JOURNAL OF CRUSTACEAN BIOLOGY, 22(1): 83–90, 2002

AN INFRALITTORAL DECAPOD CRUSTACEAN COMMUNITY OF SOUTHERN SPAIN AFFECTED BY ANTHROPOGENIC DISTURBANCES

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ABSTRACT

The structure of a decapod crustacean community on a littoral detritic bottom (coarse sand, fine gravel, *Amphioxus* sand, and abundant bioclastic remains) of Southern Spain (Barbate Bay, near the Straits of Gibraltar), at 15–24-m depth, from October 1993 to August 1995, has shown annual changes. These changes could be due to natural factors (river flow as consequence of differences in pluviometry between years) and anthropogenic disturbances happening in front of the sampling area during a second period (namely the dredging and enlargement of the harbour and the restoration of a beach), which affected directly or indirectly (through the movement of particulate matter) the structure of decapod community. As a result, there was a decrease in the total abundance and in the number of specimens of the dominant species (mainly *Diogenes pugilator* and *Galathea intermedia*) some of them associated with seaweed (*G. intermedia* and *Pisidia longicornis*), a reduction of the seasonality, and fluctuations in the values of the richness and diversity indices. However, before and during the disturbances, the dominant species remained the same, with only slight modification in the dominance order. In addition, the accumulative total annual values of the diversity indices are very similar. All these results could mean the existence of higher resistance to disturbances (none strong) in the decapod community from hydrodynamic areas. On the other hand, the strong currents increase the dispersion of the sediments, reduce the turbidity, and facilitate a more rapid return to the previous conditions, increasing the elasticity of the system, in which the decapod community presents a cyclic structure.

The majority of studies regarding decapods of Southern Spain are taxonomic or biogeographic (see García Raso, 1996), whereas analyses of the quantitative structure of communities in annual cycles are few, and mostly restricted to the Alboran Sea (West Mediterranean) (García Raso, 1987, 1988, 1990; García Raso and Fernández, 1987; García Raso *et al.*, 1996). In Atlantic waters, on the littoral of Cádiz, there are some general studies on crustacean communities from Algeciras Bay (Sánchez Moyano, 1996; Sánchez Moyano and García Gómez, 1998) and, also, a decapod community from detritic sediments under the influence of bottom currents has been studied (Manjón Cabeza and García Raso, 1998a, b).

General data on communities living on shallow detritic biotopes can be found in Pérès and Picard (1964), Ledoyer (1966, 1968), Cabioch (1968), Gilat (1969), Guille (1971), Dauvin (1997). On these substrates there is a predominance of bioclastic elements and, as a consequence of the strong tidal bottom currents, the macrofauna is washed away, dispersed and, consequently, there is a relatively low richness (Pérès and Picard, 1964). On the other hand, the nature of detritic formation could be very diverse and depends on the characteristics of surrounding substratum.

Studies of changes of the macrobenthic assemblages have been made in the Atlantic European coast (e.g., Germany, England, France) (Dörjes *et al.*, 1986; Davoult *et al.*, 1993; Fromentin *et al.*, 1997), some of them in relation to pollution (Cabioch *et al.*, 1982), but such works are very scarce for Spanish littoral areas (López-Jamar *et al.*, 1986).

The aim of the present paper is to show changes detected in a decapod community from a littoral detritic bottom with strong hydrodynamic conditions from Southern Spain, caused (at least in part) by anthropogenic disturbances.

MATERIALS AND METHODS

The studied area (Fig. 1) is located in Atlantic waters in Province of Cadiz, in Barbate Bay, near of Punta del Tajo and Trafalgar Cape and very close to the Straits of Gibraltar (South of Spain), between 36°08.73′–36°09.71′N and 05°55.19′–05°53.59′W. This is an area with very strong hydrodynamic conditions due to tidal currents (tidal amplitude somewhat more than 3 m), which are increased by the existence of underwater flagstones that guide and intensify them, and by the strong influence of the inflow–outflow current through the Straits of Gibraltar.

Four samples were taken each month, in the morning, two at 15–18-m (B1, R1) and two at 24-m (B2, R2) depth, at two transects separated by 2.5 km (Fig. 1) during October 1993–August 1995. For sampling, we used a small rock dredge, with a rectangular frame of 42 × 22 cm mounted with a double net, the size of the inner mesh being 4.5 mm and the outer 10 mm. A large sampling area was dredged (15 min at 1 kt) in order to cover the minimum area (Manjón-Cabeza and García Raso, 1998a). The detritic sediment was mostly coarse sand, fine gravel, and *Amphioxus* sand with abundant bioclastic remains (Rueda *et al.*, 2000). In this study the four monthly samples were grouped after they had been analysed separately to verify that the composition was similar. This allowed a global view of the community in the area and reduced the effect of possible local and sporadic perturbations (e.g., as consequence of tidal currents in different hours or days). For separating fauna in the laboratory, the sediment was washed over a sieve column with a mesh size between 1 cm and 1 mm. The general structure of the decapod community and the population structure of the dominant species during a first study were presented in Manjón-Cabeza and García Raso (1998a, b).

During study of a second sampling period (November 1994 to August 1995), the dredging and enlargement of the harbour and the restoration of a beach on the coast facing the sampling points affected temporally the composition of the sediment. In this way there was an increase in the proportions of fine sand and muddy sand (mainly in the stations B1 and B2).

In this community study, the values of "permanence of presence" throughout the year (Ci%) and "dominance or relative abundance" (Di%) (García Raso and Fernández, 1987; López and García Raso, 1992) allowed us to understand the importance of each species within the community. Also, the diversity index (Shannon-Wiener, as defined in Krebs, 1989) and evenness index (Pielou, 1966) were employed, and the significance of H′ between years was determined (Magurran, 1989). In addition, a correspondence analysis (Ter Braak and Prentice, 1988) was applied to sample data.

RESULTS

The quantitative results found during the second sampling period (November 1994–August 1995), in which the anthropogenic disturbances happened, are shown in Table 1. In this community hermit crab species were quantitatively dominant, especially *Diogenes pugilator* representing more than 75% of the total specimens caught (Table 1, Fig. 2).

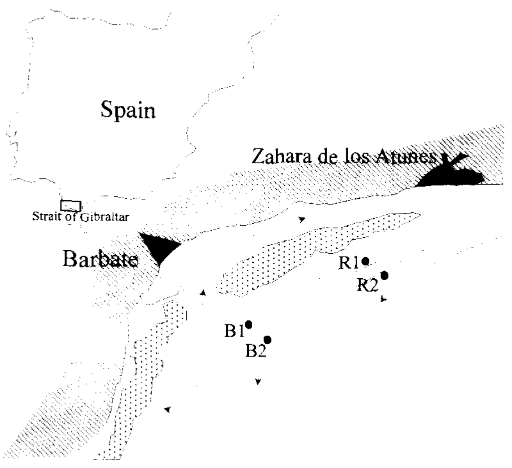

Fig. 1. Area of study and sampling points (R1, R2, B1, and B2). Stippled areas: rocks (flagstones) underwater. Arrows: normal flow of tidal currents.

During late summer and early autumn 1995, particularly in August (and at the end of July), seaweeds occurred. This circumstance was associated with a modification of the number of specimens of some species (a decrease in hermit crabs and an increase in the porcellanid *Pisidia longicornis* and the galatheid *Galathea intermedia*) (Table 1) and a slight change in the structure of the community (increase in the values of H′ and J′, Table 2). In this way, in ordination analysis (Fig. 3), August, the month with abundant seaweeds, was clearly separated from the others.

The analysis of S and H′ indices during the studied period (Table 2, Fig. 4) show oscillations but not an evident seasonality.

On the other hand, comparative analysis of the monthly changes of these ecological indices (H′ and J′) from a cumulative point of view, between years (without and with anthropogenic disturbances), show differences (Fig. 5), probably as a result of the strong reduction of the seasonality (during the disturbance period). However, at the end of each year, the total accumulative values of H′ are very similar (Table 3), although they are significantly different ($t = 3.34$, $P < 0.001$).

DISCUSSION

The comparative analysis of the two years, one without (Manjón-Cabeza and García Raso, 1998a) and the other with anthropogenic disturbances, shows variability in the structure of the decapod crustacean community from the detritic substrates from the Barbate littoral and a relatively medium richness. However, this richness even could be considered high taken into account the general characteristic of this biotope (Pérès and Picard, 1964) and the strong hydrodynamism of the studied zone, which amplify the disper-

Table 1. Changes in the abundances of all species, from November '94 to August '95. The months with seaweed are indicated in boldface. T: total abundance, Ci%: permanance of presence during the period studied, Di%: dominanace or total relative abundance.

Species	Nov-94	Dec-94	Jan-95	Feb-95	Mar-95	Apr-95	May-95	Jun-95	**Jul-95**	**Aug-95**	T	Di%	Ci%
Diogenes pugilator (Roux, 1829)	498	*1,438*	*710*	698	204	*361*	306	329	187	132	4,836	*75.139*	*100*
Galathea intermedia Lilljeborg, 1851	30	15	51	34	33	92	44	34	14	79	426	6.582	100
Paguristes eremita (Linnaeus, 1767)	50	9	43	40	22	22	9	24	11	8	238	3.677	100
Pagurus prideaux Leach, 1815	25	42	36	45	20	18	16	12	7	7	228	3.523	100
Pisidia longicornis (Linnaeus, 1767)	27	13	30	12	18	19	25	2	2	69	217	3.353	100
Pagurus forbesii Bell, 1846	14	12	36	15	9	8	8	7	9	7	125	1.931	100
Anapagurus hyndmanni (Bell, 1846)	1	2	36	7	12	4	17	3	4		86	1.329	90
Anapagurus alboranensis García-Gómez, 1994		4	2	2	1	20	15	14	2	3	63	0.973	90
Spiropagurus elegans Miers, 1881	11	7	10	5	6	2	3	9	8	2	63	0.973	100
Ebalia tumefacta (Montagu, 1808)	4	2	5	11	5	8	4	4		1	44	0.680	90
Liocarcinus depurator (Linnaeus, 1758)	2	2	1	1	1	2	8	4	1	3	25	0.368	100
Macropodia rostrata (Linnaeus, 1761)	3	3	1	1					1	5	14	0.216	60
Liocarcinus pusillus (Leach, 1815)	1		1		1			1	5	3	12	0.185	60
Inachus dorsettensis (Pennant, 1777)	1	3	3	2						2	11	0.170	50
Atelecyclus undecimdentatus (Herbst, 1783)	1				1	1	3	3	1		10	0.155	60
Pilumnus hirtellus (Linnaeus, 1761)	2	2	2			2				2	10	0.155	50
Parthenope massena (Roux, 1830)	2		4	1	1	1					9	0.139	50
Processa macrophthalma Nouvel and Holthuis, 1957	3					1	1		2	1	8	0.124	50
Parthenope angulifrons Latreille, 1825	1		1		2	1				1	6	0.093	50
Pilumnus spinifer H. Milne Edwards, 1834	1		1	1	1	1					5	0.077	50
Dardanus arrosor (Herbst, 1796)	2						1	1			4	0.062	30
Pisa armata (Latreille, 1803)			1		1				1	1	4	0.062	40
Thia scutellata (Fabricius, 1793)	1					3					4	0.062	20
Eurynome aspera (Pennant, 1777)										4	4	0.062	10
Anapagurus laevis (Bell, 1846)		2	1								3	0.046	20
Anapagurus petiti Dechancé and Forest, 1962	2			1							3	0.046	20
Pagurus cuanensis (Bell, 1846)					2						2	0.031	10
Pagurus excavatus (Herbst, 1791)							1			1	2	0.031	20
Liocarcinus mcleayi (Barnard, 1947)				1			1				2	0.031	20
Philocheras bispinosus (Hailstone, 1835)						1					1	0.015	10
Ethusa mascarone (Herbst, 1785)						1					1	0.015	10
Liocarcinus corrugatus (Pennant, 1777)									1		1	0.015	10
Pagurus sp.							1				1	0.015	10
Pinnotheres pissum (Linnaeus, 1767)					1						1	0.015	10
Total number	682	1,556	975	877	341	569	462	447	256	331	6,496		

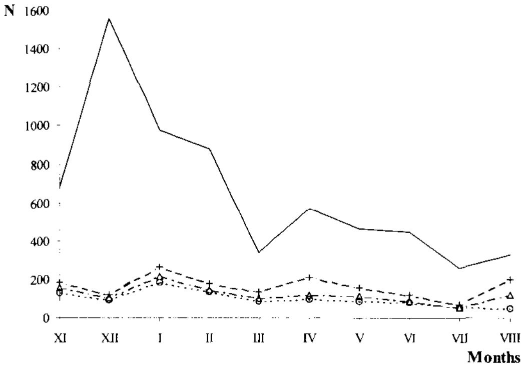

Fig. 2. Changes in the number of specimens (N). November 1994 to August 1995. Continuous line: total number; discontinuous lines: (+): without *D. pugilator* specimens, (△): without *D. pugilator* and *G. intermedia* specimens, (○): without *D. pugilator*, *G. intermedia*, and *P. longicornis* specimens.

sion of the macrofauna and should generate a relatively low richness.

The decapod community is dominated by the hermit crabs and especially by *Diogenes pugilator*. The strong dominance of this species, together with the appearance of seaweeds in late summer and beginning of autumn (which is associated with the appearance of some species or with the increasing number of specimens), are determinant of the structure and evolution of this community. This was clearly observed in the year without anthropogenic disturbances (October 1993 to September 1994, in Manjón-Cabeza and García Raso, 1998a), in which a clear and long seasonality related with a long seaweed period (June–October) appears.

Quantitative and qualitative differences between the two periods (without and with anthropogenic disturbances) exist. The qualitative are relatively small and, in this way, no more than seven species (over a total of 41 species) are not shared, which only represent 0.4% of the total abundance. In addition, the dominant species are the same and only small changes in the relative abundance order have been detected. The essential variations between both periods appears in the absolute abundances of the species (Table 2 and Manjón-Cabeza and García Raso, 1998a).

Stronger variations have been found in the study of the Mollusca community (Salas, personal communication), in which a clear influence of the sediments exists.

These inter-annual changes could be imputed, at least, to the following: A) Extrinsic

Table 2. Monthly values of numbers of specimens: total (N), total without *D. pugilator* (ND); total without *D. pugilator* and *G. intermedia* (NG); and total without *D. pugilator*, *G. intermedia*, and *P. longicornis* (NP); and values of richness (S); diversity (H′); evenness (J′); and heterogeneity (CH′) during the studied year.

	Nov–94	Dec–94	Jan–95	Feb–95	Mar–95	Apr–95	May–95	Jun–95	Jul–95	Aug–95
N	682	1,556	975	877	341	569	462	447	256	331
ND	184	118	265	179	137	208	156	118	69	199
NG	154	103	214	145	104	116	112	84	55	120
NP	127	90	184	133	86	97	87	82	53	51
S	22	15	20	17	19	21	16	14	16	19
H′	1.71	0.64	1.70	1.34	2.28	1.99	1.88	1.64	1.72	2.35
J′	0.38	0.16	0.39	0.33	0.54	0.45	0.47	0.43	0.43	0.55
CH′		0.15	0.05	0.03	0.17	0.34	0.08	0.11	0.17	0.19

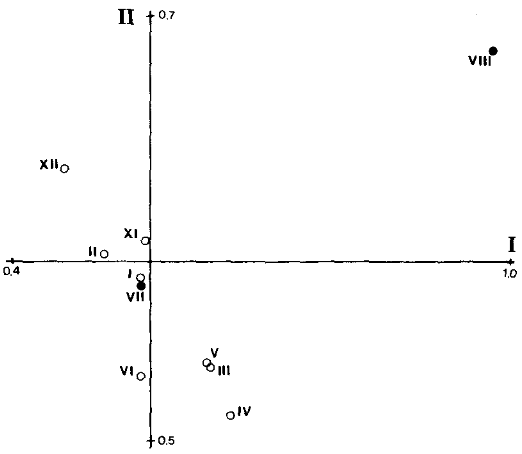

Fig. 3. Quantitative Correspondence Analysis between monthly samples. Axes I and II represented. Cumulative percentage variance and eigenvalues of the axes I, II, III, and IV respectively: 50.7, 65.3, 77.2, 84.1 and 0.137, 0.039, 0.032, 0.019. Total inertia: 0.27. Closed circles are months with seaweed.

factors related with seasonal and specific situations, which could change temporally the local conditions (such as in Fromentin *et al.*, 1997), but not as a consequence of extreme situations (as in Dörjes *et al.*, 1986). Hence, differences in pluviometry at the end of spring and in the beginning of summer between years are associated with a different intensity of flow in the Barbate river, which affects more or less the shallower localities. However these differences, between the two compared periods, were slight (data from "Instituto Nacional de Meteorología, Andalucia Occidental"). B) Anthropogenic disturbances happened during the second period, including the dredging and enlargement of the harbour and the restoration of a beach. Consequently, the sediment was reworked very near to the sampling area (mainly stations B1 and B2), producing a higher turbidity that probably affected the infaunal community, directly or indirectly through the settlement of larvae and the seasonal appearance of seaweeds. In the year with anthropogenic disturbances the period with seaweed was shorter than the previous one, without disturbances, and the algae were more scarce. This kind of disturbance affects the pelagic phases by the suspension of particulate matter, with a further effect on the benthic populations (Menzie, 1984; Bonvicini *et al.*, 1985). In this way, the delay in the appearance of seaweeds and their lower abundance in the "disturbance period" could be caused by this factor.

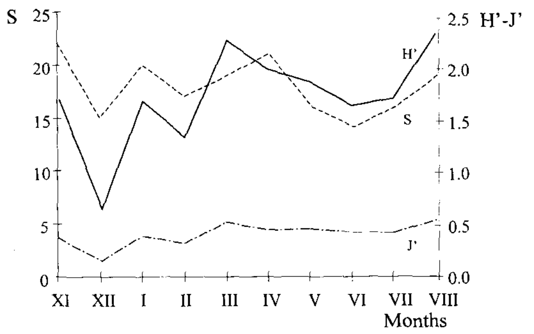

Fig. 4. Evolution of the structure of the community, November 1994 to August 1995. H′ = diversity index, J′ = evenness index, and S = richness.

On changes of macrobenthic assemblages, Dörjes *et al.* (1986), analysing the sublittoral macrozoobentos near the island of Norderney (1976–1985), found changes in the species composition, where many appear sporadically and others only develop large populations in certain years, disappearing completely or decreasing their abundance in others. Fromentin *et al.* (1997), in the study of the muddy-fine sand *Abra alba* community in the northwestern coast of France, found important changes in species composition, with rapid successions of distinct groups of species.

In our study, the dominant species of the community remained the same and only changes in the abundance values and slight modifications in the dominance order were detected, the more interesting affecting hermit crabs and species such as *Galathea intermedia, Pisidia longicornis,* and *Thoralus cranchii,* the first associated with sandy bottoms and the last three with the appearance of seaweed. In this way changes in the environmental conditions (natural and/or by human actions) would affect the algal settlement and generate changes in species composition of decapods, in the abundance of the different species, and variations in the evolution of the monthly structure of the community between years (H′, J′, S) (Fig. 4 and Figs. 3, 4 in Manjón-Cabeza and García Raso, 1998a). As a result, in the year with anthropogenic disturbances there were: a decrease in the general abundance and particularly in the number of specimens of the two dominant species (*Diogenes pugilator* and *Galathea intermedia*); more fluctuations in the monthly values of the diversity index; a increasing in the J′ values, and a strong reduction in the

Table 3. The annual relative abundance (%) of the dominant species, the total numbers of specimens (N), and the values of richness (S), diversity (H′) and evenness (J′) in the two periods compared.

	Relative abundances	
	Oct. '93–Sep. '94	Nov. '94–Aug. '95
Diogenes pugilator	76.57	75.14
Galathea intermedia	9.79	6.58
Pisidia longicornis	3.05	3.35
Paguristes eremita	2.74	3.68
Pagurus prideaux	1.52	3.52
Pagurus forbesii	0.72	1.93
Spiropagurus elegans	0.85	0.97
Ebalia tumefacta	–	0.68
Liocarcinus depurator	0.63	–
Anapagurus hyndmanni	0.51	1.33
Anapagurus alboranensis	–	0.97
	Total cumulative values	
N	8,992	6,496
S	37	34
H′	1.55	1.66
J′	0.29	0.32

seasonality (see Manjón-Cabeza and García Raso, 1998a, and present data). López-Jamar *et al.* (1986), in the study of the structure of two communities from La Coruña (Spain), found that a community living in an area with little human influence and with a stable sedimentary environment was more stable, and the fluctuations of diversity (H′) and evenness (J′) were small, in comparison to a community where there was more intense human activity, such as polluted harbour areas (where dredging operations happen), had wider fluctuations due to anthropogenic disturbance.

On the other hand, the evolution of these indices from an accumulative point of view show that the total annual results are very similar (Table 3, Fig. 5), which suggests a trend to return to the typical structure of the community (as happened in the study of Davoult *et al.*, 1993), which are variations in structure due to variations of relative abundances of a few species.

All these results could mean that the decapod community living in a strong hydrodynamic area like the one studied is well

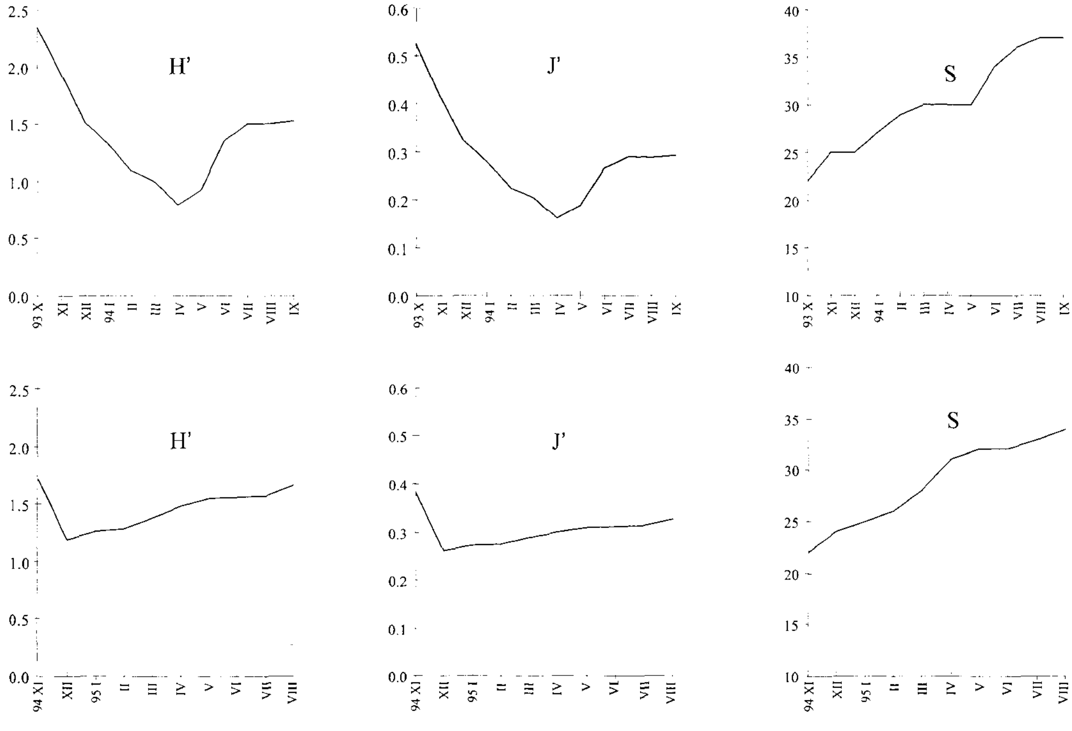

Fig. 5. The evolution of monthly cumulative values of the ecological indices (H′ = diversity, J′ = evenness, S = richness) in the two years compared (top: October 1993 to September 1994, year before disturbances (period with seaweeds: June to October); bottom: November 1994 to August 1995, year with anthropogenic disturbances (few seaweeds and mainly in August).

adapted to this condition and better resist disturbances (but none strong). Also, the fact that the dominant species of the studied community were the same in both years, with only changes in abundance, is consistent with the opinion of Boesch and Rosenberg (1981): "communities in less constant environments are more resistant to disturbance, and colonists in inconstant environments affected by disturbance are usually species already dominant in the community rather than alien opportunistic species."

On the other hand, the strong currents of the area increase the winnowing of the sediments, reduce the turbidity and facilitate a prompt return to the previous conditions, increasing the elasticity of the system (Orians, 1980), in which the decapod community presents a cyclic structure (as result of the mentioned annual seasonality).

ACKNOWLEDGEMENTS

This research is included within the Project PB92-0415, "Comunidades bentónicas del Litoral de Cádiz. Estructura y dinámica de las taxocenosis de crustáceos decápodos, moluscos y algas. Biología de las especies dominantes", supported by the Spanish M.E.C, DGICYT funds.

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RECEIVED: 5 July 2000.
ACCEPTED: 20 June 2001.