THE CRUSTACEAN DECAPOD COMMUNITIES OF THREE CORAL REEFS FROM THE SOUTHWESTERN CARIBBEAN SEA OF CUBA: SPECIES COMPOSITION, ABUNDANCE AND STRUCTURE OF THE COMMUNITIES

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ABSTRACT

The decapod communities of three coral reefs of the southwestern Caribbean Sea of Cuba (keys Juan García, Cantiles and Diego Pérez), at three different ecological levels (the reef lagoon, the reef flat and the outward slope) have been analyzed. A total of 2567 specimens belonging to 216 species were caught. The lagoons have the highest richness. The lower richness found in the reef flat may be explained because it is the more disturbed area (higher hydrodynamic conditions) and there is a decrease in the diversity of substrates. The dominance, density, and biomass of the species vary in each ecological zone and key. These also depend on the sampling methodology, in relation with the adaptation and use of the resources by the species. The geometrical distributions show that there are many species with few specimens. The qualitative ordination and similarity analysis show that the more separated key could be differentiated from the other two, and that there is a closer relationship by ecological zones between the latter. All results point out the existence of a spatial gradient and a marked specificity in the use of the environmental resources (i.e., shelters) by the species in the ecological zones of the studied keys.

The Cuban continental shelf is delimited by extensive coral reef formations where many species of decapod live, of which some represent an important economic fishing resource (the Caribbean spiny lobster *Panulirus argus* and species of the genus *Callinectes*) and many other stand out in the food webs of the reef ecosystem.

The aim of the present study is to give a first characterisation of the decapod crustacean communities of three coral reefs from three keys of the southwestern Caribbean Sea of Cuba at three different ecological levels (the reef lagoon, the reef flat complex and the beginning of the outward slope), to establish the faunal composition, the dominance, the structure of the communities and the differences between all analyzed zones and keys.

There are studies on the general structure and organization of the decapod communities in biotopes or habitats constituted by sessile organisms, such as coraligenous or calcareous seaweed, sabellariid worms, corals, etc (Fausto-Filho and Furtado, 1970; Abele, 1976a,b; Abele and Patton, 1976; Gore et al, 1978; Reed et al, 1982; García Raso and Fernández, 1987; López de la Rosa and García Raso, 1992; Snelgrove and Lewis, 1989, among others). These studies have showed the importance of the substrate in the life of the species: as permanent or temporal shelter (for adult during the breeding time or for juveniles as nursery-growth), as food source, etc. (Abele, 1974, 1976a; García Raso, 1988). In addition, some of these papers give information on the ecological structure of the communities, as results of the species adaptation and survival strategies related with reproduction and growth (García Raso, 1988), and the relationships with adjacent biotopes (García Raso et al, 1996).

Ecological studies on decapods of reef coral formations from Cuban archipelago are scarce (Zlatarski and Martínez-Estalella, 1980), the majority of them are check-lists or studies made in specific areas in which the different biotopes are analysed from a descriptive point of view (Murina et al, 1969; Gómez et al, 1980; Valdés-Muñoz, 1986; Martínez-Iglesias and Alacolado, 1990; Martínez-Iglesias et al, 1996).

Data on environmental factors (currents, temperature, salinity, sediments, etc.) and on the general structure of other animal and vegetal communities living in the studied area could be found in Emilson and Tápanes (1971), Lluis-Riera (1972, 1983a,b), Avello (1979), Gómez (1979), Alcolado (1990) and Claro and Reshetnikov (1994) among others.

Materials and Methods

In the present study the crustacean communities of three coral reefs from the Batabanó Gulf (southwestern of Cuba) located in Juan García Key, Cantiles Key and Diego Pérez Key (southwest, centre and east of the outward continental shelf respectively) (Fig. 1) have been analyzed.

The specimens were collected during February and July 1988 with the research vessels Caribe I and Tritón belonging to Ministerio de Ciencia, Tecnología y Medio Ambiente of Cuba.

In the central area of each studied reef, a profile was selected. It has allowed us to analyze the decapods distribution in the ecological zonation (Done, 1983; Geister, 1977): the reef lagoon, the reef flat (including the posterior zone, the reef flat and the crest) and the outward slope (5 to 20 m depth).

Qualitative and quantitative samples were taking in all these zones. With the latter we only wish to give a first record of the species dominance, taking into account the different sampling methodologies, and excluding all the large species, due to their size the sampled area (surface or volume) was insufficient (e.g., *P. argus, Carpilius corallinus*).

Different sampling methods were used. In the reef lagoon the material was collected using two different dredges: (1) One small, with a frame of 0.7 m and a double net. The size of the inner mesh was of 4 mm and the outer 2 cm. This dredge was trawled 3 to 5 times for 5 min. (2) The other, larger, had a frame of 1 m and was mounted with similar nets. This was trawled from a ship at speed of 1–2 kt. In Juan García lagoon this kind of sampling was impossible, because of the very shallow water.

In the reef flat complex and outward slope the samples were taken directly, by SCUBA diving, along a transect approximately 2 m wide, which covers a surface of 30–40 m^2.

The cryptofauna study was made (July 1988) in the three ecological zones by SCUBA. Clausade (1970) suggested that 1 dm^3 was the minimum volume of each habitat necessary to obtain a representative sample of the fauna, but this has not been confirmed by other authors and it may well vary according to the substrate (Hutchings 1978, 1983). In our study, and from each ecological zone, 10 samples with a variable volume, between 0.3 to 1.2 L, were taken because no two similar stones or coral pieces exist. However the total volume was always superior to 4 L.

The pieces were collected and enclosed, in situ, within a cloth bag. In the laboratory all these were broken into smaller pieces and the fauna was taken out. The remains were fixed and washed using a sieve column (smallest mesh 1.0 mm), to retain all specimens.

For the qualitative studies and only in order to obtain a complete check-list of species, other direct samples were taking in the three ecological zones of the keys.

For the quantitative study (density and biomass) only the data obtained from trawling and transect method, in which exist a defined area (large dredge in lagoon, transect in reef flat and slope) or trawling time (small dredge in lagoon), were analyzed. For the cryptofauna study, the number of specimens and biomass were related to a volume of 10 L.

The quantitative results must be considered with care, mainly with a comparative purpose between the analyzed zones, because of the limitations existing in this kind of study. These are a consequence of the heterogeneity and complexity of the system, in which many habitats and microhabitats exist, many of them not always accessible and/or identifiable, where many environmental factors interact and complex interspecific and intraspecific relationships exist.

In addition to these sampling problems, which have an incidence on determining the minimum size of sample and choosing replicates (Brander et al, 1971; Hutchings, 1983), the fragility of the

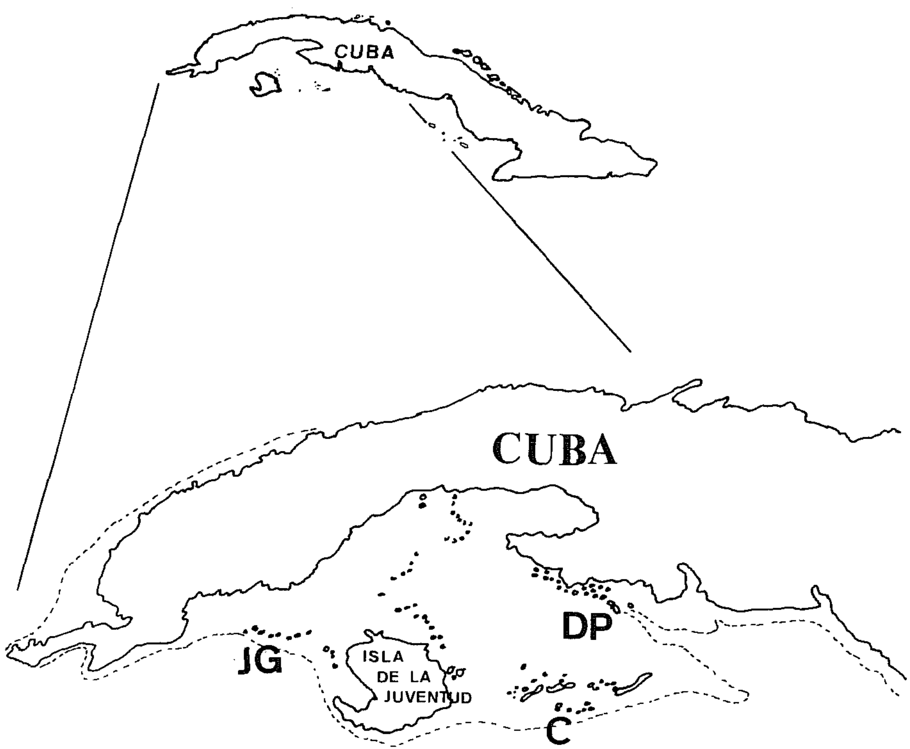

Figure 1. Location of the study-area and the keys: Juan García (JC), Cantiles (C) and Diego Pérez (DP).

reef formations should also be taken into account, to make the study the least destructive as possible.

For characterizing the communities in each ecological zone-key, the following indices have been employed:

Dominance ($D = Ni/Nt \times 100$) or relative abundance (in %).

Ni = number of specimens of the species i, Nt = total number of decapod specimens.

The Margalef's index of richness $R = (S-1)/\ln N$.

S: number of species. N: total number of specimens.

To establish the relationships between the communities a cluster analysis using the similarity coefficient of Jaccard and the agglomerative algorithm UPGMA (average linkage) and an ordination analysis (CA correspondence analysis) were employed. We have considered qualitative data in both cases, because the quantitative analysis have the limitations before quoted. Although the dominance of some species may characterize a biotope/habitat (García Raso and Fernández Muñoz, 1987; García Raso, 1990; García Raso et al, 1996), these species being considered as "preferential characteristical species" or "preferential species" (Pérès and Picard, 1964; Ledoyer, 1968), on the other hand a similarity in the specific composition implies, in general, a similarity of the habitats (Gore et al, 1978).

As descriptors of the community, the number of exclusive (caught in only one ecological zone and/or key) and shared species have been analyzed. These could provide evidence for environmental gradients between the keys and the ecological zones.

Finally, to show the species distribution, the data were arranged in geometrical classes (Ugland and Gray, 1982; Magurran, 1989) (7 classes, class 1: 1 specimen, 2: 2–3 specimens, 3: 4–7 specimens, 4: 8–15 specimens, 5: 16–31 specimens, 6: 32–63 specimens and 7: 64–127 specimens).

Results

Table 1 shows that a total of 2567 specimens belonging to 216 species were caught in the three studied keys. Some specimens could not be identified, because they are juveniles, remains or are single individuals of uncertain identification. However, the specimens identified as *Synalpheus* sp. 1 probably belong to *Synalpheus paraneptunus*.

In Table 2 the total number of species, the number of exclusive species, the shared species and Margalef's index of richness in the different keys and ecological zones are given.

In the ecological profile, in general, the richness is higher in the lagoon, drastically decreases on the reef flat and increases again on the slope. This pattern is found in the Diego Pérez Key and Cantiles Key, but in Juan García Key the richness in the slope is slightly higher than in the lagoon. However, there were some sampling limitations in the lagoon of this Key, as has been quoted in sampling methodology.

The number of exclusive species follows, in general and in the keys (except in Juan García Key), a pattern similar to that of the richness: higher in lagoons than in slopes. The higher number of exclusive species appear in the outermost Key (Cantiles), followed by Juan García and Diego Pérez respectively.

The more proximate keys (Cantiles and Diego Pérez) share the higher number of species, but always less than 50%. The lower shared number appears between the more separated (Diego Pérez and Juan García). Between ecological zones (in the whole of the three keys), the slopes share the higher number, and the reef flat the lower; however, all of these values are low.

The similarity analysis (Fig. 2B) shows a clear aggregation by ecological zones, and in the ordination analysis CA (Fig. 2A) the more separated Key (Juan García) is differentiated from the other two. Between the latter two, a closer relationship by ecological zones is shown.

The dominant (D1) and codominant (D2) species in the different keys and ecological zones (trawling and transect data, and cryptofauna study) are given in Table 3.

Many of the dominant species, mainly in the study of the cryptofauna, belong to the family Alpheidae. However, some Brachyura are also well adapted to these bottoms, such as species of the genus *Pitho* (in lagoon) and *Mithrax* (in the reef flat, in Juan García Key also *Paraliomera longimana*). The hermit crabs: *Paguristes grayi* in the slopes, and *Paguristes cadenati and Calcinus tibicen* in the reef flat are also dominant.

Although we have not done a more specific quantitative study, probably *Paguristes grayi* plays an important role in the movement of energy between ecological zones, because of its wide distribution, its abundance (biomass) and activity (diurnal and nocturnal), and mainly in Diego Pérez Key.

The data on density and biomass are given in Table 4. As it happens with the abundance, the results depend on the sampling methodology employed. With trawling and transects the Brachyura are dominant followed by Paguroidea and Natantia forms (the Stenopodidea are included). In the study of the cryptofauna the Natantia forms are dominant.

Figure 3 shows the geometrical distributions for each ecological zone and key. In these, it is obvious that the geometrical classes with minimum abundance have the higher number of species, mainly in the lagoons and slopes.

Table 1. Check list of decapod crustacean from three coral reefs key of the southwestern of Cuba. Presence - absence (JG: Juan García, C: Cantiles, DP: Diego Pérez).

	Lagoon			Reef Flat			Outside Slope		
Species	JG	C	DP	JG	C	DP	JG	C	DP
1- *Metapenaeopsis gerardoi* Pérez-Farfante, 1971	0	1	0	0	0	0	0	0	0
2- *Metapenaeopsis goodei* (Smith, 1885)	0	1	1	0	0	0	0	0	0
3- *Metapenaeopsis hobbsi* Pérez-Farfante, 1971	0	1	0	0	0	0	0	0	0
4- *Metapenaeopsis martinella* Pérez-Farfante, 1971	0	1	1	0	0	0	0	0	0
5- *Metapenaeopsis smithi* (Schmitt, 1924)	0	1	0	0	0	0	0	0	0
6- *Metapenaeopsis* sp.	0	0	1	0	0	0	0	0	0
7- *Trachypenaeus constrictus* (Stimpson, 1871)	0	1	0	0	0	0	0	0	0
8- *Sicyonia laevigata* Stimpson, 1871	0	1	0	0	0	0	0	0	0
9- *Sicyonia parri* (Burkenroad, 1934)	0	1	1	0	0	0	0	0	0
10- *Sicyonia stimpsoni* Bouvier, 1905	0	1	1	0	0	0	0	0	0
11- *Sicyonia typica* (Boeck, 1864)	0	0	1	0	0	0	0	0	0
12- *Brachycarpus biunguiculatus* (Lucas, 1849)	0	0	0	1	0	0	1	0	0
13- *Leander tenuicornis* (Say, 1818)	0	1	0	0	0	0	0	1	0
14- *Anchistioides antiguensis* (Schmitt, 1924)	0	1	0	0	0	0	0	0	0
15- *Periclimenaeus caraibicus* Holthuis, 1951	0	1	0	0	0	0	0	0	0
16- *Periclimenaeus ascidiarum* Holthuis, 1971	0	0	0	0	0	0	1	1	1
17- *Periclimenes americanus* (Kingsley, 1878)	1	1	0	0	0	0	1	1	1
18- *Periclimenes longicaudatus* (Stimpson, 1860)	0	0	0	0	0	0	1	0	0
19- *Periclimenes pedersoni* Chace, 1958	0	0	0	0	1	0	1	1	1
20- *Periclimenes rathbunae* Schmitt, 1924	0	0	0	0	0	0	0	0	1
21- *Periclimenes yucatanicus* (Ives, 1891)	0	1	0	0	0	0	0	0	1
22- *Periclimenes* sp.	1	0	0	0	1	1	0	0	1
23- *Pontonia margarita* Smith, 1869	0	0	0	0	0	0	0	0	1
24- *Gnathophyllum americanum* Guérin-Méneville, 1855	0	0	0	0	0	0	1	0	0
25- *Salmoneus ortmanni* (Rankin, 1898)	0	0	0	0	1	0	0	0	0
26- *Alpheopsis labis* Chace, 1972	0	0	0	0	0	0	1	0	0
27- *Alpheopsis trigonus* (Rathbun, 1901)	0	0	1	0	0	0	0	0	0
28- *Alpheopsis* sp 1	0	1	0	0	1	0	1	1	1
29- *Alpheopsis* sp 2	0	1	0	0	0	0	0	0	0
30- *Alpheus amblyonyx* Chace, 1972	1	0	0	1	0	1	1	1	0
31- *Alpheus armatus* Rathbun, 1901	1	0	0	0	0	0	0	1	0
32- *Alpheus armillatus* H. Milne Edwards, 1837	1	0	1	1	1	1	1	1	0
33- *Alpheus bahamensis* Rankin, 1898	0	0	0	1	1	0	0	0	0
34- *Alpheus cristulifrons* Rathbun, 1900	0	0	0	1	0	1	0	1	0
35- *Alpheus cylindricus* cylindricus Kingsley, 1878	0	0	0	0	0	0	1	0	0
36- *Alpheus floridanus* Kingsley, 1878	1	1	0	0	0	0	0	0	0
37- *Alpheus formosus* Gibbes, 1850	1	0	0	0	0	0	0	0	0
38- *Alpheus* sp 1	1	1	1	0	0	1	0	0	0
39- *Alpheus normanni* Kingsley, 1878	1	1	1	1	0	0	1	0	0
40- *Alpheus paracrinitus* Miers, 1881	0	0	0	0	0	0	1	0	0
41- *Alpheus peasei* (Armstrong, 1940)	1	1	0	1	0	0	1	1	0
42- *Alpheus thomasi* Hendrix & Gore, 1973	1	0	0	0	0	0	0	0	0
43- *Alpheus viridari* (Armstrong, 1949)	0	1	0	0	0	0	1	0	0
44- *Alpheus websteri* Kingsley, 1880	1	0	0	1	0	0	0	0	0

Table 1. Continued.

	Lagoon			Reef Flat			Outside Slope		
Species	JG	C	DP	JG	C	DP	JG	C	DP
45- *Alpheus* sp 2	1	1	0	1	1	0	1	1	1
46- *Alpheus* sp 3	1	0	0	0	0	0	0	0	0
47- *Automate evermanni* Rathbun, 1901	1	0	0	0	0	0	1	1	1
48- *Automate rectifrons* Chace, 1972	0	0	0	0	0	1	1	1	1
49- *Automate* sp.	0	0	0	0	0	0	0	0	1
50- *Metalpheus rostratipes* (Pocock, 1890)	0	1	0	1	0	1	0	0	0
51- *Salmoneus arubae* (Schmitt, 1936)	1	1	0	0	0	0	0	0	0
52- *Salmoneus* sp 2	0	0	0	0	1	0	1	0	0
53- *Synalpheus agelas* Pequegnat & Heard, 1979	1	0	0	0	0	0	1	0	0
54- *Synalpheus anasimus* Chace, 1972	0	0	0	0	0	1	0	0	0
55- *Synalpheus bousfieldi* Chace, 1972	1	0	0	0	0	0	1	0	1
56- *Synalpheus brevicarpus* (Herrick, 1891)	0	0	0	0	0	1	1	0	0
57- *Synalpheus brooksi* Coutière, 1909	1	0	0	0	0	0	1	0	0
58- *Synalpheus dominicensis* Armstrong, 1949	1	1	1	0	0	0	1	1	0
59- *Synalpheus fritzmuelleri* Coutière, 1909	1	1	0	1	0	0	0	0	0
60- *Synalpheus goodei* Coutière, 1909	1	0	0	0	0	0	1	0	0
61- *Synalpheus hemphilli* Coutière, 1909	1	0	0	0	0	0	1	0	0
62- *Synalpheus latastei* tenuispina Coutière, 1909	1	0	0	1	0	0	1	0	0
63- *Synalpheus longicarpus* (Herrick, 1891)	1	0	0	1	0	0	0	0	0
64- *Synalpheus macclendoni* Coutière, 1910	1	0	0	0	0	0	1	1	0
65- *Synalpheus minus* (Say, 1818)	1	0	0	0	0	0	1	0	0
66- *Synalpheus pandionis* Coutière, 1909	1	0	1	0	0	0	1	0	0
67- *Synalpheus paraneptunus* Coutière, 1909	1	0	0	0	0	0	1	1	0
68- *Synalpheus pectiniger* Coutière, 1907	0	0	0	0	0	0	0	1	1
69- *Synalpheus* sp 1	1	1	0	1	1	1	1	1	1
70- *Synalpheus* sp 2	1	0	0	0	0	1	0	1	1
71- *Synalpheus* sp 3	0	0	0	0	0	1	0	1	1
72- *Synalpheus* sp 4	0	0	0	0	0	0	0	1	0
73- *Thunor simus* (Guérin-Méneville, 1855)	0	0	0	1	1	1	1	1	1
74- *Prionalpheus gomezi* Martínez Iglesias & Carvacho, 1991	0	0	0	0	0	0	1	0	0
75- *Latreutes fucorum* (Fabricius, 1798)	0	1	0	0	0	0	0	0	0
76- *Lysmata rathbunae* Chace, 1970	1	0	0	0	0	0	1	0	0
77- *Thor manningi* Chace, 1972	1	1	0	0	0	0	0	0	0
78- *Thor* sp.	0	1	0	0	1	1	0	0	1
79- *Tozeuma carolinense* Kingsley, 1878	0	1	1	0	0	0	0	0	0
80- *Trachycaris restrictus* (A. Milne Edwards, 1878)	0	1	1	0	0	1	0	0	1
81- *Nikoides schmitti* Manning & Chace, 1971	0	0	1	0	0	0	0	0	0
82- *Processa bermudensis* (Rankin, 1900)	1	1	1	0	0	0	0	0	0
83- *Processa fimbriata* Manning & Chace, 1971	1	1	1	0	0	0	1	1	0
84- *Processa* sp.	0	0	0	1	1	1	1	1	1
85- *Microprosthema semilaeve* (Von Martens, 1872)	0	1	0	0	0	0	1	0	0
86- *Stenopus hispidus* (Olivier, 1811)	0	1	0	0	1	0	1	1	1
87- *Pseudocheles chacei* Kensley, 1983	0	0	0	0	0	0	1	0	0
88- *Discias serratirostris* Lebour,1949	0	0	0	0	0	0	0	0	1
89- *Dromidia antillensis* Stimpson, 1858	0	1	1	0	0	0	0	0	0

Table 1. Continued.

	Lagoon			Reef Flat			Outside Slope		
Species	JG	C	DP	JG	C	DP	JG	C	DP
90- *Calappa angusta* A. Milne Edwards, 1880	0	1	0	0	0	0	0	0	0
91- *Calappa gallus* (Herbst, 1803)	0	1	0	0	0	0	0	0	0
92- *Calappa ocellata* Holthuis, 1958	0	1	0	0	0	0	0	0	0
93- *Cycloes bairdii* Stimpson, 1860	0	1	0	0	0	0	0	0	0
94- *Ebalia cariosa* (Stimpson, 1860)	0	1	0	0	0	0	0	0	0
95- *Ebalia stimpsonii* A. Milne Edwards, 1880	0	1	1	0	0	0	0	0	0
96- *Speloeophorus elevatus* Rathbun, 1898	0	1	0	0	0	0	0	0	0
97- *Batrachonotus fragosus* Stimpson, 1871	0	0	0	0	0	0	0	1	0
98- *Podochela gracilipes* Stimpson, 1871	0	0	0	0	0	0	0	1	0
99- *Podochela riisei* Stimpson, 1860	0	1	1	0	0	0	0	0	0
100- *Podochela sidneyi* Rathbun, 1924	0	0	0	0	0	1	0	0	1
101- *Podochela* sp.	0	0	0	0	0	0	0	1	0
102- *Stenorhynchus seticornis* (Herbst, 1788)	0	0	0	0	0	0	1	1	1
103- *Macrocoeloma diplacanthum* (Stimpson, 1860)	0	1	1	0	0	0	0	0	0
104- *Macrocoeloma laevigatum* (Stimpson, 1860)	0	1	0	0	0	0	0	0	0
105- *Macrocoeloma trispinosum* (Latreille, 1825)	1	1	1	0	0	0	0	0	0
106- *Macrocoeloma trispinosum* nodipes (Desbonne, 1867)	1	0	1	0	0	0	0	0	0
107- *Macrocoeloma* sp 1	1	1	0	0	0	0	0	0	0
108- *Macrocoeloma* sp 2	0	0	1	0	0	0	0	0	0
109- *Microphrys antillensis* Rathbun, 1920	1	1	1	0	1	1	1	1	0
110- *Microphrys bicornutus* (Latreille, 1825)	1	1	1	0	1	1	0	1	0
111- *Microphrys interruptus* Rathbun, 1920	1	0	0	0	0	0	0	0	0
112- *Mithrax cinctimanus* (Stimpson, 1860)	1	0	1	0	1	0	1	1	1
113- *Mithrax coryphe* (Herbst, 1801)	1	1	1	1	1	1	1	1	1
114- *Mithrax forceps* (A. Milne Edwards, 1875)	1	1	1	1	1	1	1	1	1
115- *Mithrax ruber* (Stimpson, 1871)	1	0	0	1	0	0	1	0	0
116- *Mithrax sculptus* (Lamarck, 1818)	0	1	1	0	0	1	0	0	0
117- *Mithrax acuticornis* Stimpson, 1870	0	0	0	0	0	0	1	0	0
118- *Mithrax holderi* Stimpson, 1871	0	0	0	0	0	1	0	1	0
119- *Mithrax pilosus* Rathbun, 1892	0	1	0	1	1	0	0	0	0
120- *Mithrax pleuracanthus* Stimpson, 1871	1	1	0	0	0	0	1	1	0
121- *Mithrax spinosissimus* (Lamarck, 1818)	0	0	0	0	0	1	0	0	0
122- *Mithrax verrucosus* H. Milne Edwards, 1832	0	1	0	1	0	1	0	0	0
123- *Mithrax tortugae* Rathbun, 1920	1	1	0	0	0	0	1	0	1
124- *Mithrax caribbaeus* Rathbun, 1900	0	0	0	0	0	1	1	0	0
125- *Mithrax hemphilli* Rathbun, 1892	0	0	0	0	1	0	0	0	0
126- *Mithrax* sp.	1	0	0	0	1	0	1	1	0
127- *Thoe puella* Stimpson, 1860	0	1	0	0	1	1	0	0	0
128- *Thoe* sp.	0	0	0	0	0	0	0	1	0
129- *Pitho aculeata* (Gibbes, 1850)	0	1	1	0	0	1	0	0	0
130- *Pitho anisodon* (Von Martens, 1872)	1	0	0	0	0	0	0	0	0
131- *Pitho lherminieri* (Schramm, 1867)	1	1	1	0	1	1	1	0	0
132- *Pitho* sp.	0	1	1	0	1	1	1	1	0
133- *Chorinus heros* (Herbst, 1790)	0	0	1	0	0	0	0	0	0
134- *Thersandrus compressus* (Desbonne, 1867)	1	0	1	0	0	0	0	0	0

Table 1. Continued.

	Lagoon			Reef Flat			Outside Slope		
Species	JG	C	DP	JG	C	DP	JG	C	DP
135- *Hemus cristulipes* A. Milne Edwards, 1875	0	0	0	0	1	0	0	1	0
136- *Parthenope serrata* (H. Milne Edwards, 1834)	0	0	1	0	0	0	0	0	0
137- *Cronius tumidulus* (Stimpson, 1871)	0	1	1	0	0	0	0	0	0
138- *Portunus depressifrons* (Stimpson, 1859)	0	1	1	0	0	0	0	0	0
139- *Portunus ordwayi* (Stimpson, 1860)	0	1	1	0	0	0	0	0	0
140- *Actaea acantha* H. Milne Edwards, 1834	0	0	0	1	0	0	1	1	0
141- *Actaea bifrons* Rathbun, 1898	0	0	0	1	0	0	1	0	0
142- *Banareia palmeri* (Rathbun, 1894)	0	0	0	0	1	0	0	0	0
143- *Heteractaea ceratopus* (Stimpson, 1860)	1	0	0	1	1	0	0	0	0
144- *Paractaea rufopunctata nodosa* (Stimpson, 1860)	1	1	0	0	0	0	1	1	0
145- *Etisus maculatus* (Stimpson, 1860)	0	1	0	0	0	0	0	0	0
146- *Melybia thalamita* Stimpson, 1871	0	0	0	0	0	0	1	0	0
147- *Micropanope nuttingi* (Rathbun, 1898)	1	1	0	0	0	0	1	1	0
148- *Micropanope pusilla* A. Milne Edwards, 1880	0	1	0	0	0	0	0	0	0
149- *Micropanope granulimanus* (Stimpson, 1871)	1	1	1	0	0	0	1	0	0
150- *Micropanope* sp.	0	0	0	0	0	0	0	0	1
151- *Panopeus americanus* Saussure, 1857	0	1	0	0	0	0	0	0	0
152- *Panopeus harttii* Smith, 1869	1	1	1	0	0	0	0	1	0
153- *Panopeus occidentalis* Saussure, 1857	0	1	1	0	0	0	0	0	0
154- *Panopeus* sp.	0	1	0	0	0	0	0	1	0
155- *Cataleptodius floridanus* (Gibbes, 1850)	0	1	0	0	0	0	0	0	0
156- *Domecia acanthophora* (Desbonne & Schramm, 1867)	0	0	0	0	1	0	0	1	0
157- *Paraliomera dispar* (Stimpson, 1871)	0	0	0	1	0	0	0	0	0
158- *Paliomera longimana* (A. Milne Edwards, 1865)	0	0	0	1	0	1	0	0	0
159- *Pilumnus caribaeus* Desbonne & Schramm, 1867	0	0	1	0	0	0	0	0	0
160- *Pilumnus dasypodus* Kingsley, 1879	0	0	0	0	0	0	0	0	1
161- *Pilumnus diomedeae* Rathbun, 1894	0	0	0	1	0	0	0	0	1
162- *Pilumnus gemmatus* Stimpson, 1860	0	0	1	0	0	0	0	1	0
163- *Pilumnus holosericus* Rathbun, 1898	0	0	0	1	0	0	0	0	0
164- *Pilumnus longleyi* Rathbun, 1930	0	0	0	0	0	1	0	1	0
165- *Pilumnus marshi* Rathbun, 1901	0	0	1	0	0	1	1	0	1
166- *Pilumnus nudimanus* Rathbun, 1900	1	0	0	0	0	0	0	0	0
167- *Pilumnus pannosus* Rathbun, 1896	1	1	1	0	1	0	0	1	0
168- *Pilumnus sayi* Rathbun, 1897	0	0	0	0	1	0	0	0	0
169- *Pilumnus* sp.	0	0	1	1	0	1	1	0	1
170- *Platyactaea setigera* (H. Milne Edwards, 1834)	0	0	0	0	1	0	0	0	0
171- *Xanthodius denticulatus* (White, 1847)	1	1	0	0	1	1	0	0	0
172- *Euryplax nitida* Stimpson, 1859	0	0	1	0	0	0	0	0	0
173- *Panoplax depressa* Stimpson, 1871	1	1	0	0	0	0	0	0	0
174- *Dissodactylus borradailei* Rathbun, 1918	0	1	1	0	0	0	0	0	0
175- *Parapinnixa hendersoni* Rathbun, 1918	1	0	0	0	0	0	0	0	1
176- *Parapinnixa bouvieri* Rathbun, 1918	1	1	0	0	0	1	0	0	0
177- *Parapinnixa cubensis* Campos, 1994	0	0	0	0	0	0	1	0	0
178- *Pinnotheres* sp.	0	0	0	0	0	0	0	0	1
179- *Pachygrapsus transversus* (Gibbes, 1850)	0	0	0	1	0	0	0	0	1

Table 1. Continued.

	Lagoon			Reef Flat			Outside Slope		
Species	JG	C	DP	JG	C	DP	JG	C	DP
180- *Eucratopsis crassimanus* (Dana, 1851)	0	0	0	0	1	0	0	0	0
181- *Glyptoplax smithii* A. Milne Edwards, 1880	0	0	0	0	0	0	0	1	0
182- *Axiopsis serratifrons* (A. Milne Edwards, 1873)	0	0	0	0	1	0	0	0	0
183- *Axiopsis* sp 1	0	0	0	0	0	0	0	1	0
184- *Axiopsis* sp 2	0	0	0	0	0	0	0	0	1
185- *Coralaxius abelei* Kensley & Gore, 1981	0	1	0	0	0	0	1	0	0
186- *Upogebia affinis* (Say, 1818)	1	0	0	0	0	0	0	0	0
187- *Pomatogebia operculata* (Schmitt, 1924)	0	1	0	0	0	0	0	1	1
188- *Upogebia* sp.	0	0	0	0	0	0	0	1	0
189- *Neocallichirus* sp.	0	0	0	0	0	1	0	0	0
190- *Munida irrasa* A. Milne Edwards, 1880	0	0	0	0	0	0	1	0	0
191- *Munida* sp.	0	0	0	0	0	0	1	0	0
192- *Albunea gibbesii* Stimpson, 1859	0	1	0	0	0	0	0	0	0
193- *Calcinus tibicen* (Herbst, 1791)	0	1	0	1	1	0	1	0	0
194- *Dardanus venosus* (H. Milne Edwards, 1848)	0	1	0	0	0	0	1	0	0
195- *Paguristes cadenati* Forest, 1954	0	0	0	1	0	0	1	0	1
196- *Paguristes erythrops* Holthuis, 1959	0	0	0	0	0	0	0	1	0
197- *Paguristes grayi* Benedict, 1901	1	1	1	1	1	1	1	1	1
198- *Paguristes puncticeps* Benedict, 1901	0	0	1	0	0	0	1	0	0
199- *Paguristes perplexus* Mclaughlin & Provenzano, 1974	0	0	0	0	0	0	1	1	1
200- *Paguristes tortugae* Schmitt, 1933	0	0	0	0	0	1	0	0	0
201- *Paguristes* sp 1	0	1	1	0	0	0	1	0	1
202- *Paguristes* sp 2	0	0	1	0	0	0	1	1	0
203- *Iridopagurus globulus* De Saint Laurent-Dechancé, 1966	0	1	1	0	0	0	0	0	0
204- *Iridopagurus reticulatus* García-Gó mez, 1983	0	1	1	0	0	0	0	0	0
205- *Iripopagurus* sp 1	0	1	1	0	1	0	0	1	0
206- *Iripopagurus* sp 2	0	0	1	0	0	0	0	0	0
207- *Pagurus brevidactylus* (Stimpson, 1859)	0	1	1	0	1	0	1	1	0
208- *Pagurus carolinensis* Mclaughlin, 1975	0	0	0	0	0	0	0	1	0
209- *Pagurus marshi* Benedict, 1901	0	1	0	0	0	0	0	0	0
210- *Pagurus provenzanoi* Forest & De Saint Laurent, 1967	0	0	0	0	0	0	1	1	0
211- *Pagurus stimpsoni* (A. Milne Edwards & Bouvier, 1893)	0	1	1	0	0	0	0	0	0
212- *Pagurus* sp.	0	1	1	0	1	0	0	1	0
213- *Pachycheles pilosus* (H. Milne Edwards, 1837)	0	0	0	1	0	0	0	0	0
214- *Petrolisthes amoneus* (Gué rin-Mé neville, 1855)	0	0	0	0	0	0	0	0	1
215- *Petrolisthes galathinus* (Bosc, 1802)	0	0	0	1	1	1	1	0	1
216- *Petrolisthes jugosus* Streets, 1872	0	0	0	1	0	0	0	0	0
Total species	64	94	60	36	40	40	76	62	45

Table 2. Total number of species (Nspp), Margalef's index of richness values (R), number of exclusive species (SppNc), by keys and ecological zones, and shared species in the different keys and ecological zones.

	Juan García			Cantiles			Diego Pérez			Total	
	Nspp	R	SppNc	Nspp	R	SppNc	Nspp	R	SppNc	Nspp	R
Reef lagoon	64	12.2	7	94	12.5	22	60	10.1	10	142	19.7
Reef flat	36	7.4	4	40	8.1	7	40	7.9	4	81	13.0
Outward slope	76	12.6	12	62	11.0	10	45	8.3	9	121	17.8
Total	118		35	143		42	113		24	216	

	Ecological zones		
	Lagoon	Reef flat	Slope
Species present in the three ecological zones	15 (10.56%)	8 (9.88%)	17 (14.05%)
Species present in only one zone	81 (57.04%)	54 (66.66%)	76 (62.81%)

Keys	J.G.-C.	J.G.-D.P.	C.-D.P.	J.G.-C.-D.P.
Total species	192	173	181	216
Shared species	69 (35.9%)	58 (33.5%)	75 (41.4%)	44 (20.4%)

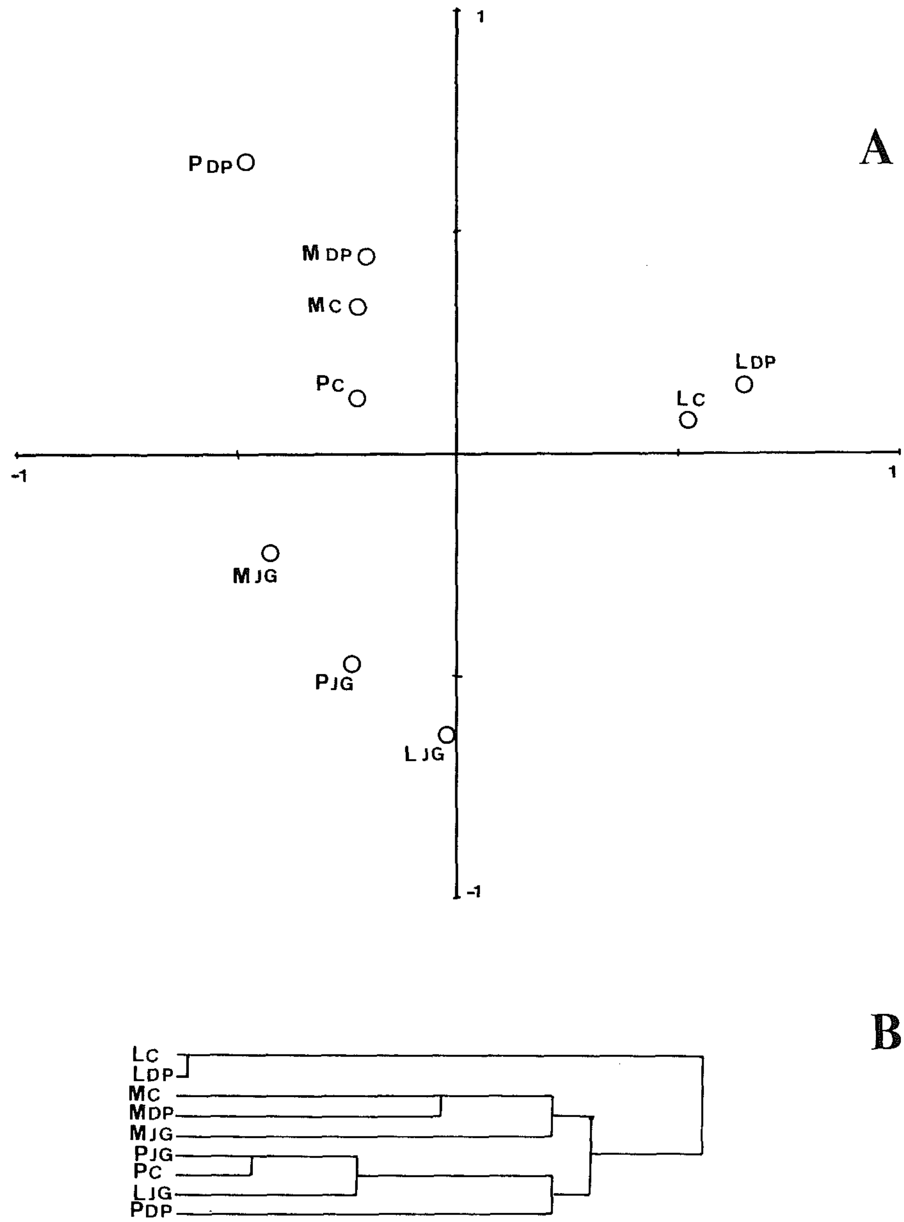

Figure 2. Results of the qualitative (presence-absence) ordination (A) and aggregation (B) analysis. The former: Correspondence Analysis, the latter: a cluster using the similarity coefficient of Jaccard and the agglomerative algorithm UPGMA. (L: lagoon, M: reef flat and P: slope; JG: Juan García, C: Cantiles and DP: Diego Pérez).

Table 3. Dominant (D1) and codominant (D2) species (%) in the different keys and ecological zones. Values obtained by trawling (in lagoon) transect (in reef flat complex and outward slope) (R) and from the study of cryptofauna (C). T: whole.

	Juan Garcia Key		Cantiles Key		Diego Pérez Key	
Reef Lagoon						
R	*Alpheus peasei*	20.5	*Pitho aculeata*	15.8	*Pitho lherminieri*	33.5
	Mithrax coryphe	11.5	*Pitho lherminieri*	15.6	*Pitho aculeata*	15.9
C	*Micropanope nuttingi*	20.3	*Synalpheus dominicensis*	16.7	—	
	Alpheus peasei	19.5	*Alpheopsis* sp.	12.9	—	
T	*Alpheus peasei*	19.2	*Pitho aculeata*	13.7		
	Micropanope nuttingi	12.9	*Pitho lherminieri*	13.5		
Reef Flat						
R	*Paraliomera longimana*	35.2	*Mithrax pilosus*	40.0	*Mithrax sculptus*	28.0
	Calcinus tibicen	23.5	*Petrolisthes galathinus*	40.0	*Mithrax holderi*	12.0
	Paguristes cadenati	23.5	*Mithrax coryphe*	20.0	*Paguristes grayi*	12.0
C	*Metalpheus rostratipes*	19.3	*Alpheus* sp1	25.0	*Thunor simus*	21.4
	Paraliomera dispar	12.1	*Processa* sp.	7.5	*Synalpheus* sp.1	17.1
T	*Metalpheus rostratipes*	10.7	*Alpheus* sp1	23.5	*Thunor simus*	15.8
	Paraliomera dispar	6.7	*Mithrax pilosus*	8.2	*Synalpheus* sp.1	12.6
Outward Slope						
R	*Paguristes grayi*	13.5	*Paguristes grayi*	25.0	*Paguristes grayi*	41.4
	Synalpheus paraneptunus	10.1	*Mithrax holderi*	15.6	*Stenorhynchus seticornis*	40.0
C	*Synalpheus paraneptunus*	45.1	*Synalpheus* sp.1	19.2	*Synalpheus* sp.1	32.4
	Synalpheus sp.1	6.2	*Synalpheus paraneptunus*	17.6	*Automate evermanni*	7.6
	Mithrax coryphe	6.2				
T	*Synalpheus paraneptunus*	31.8	*Synalpheus* sp.1	16.4	*Synalpheus* sp.1	21.9
	Mithrax coryphe	6.4	*Synalpheus paraneptunus*	15.1	*Paguristes grayi*	13.9

Note: *Synalpheus* sp.1 is probably *Synalpheus paraneptunus*.

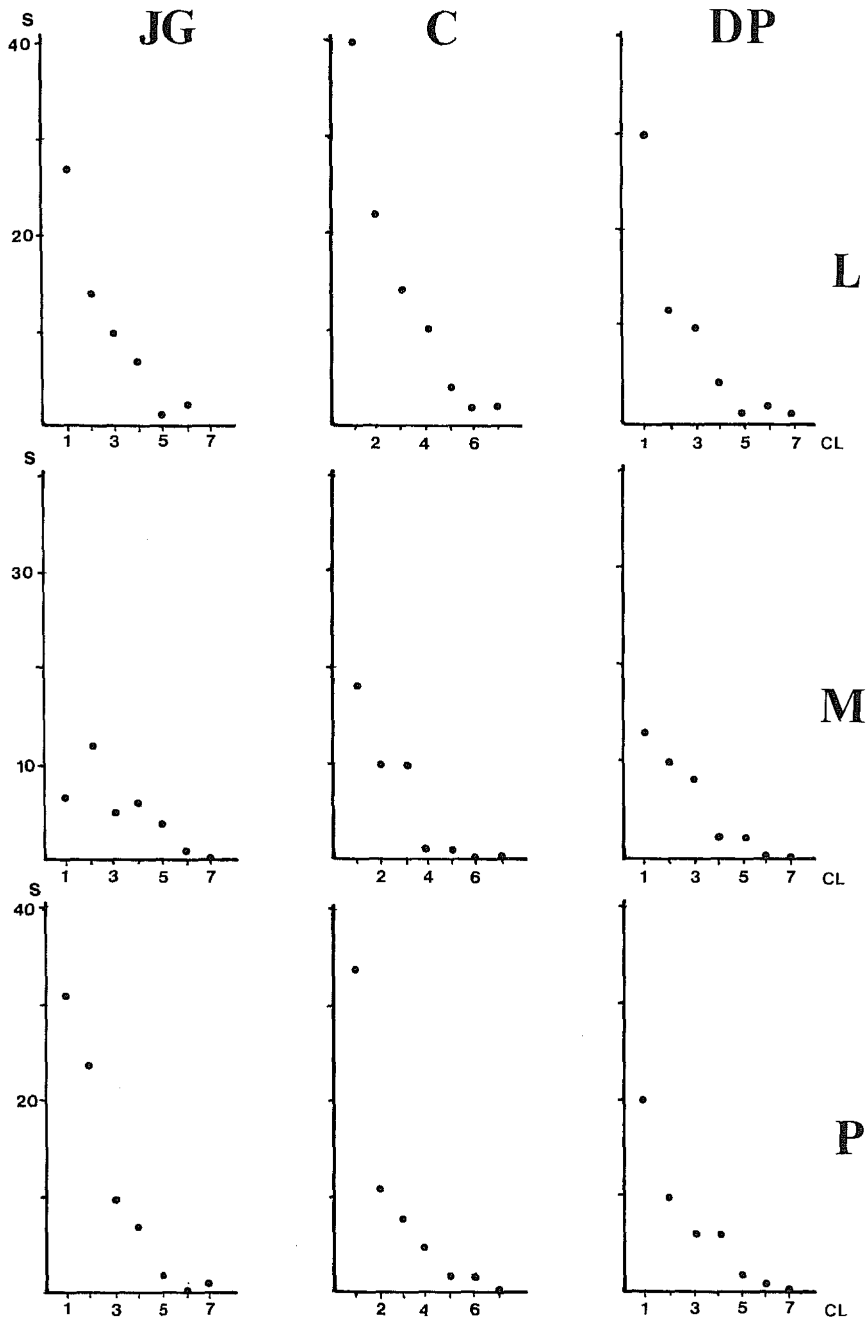

Figure 3. Distribution of species abundance (S) by ecological zones (L: lagoon, M: reef flat and P: slope) and keys (JG: Juan García, C: Cantiles and DP: Diego Pérez), grouped in 7 classes (CL) (class 1: 1 specimen, 2: 2–3 specimens, 3: 4–7 specimens, 4: 8–15 specimens, 5: 16–31 specimens, 6: 32–63 specimens and 7: 64–127 specimens).

Table 4. Density (De) and biomass (B) values found in the different keys and ecological zones. The values of the different taxonomic decapod groups (in %) and the species with higher values are quoted (in relation to an area of 100 m^2). The total values of density (number of specimens) and biomass (grams) are related to an area of 10 m^2. The data obtained by trawling with small dredge, in lagoon, are related to a time of 5 min. The data on cryptofauna are related to a volume of 10 L.

	Juan García Key			Cantiles Key			Diego Pérez Key	
	De	B		De	B		De	B
Reef Lagoon								
Trawling (big dredge)								
Brachyura	—	—	Brachyura	75.10%	90.0%	Brachyura	74.7%	42.5%
Anomura	—	—	Anomura	21.40%	9.9%	Anomura	16.6%	56.2%
Natantia	—	—	Natantia	3.48%	0.1	Natantia	8.7%	1.3%
-	—	—	*Pitho lherminieri*	6.58	3.2	*Pitho lherminieri*	16.1	3.82
Total	—	—	Total	3.73	2.0	Total	4.82	2.14
Trawling (small dredge)								
Brachyura	54.7%	92.3%	Brachyura	72.4%	79.1%	Brachyura	48.9%	76.3%
Alpheus peaei	5.33		*Pitho aculeata*	7.86	1.3	*Pitho lherminieri*	17.7	1.86
Mithax coryphe	—	1.2						
Total	24.7	2.11	Total	50.7	6.3	Total	69.4	6.9
Cryptofauna								
Natantia	57.9%	41.0%	Natantia	57.4%	41.8%	Natantia	—	
Brachyura	42.1%	58.9%	Brachyura	42.6%	58.2%	Brachyura	—	
Micropanope nuttingi	27.7	8.3	*Synalpheus dominicensis*	25.8	4.1		—	
Total	135.8	30.7	Total	143.4	34.0	Total	—	
Reef Flat								
Transect								
Brachyura	70.7%	37.3%	Brachyura	59.7%	87.5%	Brachyura	84.0%	73.5%
Anomura	29.3%	62.7%	Anomura	40.3%	12.5%	Anomura	16.0%	26.5%
Paraliomera longimana	100	—	*Mithrax pilosus*	4.8	—	*Mithrax sculptus*	10.0	—
Paguristes grayi	—	16.9	*Petrolisthes galathinus*	4.8	—	*Mithrax holderi*	5.49	
			Mithrax coryphe	—	0.52			
Total	28.3	3.46	Total	1.19	0.08	Total	3.57	1.55

Table 4. Continued.

	Juan García Key			Cantiles Key			Diego Pérez Key	
	De	B		De	B		De	B
Cryptofauna								
Natantia	53.5%	43.6%	Natantia	51.9%	38.7%	Natantia	61.8%	47.4%
Brachyura	34.3%	48.7%	Brachyura	42.1%	57.3%	Brachyura	32.8%	47.4%
Anomura	12.2%	7.6%	Anomura	6.0%	4.0%	Anomura	5.4%	5.3%
Metalpheus rostratipes	15.5	—	*Alpheus* sp.1	8.6	1.4	*Thunor simus*	3.8	0.6
Paraliomera dispar	—	3.0						
Totals	80.3	16.9	Totals	34.9	7.5	Totals	18.6	3.8
Outward Slope								
Transect								
Natantia	41.6%	6.3%	Natantia	18.7%	1.8%	Natantia	3.4%	0.1%
Brachyura	30.3%	52.7%	Brachyura	37.6%	35.1%	Brachyura	44.9%	4.6%
Anomura	28.1%	41.0%	Anomura	43.7%	63.1%	Anomura	51.7%	95.2%
Paguristes grayi	18.7	—	*Paguristes grayi*	32.0	34.8	*Paguristes grayi*	76.3	65.9
Mithrax tortugae	—	8.58						
Total	13.9	3.66	Total	12.8	9.41	Total	15.8	6.93
Cryptofauna								
Natantia	78.3%	66.1%	Natantia	80.6%	73.5%	Natantia	79.6%	71.1%
Brachyura	20.3%	33.1%	Brachyura	14.8%	24.1%	Brachyura	14.9%	24.4%
Anomura	1.4%	0.8%	Anomura	4.5%	2.4%	Anomura	5.5%	4.4%
Synalpheus paraneptunus	15.0	2.3	*Synalpheus sp.*1	8.2	1.3	*Synalpheus* sp.1	8.2	1.1
Total	32.3	6.35	Total	44.4	8.3	Total	25.5	4.5

Note: *Synalpheus* sp.1 is probably *Synalpheus paraneptunus*.

Discussion and Conclusion

The studied coral reefs show a high species richness which could be tested by comparing the result with those obtained in a general study made in the Gulf of Batabanó by Martínez-Iglesias and Alcolado (1990). This simply reflects its high environmental richness and the specific use of the resources by the fauna. In fact, in general, the coral reefs present a high local endemicity (Kensley, 1998) an many species are intensively associated with others and/or substrates (Bruce, 1977) (i.e., the snapping shrimps "Alpheidae" inside of coral formations).

The characteristic of the analyzed keys and ecological zones and the similarities found could be related to three principal factors: (1) The geographical location. In this way, the more separated key, Juan García Key, is clearly separated in the CA analysis. (2) The diversity of biotopes or substrates, which determines the specific composition (Abele, 1974). A higher number of these imply a higher number of resources (shelters, food sources, etc.) and, consequently, a higher richness. (3) The different environmental conditions of the ecological zones (more hydrodynamism in the reef flat and higher temperature in the lagoon).

The reef flat shows the lowest richness, in spite of its location between the lagoon and the slope, that could define it as a boundary or transitional area in which species of the adjacent habitats may be found (Margalef, 1980; Pielou, 1979). This lower richness is due to the reef flat being the more disturbed and fluctuating area, where there is a very strong hydrodynamism and the environmental conditions have the maximum variations (temperature stress, currents, etc.). In addition, the small extension of this zone together with the hydrodynamic conditions are associated with a decrease in the diversity of substrate-generating species such as corals (Mártinez-Estalella and Alcolado, 1990), with their individual growth (Glynn 1976) and with the settlement capacity of these species. Porter (1972), in the coral reef of Panama (Atlantic), found an increase of Decapoda diversity with depth (surface to 5–25 m). Also, dominance is more marked in this ecological zone, as it has been mentioned in other studies (Done, 1983). Only the well adapted species could efficiently exploit the available resources and live in this fluctuating habitat. The numerically dominant species are usually morphologically specialized to some aspects of their substrata or biotope (Abele, 1974; García Raso, 1988) (i.e., *Alpheus* spp. and *Synalpheus* spp. as cryptofauna, *Phito* spp. in lagoon).

A central matter in the current studies on ecology of the communities is the knowledge of the factors regulating the number and dominance of species, in relation with the environmental heterogeneity. So, the number of "local" species could reveal the state of the community in a particular ecological zone, while the total number could indicate the state of the communities in the area (e.g., a coral reef). The difference between these values illustrates the specific use of the resources and the diversity. If specificity does not exist the differences between both values must be minimum, because the number and abundance of the species are influenced by the limitation of the resources and even by its size (shelters) (Abele, 1974; Abele and Patton, 1976).

From this point of view, the results (check-lists, aggregation and ordination analysis, dominance) show the existence of a spatial gradient and a marked specificity of the use of the environmental resources by the decapod species from the reef coral habitat, in the three ecological zones.

It could be interesting to mention that the dominance, density and biomass of the species vary in each ecological zone-key, even depending of the sampling methodology. The dominance of Brachyura and Anomura in samples taking with trawling and transect methods is related to their habits and behavior (many of them could be found on the substrata). The family of the snapping shrims, Alpheidae, is clearly dominant in the criptofaunal analysis, related with their morphological adaptation, such as was pointed out in other similar substrates with cavities—in shore (Brattström, 1992), shallow waters (García Raso and Fernández Muñoz, 1987; García Raso, 1988; López de la Rosa and García Raso, 1992) and in sublittoral rocky substrates (Felder and Chaney, 1979).

In any case, the majority of species caught are associated with hard substrates, stones and corals, or within caves and shelter in areas with high hydrodynamism (Provenzano, 1959; Chace, 1972; Powers, 1977 and Williams, 1984).

The geometrical distributions according to ecological zones-keys show similar patterns (there are too many species with few specimens) which indicate a similar structure in the communities in spite of the differences in other ecological parameters.

As a general conclusion: the analyzed ecological zones and keys reveal alternations and differences in the status of dominant decapod species as result of the complex structure of the communities, the adaptation and linking of these species with the substrates and their interactions. The communities of the lagoons, reef flat and outward slopes belong to different systems but are strongly interrelated. This equilibrium is an attribute of the coral reef system that confers constancy and fragility and it is the reason for which disturbances, that could break the equilibrium of this temporally and spatially conservative system, should be avoided.

Acknowledgements

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