanipes females were found in low-flow areas in rubble and gravel substrate. Filter-feeding habits were observed for Atya lanipes. Preference for sunlit areas in low-flow conditions and gravel substrate were observed for Xiphocaris elongata. Xiphocaris feeding habits were observed to be particle picking. Macrobrachium heterochirus was found to prefer shaded areas.

Residence in cavities in rocks or under rocks and low-flow conditions. Selected anatomical characteristics were measured for Atya lanipes and Xiphocaris elongata. Atya lanipes males were found to be larger than females which would make them better adapted to high-flow conditions. Xiphocaris elongata females were found to be larger than males. The division of the Xiphocaris genus into three species (1889) using the criterion of length of rostrum differences was found to be related to body development. The rostrum length decreases with the increase in body length. These results agreed with those found by Chace and Hobbs (1969). No juvenile shrimp of any of the species were encountered in the study area.

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Transverse bands of dark color lateral lobes of adult rostrum pubacute and directed anteriorly ventral margins of pleura of second to fifth abdominal somites armed with row of small blunt spines, transverse bands of dark color at juncture of carapace and abdomen and on anterior part of sixth abdominal somite. - Asya sombre 59 ---Page Break--- 20. Orbital margin minutely serrate; appendix masculina on second pleopod of male slender, terminating in sharp point + Jonge serrel, Orbital margin not serrate; appendix masculina on second pleopod of male broad, rounded distally « 9 ‘Appendix masculina widening distally, about three-fourths as wide as long, posterior margin slightly and evenly convex toreaeeese vesee Potimtrim americana Appendix masculina ‘widest ‘proximally, ‘not more than half as wide as long, posterior margin sinuous +10 Dorsal margin of rostrum curving downward at tip; appendix masculina with deep, unarmed sinus in posterior margin seveveeeeee Botinirds ginbea Dorsal margin of rostrum straight; appendix masculina without deep, unarmed sinus in posterior margin cee Potiniria mexicana 60 ---Page Break--- Appendix Table & @ Genus Macrobrachium Bate, 1868 Key to West Indian Species (Chace and Hobbs, 1969) Rostrum long, usually overreaching antennal scale, with 5-11 dorsal teeth, including 1 or 2 on carapace posterior to level of orbital margin; second pereiopods of adult male slender, chela more than eight times as long as broad ...... 2 Rostrum short, reaching at most slightly beyond antennular peduncle, with 10-15 dorsal teeth, including at least four on carapace posterior to level of orbital margin; second pereiopods of adult male robust, chela less than seven times as long as broad sees. Rostrum armed throughout dorsal length, posterior tooth usually separated from second by distance greater than that between second and third: second pereiopod of adult male spinulose, carpus shorter than chela, fingers densely furred . M. seanthurus Rostrum unarmed in distal half or third of dorsal margin except for 2 subapical teeth

Proximal teeth subequally PEGE: second pereiopod of adult male stout, carpus longer than chela, fingers naked. Rostrum with sinuous dorsal margin, tip slightly upturned; second pereiopods of adult male similar in form if not in size, with short pubescence and short spines along outer margin of fixed finger and continued onto palm, but spines not forming a distinct crest and not hidden by pubescence. Rostrum with dorsal margin nearly straight, tip not upturned; second pereiopods of adult male unequal in both form and size, with dense long fur partially concealing crest-like row of long spines on margin of palm. Posterior teeth of dorsal rostral series not especially erect or noticeably more widely spaced than others; second pereiopods of adult male subequal, carpus shorter than merus and about half as long as palm, fingers only slightly shorter than palm, prominent tooth near end of proximal third of opposable margin of fixed finger; abdomen longitudinally striped in life. Three or more teeth of dorsal rostral series more erect and more widely spaced than anterior ones; second pereiopods of adult male usually unequal in length, major one with carpus about as long as merus and about three-fourths as long as palm, fingers about two-thirds as long as palm, none of the teeth on opposable margin of fixed finger greatly enlarged; abdomen transversely banded in life. ---Page Break--- Major second pereiopod of adult male with carpus usually longer than merus and fingers distinctly longer than palm, row of spines along mesial margin of palm and fixed finger rather long on proximal portion of palm, becoming shorter near mid-length of palm, longer near base of finger, and decreasing again distally on finger. Major second pereiopod of adult male with carpus shorter than merus and fingers slightly longer or slightly shorter than palm, row of spines along mesial margin of palm and fixed finger forming regularly graduated series, not decreasing in length along.

central portion of pal -+s-+.se.+. . 31. Gremidatun