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Some Aspects of the Ecology of the fresh water shrimps in the upper Espiritu Santo River at El Verde, PR

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SOME ASPECTS OF THE ECOLOGY OF THE FRESH WATER SHRIMPS IN THE UPPER ESPIRITU SANTO RIVER AT EL VERDE, PUERTO RICO

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Abstract

A survey was performed in the upper Espiritu Santo River to collect, identified 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 the habitat selection and the distribution were, waterflow, 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 was 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, residence 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 genus into three species using a criterion of length of rostrum was found to be related to development.

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Introduction

Although palaemonid and atyid shrimp are common in both fresh and brackish waters in Puerto Rico, little is known of their biology. Gunlach (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 then to collections from Cuba. Species identified by Gunlach included Xiphocaris elongata, Atya lanipes, Macrobrachium carcinus and others. In 1935, Schmidt in the Scientific Survey of Porto Rico and the Virgin Islands reported the presence of Macrobrachium acanthurus, M. carcinus (as M. jamaicensis), M. faustinum (as M. olfersii), Xiphocaris elongata, Atya scabra, A. innocous (as A. occidentalis) and Micratya poeyi. In addition to the species reported by Gunlack (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 rain forest 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 at. 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 their cannibalistic nature which leads them to attack the newly moulted individuals. Moulting, under artificial conditions, took place about every two weeks in young, rapidly growing animals. Although M. acanthurus appears to be tolerant of relatively high temperature but it is sensitive to cold. As temperature approach 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 Dungan and Frankes (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 Sick et. al. (1973). Several experiments revealed that ingestion rates of peaeid 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 Yuquiyu River 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 fresh water 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 were reported by Gunlach (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 waterflow was high and 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 periopods. 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 species 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 fragil when compared with those of Jamaica. This can make difference in the biology of the species of Puerto Rico related to those of Jamaica.

Gifford and Cole (1970) of the University of West Florida, studied certain aspects of the biology and distribution of fresh water decapods in the streams of the Caribbean National Forest near El Verde, Puerto Rico. Their major goals were to make exploratory surveys of the decapods crustaceans of El Verde area, to correlate their distribution with various ecological factors and to determine the major stress imposed by the environment. The species of shrimps found in the area were Atya innocous, A. lanipes, A. scabra, Micratya poeyi, Xiphocaris elongata and Macrobrachium carcinus. Their survey took place on the Sonadora and Espiritu Santo Rivers.

The distribution of Atya innocous in the study area indicates the animals tend to favor the slower flowing streams. Eggleton (1939) emphasized that one of the most far reaching environmentals factors, indeed the most characteristics and powerful one, in lotic communities is water flow. Either directly or indirectly its 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 in the aquatic crustacean fauna and is probably the single most important species for the recycling of detritus and nutrients washed into the streams. The distribution of A. lanipes is interesting because they are found where apparently A. innocous cannot live.

Atya scabra appers to be the most ecologically restricted and most especialized 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 periopods indicate 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 sunlit 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 pereiopods, a particle-picking mode of feeding is implicated.

Macrobrachium carcinus were collected by trap from the larger streams. Their apparent feeding pattern is 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 fresh water shrimps of Puerto Rico and provides some information in 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

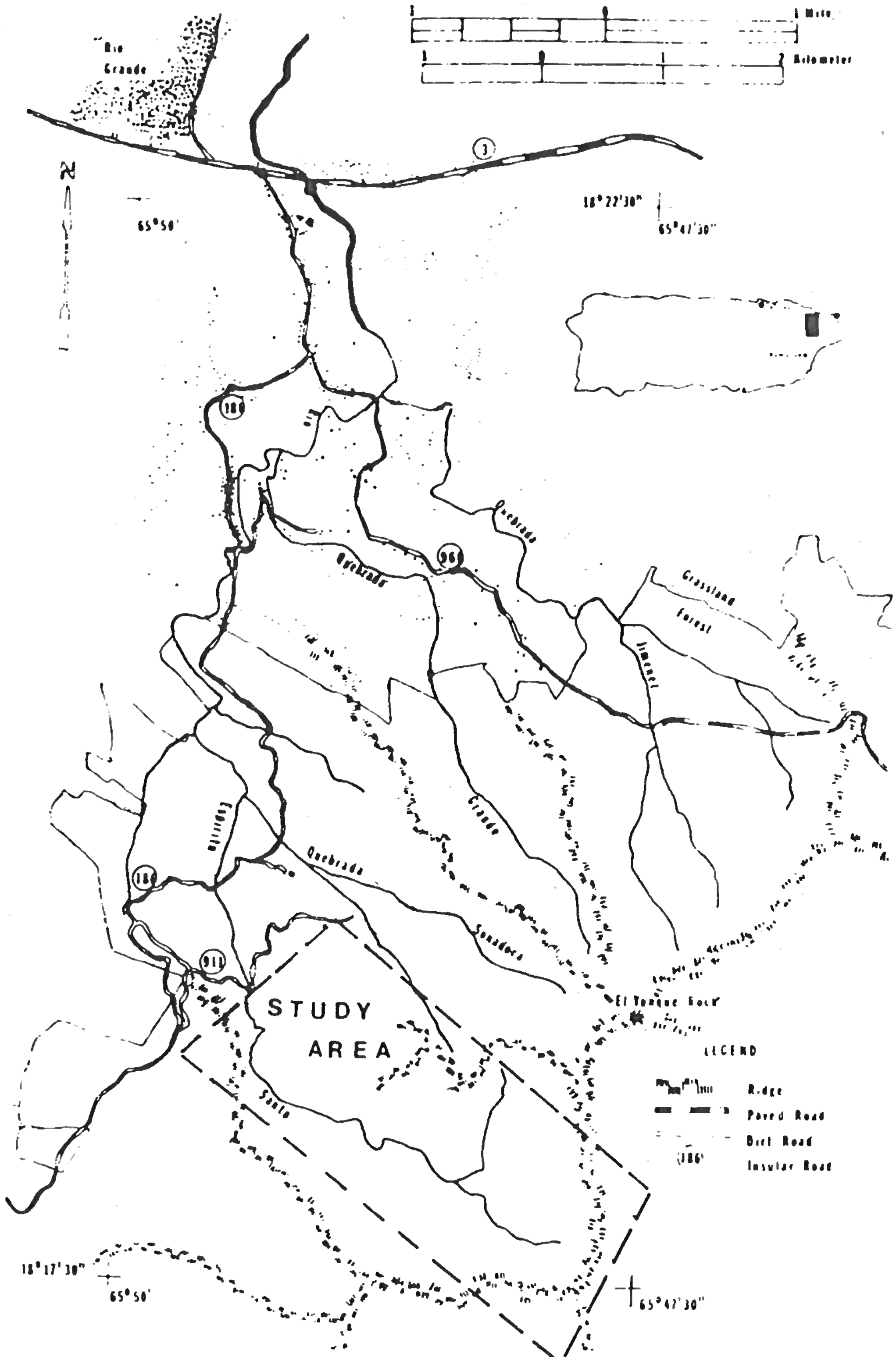


Figure 1: Espiritu Santo Drainage Basin

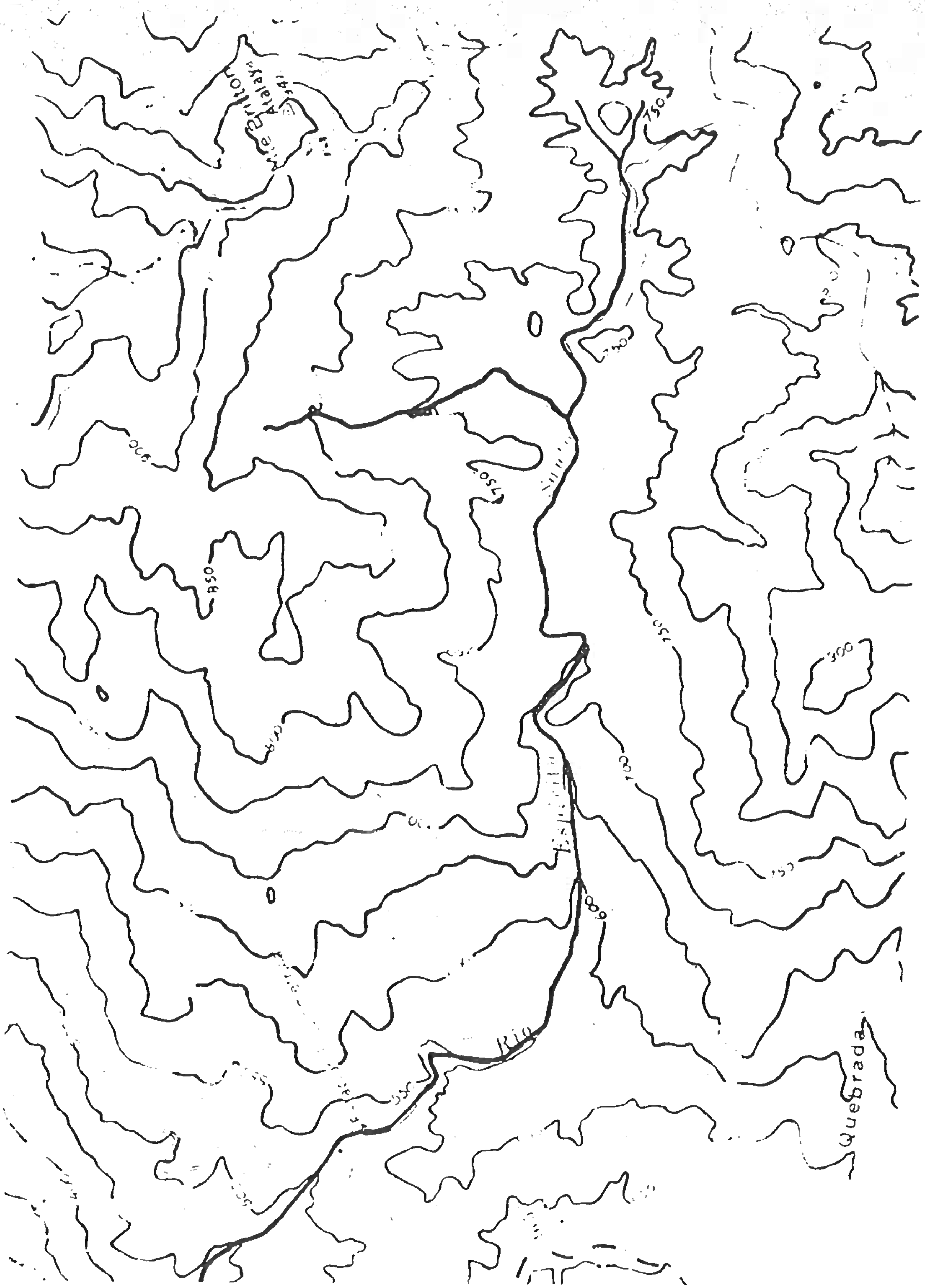


FIG. 2 STUDY AREA

many feeder brooks that drains 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 consist of three principal geologic formations. These are the Quartz Diorite and Diorite, the Hato Puerto and the Tabonuco.

The Quartz-Diorite and Diorite formation is of Paleocene origin and the residual soils formed are 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 consist of massive tuffs and volcanic breccias. This is the dominant of 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 tabonuco 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, 1951). The Dwarf Forest association is restricted to the ridges lines above the 850 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:

a. To identify and determine the distribution of the shrimps in the upper Espiritu Santo River.

b. To study relationship between the distribution of each specie and various physical chemical factors.

c. To determine and describe the habitat of each specie.

d. To measure, describe and compare selected physical attributes of individuals within and among species.

Methods

The upper Espiritu Santo river was divided in five zones (fig. 3) according to differences in topography and preliminary field observations.

Preliminary surveys suggested that because 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 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

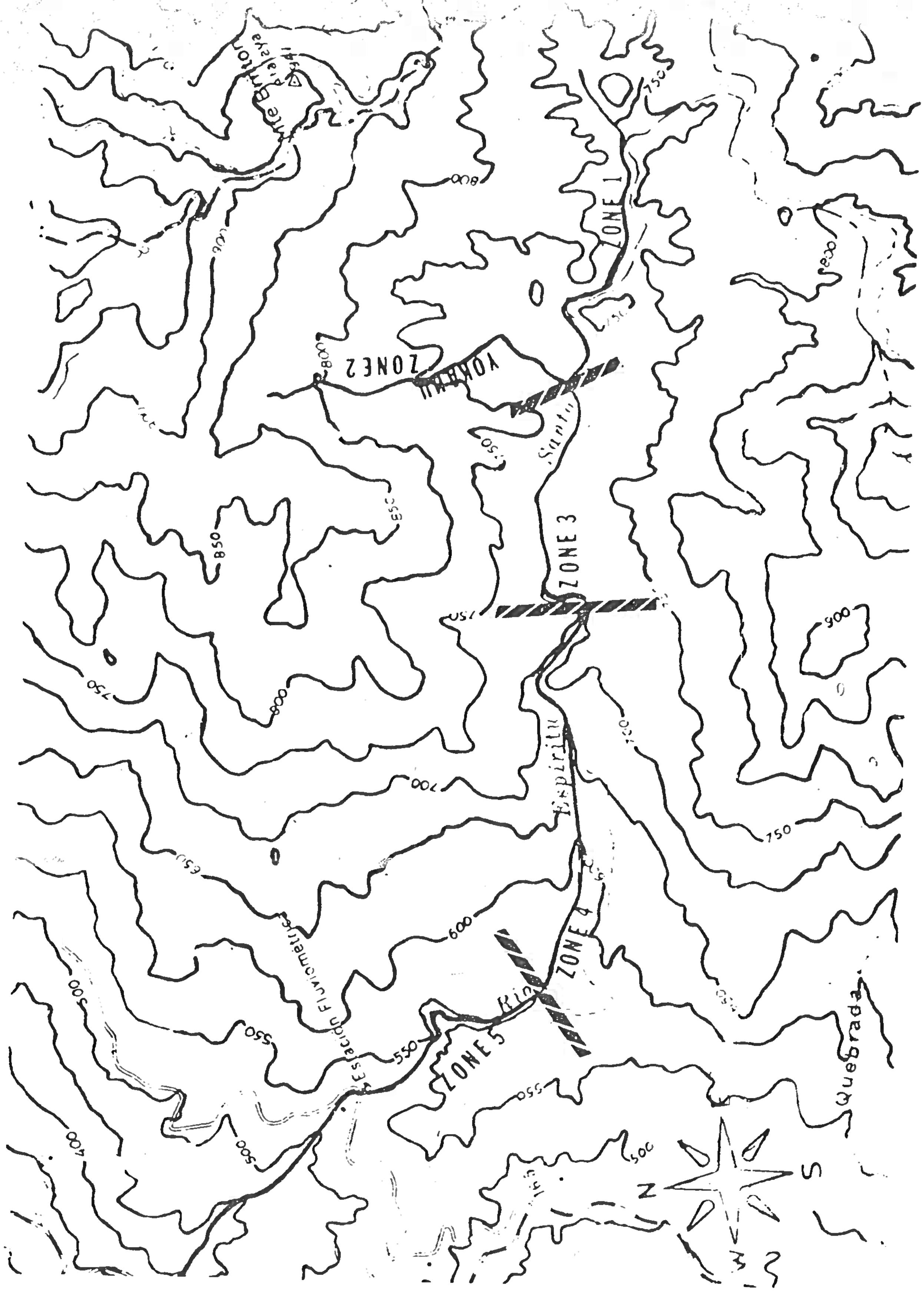


FIG 3 ZONES AT THE UPPER ESPIRITU SANTO

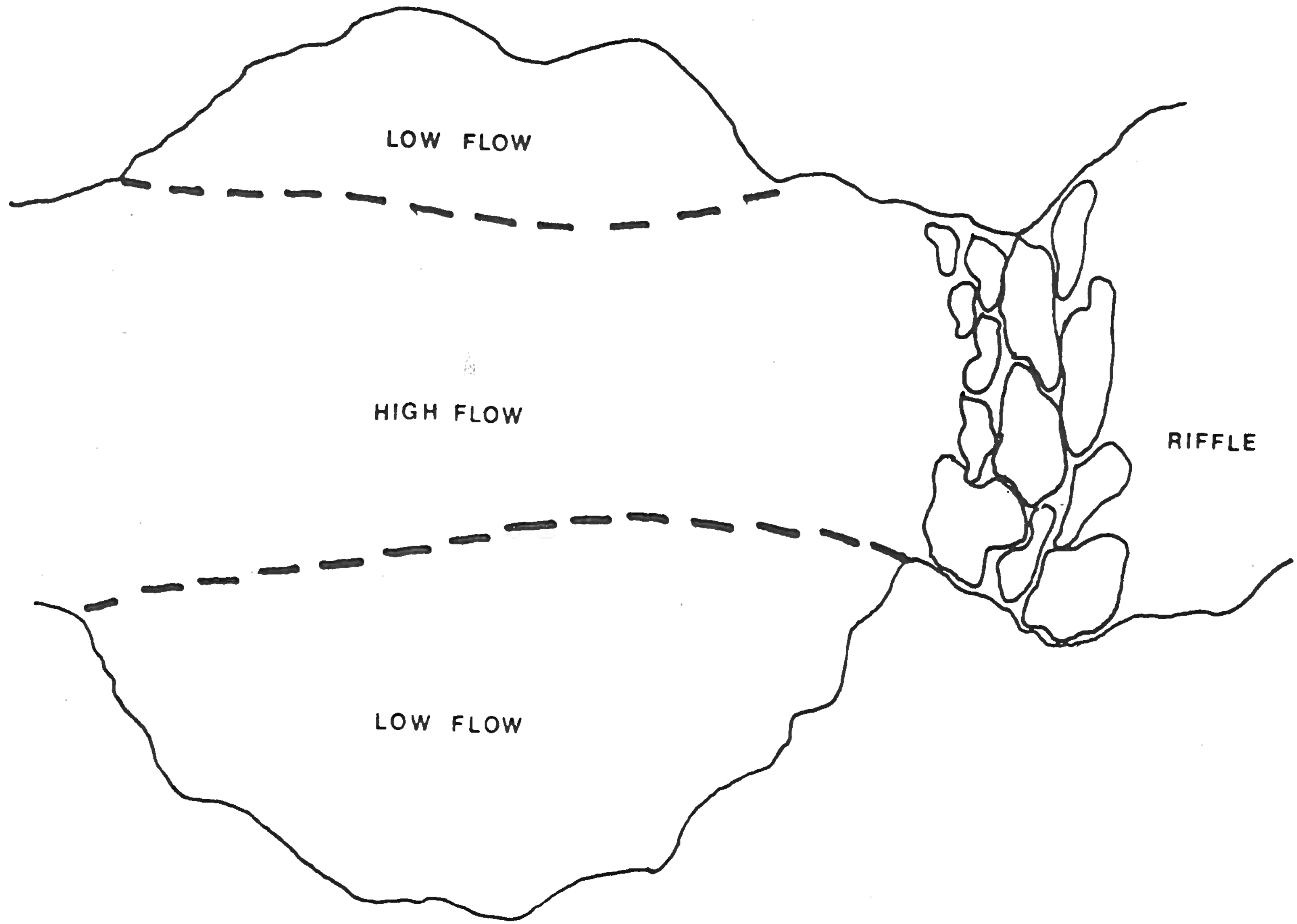


Fig. 4 Diagammatic Sketch of a Typical Pool Showing the Zonation Used in the Study.

by skin diving to record observations on the species present, behaviour 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 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, sulphate, salinity, sodium, magnesium, calcium and potassium.

The physical variables included; elevation, waterflow, substrate analysis, visibility, water depth and the amount of particles difting in the water.

All measurements and samples were taken only once at each station and under base flow conditions.

The following method and/or instruments were used for the determination of the parameters mentioned above.

Chloride and pH measurement were determined using a Orion Specific ion meter Model 404 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 titrametric 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 sulphate. 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 01449. The amount of drifting particles in the water were measured with the used 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 zone. This analysis was conducted according to the procedures setforth in Biological field and laboratory methods for measuring the quality fo surface waters by the EPA 91973), using U.S. standard sieves number 10, 35, 120 and 230. The soil particles size classification was as established in Table 1.

Table 1. Soil Particles Size Classification

Name	Particles size (mm)	U.S Standard sieve series #
Boulder	256	
Rubble	64-256	
Coarse gravel	32-64	
Medium gravel	8-32	+
Fine gravel	2-8	10
Coarse sand	0.5-2	35
Medium sand	0.25-0.5	120
Fine sand	0.125-0.25	230
Very fine sand	0.0625-0.125	
Silt	0.0039-0.0625	Centrifuge (750 rpm, 3 min) + +
Clay	0 0039	Evaporate and weight residue

Results and Discussion

The study area was divided in 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

Table 2. Locations, elevation and site description of the survey stations at the upper Espiritu Santo

Station	Vegetation type	Elevation	Waterflow**	Approx. Depth	Water visibility	Site description
Zone 1						
Low-flow A	Palm break	750 m.	5 cm/sec.	.33 m.	.33 m.	Small cave with bouldes on river bed, shaded area
Low-flow B	Palm break	750 m.	5 cm/sec.	.33 m.	.33 m.	Shallow pool, sandy bottom, shaded area
Low-flow C	Palm break	750 m.	5 cm/sec.	.33 m.	.33 m.	Shallow pool, sandy bottom, open area
High-flow (a)	Palm break	750 m.	10 cm/sec.	.33 m.	.33 m.	Medium sand bottom, rubble and gravel, open area
High-flow (b)	Palm break	750 m.	15 cm/sec.	.33 m.	.33 m.	Sandy bottom (coarse and medium sand) shaded area
High-flow (c)	Palm break	750 m.	20 cm/sec.	.33 m.	.33 m.	Boulders on river bed, open area
Zone 2						
Low-flow A	Palm break	820 m.	5 cm/sec.	.66 m.	.66 m.	Large cave with sand and gravel on the bottom, shaded area
Low-flow B	Palm break	810 m.	5 cm/sec.	.33 m.	.66 m.	Shallow pool with medium sand and gravel on the bottom, open area
Low-flow C	Palm break	805 m.	5 cm/sec.	.66 m.	.66 m.	Sandy river bank with gravel and rubble on bottom
High-flow (a)	Palm break	810 m.	15 cm/sec.	.66 m.	.66 m.	Shallow, open area, rubble on river bed
High-flow (b)	Palm break	812 m.	10 cm/sec.	1 m.	1 m.	Boulders and rubble on river bed, open area very shallow
High-flow (c)	Palo colorado	810 m.	10 cm/sec.	1 m.	1 m.	Boulders and rubble on river bed, shaded area
Riffle 1	Palm break	805 m.	40 cm/sec.	*	*	Rocky banks, rubble and boulders on river bed, open area
Riffle 2	Palo colorado	800 m.	50 cm/sec.	*	*	Rubble, boulders on river bed, shallow
Riffle 3	Palo colorado	790 m.	50 cm/sec.	*	*	Rubble, boulders on river bed, gravel on the bank, open area
Zone 3						
Low-flow A	Palo colorado	720 m.	10 cm/sec.	2 m.	2 m.	Deep pool, open area, sandy bottom
Low-flow B	Palo colorado	720 m.	10 cm/sec.	1 m.	1 m.	Shallow pool, open area, snad, rubble and gravel on river bed
Low-flow C	Palo colorado	720 m.	10 cm/sec.	3 m.	3 m.	Deep pool, open area sand and rubble on river bed
High-flow (a)	Palo colorado	721 m.	20 cm/sec.	2 m.	2 m.	Open area, rubble and boulder on river bed
High-flow (b)	Palm break	722 m.	20 cm/sec.	2 m.	2 m.	Rubble on river bank, boulders and rubble on river bed, shaded area
High-flow (c)	Palo colorado	720 m.	20 cm/sec.	1.5 m.	1.5 m.	Boulders and rubble on river bed, open area
Riffle 1	Palo colorado	710 m.	80 cm/sec.	*	*	Large boulders on river bed, open area
Riffle 2	Palm break	720 m.	80 cm/sec.	*	*	Large boulders on river bed, gravel on river banks
Riffle 3	Palo colorado	715 m.	85 cm/sec.	*	*	Large boulders on river bed, open area
Zone 4						
Low-flow A	Palo colorado	655 m.	20 cm/sec.	5.5 m.	4 m.	Deep pool, open area, rocky bottom
Low-flow B	Palo colorado	621 m.	5 cm/sec.	3 m.	3 m.	Deep pool, open area, rubble and boulders on river bed
Low-flow C	Palo colorado	620 m.	cm/sec.	2 m.	2 m.	Deep pool, shaded area, rocky river bed
High-flow (a)	Palo colorado	655 m.	20 cm/sec.	4 m.	4 m.	Deep pool, open area, rubble and gravel river bed
High-flow (b)	Palo colorado	655 m.	25 cm/sec.	3 m.	3 m.	Deep pool, open area, rubble and boulders on river bed
High-flow (c)	Palo colorado	660 m.	20 cm/sec.	2 m.	2 m.	Open area, rocky bottom, next to a water fall
Riffle 1	Palo colorado	655 m.	40 cm/sec.	*	*	Boulders on river bed, open area
Riffle 2	Palo colorado	655 m.	45 cm/sec.	*	*	Boulders on river bed
Riffle 3	Palo colorado	658 m.	50 cm/sec.	*	*	Boulders on river bed
Zone 5						
Low-flow A	Palo colorado	550 m.	5 cm/sec.	.33 m.	.33 m.	Shallow pool just after dam, open area, rubble and gravel
Low-flow B	Palo colorado	550 m.	5 cm/sec.	.33 m.	.33 m.	Shallow pool before dam, open area, sand and rubble on river bed
Low-flow C	Palo colorado	550 m.	5 cm/sec.	.33 m.	.33 m.	Shallow pool, sand and boulders on bottom, shaded
High-flow (a)	Palo colorado	550 m.	20 cm/sec.	.66 m.	.33 m.	Shallow pool, rocky bottom, open area
High-flow (b)	Palo colorado	550 m.	15 cm/sec.	1 m.	1 m.	Shallow pool, rubble and boulders on bottom, open area
High-flow (c)	Palo colorado	550 m.	25 cm/sec.	.66 m.	.66 m.	Shallow pool, gravel. rubble and small boulders on bottom open area
Riffle 1	Palo colorado	550 m.	60 cm/sec.	*	*	Large boulders, after dam, open area
Riffle 2	Palo colorado	550 m.	80 cm/sec.	*	*	Large riffle after dam, large boulders, open area
Riffle 3	Palo colorado	550 m.	50 cm/sec.	*	*	Boulders and rubble on river bed, sandy river bank

* Not applicable
** Base flow conditions

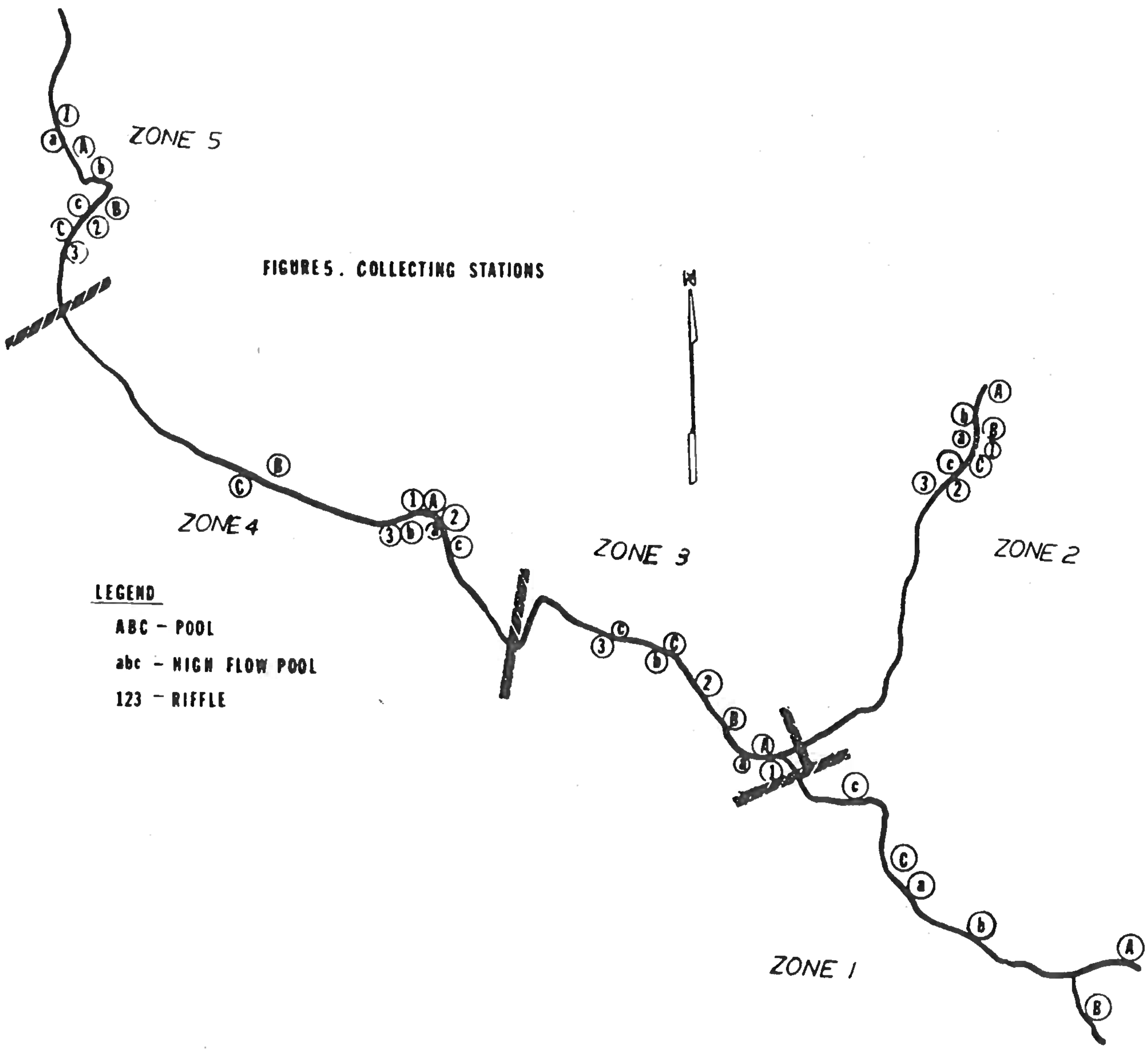


FIGURE 5. COLLECTING STATIONS

of 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 specially 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 rate 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 91.4 percent (see Table 7).

Zone 2. The area set aside as zone 2 is that area embracing what has been identified as the northfork of the headwaters (see Figure 5). The stream originates in a cave at 820 m elevation. Above this elevation, the stream apparently flow underground and drain 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 consist 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 stream emanating from zones 1 and 2 (elev. 750 m.) and extends down stream 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 70-92 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 depth 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) suggest 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 2). Water flow rates in the slowing 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 half of those in zone 3. The Palo colorado association dominates the area.

Zone 5. Zone 5 (see Fig. 5) begins at an elevation of 550 meters and extends downstream to the Forest Service Road (elevation 520 m.) 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 m. 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 this circumastances the missing collecting 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 3. 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 Espiritu Santo River were collected and a labelled reference collection was established at El Verde Field Station. The species identified were:

Order: Decapoda

Suborder: Natantia

Section: Caridea

Family: Atyidae

1. Atya lanipes

2. Atya innocous

3. Xiphocaris elongata

Family: Palemonidae

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 been properly identified the individuals were classified by sex and measured.

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. Rostral length was measured from the posterior most part of the orbitals anteriorally 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 purpose of this study to length to the telson was included.

The diagnosis of each specie 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; fresh water 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 margins of abdominal pleura unarmed. Basal segment of antennular penduncle without dorsal spines proximal to series bordening distal margin. Pereiopods bearing tufts of long hair. Carpus of second pereiopod broader than long. Last three pereiopods without horny scales or tubercles. Merus, carpus, and prododus 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. This 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 44.18 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 to low flow B, Zone 3 lowflow A., Zone 5 lowflow A, C.

Xiphocaris elongata (Guérin - Méneville)

Hippolyte elongatus, Guérin - Méneville, 1855

Oplophorus americanus, De Saussre, 1858

Xiphocaris elongata, Von Martens, 1872

Xiphocaris gladiator, Pocock, 1889

Xiphocaris gladiator var. intermedia

Xiphocaris brevirostris, Pocock, 1889

Oplophorus elongatus, Sharp, 1893

Xiphocaris elongata, Chace and Hobbs, 1969

Type locality - Habana, Cuba

Distribution - Confined to the West Indian Islands; freshwater streams.

Diagnosis: "Rostrum armed dorsally and ventally, 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 penduncle without dorsal spines proximal to those bordering distal margin. Expodops well-developed and present on all perejopods. First and second pereiopods without terminal tufts of setae. Last three pereiopods without horny scale of tubercles, or spinces. Ambulatories all of approximately equal size and rather slender. Appendix masculina subcylindrical, armed distally with crown of moderately long spinces, and shorter than appendix interna. Medium-sized species, maximum postorbita) 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 15.40 mm with an average of 13.43 mm. Males carapace length ranged from 7.25 mm to 12.30 mm with an average of 10.73 mm.

Occurrence: *Xiphocaris elongata* was encountered in almost all sampling sites with the exception of Zone 1 lowflow A, B; highflow a, b, c, Zone 2 riffle 2. Zone 3, riffle 1, 2, 3,; Zone 4 highflow b and riffle 2, 3; and Zone 5 riffle 1, 3.

Family Palaemoninae

Macrobrachium heterochirus Weigmann, 1836

Palaemon heterochirus Weigmann, 1836

Macrobrachium heterochirus Chace and Hobbs, 1969

Type locality - East cost 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 penduncle, dorsal margin sinnuous, tip slightly upturned; armed with 10 to 13 dorsal and 2 to 4 ventral teeth; posterior 4 to 6 teeth of dorsal teeth of dorsal 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 legth; 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 edge; 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 fixed finger; 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 tergires and dark borders on pleura. A medium-sized species, maximum postorbital carapace length about 34 mm.

Material examined: A total of 4 specimens were obtained, two females (carapace lengths 30 mm - 45 mm) and two males (carapace lengths 48 mm - 59 mm).

Occurrence: Zone 3 lowflow A, B. Zone 4 highflow a; Zone 5 lowflow C.

Atya innocous Herbst, 1772

Cancer (Astacus) Innocous Herbst, 1772

Atya innocous Chace and Hobbs, 1969

Type locality - Martinique

Distribution - Nicaragua to Panama and the West Indies; fresh water streams.

Diagnosis: "Rostrum, when viewed dorsally, possesses shoulders at junction of rostrum and carapace. If equidistant lines are drawn from the laterial most edge of the shoulders and the tip of the rostrum, the angle at the intersection of these lines is obtuse. Ventral margins of abdominal pleura bear row of small, sharp denticles, excepting the second segment which is unarmed. Basal segment of antennular penduncle without dorsal soines 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 ambulatories 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 wide bladed sickle, hooking toward anus, and possessing harply pointed bluff in bend of hook. Two color phases, green and brown (for a 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 male around 5.0 mm carapace length (Gifford and Cole, 1972). Note: Chace & Hobbs, (1969) found that the appendix masculina at this size is occassionally subsequal 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 specie.

Occurrence: Zone 5 riffle 2.

Distribution of Species

The distribution of the species captured and identified throughout the study area are summarized in Table 3. The presence or absences of the species in a collecting site were confirmed by direct observations of the area by skin diving (and by trapping).

Atya lanipes were found to be ubiquotous throughout the study area. (See Table 3). This specie does not appear to be restricted by the 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

Station	Atya lanipes	A. innocous	Xiphocaris elongata	Macrobrachium heterochirus
Zone 1				
Low-flow A	P*	A*	A	A*
Low-flow B	P	A	A	A
Low-flow C	P	A	P	A
High-flow (a)	P	A	P	A
High-flow (b)	P	A	P	A
High-flow (c)	P	A	P	A
Zone 2				
Low-flow A	P	A	P	A
Low-flow B	P	A	P	A
Low-flow C	P	A	P	A
High-flow (a)	P	A	P	A
High-flow (b)	P	A	P	A
High-flow (c)	P	A	P	A
Riffle 1	P	A	A	A
Riffle 2	P	A	A	A
Riffle 3	P	A	A	A
Zone 3				
Low-flow A	A	A	P	P
Low-flow B	P	A	P	P
Low-flow C	P	A	P	A
High-flow (a)	P	A	P	A
High-flow (b)	P	A	P	A
High-flow (c)	P	A	P	A
Riffle 1	P	A	A	A
Riffle 2	P	A	A	A
Riffle 3	P	A	A	A
Zone 4				
Low-flow A	P	A	P	A
Low-flow B	P	A	P	A
Low-flow C	P	A	P	A
High-flow (a)	P	A	P	P
High-flow (b)	P	A	A	A
High-flow (c)	P	A	P	A
Riffle 1	P	A	P	A
Riffle 2	P	A	A	A
Riffle 3	P	A	A	A
Zone 5				
Low-flow A	A	A	P	A
Low-flow B	P	A	P	A
Low-flow C	A	A	P	P
High-flow (a)	P	A	P	A
High-flow (b)	P	A	P	A
High-flow (c)	P	A	P	A
Riffle 1	P	A	A	A
Riffle 2	P	P	P	A
Riffle 3	P	A	A	A

*P - Present
*A - Absent

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 absences of Xiphocaris. Their presence in this riffle was affected by high flow conditions. The average waterflow 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 around. The captured Macrobrachium were found to be restricted to lower elevations all year around. 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 specie found in the upper Espiritu Santo will be discussed separetely in the following paragraphs.

Atya lanipes

Atya lanipes is the dominant element in the aquatic crustacean fauna, because of its number and relative size compared to the majority of the decapod fauna. Is probably the single most important specie for the recycling of detritus and nutrients washed into the stream (Gifford and Cole, 1972). In a pool approximately 48 square feet, a minimum of 26 individuals were counted by Gifford and Cole. Through skin-diving and 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 preferred high-flow and boulders substrate conditions in the pool (see Fig. 6, c and f). They are

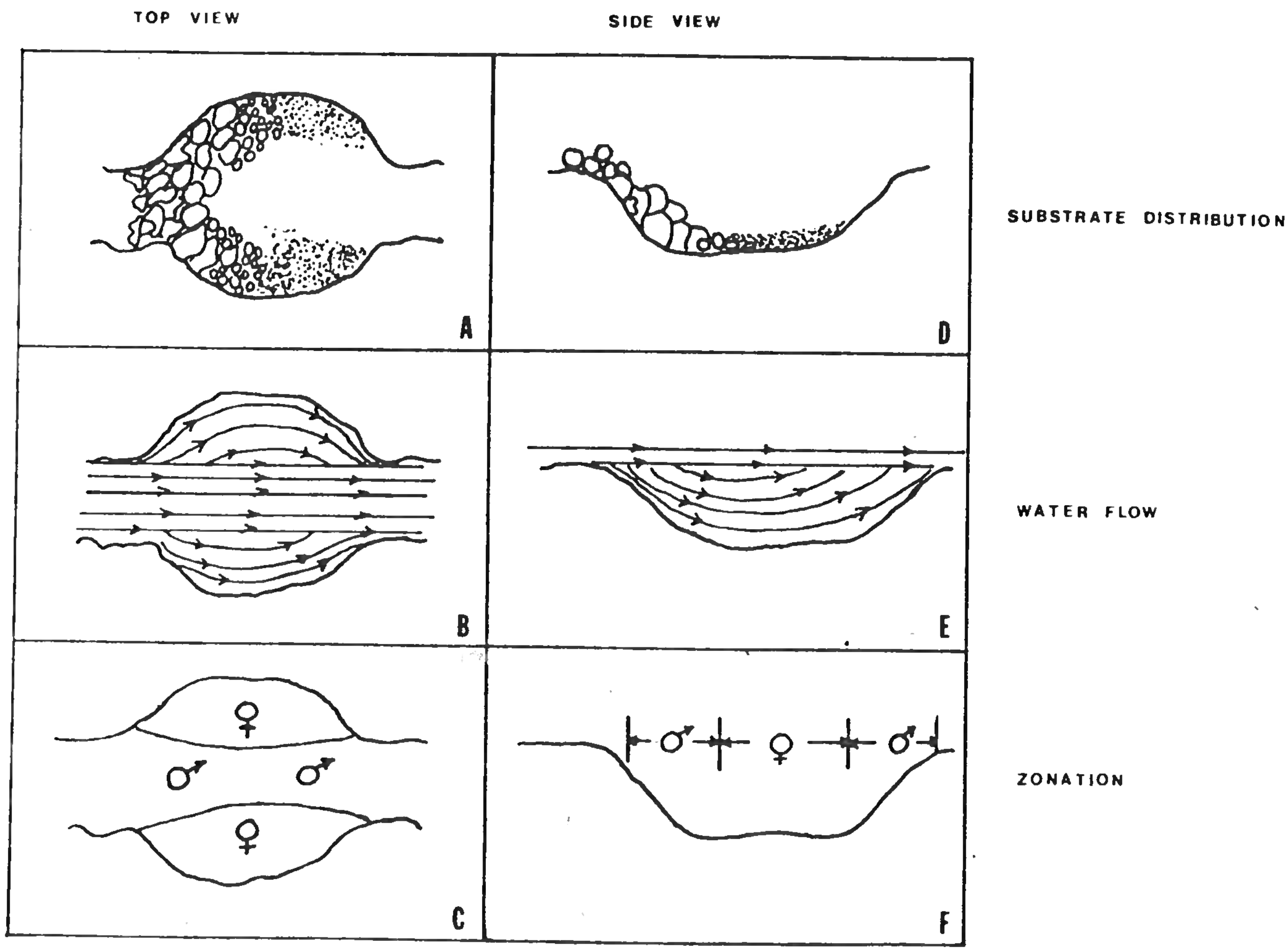


Fig. 6 Patterns of Water Flow and Substrate Distribution in a Typical Pool and their Relationship to *Atya lanipes* Habitat Selection.

established in the sides of the pools, especially near the bank, sharing habitat with Xiphocaris elongata, Macrobrachium heterochirus and a fish, Sicydium plumieri.

Filter feeding was observed for A. lanipes. The method of feeding is to face into the current, preferably immediately below a riffle area, 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 the individuals feeding by direct grazing on the algae over 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. On areas where the substrate is composed of more than 50% of sand, Xiphocaris were not found. Preference to low-flow areas were notice throughout the collecting sites. In fast moving waters, more than 70 cm/sec, Xiphocaris were not found. Preference to low-flow areas were notice 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 zone 4 (see Table 2). Preference to sunlit areas was noticed on the majority of the stations, where they were captured.

The only feeding habit observed for Xiphocaris was particle picking using the first pair of periopods. 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 on 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 M. heterochirus are restricted to riffle and low cascades sharing the habitat with Atya lanipes. 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 on the dry season. The individuals observed in this study were captured during the rainy season, and it appear that this is the highest altitude limit for the specie (800 m.). This specie 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) foudn the distribution of Atya innocous in their study area indicates the animals tend to favor the slower

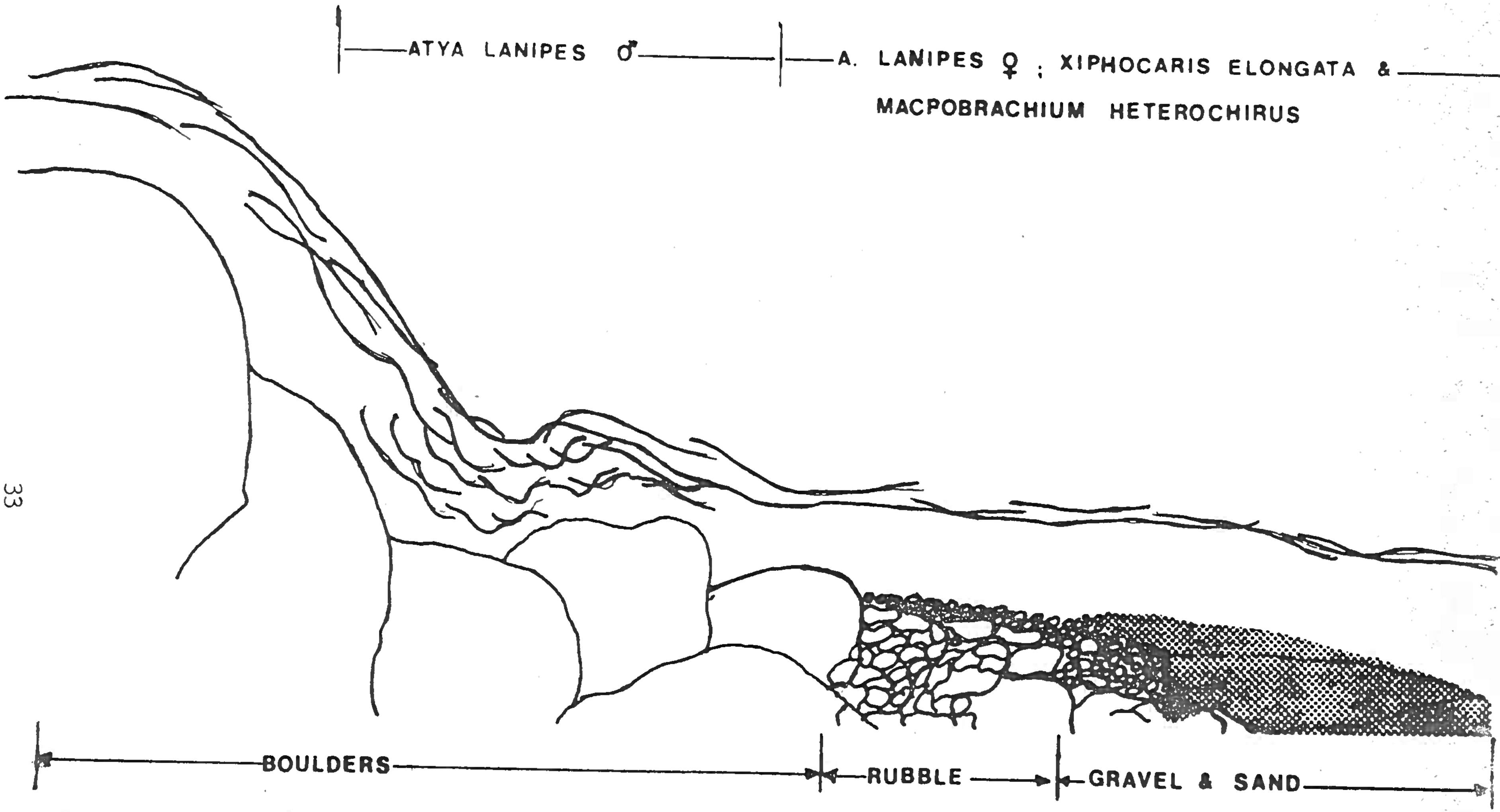


Fig. 7 SPECIES ZONATION AT THE ESPIRITU SANTO.

Table 4. Number of Individuals Captured in the Colleting Site.

Station	Atya lanipes	A. innocous	Xiphocaris elongata	Macrobrachium heterochirus
Zone 1				
Low-flow A	10	-	-	-
Low-flow B	4	-	-	-
Low-flow C	10	-	5	-
High-flow (a)	13	-	-	-
High-flow (b)	8	-	-	-
High-flow (c)	10	-	-	-
Zone 2				
Low-flow A	6	-	11	-
Low-flow B	10	-	8	-
Low-flow C	7		10	-
High-flow (a)	8	-	6	-
High-flow (b)	11	-	8	-
High-flow (c)	9	-	7	-
Riffle 1	7	-	5	-
Riffle 2	12	-	4	-
Riffle 3	6	-	4	-
Zone 3				
Low-flow A	12	-	20	1
Low-flow B	8	-	15	1
Low-flow C	10	-	12	-
High-flow (a)	15	-	17	-
High-flow (b)	17	-	24	-
High-flow (c)	6	-	13	-
Riffle 1	12	-	-	-
Riffle 2	16	-	-	-
Riffle 3	8	-	-	-
Zone 4				
Low-flow A	4	-	20	-
Low-flow B	5	-	18	-
Low-flow C	1	-	23	-
High-flow (a)	12	-	22	2
High-flow (b)	10	-	-	-
High-flow (c)	6	-	20	-
Riffle 1	15	-	8	-
Riffle 2	11	-	-	-
Riffle 3	16	-	-	-
Zone 5				
Low-flow A	-	-	23	-
Low-flow B	12	-	20	-
Low-flow C	-	-	21	2
High-flow (a)	14	-	11	-
High-flow (b)	12	-	18	-
High-flow (c)	5	-	16	-
Riffle 1	16	-	-	-
Riffle 2	18	1	6	-
Riffle 3	10	-	-	-

Table 5. Average size of the individuals captured at each collecting site.

Station	*Xiphocaris elongata* carapace 0	*Xiphocaris elongata* length 0	*Atya lanipes* overall 0	*Atya lanipes* length 0
Zone 1				
Low-flow A	-	-	54.9	68.25
Low-flow B	-	-	-	62.25
Low-flow C	12.23	11.95	52.22	65.8
High-flow (a)	-	-	53.39	67.28
High-flow (b)	-	-	47.58	66.55
High-flow (c)	-	-	49.55	62.35
Zone 2				
Low-flow A	13.82	11.07	34.5	65.0
Low-flow B	14.01	10.93	40.08	59.58
Low-flow C	14.05	11.09	41.04	57.60
High-flow (a)	12.75	10.34	33.03	60.0
High-flow (b)	12.05	10.45	36.01	58.04
High-flow (c)	14.02	10.03	39.02	57.03
Riffle 1	-	7.82	-	45.87
Riffle 2	12.50	10.5	-	56.67
Riffle 3	13.04	11.02	35.42	59.04
Zone 3				
Low-flow A	13.75	11.5	-	-
Low-flow B	12.05	10.04	39.05	-
Low-flow C	12.80	11.01	38.01	45.85
High-flow (a)	14.01	10.5	33.03	57.60
High-flow (b)	12.55	7.85	33.52	57.8
High-flow (c)	14.02	11.02	35.45	59.05
Riffle 1	12.01	8.59	39.04	60.01
Riffle 2	-	-	35.02	58.9
Riffle 3	-	-	32.03	52.01
Zone 4				
Low-flow A	12.49	-	35.47	-
Low-flow B	12.80	-	-	39.65
Low-flow C	12.74	10.53	32.60	-
High-flow (a)	12.60	10.90	-	-
High-flow (b)	-	-	42.7	-
High-flow (c)	12.52	11.02	33.4	62.4
Riffle 1	-	10.95	-	59.47
Riffle 2	-	-	-	58.03
Riffle 3	-	-	-	59.55
Zone 6				
Low-flow A	13.5	10.04	-	-
Low-flow B	12.05	10.55	34.01	-
Low-flow C	12.72	9.06	-	-
High-flow (a)	13.01	10.00	32.34	59.42
High-flow (b)	12.04	9.59	38.03	58.45
High-flow (c)	12.75	10.90	39.01	57.09
Riffle 1	-	-	41.01	55.01
Riffle 2	12.02	-	32.05	61.02
Riffle 3	-	-	33.02	59.03

flowing streams. No specimens were captured from the Sonadora or Espiritu Santo Rivers. But the captured individual was from a small riffle 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 quite upland pools and in low lying brooks.

Its feeding habits are similar to those described for Atya lanipes. The position of Atya innocous in the crustacean funa 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 draw (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 elevations zones (see Table 4). 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 populations size and distribution is not known. Groups of Xiphocaris elongata have been observed at low elevations migrating upstream, probably orienting against the current (pers. comm. with José A Colón).

The individuals who reach high elevation areas in the streams are in the average larger in size and fewer than those of low elevation areas (see Table 4 and 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 relative larger size of the individuals in high elevation increases could be due to migration.

It can be summarized that fewer individuals reach to high elevation zones (see Table 4) 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 migrates 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 specie, 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 15% 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.

Atya lanipes

A plot of the overall length of *A. lanipes* in the form of a histogram reveled 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 ($\bar{x}$ 61.87 mm vs. $\bar{x}$ 44.18 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 stream.

Holthuis (1963) described *Atya lanipes*, the description being based on two specimens from St. Thomas, Virgin Island, preserved in the Rijks museum van Natuurlijke Historie, Leiden, Holland. He described the last three periopods being densely clothed in hair; dense enough to conceal underlying surface. Chace and Hobbs (1969) reported the presence of *A. lanipes* from Puerto Rico in the collections of the U.S. National Museums 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

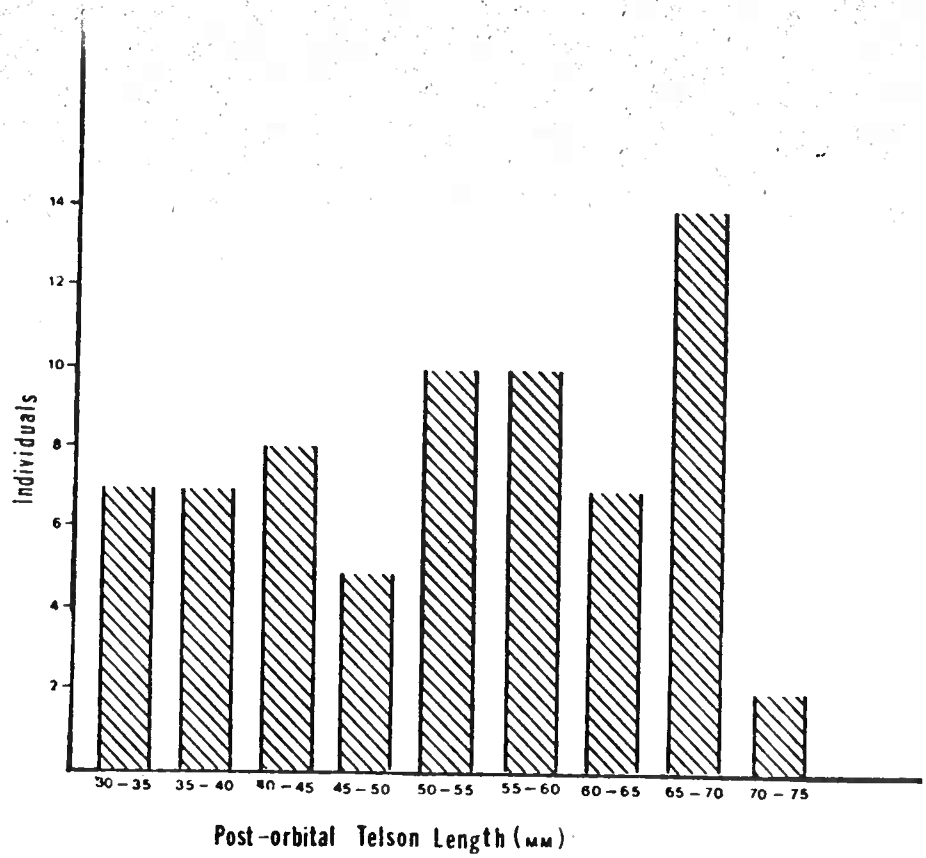


Fig. 8 A. lanipes HISTOGRAM

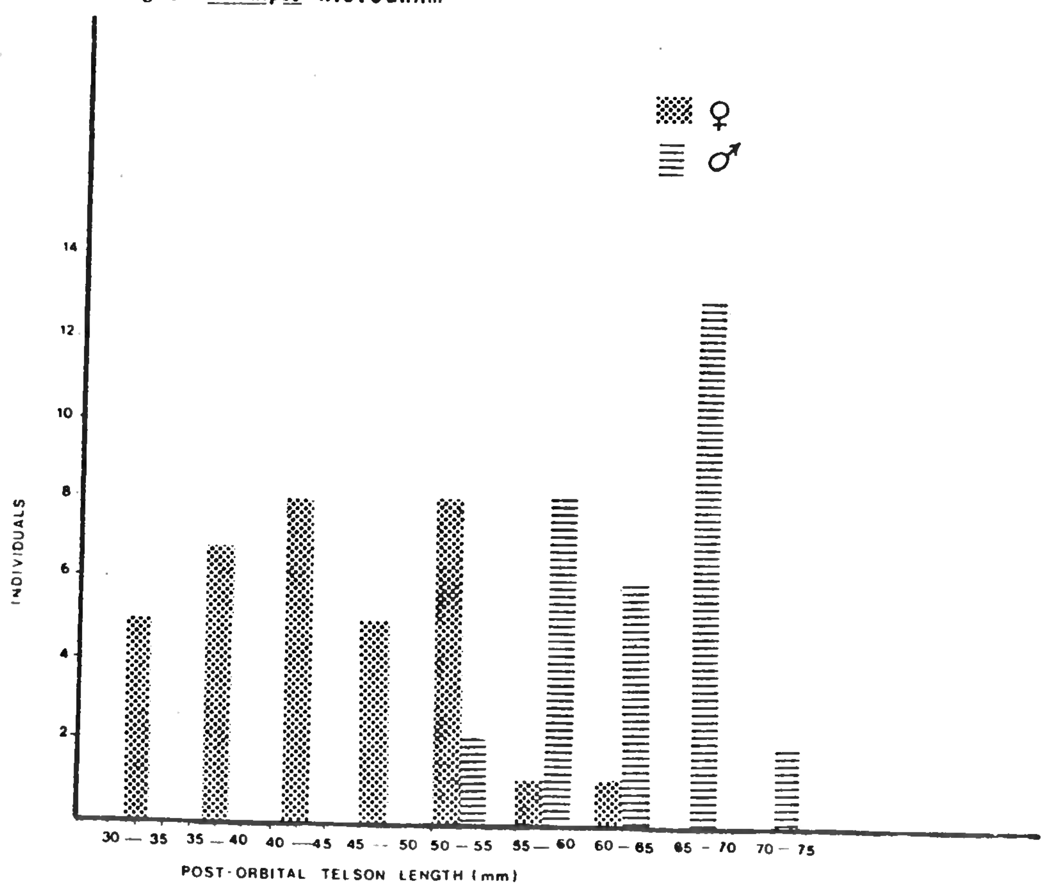


Fig. 9 Atya lanipes POPULATION HISTOGRAM, DIVIDED BY SEX

Hunte) confirmed that some of the Puerto Rican specimens did indeed show quite strong differences from the type description. All of the *Atya lanipes* captured on 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. comm. 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 dueing 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. 11) 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 (1889) 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*.

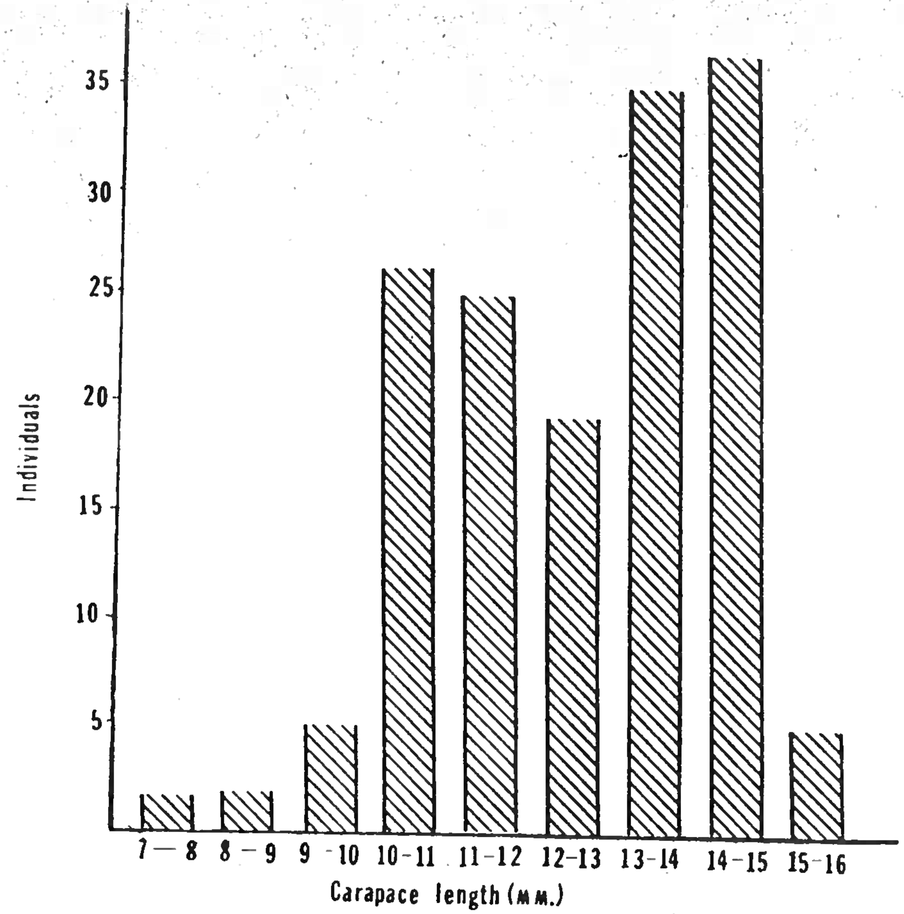


Fig. 10 X. elongata HISTOGRAM

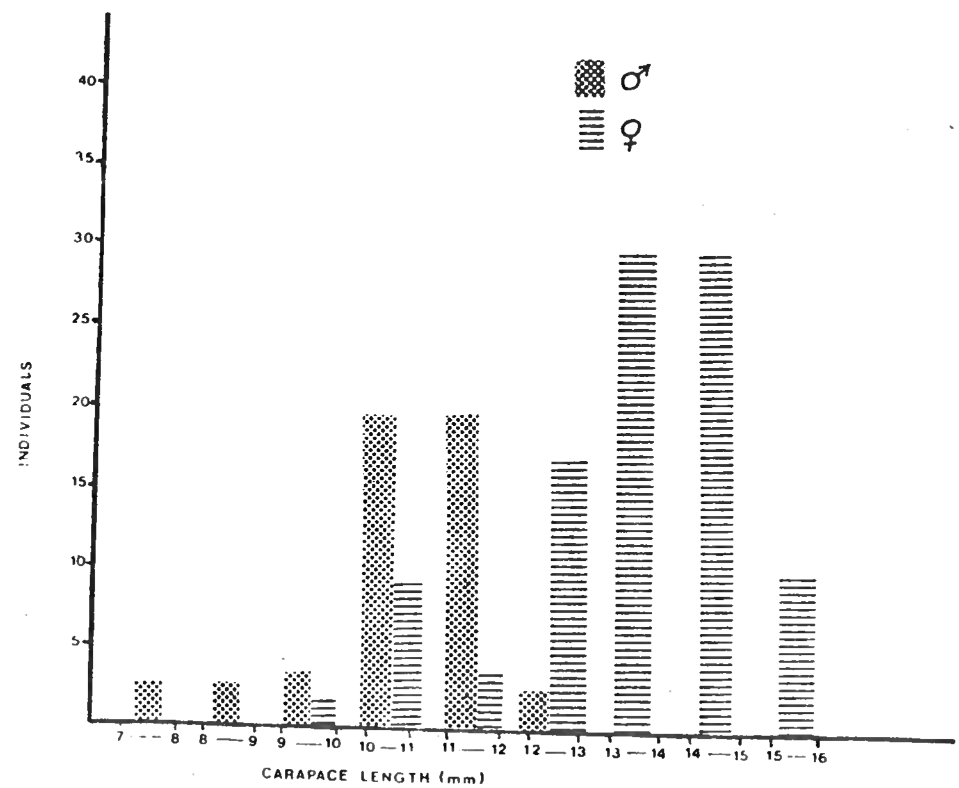


Fig. 11 X. elongata POPULATION HISTOGRAM, DIVIDED BY SEX

Chace and Hobbs (1969) disagree with this proposal, stati..g 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 1.0 to 1.3, and the range from 0.8 to 1.3 was set for the nature 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 Pocok'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 ploted (see Fig. 10). Chace and Hobbs (1969) state that the carapace length of adult Xiphocaris ranges from 8 mm to 12 mm. Based this criteria 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

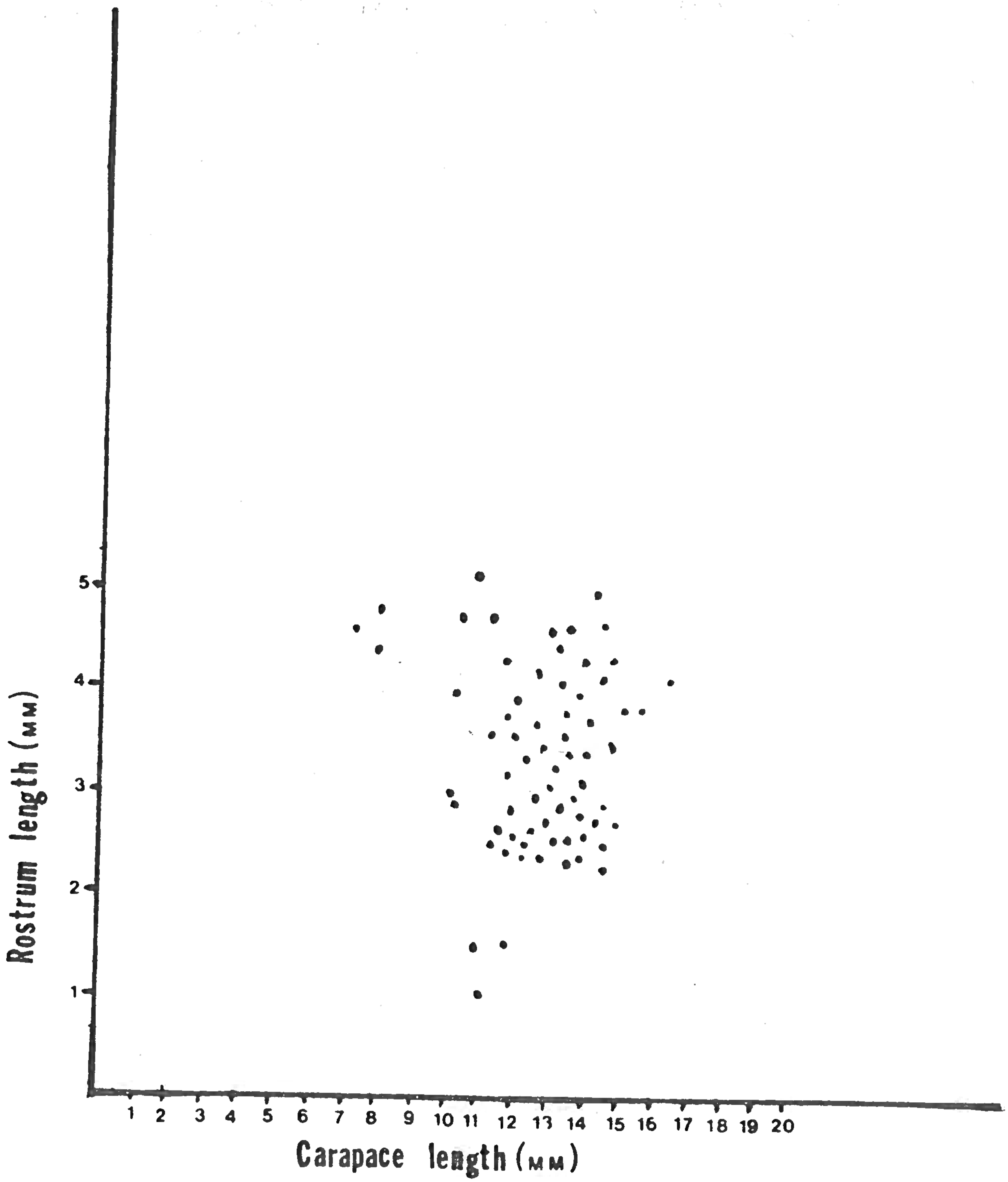


Fig. 12 CARAPACE vs ROSTRUM, X. elongata

each set of measurements taken from the adults and juveniles. No correlation analysis was performed on their data. This relationship was examined in this study by ploting rostrum length versus carapace length (see Fig. 12) and the data subjected to a correlated regression analysis. No correlation was found ($R^2 = 0.014$). 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 this 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. 1) in the range of adult carapace length. In view of these results we can state that Pocok'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 in 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 affects the distribution of shrimps are the water-flow or current and the type of substrate on the river bed. Eggleton (1939) states that one of the most far reaching environmental factors, indeed

Table 7. Substrate Analysis (See Table 1).

Station	Gravel*	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very fine Sand
Zone 1						
Pool A Headwaters 750 m.	6%	12%	25%	51%	6%	.5%
Pool B Headwaters 750 m.	2.6%	6%	12%	63%	14%	2.4%
Zone 2						
Pool A 820 m.	40%	10%	24%	25%	3%	0
Pool B 810 m.	45%	8%	26%	26%	2%	0
Zone 3						
Pool A 720 m.	75%	17%	4%	2%	0	0
Pool B 720 m.	50%	20%	30%	6%	0	0
Zone 4						
Pool A 655 m.	80%	12%	5%	1.8%	0	0
Pool B 620 m.	45%	25%	24%	6%	.7%	0
Zone 5						
Pool A 550 m.	39%	10%	25%	25%	2%	0
Pool B 550 m.	70%	16%	8%	6%	0	0

*Gravel - includes coarse and medium gravel 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 91.5% 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 "particles 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 susbtrate.

This could be one of the reasons why in Zone 1 Xiphocaris elongata was not found in two of the pools (see Table 3).

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 4 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 4 meters in pools of Zone 4 (see Table 2). This behaviour 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, was 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 most 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 and 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.

Station	grams*/ cubic meter**	Water-flow in cubic meters/sec.	Amount of Particulate matter in gms/ hour
Zone 1 Riffle 2	.02919	.0098	34.37
Zone 2 Riffle 2	.0191	.0147	33.84
Zone 3 Riffle 1	.248	.0147	439.30
Zone 4 Riffle 1	.0001	.0296	0.24
Zone 5 Riffle 2	.0040	.0147	7.086

*dry weight
**at base flow conditions

the individual will effectively foktrate 0.2% of a cubic meter of water. The anount of particulate matter available in Zone 1 is .012919 grams/ cubic meter of water (see Table 6). The above mentioned shrimp filtering a core of 2.54 cm in diameter by 100 cm long will filter approximately 0.00006 grams/hour.

Conclusions reached on the basis of physical measurements are as follows. High stream velocity is a limiting factor for the distribution of *Xiphocaris elongata*. Substrate composition affects the species diversity of a given area. The amount of particulate 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 6.8. 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 8). This suggests that the 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, (Hart, 1961). Water hardness in the study area ranged from 4 mg/l to 8 mg/l $CaCO_3$, with a mean value of 7.62 mg/l $CaCO_3$. The USGS Water Resources data for Puerto Rico from the period of 1968 to 1972 (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. Hart (1964) found in some streams of Jamaica a mean water hardness of 122.98 mg/l which is considerably higher than that observed for the Espiritu Santo River. In the Luquillo National Forest, Rio La Mina; a

Table 8. Chemical Data of the Sampling Stations

Station	Elevation	pH	O_2 in mg/1	Free CO_2 in mg/1	$CaCO_3$ in mg/1	Sulfate in mg/1	Phosphate in mg/1	Salinity in mg/l	Na in PPM	Ca in PPM	Mg in PPM	Potassium in PPM	Fe in mg/1
Zone 1													
Low flow A	750 m.	6.9	8.2	2.45	4	0.1	0.1	22.8	4.8	.69	1.6	.3	0.15
Low Flow B	750 m.	7.1	8.2	2.20	4	0.1	0.1	22.9	4.8	.69	1.1	.3	0.15
Low Flow C	750 m.	7.0	8.1	2.48	4	0.1	0.1	23.1	4.8	.63	1.1	.3	0.15
High flow (a)	750 m.	6.6	8.3	2.30	6	0.1	0.1	23.1	4.8	.69	1.6	.3	0.20
High flow (b)	750 m.	6.7	8.1	2.43	6	0.1	0.1	23.2	4.8	.69	1.6	.3	0.20
High flow (c)	750 m.	6.8	8.4	2.55	8	0.1	0.1	23.4	4.8	.63	1.1	.3	0.20
Zone 2													
Low flow A	820 m.	6.8	8.1	2.48	8	0.5	0.15	23.1	5.5	.65	1.1	.6	0.15
Low flow B	810 m.	6.9	8.3	2.60	8	0.5	0.15	23.3	5.2	.65	1.1	.6	0.15
Low flow C	805 m.	6.8	8.4	2.35	8	0.5	0.15	23.5	5.5	.53	1.1	.4	0.15
High flow (a)	810 m.	7.0	8.5	2.40	8	0.5	0.15	23.6	5.5	.65	1.1	.6	0.15
High flow (b)	812 m.	7.1	8.6	2.43	8	0.5	0.15	23.7	5.5	.65	1.0	.6	0.15
High flow (c)	810 m.	6.9	8.5	2.54	8	0.5	0.15	23.4	5.2	.53	1.1	.4	0.15
Riffle 1	805 m.	6.8	8.6	2.53	8	0.5	0.15	23.2	5.5	.65	1.1	.6	0.15
Riffle 2	800 m.	6.9	8.7	2.45	8	0.5	0.15	23.4	5.5	.65	1.1	.6	0.15
Riffle 3	790 m.	7.1	8.5	2.50	8	0.5	0.15	23.1	5.2	.53	1.0	.4	0.15
Zone 3													
Low flow A	720 m.	7.0	8.2	2.48	8	0.5	0.15	23.3	5.3	.65	1.1	.6	0.15
Low flow B	720 m.	7.1	8.3	2.54	8	0.5	0.15	23.4	5.3	.65	1.0	.6	0.15
Low flow C	720 m.	7.0	8.2	2.60	8	0.4	0.15	23.5	4.8	.67	1.1	.6	0.15
High flow (a)	721 m.	6.8	8.4	2.39	8	0.5	0.15	23.6	5.3	.65	1.1	.6	0.15
High flow (b)	722 m.	6.9	8.5	2.42	8	0.5	0.15	23.1	5.3	.65	1.0	.6	0.15
High flow (c)	720 m.	7.1	8.4	2.48	8	0.5	0.15	23.2	5.4	.67	1.1	.6	0.15
Riffle 1	710 m.	6.8	8.6	2.36	8	0.5	0.15	23.5	5.3	.65	1.1	.6	0.15
Riffle 2	720 m.	6.9	8.7	2.40	8	0.5	0.15	23.1	5.3	.65	1.1	.6	0.15
Riffle 3	715 m.	7.0	8.5	2.45	8	0.5	0.15	23.6	5.4	.67	1.0	.6	0.15
Zone 4													
Low flow A	655 m.	6.1	8.1	2.45	8	0.4	0.1	23.3	3.8	.61	1.5	.4	0.15
Low flow B	621 m.	6.5	8.2	2.60	8	0.4	0.1	23.1	4.8	.61	1.5	.3	0.15
Low flow C	620 m.	6.3	8.0	2.39	8	0.4	0.1	23.2	4.8	.65	1.4	.3	0.15
High flow (a)	655 m.	7.0	8.7	2.41	8	0.5	0.1	24.0	3.8	.61	1.4	.4	0.15
High flow (b)	655 m.	7.1	8.6	2.46	8	0.5	0.1	23.1	4.8	.61	1.5	.4	0.15
High flow (c)	658 m.	6.8	8.6	2.43	8	0.5	0.1	23.2	4.8	.65	1.4	.3	0.15
Riffle 1	655 m.	6.6	8.3	2.38	8	0.5	0.12	23.4	3.8	.61	1.5	.4	0.20
Riffle 2	655 m.	6.8	8.8	2.40	8	0.5	0.12	23.1	4.8	.61	1.5	.4	0.15
Riffle 3	658 m.	7.0	8.7	2.45	8	0.5	0.1	23.2	4.8	.65	1.4	.3	0.15
Zone 5													
Low flow A	550 m.	7.1	7.0	2.40	8	0.5	0.15	23.4	5.3	.67	1.2	.2	0.20
Low flow B	550 m.	6.8	7.2	2.43	8	0.5	0.15	23.1	5.5	.67	1.2	.4	0.15
Low flow C	550 m.	6.9	7.4	2.44	8	0.5	0.15	23.3	5.5	.67	1.2	.5	0.20
High flow (a)	550 m.	6.8	8.0	2.38	8	0.5	0.15	24.0	5.3	.67	1.2	.2	0.15
High flow (b)	550 m.	6.9	8.5	2.45	8	0.5	0.15	23.3	5.5	.67	1.2	.4	0.15
High flow (c)	550 m.	7.0	7.1	2.39	8	0.5	0.15	23.3	5.5	.67	1.2	.5	0.15
Riffle 1	550 m.	7.1	7.8	2.43	8	0.5	0.15	23.6	5.8	.67	1.2	.2	0.20
Riffle 2	550 m.	6.8	8.0	2.44	8	0.5	0.15	22.9	5.5	.67	1.2	.4	0.15
Riffle 3	550 m.	7.0	8.0	2.44	8	0.5	0.15	23.1	5.5	.67	1.2	.5	0.15

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. Hart (1961) found that the carapace of the shrimp of La Mina river were 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_2) when present in all surface waters in amounts generally less than 10 mg/l (APHA, 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 2.44 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 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 are fairly constant through the stream. Here again, low concentrations of these three micronutrients could not be considered critical for the distribution of the shrimps. The mean concentration of sulfate was 0.41 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_4) 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^{3+}). The mean concentration of iron in the study area was 0.17 mg/l ranging from 0.15 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 24.0 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 .44 ppm with a range of measured values from .2 ppm to .6 ppm. Low calcium concentrations were found in the studied area, the mean concentration was .64 ppm ranging from .53 ppm to .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 shrimps 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 its 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 inside 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, identified and describe the distribution of the shrimps. The species encountered in the study area were <u>Atya lanipes</u>, <u>Xiphocaris elongata</u>, <u>Macrobrachium heterochirus</u> and <u>Atya innocous</u>. 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_2), pH, water hardness, iron, orthophosphate, sulfate, salinity, sodium (Na), calcium (Ca), potassium (K), and magnesium (Mg). The physical parameters which affects 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 a constancy in chemical concentrations across 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 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 daylight 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 a 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.

Literature Cited

American Public Health Association, 1971. Standard Methods for the Examination of Water and Wastewater, 13th. Edition, American Public Health Association, N.Y., 874 pp.

Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. Environmental Monitoring Service, EPA-670/4-001, July, 1973.

United States Department of Interior. Geological Survey, 1974. Water Resources Data for Puerto Rico, Part 2a, Water Quality Records 1968-1972, United States Department of Interior Geological Survey, Washington, D.C. 410 pp.

Chace, F.A. and H.H. Hobbs, 1969. The Fresh Water and Terrestrial Decapod Crustaceans of the West Indies with Special References To Dominica. Bulletin 292, Smithsonian Institute, U.S. National Museum, Washington, D.C.

Cuevas, E., 1975. Changes in Selected Water Quality Parameters as Influenced by Land Use Patterns in the Espiritu Santo Drainage Basin. Master of Science Thesis, University of Puerto Rico, Rio Piedras, Puerto Rico.

Dungan, C.C. and Thomas A. Frankes, 1972. Culture of Brackish-Freshwater Shrimp Macrobrachium acanthurus, M. carcinus and M. ohione. Proceedings of the Third Annual Workshop-World Mariculture Society, St. Petersburg, Florida.

Eggleton, F.E., 1939. The Fresh Water Communities. The American Midland Naturalist, 56-74.

Erdman, D.S., 1972. Los peces de las Aguas Interiores de Puerto Rico. Estado Libre Asociado de Puerto Rico. Departamento de Agricultura, Vol. IV, Num. 2, Diciembre, 1972.

Gifford, C.A., and T.J. Cole, 1970. Decapod Crustaceans of the Luquillo Experimental Forest (unpublished).

Gundlach, D.J., 1887. Apuntes para la fauna Puertorriqueña, VI. Crustaceos Ann. Soc. Española Hist. Nat. 16: 115-133.

Hart, C.W., 1961. Freshwater Shrimp Atyidae and Palaemonidae of Jamaica, West Indies, Proc. Acad. Nat. Sci. Phila.

Hart, C.W., 1964. A Contribution to the Limnology of Jamaica and Puerto Rico. Carib. J. Sci. 4: (page no.).

Holthius, L.B., 1963. Two new species of freshwater shrimp (Crustacea decapoda) from the West Indies. Proc. Kon. Ned, Akad, Wetensch, Amsterdam, (C) 66: 61-69, figs. 1-3.

Hunte, W, 1975. _Atya lanipes_ Holthuis, 1963. In Jamaica, Including Taxonomic Notes and Description of the First Larval Stage (Decapoda, Atyidae) Crustaceana, Vol. 28, Part 1, 1975.

Ingle, R.M. and B. Elfred, 1960. Notes on the Artificial Cultivation of Fresh Water Shrimp. West Indies 4: pp. 1-5.

Lewis, J.B., J. Ward and A. McIver, 1966. The Breeding Cycle, Growth and Food of the Freshwater Shrimp _Macrobrachium carcinus_ (Linnaeus), Crustaceana.

Odum, H.T. and R.F. Pigeon, 1970. A Tropical Rain Forest, A Study of Irradiation and Ecology at El Verde, Puerto Rico. USAEC Tech. Publ. PRNC-138 (TID-34270) Chapt.

Pocock, R.I., 1889. Contribution to our Knowledge of the Crustaceae of Dominica, Ann. Mag. Nat. Hist. Ser.6,

Schmidt, W.L., 1935. Crustacea Macrura and Anomura of Porto Rico and Virgin Island, Scientific Survey of Porto Rico and the Virgin Island, New York Acad. Sci. XV, pp. 125-262.

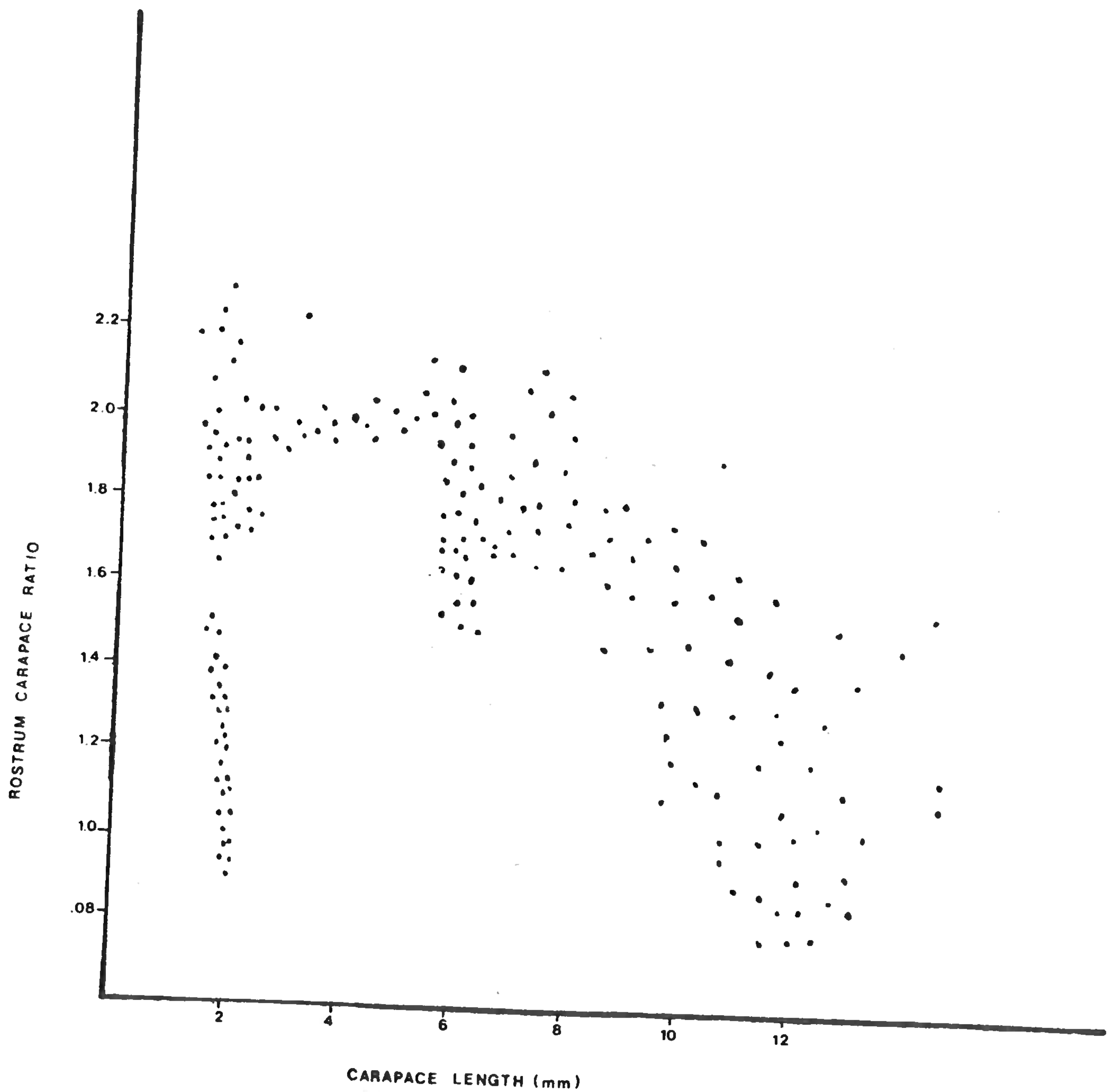
Seiders, V.M., 1971. Geologic Map of the El Yunque Quadrangle, Puerto Rico. Map. 1-658. United States Geologic Survey, Washington D.C.

Seiders, V.M., 1971. Cretaceous and Lower Tertiary Stratigraphy of the Gurabo and El Yunque Quadrangles, Puerto Rico. Geologic Survey Bulletin 1294-F. United States Geologic Survey, Washington, D.C. 58-99.

Sick, L.V., D. White and G. Baptist, 1973. The Effect of Duration of Feeding, Amount of Food, Light Intensity and Animal Size on Rate of Ingestion of Pelleted Food by Juvenile Pnaeid Shrimp. Fish-Cul. 35: 22-26.

Wadsworth, F.N., 1951. Forest Management in the Luquillo Mountains; I. Setting. Carib. Forester 12: 93-114.

Appendix



Appendix Figure 1.

Scatter Diagram Showing Correlation of the Proportinate Length of the Rostrum with Growth in Specimens of *Xiphocaris elongata* Collected in Dominica in 1964. Chace and Hobbs 1969.

Appendix Table 1

Family Atyidae

Key to Species (Chace and Hobbs, 1969)

1. Chelae of first and second pereiopods without tufts of long hairs at ends of fingers .... Xiphocaris elongata
   Chelae of first and second pereiopods with tufts of long hairs at ends of fingers 2

2. Eyes, reduced, cornea limited to distolateral pigment spot on eyestalk; pereiopods with exopods; subterranean species 3
   Eyes normal, cornea nearly as broad as or broader than eyestalk; pereiopods without exopods; epigean species ... 4

3. Exopod on fifth pereiopod nearly as well developed as those on preceding ones .... Typhlatya garcial
   Exopod on fifth pereiopod greatly reduced, barely discernible .... Typhlatya monae

4. Rostrum with dorsal teeth .... Micratya poeyi
   Rostrum without dorsal teeth 5

5. Carpus of second pereiopod broader than long 6
   Carpus of second pereiopod much longer than broad 8

6. Adults without horizontal lateral lobe or tooth on either side of rostrum, third pereiopod not bearing horny scales or tubercles and only slightly more robust than fourth pereiopod .... Atya lanipes
   Adults with distinct horizontal lateral lobe or tooth on either side of rostrum; third pereiopod bearing prominent horny scales or tubercles and considerably larger and more robust than fourth pereiopod 7

7. Lateral lobes of adult rostrum obtuse; pleuron of second abdominal somite without blunt marginal spines although pleura of third to fifth somites may bear acute marginal denticles body without transverse bands of dark color ... . Atya innocous
   Lateral lobes of adult rostrum subacute 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 uncture of carapace and abdomen and on anterior part of sixth abdominal somite ... . Atya scabra

8. Orbital margin minutely serrate; appendix masculina on second pleopod of male slender, terminating in sharp point .. .. *Jonga serrei*

Orbital margin not serrate; appendix masculina on second pleopod of male broad, rounded distally 9

9. Appendix masculina widening distally, about three-fourths as wide as long, posterior margin slightly and evenly convex .... *Potimirim americana*

Appendix masculina widest proximally, not more than half as wide as long, posterior margin sinuous 10

10. Dorsal margin of rostrum curving downward at tip; appendix masculina with deep, unarmed sinus in posterior margin .... *Potimirim glabra*

Dorsal margin of rostrum nearly straight; appendix masculina without deep, unarmed sinus in posterior margin .... *Potimirim mexicana*

Appendix Table 2

Genus Macrobrachium Bate, 1868

Key to West Indian Species (Chace and Hobbs, 1969)

1. 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 penduncle, with 10-15 dorsal teeth, including at least 4 on carapace posterior to level of orbital margin; second pereiopods of adult male robust, chela less than seven time as long as broad 3

2. (1) 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. acanthurus
Rostrum unarmed in distal half or third of dorsal margin except for 2 subapical teeth proximal teeth subequally spaced; second pereiopod of adult male smooth, carpus longer than chela, fingers naked .... M. jelskii

3. (2) Rostrum with sinuous dorsal margin, tip slightly upturned; second pereiopods of adult male similar in form it not in size, with short pubescence and short spines along outer margin of fixed finger and continued onto palm, but spines not forming distinct crest and not hidden by pubescens 4
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 crestlike row of long spines on margin of palm 5

4. (3) 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 .... M. carcinus
Three or 4 teeth of dorsal rostral series more erect and more widely spaced than anterior ones; second pereiopods of adult male usually unequal in legth, 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 teeth on opposable margin of fixed finger greatly enlarged; abdomen transversely banded in life ....
.... M. heterochirus

5. Major second pereiopod of adult male with carpus usually
(3) longer than merus and fingers distinctly longer than palm, row of spines along mesual margin of palm and fixed finger rather long on proximal portion of palm, becoming shorter near midlength of palm, longer near base of finger, and decreasing again distally on finger.. *M. faustinum*

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 palm .... *M. crenulatum*