Morphological adaptation of the second maxilliped in semiterrestrial crabs of the genus *Uca* Leach, 1814 (Decapoda, Ocypodidae) from a subtropical Brazilian mangrove.

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Abstract

The morphological adaptation of the 2nd maxilliped was studied in six species of the genus *Uca*. Crabs were collected at the confluence of the rivers Comprido and Escuro, Ubatuba, São Paulo, Brazil. The 2nd maxilliped of at least five specimens of *U. burgersi, U. leptodactyla, U. rapax, U. thayeri, U. uruguayensis* and *U. vocator* was removed and analyzed under an optical stereomicroscope. The merus was examined to verify the presence of specialized setae in each species. Species inhabiting muddy/sand areas (*U. leptodactyla, U. rapax* and *U. uruguayensis*) present spoon-tipped setae specialized for the removal of organic material from coarser sediments, while species living in fine and very fine sands (*U. thayeri* and *U. vocator*) present plumose and simple setae. The species *U. burgersi*, which lives in areas where coarse sand prevails, presents only a few spoon-tipped setae. Morphology of mouthparts is apparently highly adapted to deposit feeding, as indicated by the variation of setal morphology in species inhabiting areas with different sediment texture.

Key words: Morphology, maxilliped, *Uca,* Ocypodid crabs.

Introduction

Ocypodid crabs of the genus *Uca* are known for all continents, except Antarctica (Crane, 1975). They are all intertidal, but their burrows are not necessarily either covered by water or exposed every day. The sediment texture where these organisms are found ranges from muddy to sandy containing a minimum of silt (Crane, 1975). *Uca* species can be found living in open areas such as salt marshes, or in vegetated areas such as mangroves.

The ecological distribution of a given organism can be influenced or even determined by its ability to obtain the resources needed for its survival from the environment. If an animal becomes uniquely adapted to obtain food in a specific manner, the variety of habitats in which it can live becomes limited accordingly (Miller, 1961). The main barriers for the distribution of fiddler crabs are associated with the texture of the substratum in which they live and their feeding habits. Those patterns allow the consideration of eventual adaptive features permitting their association with sediments of given characteristics (Aspey, 1978; Icely and Jones, 1978; Thurman II, 1987 and Macintosh, 1988).

The mouthparts of crabs consist of three pairs of outer thoracic appendages (3rd, 2nd and 1st maxillipeds) and three inner cephalic appendages (2nd and 1st maxilla and mandible). In ocypodid crabs, which are known to be deposit feeders, mouthparts are used to manipulate and select the food particles to be ingested. Deposit feeding is a process whereby sediment picked from the surface layer of the substratum is re-suspended within the buccal cavity and is sifted by the mouthparts to extract organic material (Maitland, 1990). Water, which is essential for this process, is pumped to the mouthparts from the branchial chamber (Miller, 1961).

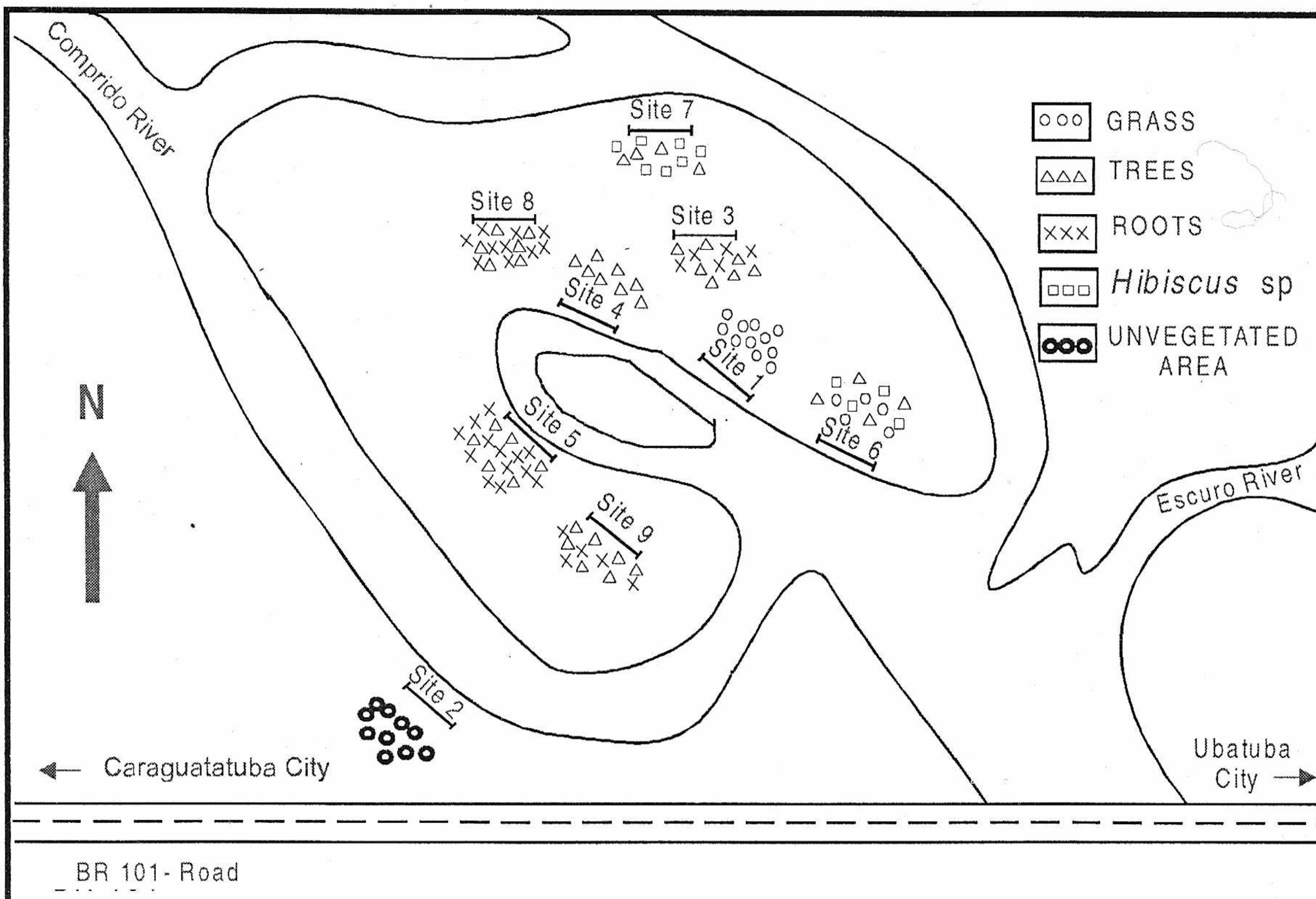
The role of the 1st and 2nd maxillipeds in the feeding process can vary according to the kind of substratum on which a fiddler crab feeds (Miller, 1961). Several authors have shown the presence of specialized setae in these appendages, indicating an adaptation to cope with deposit feeding from sediments of different grain size composition (Miller, 1961; Icely and Jones, 1978; Thurman II, 1987; Maitland, 1990; O'Connor, 1990; Wolcott and O'Connor, 1992 and Mouton and Felder, 1996). Such an adaptation is considered to influence the distribution of *Uca* species and can be used, at least part to explain the complex distribution patterns of these organisms in mangroves (Jones, 1984).

According to Maitland (1990), the mouthpart morphology of deposit feeding crabs and the degree of sifting performed prior to ingestion are strongly correlated with the habitat type. In several species of fiddler crabs, the number of spoon-tipped setae is higher in species living in areas where sand prevails (Crane, 1975; Icely and Jones, 1978; Robertson and Newell, 1982). The spoon-tipped setae are used during feeding to draw large particles across the first maxilliped endites (Miller, 1961).

The purpose of this paper is to determine the association between the setation of the 2nd maxilliped and the texture of the sediment for six *Uca* species in a subtropical mangrove ecosystem in Ubatuba, SP, Brazil.

Material and Methods

Fiddler crabs were sampled in a mangrove area adjacent to the rivers Comprido and Escuro that flow to "Dura" Beach (23° 29'S and 45° 09'W). The sampling area is located in Ubatuba, northern coast of São Paulo State, Brazil (Fig. 1).



e 1: Schematic partial map of the studied mangrove, (Ubatuba, SP), indicating the sampled sites and respective vegetation type.

Sampling was performed monthly throughout a 1-year period (1997) along nine transects (5m *vs.* 0.20m). The location of each site was chosen according to the surrounding vegetation and the distance from the river margin. Crabs were collected along each transect with the aid of a diving knife during low tide periods. Captured crabs were immediately packed in labeled plastic bags, and frozen for later laboratory procedures. All individuals were fixed in 10% formalin for 24 h before being transferred to 70% ethanol.

Identification was carried out following Melo (1996).

The 2nd maxilliped of at least five crabs of each species was carefully removed and mounted on a microscope slide for examination. Only crabs of similar size were used to allow adequate morphological comparisons. Slides were observed in a Zeiss SV6 microscope provided with an Axiovision image analysis system. The presence and location of spoon-tipped (either short or long) plumose and simple setae in the endopod merus were recorded. A schematic representation of the 2nd maxilliped showing the position of each kind of seta is provided for each species.

Sediment samples were obtained from the study site to determine grain size composition, organic content and humidity. In the laboratory, three 100g subsamples were placed in labeled Petri dishes in a stove at 70° C for 72 hours. After drying, sediment subsamples were weighed to obtain measurements of humidity. These dried subsamples were then placed in a stove at 550° C for 5 hours to determine their organic content by ash-weighing. Comparisons of organic matter content and humidity among sites were performed using the analysis at the 5% significance level (Sokal and Rohlf, 1985).

Subsamples (50g of sediment) were transferred to a Becker containing 250 ml of a 0.1N NaOH solution and homogenized for 5 minutes to determine the grain size composition. This material was maintained in a shaker for 10 min and filtered through a 0.063 mm sieve in order to extract silt plus clay particles and water. After extracting the finer particles, the subsamples were placed in a stove for 24h at 70° C. Granulometric fractions were obtained by the differential sifting, according to the Wentworth scale (Wentworth, 1922).

Spearman correlation analyses were performed in order to verify the existence of significant relationships between the abundance of the studied species and the analyzed environmental factor (Sokal and Rohlf, 1985).

Results

The examined material comprised six *Uca* species: *U. burgersi* Holthuis, 1967, *U. leptodactyla* Rathbun, 1898, *U. rapax* (Smith, 1879), *U. thayeri* (Rathbun, 1900), *U. uruguayensis* Nobili, 1901 and *U. vocator* (Herbst, 1804).

The analyses of grain size composition indicated a higher texture uniformity at site 2, located on the outer river margin, where there is a predominance of silt and clay followed by coarse and medium sand. Sediment at the remaining sites, located in the inner sampling area, were mainly composed of very fine sand (Fig. 2).

Results of humidity and organic matter content are presented in table I. The organic matter content in the sediment was higher at the sites that are flooded by the high tides (9, 2, 5, 8 and 4), and presented significant differences between each and the remaining sites ($p<0.05$). None of such differences were found among sites 6, 3, 7 and 1, located in the upper littoral region. Relative humidity was higher at sites 8 and 4, which are flooded during the high tides, compared with the remaining sites ($p<0.05$). No significant differences were found between sites 1 and 7, 3 and 2, and among 6, 5, 9 and 3.

Table I: Results from among-sites ANOVA comparisons of average percentage of organic matter and humidity in the sediments sampled at the nine studied sites.

Sites	Organic matter Mean ± sd		Sites	Humidity Mean ± sd	
6	1.69 ± 0.0808	f*	1	21.5± 0.336	e
3	1.79 ± 0.2715	f	7	22.1 ± 0.296	e
7	1.79 ± 0.0814	f	6	25.6 ± 0.909	d
1	1.98 ± 0.2815	f	5	26.8 ± 0.505	d
4	3.46 ± 0.0458	e	9	27.2 ± 0.342	d
8	4.53 ± 0.0208	d	3	28.9 ± 2.030	cd
5	4.99 ± 0.2566	c	2	30.4 ± 0.741	c
2	5.88 ± 0.2113	b	4	32.1 ± 1.506	b
9	6.72 ± 0.1833	a	8	34.2 ± 0.804	a

* For both variables, means sharing at least one letter did not differ statistically (p>0,05).

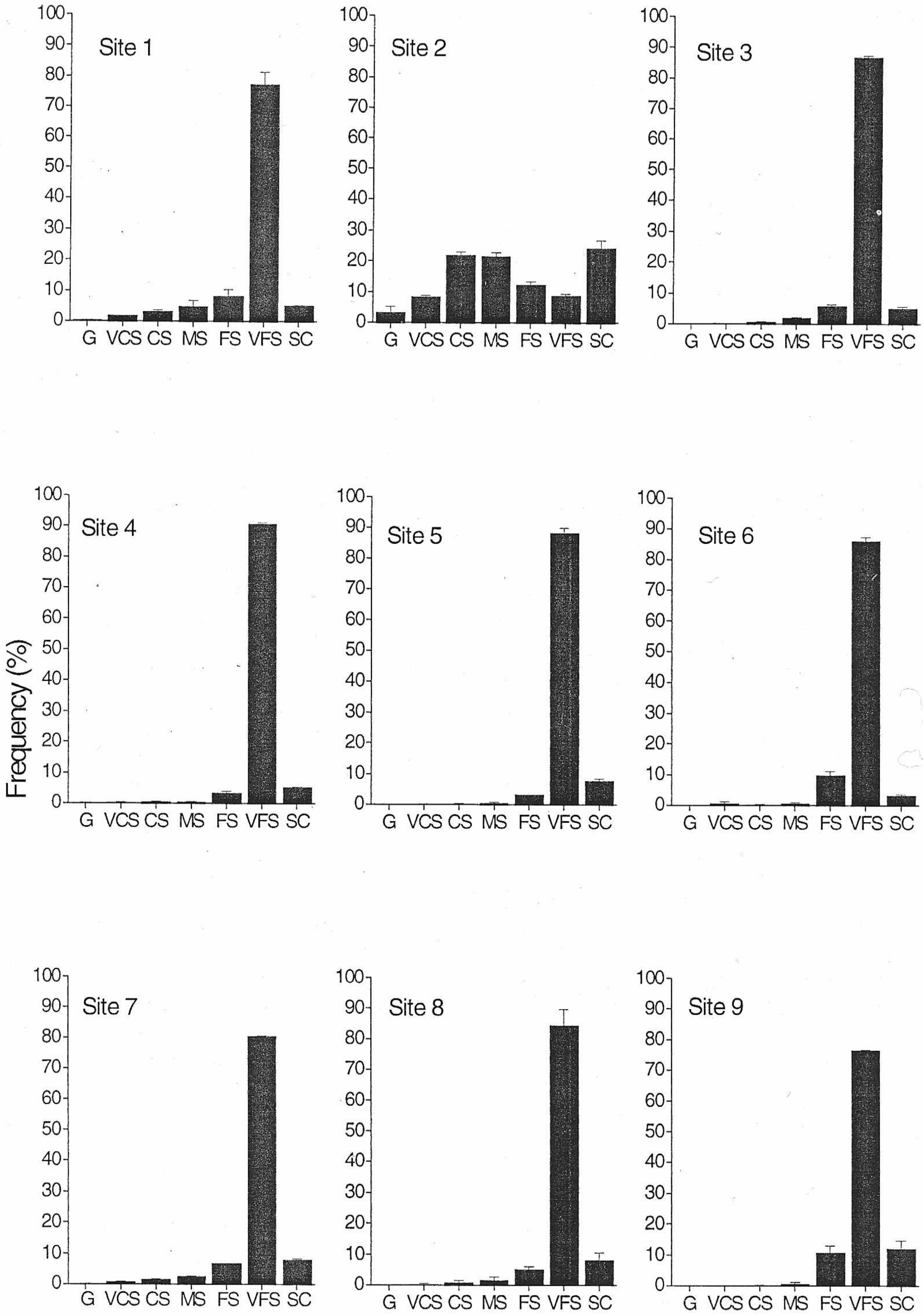


Figure 2: Granulometric composition of the sediment at each site. Line above the bars indicate standard deviation. G = gravel; VCS = very coarse sand; CS = coarse sand; MS = medium sand; FS = fine sand; VFS = very fine sand and SC = silt + clay.

The abundance of each species at the sampling sites is presented in figure 3. *U. burgersi* was most abundant at sites 1, 6 and 7, *U. leptodactyla* at sites 2 and 6, *U. rapax* at sites 7, 2 and 6, *U. thayeri* at sites 9, 5 and 4, *U. uruguayensis* at sites 3 and 2, while *U. vocator* was found only at sites 6, 8 and 9. Correlation analyses between species abundance and proportion of each sediment fraction are presented in table II.

The species *U. leptodactyla, U. rapax* and *U. uruguayensis* inhabit areas with similar sediments. Theses species are usually found in sandy-mud sediments, presenting a positive correlation with proportions of gravel, very coarse sand, coarse sand, medium sand and fine sand, while a negative correlation was found for very fine sand. No significant correlations were obtained in the case of silt, clay and organic matter contents. These species present larger areas of the 2nd maxilliped provided with short and long spoon-tipped setae.

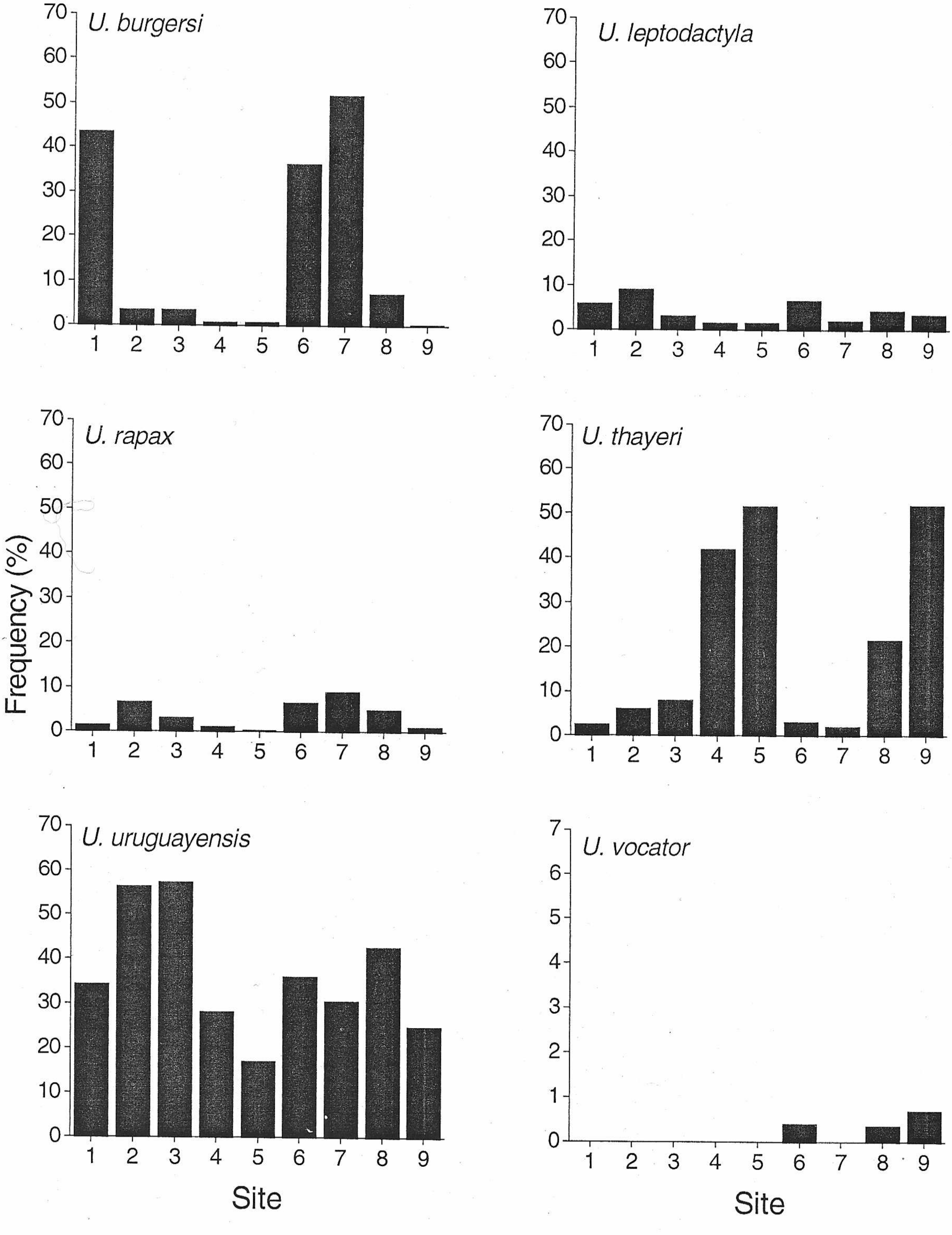


Figure 3: Relative abundance of *Uca* species at each studied site.

Table II: Correlation coefficients obtained in Spearman correlation analyses between environmental factors and abundance of the studied species.

Factor / Species	*Uca burgersi*	*Uca leptodactyla*	*Uca rapax*	*Uca thayeri*	*Uca uruguayensis*
Sediment granulometry					
Gravel	0.39 ns	0.340 *	0.500 **	-0.208 ns	0.368 *
Very coarse sand	0.556 ***	0.555 ***	0.561 ***	-0.385 *	0.464 **
Coarse sand	0.500 **	0.487 **	0.555 ***	-0.305 ns	0.519 **
Medium sand	0.436 *	0.576 ***	0.569 ***	-0.258 ns	0.584 ***
Fine sand	0.294 ns	0.567 ***	0.396 *	-0.222 ns	0.357 *
Very fine sand	-0.288 ns	-0.492 **	-0.500 **	0.131 ns	-0.411 *
Silt + clay	-0.221 ns	0.123 ns	0.255 ns	0.410 *	0.207 ns
Humidity	-0.504 **	0.065 ns	0.199 ns	0.645 ***	0.383 *
Organic matter	-0,.73 **	0.221 ns	-0.121 ns	0.649 ***	0.230 ns

* p<0.05; ** p<0.01; *** p<0.001; ns p>0.05

The species *U. burgersi*, which is mostly found associated with coarse grains (>0.25 mm) presents a low density of spoon-tipped setae in the 2nd maxilliped. With an affinity for the finest grains of silt and clay and high organic matter contents, the 2nd maxilliped of *U. thayeri* has a smaller area covered by spoon-tipped setae, while *U. vocator*, which lives in a similar environment, does not present these modified setae on it.

Plumose setae were observed in all species, with the exception of *U. rapax* (Fig. 4). These setae are known to be related to the selection of organic matter among fine grains.

Discussion

The distribution of fiddler crabs and other ocypodids is probably determined not only by their tolerance to air exposure, but also by their ability to extract organic matter from sediments of a certain particle size (Macintosh, 1988). Several authors have pointed out the importance of some abiotic factors (e.g. organic matter content, sediment humidity) in the ecological distribution of fiddler crabs (Icely and Jones, 1978; Christy and Salmon, 1984; Thurman II, 1987; Genoni, 1991 and Mouton and Felder, 1996).

In this study, only three of the six species analyzed presented significatives correlatives with such abiotic factors, where *U. burgersi* preference inhabit area of sediment with coarse grains, presented negative correlation with humidity and matter content, while *U. thayeri* preferentially inhabits area with sediment more fine, presented positives correlations with such factors. The species *U. uruguayensis* encountered usually in the area with sediment sandy-muddy, presented positive correlations with humidity factor.

Thurman II (1987) studied the relationship between the grain size of sediments and the distribution of fiddler crabs along the eastern coast of Mexico. This author showed that each analyzed species occupies a distinct position in the studied area: *U. leptodactyla* inhabits sandy bottoms, *U. rapax* muddy-sandy bottoms, *U. burgersi* sandy-muddy bottoms and *U. thayeri* and *U. vocator* silty-muddy bottoms. In this study, the observed affinity of the examined species with particular granulometric fractions of the sediment agrees with the results obtained by Thurman II (1987).

Ocypodid crabs obtain their food by grasping the organic matter from larger particles, using special and modified setae present in the 2nd maxilliped (Wolcott and O'Connor, 1992). Fiddler crabs that feed on muddy sediments present plumose setae (Maitland, 1990). Except *U. rapax*, overall species sampling presented plumose setae, what probable indicate that only *U. rapax* not presented the ability their food once fine sediment.

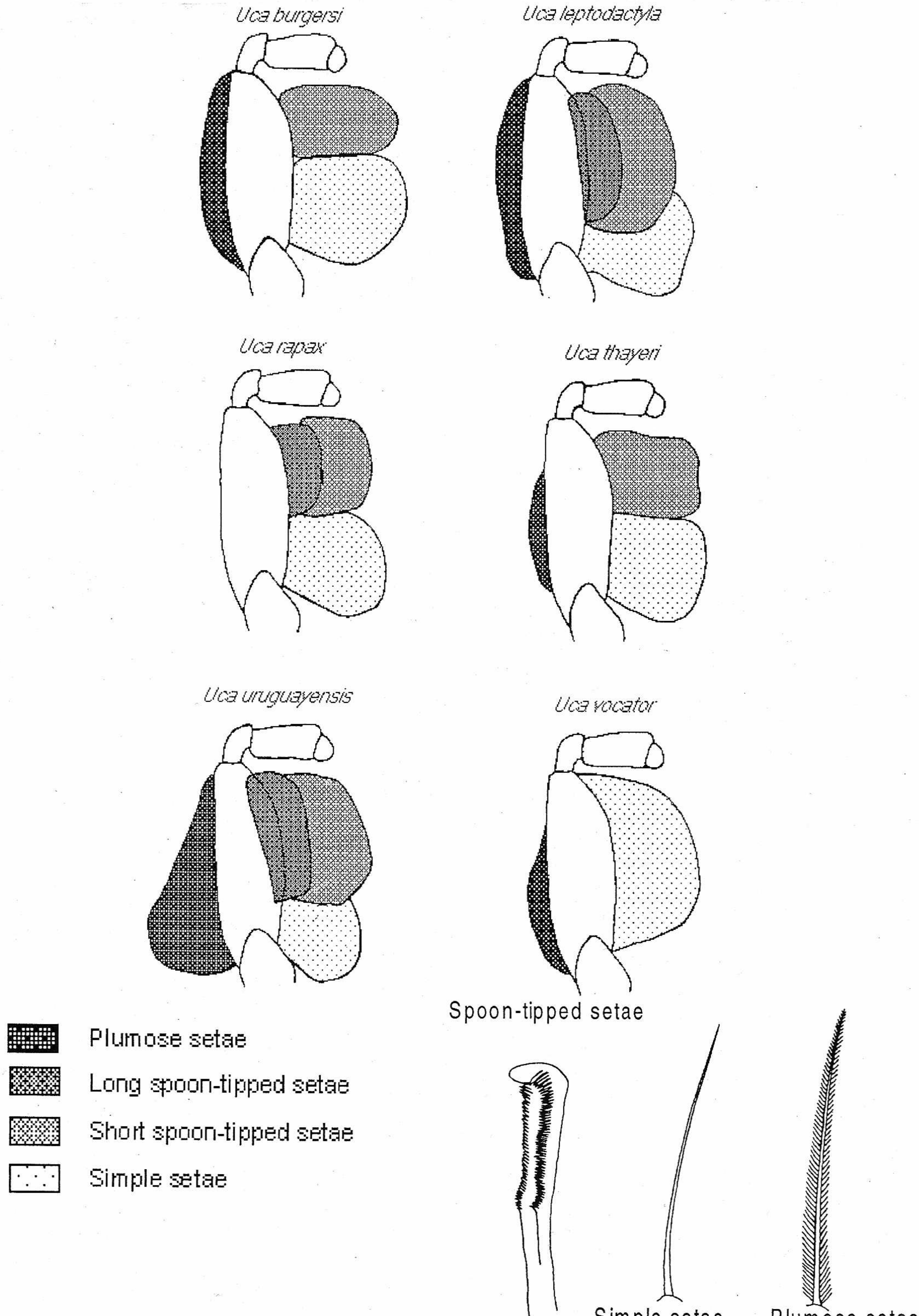


Figure 4: Schematic representation of the second maxilliped setal coverage for the six analyzed species.

Species incapable of retaining fine particles may shift to muddy areas where organic matter content is higher, thus overlapping with species that typically inhabit organically enriched environments. Species that are adapted to extract food from fine sediments are otherwise more restricted to areas where organic content is high, since they are incapable of obtaining the required quantity of food from coarse sediments usually containing less organic matter (Jones, 1984).

According to Jones (1984), the absence of spoon-tipped setae in *U. vocator* probably indicates that this species occurs preferentially in fine sediments with a high organic content, since these setae are responsible for the extraction of the organic matter from coarser grains. In this study of obtained kind for *U. vocator* agrees with the Jones (1984). This specie not presented spoon-tipped setae and, three place in the *U. vocator* were sampling, two place (9 and 8 respectively) the organic matter content were higher.

On the other hand, Thurman II (1987) found a great morphological variation in the mouthparts of *U. burgersi*. When compared with others species inhabit preference similar area, from coarse sediment (with *U. leptodactyla, U. rapax* and *U. uruguayensis*), the obtained kind for *U. burgersi* were corroborate for Thurman II (1987) while this species presented smaller area with spoon-tipped setae, contrary the species to cite above. The species *U. burgersi* was more abundant in the places 1, 6 and 7 were presented smaller organic matter content and humidity, presented too, negative correlation with such factors. However this species too present area with plumose setae, according Maitland (1990) were found in fiddler crabs feeding muddy sediment. This probably indicates that this species is able to extract organic matter from sediment of different grain sizes. Testing this hypothesis would however require a more detailed study.

Icely and Jones (1978) observed a progressive reduction of the area with spoon-tipped setae with a proportional increase of plumose setae in *U. tetragonon, U. vocans* and *U. chlorophthalmus*. This was shown to be a gradual trend from species occupying sandy to muddy habitats. It was suggested that plumose setae are probably more efficient to sort and remove the organic matter associated with the finest sediments. However, this pattern is not verified in the present study since the larger areas of plumose setae were found in *U. uruguayensis*, which is predominant in sandy-muddy substrata. The role of plumose setae in the extraction of organic matter from sediments should therefore be better examined.

Acknowledgements

MLNF is indebted with FAPESP (# 98/03136-5) for the finanancial suport of the optic equipment used here. To Roberto M. Shimizu (Departamento de Ecologia – IB – USP) for his valuable comments in the early drafts of this manuscript.

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Received: 15th Dec 2000
Accepted: 15th Dec 2001