

Structure and evolution of a decapod crustacean community from the coastal detritic bottoms of Barbate (Cadiz, Southern Spain)

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During 1993–1994 the decapod crustacean community of littoral detritic bottoms (15–24 m deep) from Southern Spain (Barbate Bay, near the Straits of Gibraltar) were studied. The substrata include coarse sand, fine gravel, *Amphioxus* sand, and contain abundant bioclastic remains (bivalve and gastropod shells), which are under the influence of bottom currents. The taxocoenosis shows a clear dominance of the Anomura, 87% of those being hermit crabs; among them, *Diogenes pugilator* (Roux, 1829) is the dominant species (76.6%). The structure and development of the taxocoenosis during an annual cycle (number of specimens, richness, diversity, evenness and heterogeneity) is controlled by the cycle of *D. pugilator*, a characteristic species of shallow fine sand bottoms, and by the appearance of, or increase in, seaweed in the late summer and autumn; this produces a notable seasonal variation and modifies the dominance and composition of species.

KEYWORDS: Decapoda, crustacean community, annual cycle, detritic bottoms, Spain.

Introduction

Studies on the decapod fauna of the littoral of Cádiz are scarce and most of them are part of the results of expeditions that deal with the deeper waters of the Gulf of Cádiz (see García Raso, 1996). Other authors that mention littoral species from this zone are Pozuelo *et al.* (1976), Holthuis (1977), García Raso (1983, 1985), González Gordillo *et al.* (1990), Cuesta Mariscal *et al.* (1991), Cuesta Mariscal *et al.* (1992), García Raso and Manjón-Cabeza (1994), and López de la Rosa (in press).

Data regarding the quantitative structure of communities, specifically on the decapod taxocoenosis of detritic beds, are only found in several general studies (Pérès and Picard, 1964; Ledoyer, 1966, 1968; Cabioch, 1968; Gilat, 1969; Guille, 1971, etc.).

The aim of this work was to investigate community structure and temporal evolution of a decapod taxocoenosis, as well as to find the factors which could influence its dynamics.

Material and methods

The area studied (figure 1) is located in Barbate Bay, province of Cádiz, in the region of the Straits of Gibraltar, between 36°08'73"–36°09'71" N and 05°55'19"–05°53'59" W.

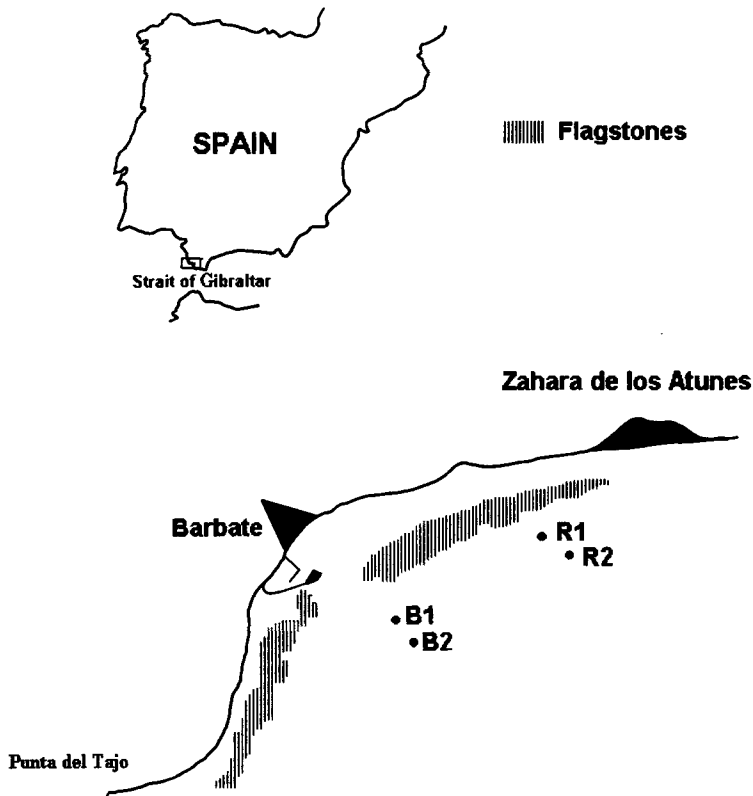


FIG. 1. Area of study and sampling points (R1, R2, B1 and B2).

The bottoms analysed are situated between 15 and 24 m deep, and we selected two transects, separated by 2.5 km, one in front of the village of Barbate (B) and the other one further east, in front of Retín (R), taking from each one two samples at 15–18 m (B1, R1) and at 24 m (B2, R2) respectively.

The sediment is mostly detritic with coarse sand, fine gravel and *Amphioxus* sand with abundant bioclastic remains. The main currents in this area (next to the Strait of Gibraltar) are influenced by the proximity of Punta del Tajo and Trafalgar Cape and the frequent flagstones could play a role in the amplification and channelling of tidal currents in this area. Bottoms and tidal currents are also of great importance because of the special coastal configuration.

The surrounding shallow bottoms are sandy. For this reason, in the shallower sampling point B1, which is closer to the beach and the Barbate river mouth, the percentage of fine sand is higher. Sampling point B2 is deeper and closer to Punta del Tajo and Trafalgar Cape.

Monthly samples were taken using a small and heavy rock dredge, with a rectangular frame of 42 × 22 cm and a double net; the size of the inner mesh was 4.5 mm knot to knot.

The minimum sample area was determined prior to the study of the decapod community. This is difficult to establish due to the number of factors that affect it through the annual cycle. Some influences are temporary, seasonal and/or local and

may, also, affect each species differently. Different methodologies have been tested (Borja, 1986) and we selected that by Pichon (1978).

In the laboratory, the sediment was washed over a sieve column with a mesh size between 1 cm and 1 mm. The fauna was separated, and identified by reference to Zariquiey Álvarez (1968), Ingle (1993) and Garcia Gomez (1994).

In the community study, three values were calculated to analyse the importance of each species within the community: permanence or presence through the cycle ($C_i\%$), considering five categories (Mora, 1980): permanent species (100–76%), very common species (75–51%), common species (50–26%), not-so-common species (25–13%) and rare or accidental species (12–0%); dominance or density ($D_i\%$), and the value of the multiplication of $C_i \times D_i\%$.

Several ecological indices have been employed: diversity index (α -diversity) (Shannon and Weaver, 1963), evenness index (Pielou, 1969) and heterogeneity index (β -diversity) (Margalef, 1957, according to Niell and Rucabado, 1981).

The quantitative percentage index has been used to evaluate the degree of similarity (Renkonen, 1938, in Krebs, 1989). Both the Jaccard coefficient (Jaccard, 1908; Real and Vargas, 1996) with the UPGMA agglomeration algorithm (Sneath and Sokal, 1973), and correspondence analysis (Ter Braak and Prentice, 1988) have been applied for grouping and ordering samples.

Results

The minimum sample area corresponds to 130 m² (10 min of dredging). However, according to the special characteristics of the bottoms studied (unstable, with strong bottom currents), we sampled each sampling point monthly for 15 min, covering most of the minimum area and reducing the effect of possible temporal perturbations.

The four sampling points were analysed separately (qualitatively and quantitatively) (figure 2) and later were grouped together for the results of the faunistic studies. Thus, qualitative analysis showed a high percentage of shared species, both between depths and between transects (80–84%), and even between sampling points (R1–R2: 93.17%; R1–B1: 84.44%; R1–R2: 85.67%; R1–B2: 68.0%; R2–B1: 57.21%, R2–B2: 91.0%), the non-shared species being uncommon or accidental (e.g. the commensal crab *Pinnotheres*), except for one case: *Thorulus cranchii*. This species was moderately abundant but was seasonal, its occurrence in the samples being related to the appearance of seaweed in the summer (Seoane-Camba, 1965), and local, as it only appears at B2 and in June–July. These circumstances make B2 appear qualitatively and quantitatively different, although it is only a brief seasonal situation that affects very few species.

The total fauna is shown in table 1. Among the 37 species found, nine can be considered permanent (and with a $C_i D_i\%$ value > 5.0) and dominant (representing 96% of the total number of specimens), of which *Diogenes pugilator* is the dominant species (76.6%); five species are very common ($5.0 > C_i D_i\% > 1.0$), 10 species are common ($1.0 > C_i D_i\% > 0.2$); and, of the rest, seven are not-so-common and six are rare or accidental.

The development of the structure of the community through the cycle, number of specimens (N), species richness (S), diversity (H'), evenness (J') and heterogeneity (CH') are displayed in table 2 and figure 3. In February, there is a maximum number of specimens due to *Diogenes pugilator* recruitment. However, if this species was not taken into account, the maximum would be located in June, the period of maximum density of the remaining species, as well as the higher species richness, diversity and

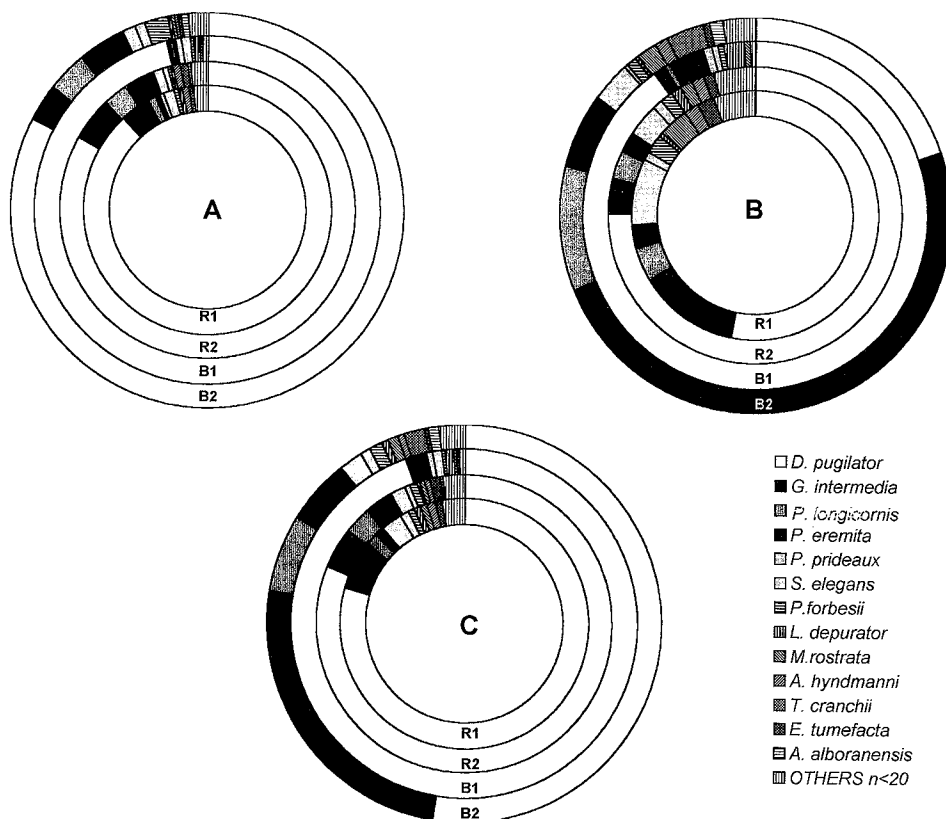


FIG. 2. Number of specimens of the dominant species at the four sampling points during: A, months without seaweed (November to May). B, months with seaweed (June to October). C, all year.

evenness. Consequently, the higher values of heterogeneity appear between May to June. Richness, diversity and evenness values follow a similar pattern.

From a qualitative point of view, the Jaccard index as well as the correspondence analysis reflect similar results (figures 4, 5), related to seasonal evolution. Late autumn–winter and spring (minimum S) and summer–early autumn (maximum S) are groups, weakly isolated, in the cluster of similarity analysis (at $P < 0.0005$) and in the correspondence analysis with a similar order of those months.

From the quantitative viewpoint (figure 6), the strong dominance of the three most abundant species, together with the increase of species richness that occurs in summer (factors that control the community structure, number of specimens, diversity and evenness) builds an order which brings together the winter and spring months, in which *D. pugilator* clearly dominates. This is also shown by minimal values for H' , J' and S' during those months, as opposed to the maximum values when the seaweed appears (June to October) (table 2).

Discussion

The few decapod species or genera of detritic bottoms referred to in general studies of the Mediterranean Sea (Péres and Picard, 1964; Ledoyer 1966, 1968;

Table 1. Faunistic results (explanation in text).

	Oct-93	Nov-93	Dec-93	Jan-94	Feb-94	Mar-94	Apr-94	May-94	Jun-94	Jul-94	Aug-94	Sep-94	Total	Di %	Ci	Ci %	Ci × Di %
<i>Athanas nitescens</i> (Leach, 1814)						1	2			2			5	0.06	3	25	0.170
<i>Processa macrophthalma</i> Nouvel & Holthuis, 1957	1	3	1					2	2	5	1	3	18	0.20	8	67	1.600
<i>Thoralus cranchii</i> (Leach, 1817)									29	14			43	0.48	2	17	0.960
<i>Galathea intermedia</i> Lilljeborg, 1851	43	48	14	2	2	12	17	14	439	201	63	25	880	9.79	12	100	117.440
<i>Pisidia longicornis</i> (Linnaeus, 1767)	62	18	6	1	9	1		5	115	30	16	11	274	3.05	11	92	33.520
<i>Anapagurus alboranensis</i> García-Gómez, 1994	2	2	3	3	1			8	16				35	0.39	7	58	2.720
<i>Anapagurus breviaculatus</i> Fenizia, 1937									1				1	0.01	1	8	0.010
<i>Anapagurus hyndmanni</i> (Bell, 1846)	6	1	9		4		2		17	3	2	2	46	0.51	9	75	4.600
<i>Anapagurus petiti</i> Dechancé & Forest, 1962									2				2	0.02	1	8	0.020
<i>Pagurus cuanensis</i> Bell, 1846	2		2	1		1	1			1			8	0.09	6	50	0.530
<i>Pagurus forbesii</i> Bell, 1846	17	1	5	9	2	2	1	2	5	12	8	1	65	0.72	12	100	8.670
<i>Pagurus prideaux</i> Leach, 1815	10	3	5	8	11	1	4	4	18	23	19	31	137	1.52	12	100	18.280
<i>Pagurus</i> sp.									3				3	0.03	1	8	0.030
<i>Spiropagurus elegans</i> Miers, 1881	7	3	15	3	20	1	4	4	5	3	8	3	76	0.85	12	100	10.140
<i>Dardanus arrosor</i> (Herbst, 1796)									1	1			2	0.02	2	17	0.040
<i>Diogenes pugilator</i> (Roux, 1829)	266	400	733	567	1309	698	852	525	184	121	765	465	6885	76.57	12	100	918.820
<i>Paguristes eremita</i> (Linnaeus, 1767)	36	9	15	4	35	8	4	4	14	26	42	49	246	2.74	12	100	32.830
<i>Atelecyclus undecimdentatus</i> (Herbst, 1783)				1				7	5	3	1		17	0.19	5	42	0.950
<i>Calappa granulata</i> (Linnaeus, 1758)					2					1			3	0.03	2	17	0.070
<i>Ebalia cranchii</i> Leach, 1817											1		1	0.01	1	8	0.010
<i>Ebalia tuberosa</i> (Pennant, 1777)				1				1	1			1	6	0.07	5	42	0.330
<i>Ebalia tumefacta</i> (Montagu, 1808)	3	1	3	2	3	6	1	1	3	3	2	11	39	0.43	12	100	5.200
<i>Ethusa mascarone</i> (Herbst, 1785)		1	1	2	1			1				1	7	0.08	6	50	0.470
<i>Euryome aspera</i> (Pennant, 1777)	3		1					1			1	2	8	0.09	5	42	0.440
<i>Inachus dorsetensis</i> (Pennant, 1777)	1		1	2	1				3	4	3	1	16	0.18	8	67	1.420
<i>Liocarcinus depurator</i> (Linnaeus, 1758)		7	2	5	1	4	4	4	8	4	12	6	57	0.63	11	92	6.970
<i>Liocarcinus mcleayi</i> (Barnard, 1947)	1	2		1	1								5	0.06	4	33	0.220
<i>Liocarcinus pusillus</i> Leach, 1815)	1	3								1	2		7	0.08	4	33	0.310
<i>Macropodia rostrata</i> (Linnaeus, 1761)	3	2						1	12	17	12	4	51	0.57	7	58	3.970
<i>Parthenope angulifrons</i> Latreille, 1825	1				1		1	1		1	1		6	0.07	6	50	0.400
<i>Parthenope massena</i> (Roux, 1830)	4	4	2						2	1		1	14	0.16	6	50	0.930
<i>Pilumnus hirtellus</i> (Linnaeus, 1761)	2								1		1		4	0.04	3	25	0.130
<i>Pilumnus spinifer</i> H. Milne Edwards, 1834		1			1			3		1		2	8	0.09	5	42	0.440
<i>Pinnotheres</i> sp.										1			1	0.01	1	8	0.010
<i>Pinnotheres pisum</i> (Linnaeus, 1767)	1								2				3	0.03	2	17	0.070
<i>Pisa armata</i> (Latreille, 1803)	1						1					8	10	0.11	3	25	0.330
<i>Thia scutellata</i> (Fabricius, 1793)					3								3	0.03	1	8	0.030

Table 2. Monthly values of the ecological index through cycle. N: total number of specimens, Nd: number of specimens without *D. pugilator*. Ng: number of specimens without *D. pugilator* and *G. intermedia*, Np: number of specimens without *D. pugilator*, *G. intermedia* and *P. longicornis*; S: species richness; H': diversity; J': evenness and CH: heterogeneity.

	Oct-93	Nov-93	Dec-93	Jan-94	Feb-94	Mar-94	Apr-94	May-94	Jun-94	Jul-94	Aug-94	Sep-94
N	473	509	818	612	1407	735	894	588	887	479	963	627
Nd	207	109	85	45	98	37	42	63	703	358	198	162
Ng	164	61	71	43	96	25	25	49	264	157	135	137
Np	102	43	65	42	87	24	25	44	149	127	119	126
S	22	18	17	16	18	11	13	18	23	24	21	19
H'	2.34	1.37	0.84	0.64	0.57	0.42	0.41	0.88	2.41	2.72	1.36	1.63
J'	0.52	0.33	0.20	0.16	0.14	0.13	0.11	0.21	0.53	0.60	0.31	0.38
CH		0,08	0,01	0,04	0,01	0,05	0,01	0,02	0,58	0,01	0,02	0,01

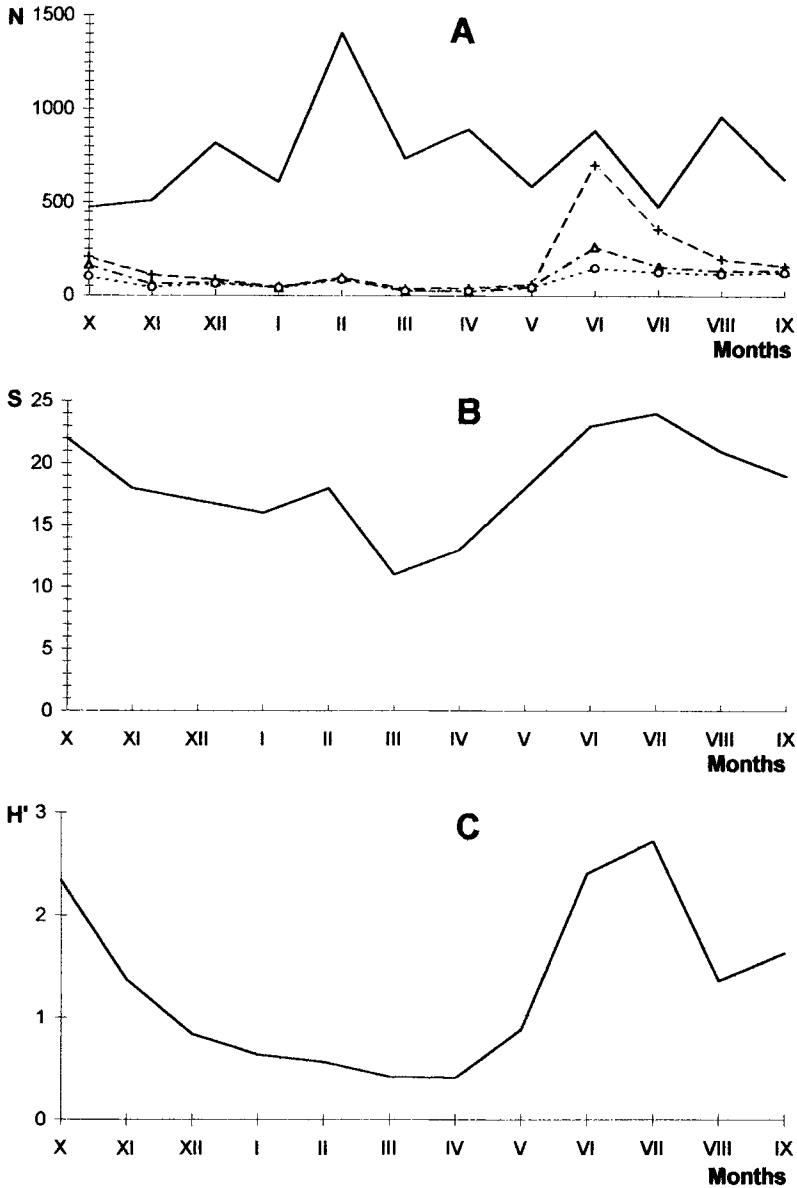


FIG. 3 (A-C). Evolution of the structure of the community through the cycle. A, number of specimens (N). Continuous line: total number; discontinuous lines: with +: without *D. pugilator* specimens, with Δ : without *D. pugilator* and *G. intermedia* specimens, with O without *D. pugilator*, *G. intermedia* and *P. longicornis* specimens. B, species richness (S). C, diversity (H').

Cabioch, 1968; Gilat, 1969; Guille, 1971) are similar to our data (*Ebalia* spp., *Anapagurus hyndmanni*, *Pisidia longicornis*, *Parthenope massena*, *Pagurus* spp. etc).

The anomurans are an important component in these studies although, due to the variety of detritic bottoms and sampling methodologies, the quantitative results are not quite comparable. In our results, this dominance is clear because seven out

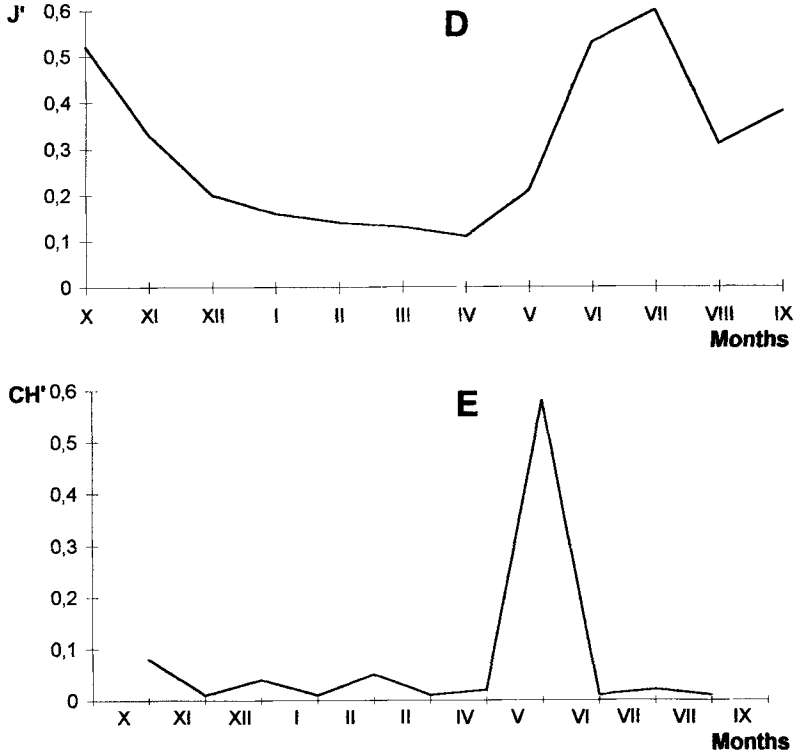


FIG. 3 (D, E). D, evenness (J'). E, heterogeneity (CH).

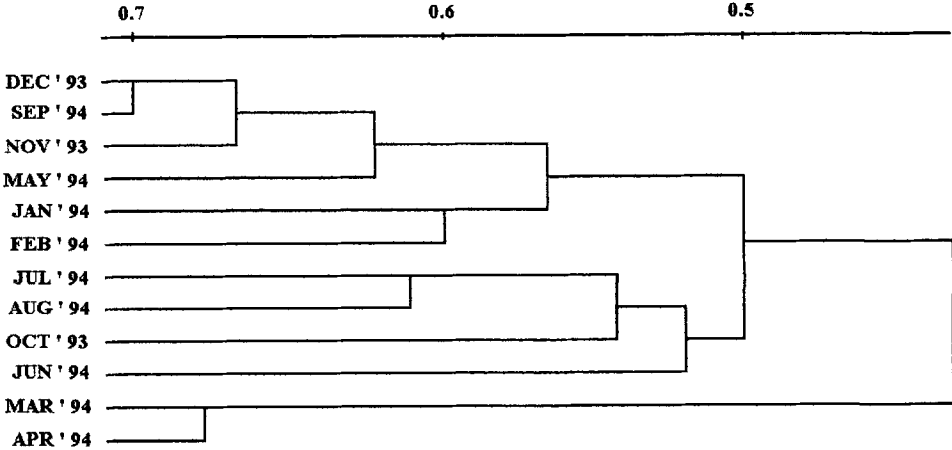


FIG. 4. Qualitative analysis of similarity between monthly samples (Jaccard coefficient and UPGMA agglomeration algorithm).

of the nine permanent species of the community are Anomura (representing 96% of the specimens, 87% of which are hermit crabs). This dominance coincides with data from other coarse bottoms, such as those from Columbretes Islands ('facies des prâlines' and 'maërl', according to Pérès and Picard, 1964), where the hermit crabs

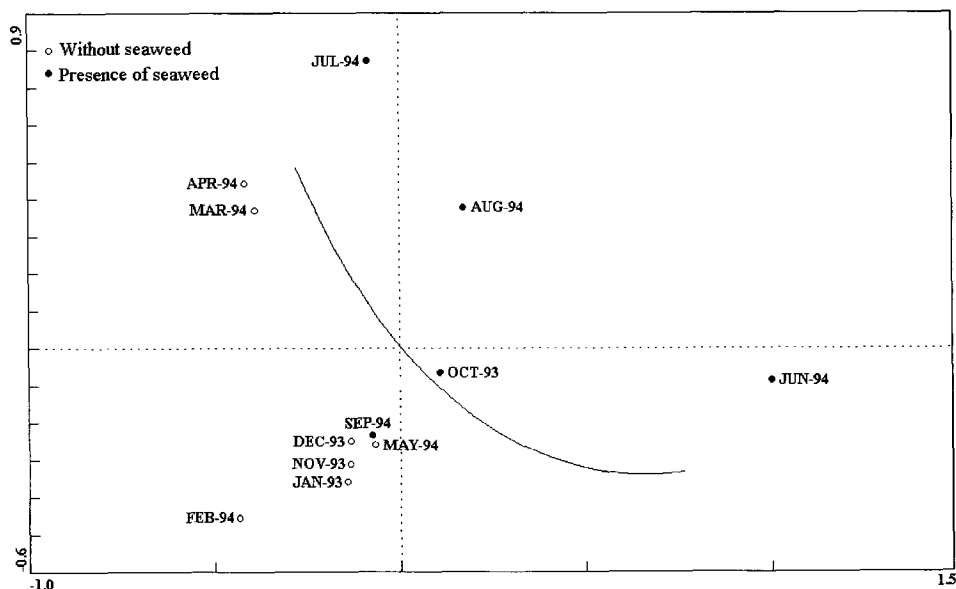


FIG. 5. Qualitative correspondence analysis between monthly samples. Axes I, II, III and IV; eigenvalues and cumulative percentage variance of species data: 0.209, 0.148, 0.131, 0.125 and 22.4, 38.3, 52.3, 65.7 respectively.

Cestopagurus timidus (Roux) and *Calcinus tubularis* (Linnaeus) are the most abundant (García Raso, unpublished data from Fauna Ibérica, IV Expedition).

This greater density of anomurans, especially of hermit crabs, could be related to a better adaptation to this type of bottom. Abele (1974) suggested that both composition of species and dominance are determined by the substratum. Likewise, feeding behaviour and the gastropod shells where they live, allow them to survive among the shell remains and gravel, protected from the strong bottom currents.

The existence of a strong dominance by one or two species over the others seems to be a common occurrence in decapod taxocoenosis (Gore *et al.*, 1981; Ledoyer, 1984; García Raso and Fernández Muñoz, 1987; García Raso, 1988, 1990), therefore the values of the evenness index are expectedly low.

Pérès and Picard (1964) also suggest that on these bottoms there is a dominance of bioclastic elements and that, as a consequence of the bottom currents, the macrofauna is washed away, dispersed and there is a low richness.

Moreover, the nature of detritic formations is very diverse and depends on the characteristics of the surrounding substratum. The dominance of *D. pugilator* in the taxocoenosis studied, is a clear example, as it is a characteristic and dominant species in fine sand shallow bottoms (Pérès and Picard, 1964; Ledoyer, 1968; García Raso, 1987).

Other factors such as the presence, or the increase, of seaweed could affect the structure of decapod taxocoenosis (Thorhaug and Roessler, 1977; Gore *et al.*, 1981).

The quantitative differences between B1 and B2 (figure 2), the development of the community structure through the cycle, and seasonal variations (figure 3), can be explained now on the basis of the previous arguments. B1, as it is closer to the beach and Barbate river mouth, has a greater amount of fine sands and this favours

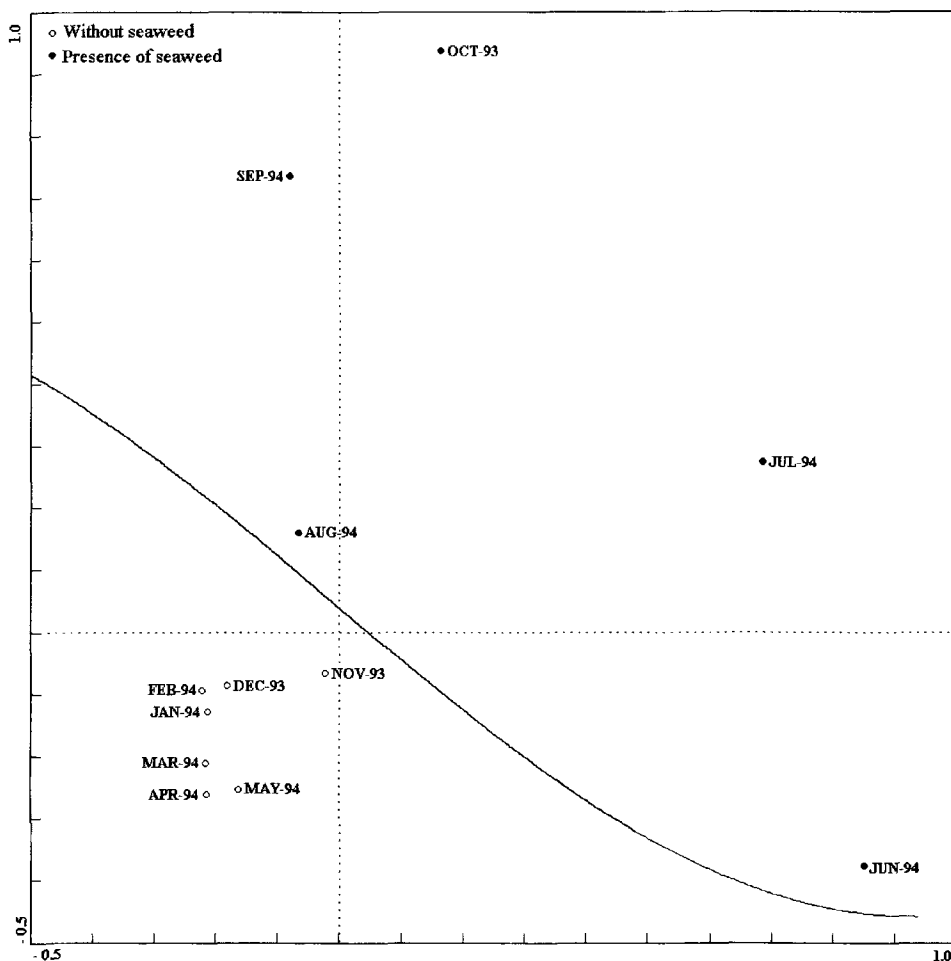


FIG. 6. Quantitative correspondence analysis between monthly samples. Axes I, II, III and IV: eigenvalues and cumulative percentage variance of species data: 0.441, 0.050, 0.033, 0.017 and 77.6, 85.3, 91.0, 94.0 respectively.

Diogenes pugilator quantitatively. B2, deeper and closer to Punta del Tajo-Cape Trafalgar, has the highest seasonal appearance of seaweed in summer which favours a seasonal increase of associated species. Thus, *Thorulus cranchii* has been found only in B2 and during June and July, and other species such as *Pisidia longicornis* and *Galathea intermedia* show a strong increase in number of specimens, which after the seaweed disappearance in November, decreases to the usual and general values (table 1, figures 2A,B).

The type of substratum (sediment and seaweed) and its evolution determine the dominance and composition of species through the cycle in the decapod community of the studied detritic bottom.

As a final comment and according to our data (obtained during 1993 to 1996), the seasonal appearance of seaweed in the summer may or may not be annual at all sampling localities or may vary in intensity or seasonally.

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