Study of the crustacean community associated to the invasive seaweed *Asparagopsis armata* Harvey, 1855 along the coast of the Iberian Peninsula

Estudio de la comunidad de crustáceos asociados al alga invasora *Asparagopsis armata* Harvey, 1855 del litoral de la Península Ibérica

M. M. Soler-Hurtado & J. M. Guerra-García

Laboratorio de Biología Marina, Departamento de Fisiología y Zoología, Facultad de Biología, Universidad de Sevilla, Avenida de Reina Mercedes 6, 41012, Sevilla (Spain).
Fax: 0034954233480; E-mail: mar.s.hurtado@gmail.com
Corresponding autor: JMGG (jmguerra@us.es)

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Palabras clave: *Asparagopsis armata*, especie invasora, peracáridos, Crustacea, Gammaridea, Caprellidea, Isopoda, Tanaidacea, Decapoda.

ABSTRACT

We studied the community of crustaceans associated to the seaweed *Asparagopsis armata* along the coast of the Iberian Peninsula. Nineteen stations were selected along the Cantabrian, Atlantic and Mediterranean coast. In the intertidal, five physicochemical parameters (temperature, dissolved oxygen, salinity, pH and turbidity) were measured at each station; algae samples were collected (three replicates of 20x20 cm), and its coverage was estimated (five grids of 50x50 cm). Crustaceans were the dominant group (over 80% in number of specimens) followed by annelids, molluscs and echinoderms. We identified a total of 60 crustacean species (38 gammarids, seven caprellids, nine isopods, four decapods and two tanaids). The caprellids and gammarids were dominant in number. Although univariate analysis showed no significant differences regarding the number of species, abundance, diversity and evenness of Pielou among stations, the multivariate analysis showed different species composition. According to the canonical correspondence analysis, the biomass of algae, as well as the oxygen concentration, pH and salinity were the variables that best explained the distribution of species. The number of crustacean species found on *A. armata* in this study is similar to that recorded in the literature for other native algae.

RESUMEN

Se estudió la comunidad de crustáceos asociados al alga *Asparagopsis armata* en el litoral de la península Ibérica. Se seleccionaron un total de 19 estaciones situadas a lo largo de toda la costa cantábrica, atlántica y mediterránea En cada estación se midieron cinco parámetros fisicoquímicos (temperatura, oxígeno disuelto, salinidad, pH y turbidez), se recolectaron muestras del alga (tres réplicas de 20x20 cm), y se estimó su cobertura (cinco cuadrículas de 50x50 cm) en el intermareal. Los crustáceos fueron el grupo dominante (más del 80% en número de individuos), seguido de anélidos, moluscos y equinodermos. Se identificaron 60 especies de crustáceos (38 gammáridos, siete caprélidos, nueve isópodos, cuatro decápodos y dos tanaidáceos). Los gammáridos y los caprélidos fueron dominantes en número. Aunque los análisis univariantes no reflejaron diferencias significativas en el número de especies, abundancia, diversidad de Shannon y equitatividad de Pielou entre las distintas estaciones, los multivariantes mostraron diferencias en la composición de especies. Según el análisis canónico de correspondencias, la biomasa de alga, la concentración de oxígeno, el pH y la salinidad fueron las variables que mejor explicaron la distribución de las especies. El número de especies de crustáceos encontrado sobre *A. armata* en este estudio es similar a los registrados en la literatura para otras algas autóctonas.

INTRODUCTION

The morphology of the genus *Asparagopsis* (Bonnemaisoniales, Rhodophyta) (Bonin & Hawkes, 1987), its life cycle (Chihara, 1961, 1962), its cytology (Svedelius, 1933) and its physiology (Oza, 1977; Guiry & Dawes, 1992) have been well studied. *Asparagopsis armata* is endemic to the southern hemisphere and native from Australia, including Tasmania and New Zealand; it was introduced into the Atlantic and Mediterranean in the 1920s (Feldmann & Feldmann, 1942). It has spread out in short time, colonizing a wide area of the Mediterranean, displacing native species and causing a drastic change in endemic marine communities. The successful dispersal and establishment of this alga seems to lie in the strategy it adopts to fend off herbivores, releasing caulerpina. This makes many herbivores to reject it, similarly to the defence system used by other red algae, which are indigestible to indigenous fish.

Asparagopsis armata is mainly found in the low intertidal zone (Fa *et al*., 1997), extending to the first meters of the subtidal zone. Intertidal ecosystems represent areas where various parameters define an environment subjected to sudden changes in a small spatial and temporal scale. These factors are further modified by regular events (for example, tides) and stochastic (such as wave action).

There are few studies on fauna associated to algae along the Iberian Peninsula; it is probably due to the complexity of separation and identification of samples and the great dedication that it requires. We can highlight the study of Sanchez-Moyano (1996), Sánchez-Moyano & García-Gómez (1998) and Sánchez-Moyano *et al.* (2000a, 2000b, 2001, 2002, 2007) on the animal communities associated to *Caulerpa prolifera* (Forsskål) Lamouroux and *Stypocaulon scoparium* (L.) Kützing., and the study of Guerra-García *et al.* (2009) on the diversity and biogeography of peracaridean crustacea associated to *Corallina elongata* in the Strait of Gibraltar. These contributions focused on the description of the epiphytic fauna are focused in order to characterize the overall diversity of the marine ecosystems and to understand patterns of distribution and abundance of organisms. Moreover, invertebrate communities associated to algae reflect the environmental characteristics of the area and they can be used as indicators of the quality of water (Guerra-García & García-Gómez, 2001). Crustaceans are one of the dominant groups of macrofauna associated to macroalgae at rocky substrates, especially in the intertidal zone (Lewis, 1987). Their abundance and diversity depend mainly on factors such as interactions with predators (Caine, 1980), wave exposure and habitat complexity (Guerra-Garcia, 2001) as well as the diversity of resources and the physiological tolerance range to the environmental physicochemical conditions in which they live. The dispersal ability of the peracarid crustacean is low compared to other crustaceans, such as decapods (Lopes *et al.*, 1993). They have direct development (Thiel & Vásquez, 2000) and lack pelagic larval stage, which could be considered relevant for displacement over long distances along the ocean. On the other hand, the abundance and distribution of peracarid crustaceans present in rocky coastlines are also influenced by the shape and morphological complexity of the host algae (Guerra-García, 2001). Peracarid crustaceans are a food source for fish and birds in marine environments, and for fish, birds, amphibians and insects in freshwater environments. They are also widely used as a bioindicator and in toxicology studies. Marine algae are known to provide habitats for a wide range of animal species (Pereira *et al.*, 2006).

This study contributes to our understanding of the factors which determine the distribution of *Asparagopsis armata* in the Iberian Peninsula, and the impact that this algae might have on the macroinvertebrate fauna, especially crustaceans. The main objectives of the present study are: (1) to describe the crustacean fauna associated to *A. armata* and its pattern of abundance and distribution; (2) to quantify the coverage and biomass of *A. armata* at the stations selected; (3) to explore the relationships between the fauna associated to algae *A. armata* with physical-chemical environmental variables as water temperature, conductivity, pH, oxygen and biomass of the algae itself.

MATERIALS AND METHODS

The study area covered the entire coast of the Iberian Peninsula. Sampling was carried out in the summer of 2008 (from 5 July to 5 August); it was conducted in the intertidal zone and gametophyte phase of *A. armata* was collected at low tide. Nineteen stations were selected along the north and south coasts of Spain and Portugal (Figure 1). The alga was present

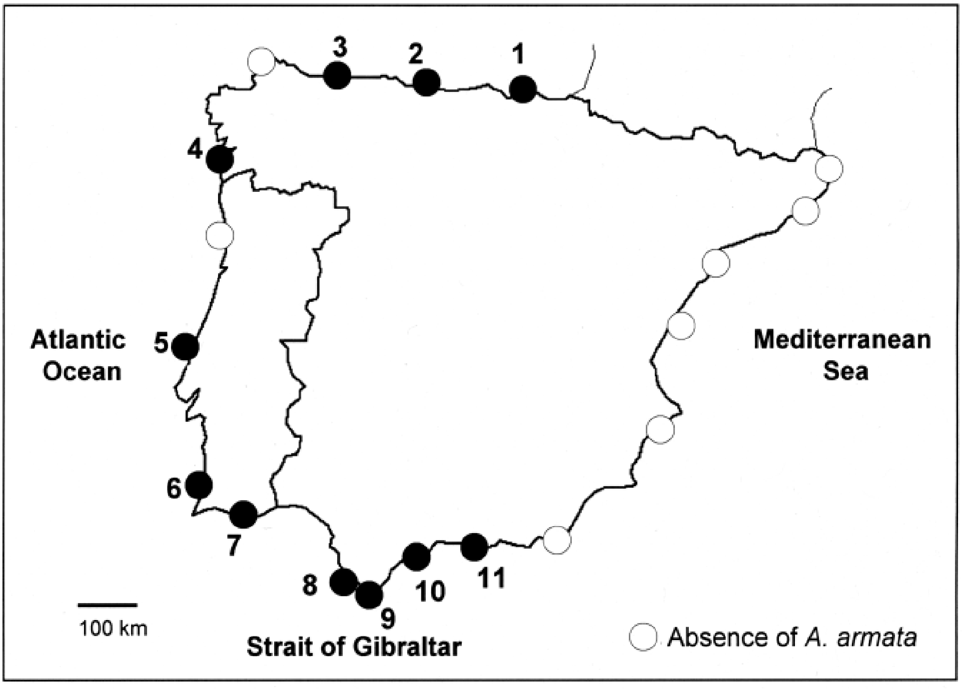

Fig. 1.—Sampling stations along the Iberian Peninsula. White circles indicate stations where *A. armata* was not present. (1) Ogella; (2) Oyambre; (3) Cetarea; (4) Cabo Silleiro; (5) Playa Azul; (6) Labruge; (7) Castelo; (8) Bolonia; (9) Tarifa; (10) Torreguadiaro; (11) Cerro Gordo-Herradura.

Fig. 1.—Estaciones de muestreos a lo largo de la Península Ibérica. Los círculos blancos indican las estaciones en las que *A. armata* no estuvo presente. (1) Ogella; (2) Oyambre; (3) Cetarea; (4) Cabo Silleiro; (5) Playa Azul; (6) Labruge; (7) Castelo; (8) Bolonia; (9) Tarifa; (10) Torreguadiaro; (11) Cerro Gordo-Herradura.

in the Cantabrian and Portuguese coasts and in the Strait of Gibraltar, but it was not found in the Mediterranean stations sampled. Natural rocky shores with low anthropogenic influence were selected to prevent that the natural biogeographic patterns could be affected by the effects of pollution, tourism or other human activities. We selected sites with the same degree of exposure and orientation. Regarding to the environmental parameters, pH and salinity were measured in each station with a probe CRISON MM40, temperature and oxygen concentration with a probe OXI 45 P, and turbidity with a portable turbidimeter WTW 355 IR. Details of measures can be found in Guerra-García & Izquierdo (2010). We conducted a total of three measures and calculated the mean and standard deviation for each sampling point. At each station, *A. armata* was collected with a grid of 20 x 20 cm by scraping. We selected three replicates per station in order to avoid the effect of aggregation and to cover the maximum potential diversity of crustaceans. The samples (macrofauna associated and algae) were bagged and preserved in 70% ethanol. To estimate the coverage of algae at each station, we used 0,5 x 0,5 m subdivided into 25 units of 0.1 x 0.1. At each unit, we scored the presence or absence of *A. armata* from a total of five replicates.

In the laboratory, samples were sieved through a mesh size of 0.5 mm, and all fauna of the alga was sorted and identified at the level of large groups: crustaceans (amphipods, isopods, tanaids and decapods), echinoderms (ophiuroids, echinoids, asteroids and crinoids), molluscs (gastropods, bivalves and polyplacophoran) and annelida (polychaetes and oligochaetes). Crustaceans were identified to species level. The volume of each algal sample was estimated measuring the water displaced by the algae in a test tube. After the volume had been measured we obtained the dry weight of the samples (after 24 hours at 70 º C).

The total number of species, the Shannon–Weiner diversity index (Shannon & Weaver, 1963), and Pielou's evenness index (Pielou, 1966) were calculated for each station. Any differences between seasons were tested with ANOVA checked for normality with the Kolmogorov-Smirnov test, and homogeneity of variances with the Levene test. The affinities among stations based on the peracarid species were established by cluster analysis using UPGMA (unweighted pair group method using arithmetic averages). A multivariate canonical correspondence analysis (CCA) was also conducted to explore relationships among crustacean species, cover of *A. armata* and environmental measures.

RESULTS

Biomass of *Asparagopsis armata* was similar through the stations, while higher covers of the algae were found in stations located in the Strait of Gibraltar zone (Figure 2). Details of physicochemical data of each station are detailed in Guerra-García and Izquierdo (2010).

Crustaceans (identified to species level in this study) were the most abundant group of associated macrofauna compared to echinoderms, molluscs and annelids (Figure 3). Sixty crustacean species were collected (38 gammarids, 7 caprellids, 9 isopods, 4 decapods and 2 tanaid) (Table I). The most common species collected during the present study were the gammarids *Hyale schmidtii* (1469 ind/m^2), *Hyale pontica* (262 ind/m^2), *Aora spinicornis* (136 ind./m^2) and *Apherusa bispinosa* (105 ind/m^2); the caprellids *Caprella penantis* (4564 ind/m^2) *Caprella liparotensis* (98 ind/m^2); the isopod *Dynamene magnitorata* (18 ind./m^2) and the tanaid *Tanais dulongii* (25 ind/m^2). Amphipod was the dominant group in all the stations; gammarids were more abundant in the Atlantic stations, while caprellids showed high

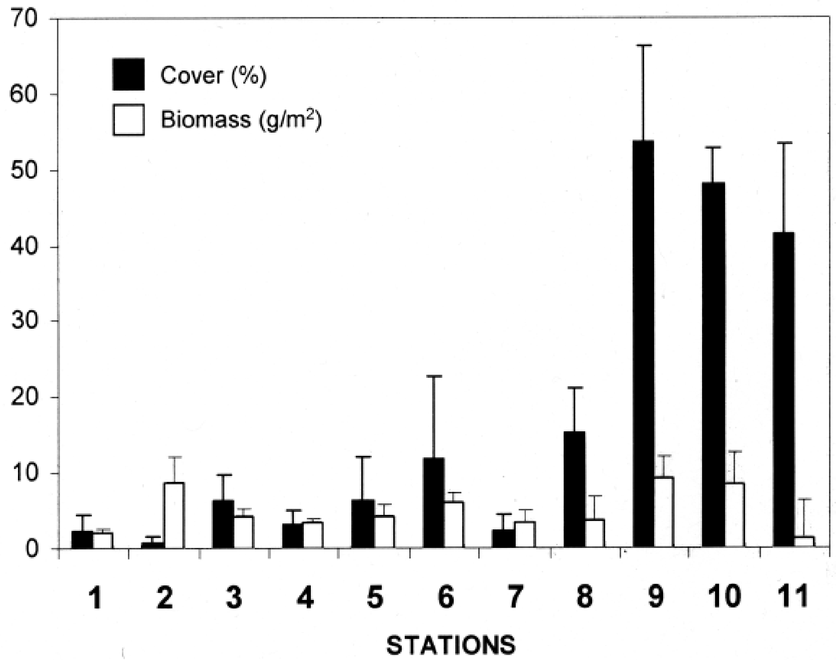

Fig. 2.—Cover (%) and biomass (g/m^2) of *A. armata* at each sampling station.
Fig. 2.—Cobertura (%) y biomasa (g/m^2) de *A. armata* en cada estación de muestreo.

densities around the Strait of Gibraltar and stations with Mediterranean influence (Figure 4).

The number of species was similar in all stations, although it was a trend of decrease from Atlantic to Mediterranean stations (Figure 4). The highest abundance was measured in station 6, due to the high density of the caprellid *Caprella penantis*. Shannon diversity index and Pielou evenness were lower at stations 6, 9 and 10, showing maximum values in stations 7 (Figure 5). However, according to the results of the ANOVA, regardless of the identity of the species, no significant differences in species richness, abundance, diversity and evenness among stations were found (Species richness: F=1.8, p=0.2; Abundance: F=0.4, p=0.6; Diversity (H'): F=1.4, p=0.2; Evenness (J): F=1.1, p=0.4).

Regarding with the multivariate analysis, cluster showed a different crustacean composition in stations 9, 10, 11 with Mediterranean influence (Figure 6). Axis 1 of the CCA (Figure 7, Table II) explained almost 30% of the variance of the data and negatively correlated with biomass of *A. armata* and salinity. Atlantic stations 1-5 were mainly influenced by higher

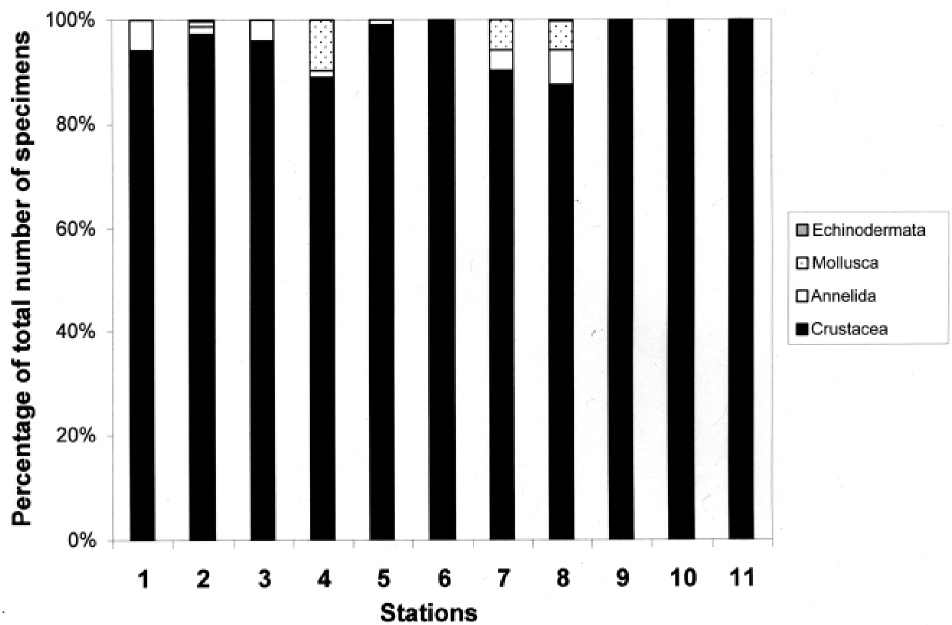

Fig. 3.—Contribution of each macrofaunal group to the total abundance per station.
Fig. 3.—Contribución de cada grupo de macrofauna a la abundancia total en cada estación.

Table I.—Abundance of crustacean species associated to *A. armata* (ind/ m^2) in the eleven stations studied.
Tabla I.—Abundancia de las especies de crustáceas asociadas a *A. armata* (ind/ m^2) en las once estaciones estudiadas.

	1	2	3	4	5	6	7	8	9	10	11
AMPHIPODA											
Caprellidea											
Caprella acanthifera Leach, 1814	-	-	8	-	-	-	91	8	-	50	841
Caprella danilevskii Czerniavskii, 1868	-	-	16	33	-	-	41	375	-	-	-
Caprella grandimana Mayer, 1882	-	-	-	-	-	-	-	-	-	8	-
Caprella hirsuta Mayer, 1890	-	-	-	-	-	-	-	-	-	358	-
Caprella liparotensis Haller, 1879	-	-	-	-	-	-	-	91	-	683	300
Caprella penantis Leach, 1814	125	531	8	33	866	31800	108	50	6933	9750	-
Pseudoprotella phasma Montagu, 1804	-	-	-	-	-	-	-	-	-	-	8
Gammaridea											
Ampelisca serraticuada Chevreux, 1888	-	-	-	-	-	-	-	8	-	-	-
Amphilochus neapolinatus Della Valle, 1893	-	-	-	25	-	16	-	-	-	-	-
Ampithoe ferox (Chevreux, 1902)	-	-	-	-	-	-	-	-	25	-	133
Ampithoe gammaroides (Bate, 1856)	-	3	25	-	-	-	-	-	-	-	-
Ampithoe neglecta Lincoln, 1976	-	3	-	16	-	41	-	-	-	-	-
Ampithoe ramondi Audouin, 1826	-	-	-	-	-	150	8	-	-	16	8
Aora spinicornis Lincoln, 1976	100	64	125	558	458	41	83	-	-	-	66
Apherusa bispinosa (Bate, 1857)	-	6	133	275	383	141	175	41	-	-	-
Apherusa chiereghinii Giordani-Soika, 1950	-	-	-	-	-	-	-	-	41	-	-
Apherusa mediterranea Chevreux, 1911	-	-	-	-	-	-	-	-	116	-	-
Apherusa ovalipes Norman & Scott, 1906	-	-	-	-	-	-	66	16	-	-	-
Apocorophium acutum (Chevreux, 1908)	-	-	-	-	-	-	-	33	-	-	-
Dexamine spiniventris (Costa, 1853)	41	52	108	458	191	58	116	50	-	8	8
Dexamine spinosa (Montagu, 1813)	-	-	41	-	-	-	-	-	-	-	-
Echinogammarus sp.	-	-	16	-	-	-	-	-	-	-	-
Elasmopus pocillimanus (Bate, 1862)	-	-	-	-	-	-	-	166	33	50	33
Elasmopus rapax Costa, 1853	8	5	-	-	8	-	-	-	-	-	-
Elasmopus sp.	-	-	-	-	-	-	16	-	-	-	-
Elasmopus vachoni Mateus & Mateus, 1966	-	-	-	-	33	316	-	-	91	-	16
Gammaropsis maculata (Johnston, 1828)	-	-	-	-	-	-	-	8	-	-	16
Hyale nilssoni (Rathke, 1843)	-	121	16	25	0	75	-	-	-	-	-
Hyale perieri (Lucas, 1849)	-	-	-	-	-	-	-	-	16	-	-
Hyale pontica Rathke, 1837	433	769	1183	341	158	-	-	-	-	-	-
Hyale schmidtii (Heller, 1866)	116	938	1266	2116	4116	3200	150	983	2066	1075	133
Hyale sp.	-	-	-	-	-	-	-	-	8	-	-

Table I.—*(Continued)*.
Tabla I.—*(Continuación)*.

	1	2	3	4	5	6	7	8	9	10	11
Jassa dentex Chevreux & Fage, 1925	16	24	-	-	-	-	-	-	-	-	-
Jassa marmorata Holmes, 1903	-	25	-	-	8	975	-	-	16	8	-
Jassa sp1.	25	17	-	-	-	-	-	-	-	-	-
Jassa sp2.	-	-	25	-	-	-	-	-	-	-	-
Leptocheirus guttatus (Grube, 1864)	-	-	-	-	8	-	-	8	-	-	-
Maera inaequipes (Costa, 1857)	-	-	-	-	-	-	-	-	-	-	91
Melita bulla Karaman 1978	-	-	-	-	-	-	-	-	8	-	-
Microdeutopus chelifer (Bate, 1862)	-	-	-	16	-	25	-	-	-	-	-
Parajassa pelagica Leach, 1814	8	27	-	-	-	0	-	-	-	-	-
Podocerus varigeatus Leach, 1814	-	9	-	41	58	625	-	8	-	-	-
Stenothoe gallensis Walker, 1904	-	-	-	-	-	-	-	-	-	141	41
Stenothoe monoculoides (Montagu, 1813)	-	-	-	175	33	725	41	-	-	-	-
Stenothoe sp.	8	5	-	-	-	-	-	-	-	-	-
ISOPODA											
Cymodoce truncata Leach, 1814	16	11	-	-	8	-	-	-	-	-	-
Dynamene magnitorata Holdich, 1968	33	23	66	25	-	16	8	16	-	8	-
Dynamene torellidae Holdich, 1968	-	-	-	41	-	-	8	-	-	-	-
Idotea pelagica Leach, 1815	-	3	-	-	-	-	-	-	-	-	-
Jaeropsis brevicornis Koehler, 1855	-	-	-	-	-	8	-	-	-	-	-
Paranthura costana Bate & Westwood, 1868	33	26	50	-	-	-	-	16	16	-	-
Synisoma acuminatum (Leach, 1815)	-	-	-	-	-	-	-	0	16	-	-
Synisoma capito (Rathke, 1837)	-	-	-	-	-	-	-	16	-	-	-
Synisoma lancifer (Miers, 1881)	-	-	-	-	33	-	-	-	-	-	-
TANAIDACEA											
Leptochelia dubia (Krøyer, 1842)	-	-	-	-	-	-	8	-	-	-	-
Tanais dulongii (Audouin, 1826)	100	71	-	8	-	58	8	8	-	8	8
DECAPODA											
Acanthonyx lunulatus (Risso, 1816)	-	-	-	-	-	-	-	-	-	8	-
Hipolyte sp.	-	-	-	-	-	-	-	8	-	-	-
Pilumnus hirtellus Linnaeus, 1758	-	-	-	-	-	-	-	-	-	-	16
Thoralus cranchii (Leach, 1817)	16	11	-	50	-	-	-	-	-	-	-

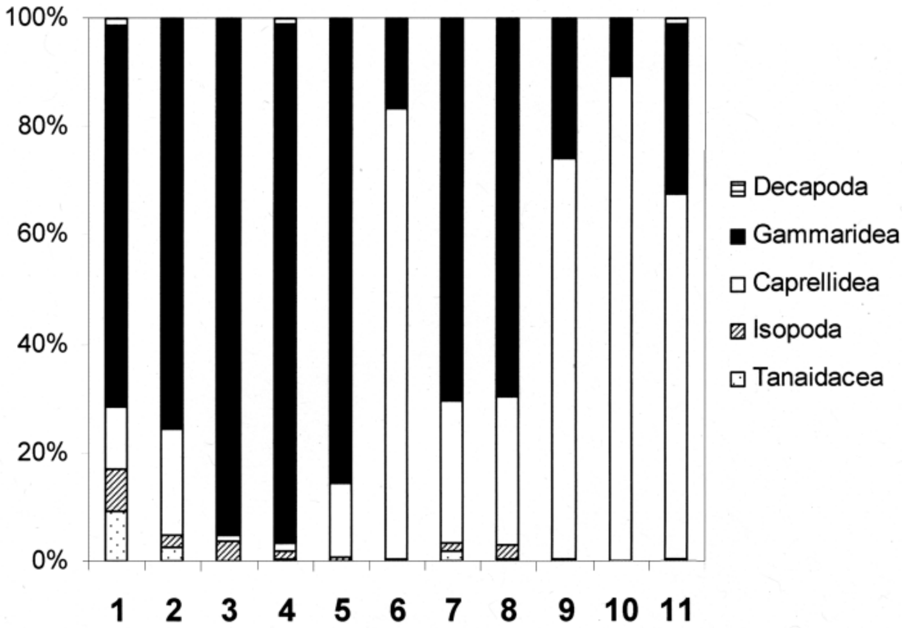

Fig. 4.—Contribution of each group of crustaceans to the total abundance per station.
Fig. 4.—Contribución de cada grupo de crustáceos a la abundancia total en cada estación.

values of pH and oxygen. In fact, second axis separated the stations and species associated mainly by the oxygen concentration (Table II).

Table II.—Summary of the results of the CCA análisis. *p<0.05, **p<0.01
Tabla II.—Resumen de los resultados del análisis CCA. *p<0.05, **p<0.01

	Axis 1	*Axis 2*	*Axis 3*
Eigenvalue	0.59	0.38	0.19
Species-environment correlation	0.98	0.83	0.94
Percentage of species variance	28.9	18.4	9.2
Correlation with environmental variables			
Temperature	—	—	–0.63*
pH	—	—	–0.91**
Oxygen	—	–072**	—
Salinity	–0.56*	0.55*	—
Biomass *Asparagopsis*	–0.76**	–0.63*	—

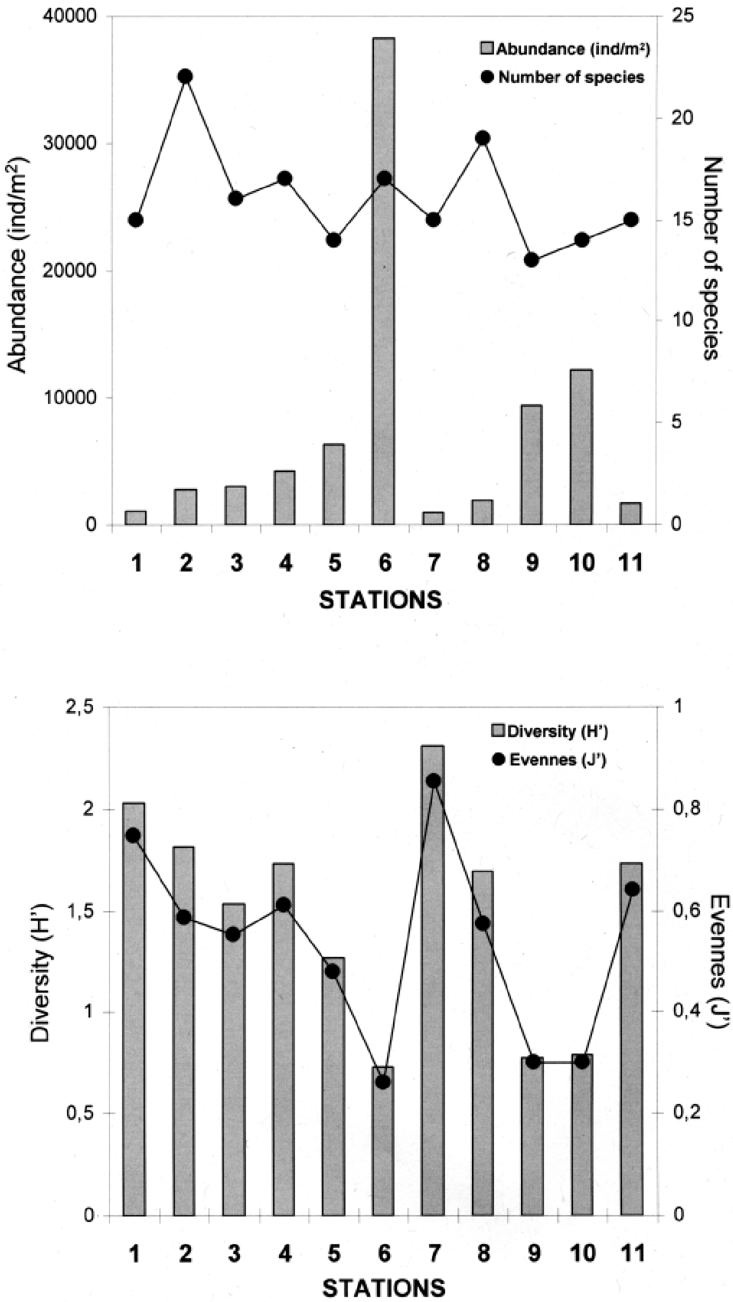

Fig. 5.—Number of species, abundance, diversity (H') and Evenness (J) of crustaceans at each station.

Fig. 5.—Número de especies, abundancia, diversidad (H') y equitatividad (J) de crustáceos en cada estación.

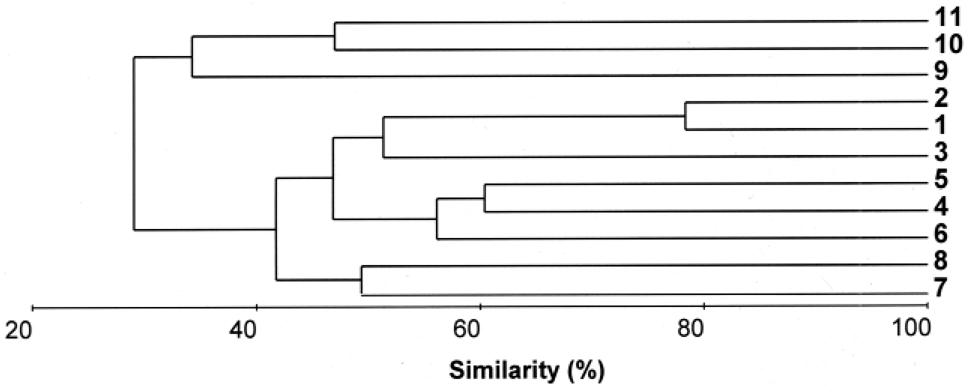

Fig. 6.—Cluster analysis for the epifaunal crustacean assemblages from the alga *A. armata* based on abundance data.
Fig. 6.—Análisis de cluster para la comunidad de crustaceos asociados al alga *A. armata*, basado en los datos de abundancia.

DISCUSSION

Flores-Moya & Conde (1992) in a study based on the reproductive phenology of *A. armata* in the Alboran Sea, pointed out the role of temperature controlling the meiosis in tetrasporophytes of *A. armata*; this species is distributed along the coasts of the Alboran Sea, the Gulf of Lions, Sardinia, Messina Strait, the northern Aegean Sea and Algeria. These zones are the coolest ones along the Mediterranean and the temperature does not exceed 14 ° C in February or 24 ° C in September. This is also reflected in our study since the species was not found in the warmer stations of the Mediterranean side of the Iberian Peninsula. Higher cover of the algae were found along the Strait of Gibraltar stations, probably due to the particular oceanographic conditions, specially currents and hydrodynamics, in this area.

Most of the species associated to *A. armata* found in this study show a wide distribution along the latitudinal gradient of the Iberian Peninsula; rafting of juveniles and adults could be a very important way of transport. Thiel & Guttow (2005a, b) conducted a study along the Pacific coast of Chile and observed the existence of large macroalgae species that have a floating potential (eg, *Macrocystis pyrifera*, *Durvillea antarctica*) and are often adrift in coastal waters. Several species of macrofauna with direct development commonly colonize these floating algae. The distribution range of most peracaridean was quite large (> 1000 km along the Pacific coast of Chile). It was shown that these peracaridean use algae as food and

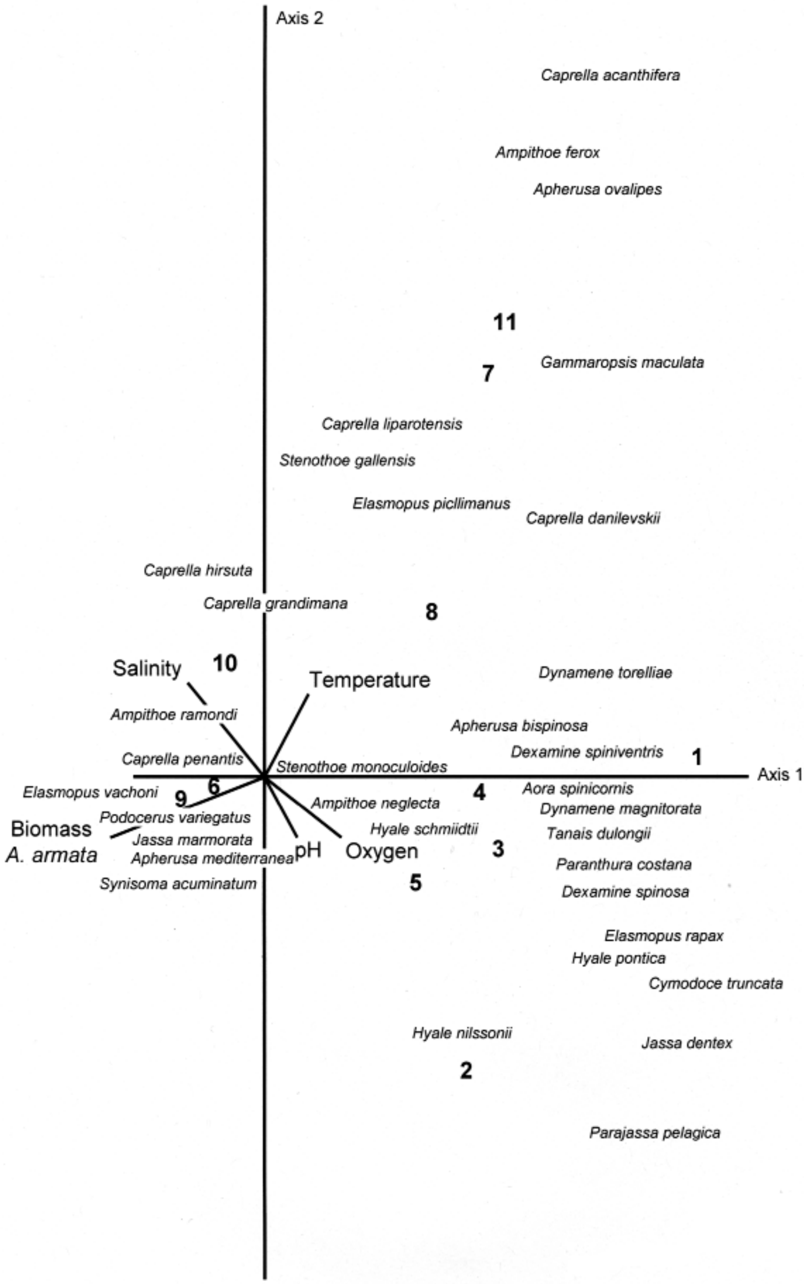

Fig. 7.—Graph representation of the stations and crustacean species with respect to the first two axes of the Canonical Correspondence Analysis (CCA).
Fig. 7.—Representación gráfica de las estaciones y las especies de crustáceos frente a los dos primeros ejes del Análisis Canónico de Correspondencias (CCA).

shelter, which can persist for long periods of time. The dispersion in these floating algae may represent an important mechanism for colonization of new coastal habitats. This is important to our study because it was found that, although there is some replacement of species, the dominant taxa are similar in all stations.

In the Strait of Gibraltar, *A. armata* has invaded the low intertidal and shallow sublittoral, naturally occupied by the native *Corallina elongata* (Guerra-García *et al.*, 2006). Considering the fact of being invasive seaweed that produces toxic substances, we could hypothesize that the new substrate would involve a loss of associated crustacean diversity. Guerra-García *et al.* (2009) studied the peracarid crustaceans associated to *C. elongata* along the whole Strait of Gibraltar (25 stations at Southern Spain and Northern Morocco) and found 40 species. The number of peracarid species registered in *A. armata* at the 11 stations sampled in the present study was 56 species (excluding the 4 species of decapods). Consequently, the presence of *A. armata*, displacing *C. elongata*, seems not to reduce the species richness of the crustacean community, although some species and their abundance can change. Several works have dealt with associated fauna inhabiting subtidal native algae from the Strait of Gibraltar and Iberian Peninsula. Sánchez-Moyano & García-Gómez (1998) and Sánchez-Moyano *et al.* (2000b) carried out an annual study of the macrofauna associated to *Stypocaulon scoparium (=Halopteris scoparia)* in Algeciras Bay, southern Spain, where 13 sampling stations were considered. From a total of 309 taxa collected (including molluscs, polychaetes, echinoderms and crustaceans) 100 species of crustaceans were reported. We should take into account that *H. scoparia* is found in subtidal level and in this zone is expected to record higher number of species than in the intertidal level, where the present study (*A. armata*) and the study of Guerra-García *et al.* (2009) (*C. elongata*) were conducted. Jimeno & Turón (1995) reported 14 crustacean species from the alga *Ulva* sp, and 57 species from *Codium vermilara*, collected along the Northeast coast of the Iberian Peninsula. In El Truhán Inlet, Northern Spain, Viejo (1999) studied the mobile epifauna associated with the invasive brown alga *Sargassum muticum* and other local seaweeds such as *Fucus vesiculosus* and *Cystoseira nodicaulis*. The number of crustacean species in *Sargassum muticum* varied between 24 and 34 species while 14 and 24 species were registered on the native seaweeds respectively. Menoui (1988) studied the epifauna associated to subtidal algae from 3 stations in Morocco (Rabat, Tánger and Nador). The number of crustacean species reported was: *Cystoseira* 24-63 species, *Stypocaulon scoparium* 62-72 species, *Corallina elongata* 45-69 species and *Jania Rubens* 31-75 species. Vázquez-Luis *et al.* (2008, 2009) carried out a study in Santa Pola, Alicante, Southeast Spain, dealing with other invasive alga, *Caulerpa racemosa* and its influence on the associated fauna. Three stations were selected with similar exposure to light and swell, considering both invaded and non-invaded rocky habitats. A total of 16-27 amphipod species were recorded. In conclusion, the presence of *Asparagopsis armata* does not seem to affect the number of species and abundance of epifauna in a negative way, at least concerning crustacean community.

Summarising, the main conclusions of the present study were: (1) the crustacean community associated to the invasive alga *A. armata* showed a total of 60 species of crustaceans (38 gammarids, seven caprellids, nine isopods, four decapods and two tanaidaceans); (2) crustaceans were dominant in number (more than 80%) compared to molluscs, annelids and echinoderms. Amphipods showed the highest densities with caprellids being more abundant along the Alboran Sea and Portugal; (3) no significant differences in the number of species, abundance, Shannon diversity and Pielou evenness among the different stations of the Iberian coast were found, although multivariate analysis showed a high degree of dissimilarity between stations, because some species were only present in some stations; (4) the higher values of *A. armata* cover were recorded at the stations in the Straits of Gibraltar, although this increased coverage was not correlated with an increased species richness in those stations; (5) the number of crustaceans found on *A. armata* in this study is similar to that of algae indigenous to the area, so apparently, we can discard a negative effect of this algae on associated communities, at least, regarding the crustacean fauna.

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REFERENCES

Bonin, D. R. & Hawkes, M. W. 1987. Systematics and life histories of New Zealand Bonnemaisoniaceae (Bonnemaisoniales, Rhodophyta): I. The genus *Asparagopsis*. *New Zealand Journal of Botany*, 25: 577-590.

Caine, E. A. 1980 Ecology of two littoral species of caprellid amphipods (Crustacea) from Washington, USA. *Marine Biology*, 56: 327-335.

Chihara, M. 1961. Life cycle of the Bonnemaisoniaceous algae in Japan (1). Science Reports of the Tokyo Kyoiku Daigaku, vol. 10, pp. 121-154.

— 1962. Life cycle of the Bonnemaisoniaceous algae in Japan (2). Science Reports of the Tokyo Kyoiku Daigaku, vol. 11, pp. 27-53.

Fa, D., García-Gómez, J. C., García-Adiego, E., Sánchez-Moyano, J. E. & Estacio, F. 1997. El litoral II: zonas de transición. Las zonas supralitoral y mediolitoral. En: García-Gómez, J.C. (Coordinador). El mar (tomo 2). Naturaleza de Andalucía. Ediciones Giralda, pp. 171-194.

Feldmann, J. & Feldmann, G. 1942. Recherches sur les Bonnemaisoniaces et leur alternances de générations. Annales des Sciences Naturelles, Botanie, séries II, 3, pp. 75-175.

Flores-Moya, A. & Conde, F. 1992. Fenología y corología de *Asparagopsis armata* (Bonnemaisoniaceae, Rhodophyta) en el Mediterraneo. *Acta Botanica Malacitana*, 17: 245-260.

Guiry, M. D. & Dawes, C. J. 1992. Day length, temperature and nutrient control of tetrasporogenesis in *Asparagopsis armata* (Rhodophyte). *Journal of Experimental Marine Biology and Ecology*, 158: 197-217.

Guerra-García, J. M. 2001. Habitat use of the Caprellidea (Crustace: Amphipoda) from Ceuta, North Africa. *Ophelia*, 55: 27-38.

Guerra-García, J. M. & García-Gómez, J. C. 2001.The spatial distribution of Caprellidea (Crustacea: Amphipoda): a stress bioindicator in Ceuta (North Africa, Gibraltar area). *PSZN Marine Ecology*, 22: 357-367.

Guerra-García, J. M., Cabezas, M. P., Baeza-Rojano, E., Espinosa F. & García-Gómez, J. C. 2009. Is the north side of the Strait of Gibraltar more diverse than the south side? A case study using the intertidal peracarids (Crustacea: Malacostraca) associated to the seaweed *Corallina elongata*. *Journal of the Marine Biological Association of UK,* 89: 387-397.

Guerra-García, J. M. & Izquierdo, D. 2010. Caprellids (Crustacea: Ampipoda) associated with the intertidal alga *Corallina elongata* along the Iberian Peninsula. *Marine Biodiversity Records* 3: 1-7.

Guerra-García, J. M., Maestre, M. J., González, A. R. & García-Gómez, J. C. 2006. Assessing a quick monitoring method using rocky intertidal communities as a bioindicator: a multivariate approach in Algeciras Bay. *Environmental Monitoring and Assessment,* 116: 345-361.

Jimeno, A. & Turón, X. 1995. Gammaridea and caprellidea of the northeast coast of Spain: ecological distribution on different types of substrata. *Polskie Archiwum Hydrobiologii*, 42: 495-516.

Lewis, F. G. 1987. Crustacean epifauna of seagrass and macroalgae in Apalachee BAy, Florida, EEUU. *Marine Biology*, 94: 219-229.

Lopes, M. F. R., Marques, J. C. & Bellan-Santini, D. 1993. The benthic amphipod fauna of the Azores (Portugal): an up-to-date annotated list of species, and some biogeographic considerations. *Crustaceana*, 65: 204-217.

Menoui, M. 1988. Contribution à la connaissance des peuplements infralittoraux superficiels des côtes atlanto-mediterranèennes du Maroc. Tesis doctoral, Universidad Mohammed V, Agdal-Facultad de ciencias. 256 pp.

OZA, R. M. 1977. Culture studies on induction tetraspores and their subsequent development the red alga Falkenbergiar rufolanosa (Harvey) Schmitz. *Botanica Marina*, 20: 29-32.

PEREIRA, S. G., LIMA, F. P., QUEIROZ, N. C., RIBEIRO, P. A. & SANTOS, A. M. 2006. Biogeographic patterns of intertidal macroinvertebrates and their association with macroalgae distribution along the Portuguese coast. *Hydrobiologia*, 555: 185-192.

PIELOU, E. C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*, 13: 131-144.

SÁNCHEZ-MOYANO, J. E. 1996. Variación espacio-temporal en la composición de las comunidades animales asociadas a macroalgas como respuestas a cambios en el medio. Implicaciones en la caracterización ambiental de las áreas costeras. Tesis Doctoral, Universidad de Sevilla, 407 pp.

SÁNCHEZ-MOYANO, J. E. & GARCÍA-GÓMEZ, J. C. 1998. The arthropod community, especially crustacean, as a bioindicator in Algeciras Bay (Southern Spain) based on a spatial distribution. *Journal of Coastal Research* 14: 1119-1133.

SÁNCHEZ-MOYANO, J. E., ESTACIO, F. J., GARCÍA-ADIEGO, E. M. & GARCÍA-GÓMEZ, J. C. 2000a. The molluscan epifauna of the alga *Halopteris scoparia* in southern Spain as a bioindicator of coastal environmental conditions. *Journal of Molluscan Studies* 66: 431-448.

— 2001. Effect of the vegetative cycle of *Caulerpa prolifera* on the spatio-temporal variation of invertebrate macrofauna. *Aquatic Botany*, 1453: 1-12.

SÁNCHEZ-MOYANO, J. E., GARCÍA-ADIEGO, E. M., ESTACIO, F. J. & GARCÍA-GÓMEZ, J. C. 2000b. Effects of environmental factors on the spatial distribution of the epifauna of the alga *Halopteris scoparia* in Algeciras Bay, Southern Spain. *Aquatic Ecology,* 34: 355-367.

— 2002. Effect of environmental factors on the spatial variation of the epifaunal polychaetes of the alga *Halopteris scoparia* in Algeciras Bay (Strait of Gibraltar). *Hydrobiologia*, 470: 133-148.

SÁNCHEZ-MOYANO, J. E., GARCÍA-ASENCIO, I. M. & GARCÍA-GÓMEZ, J. C. 2007. Effects of temporal variation of the seaweed *Caulerpa prolifera* cover on the associated crustacean community. *Marine Ecology*, 28: 324-337.

SHANNON, C. E. & WEAVER, W. 1963. The Mathematical Theory of Communications. Urbana: University of Illinois Press.

SVEDELIUS, N. 1933. On the developmenl of *Asparagopsisa armata* Harv. and *Bonnemaisoniaa sparagoides* (Woodw.) Ag. A contribution to the cytology of the haplobiontic Rhodophyceae. Nova Acta R. Soc. Sci. Upps. Ser. 4, Vol. 9, No. pp. l-61.

THIEL, M. & VÁSQUEZ, J. S. 2000. Are kelp holdfasts islands on the ocean floor? Indication for temporarily closed aggregations of peracarid crustaceans. *Hydrobiologia*, 440: 45-54.

THIEL, M. & GUTTOW, L. 2005a. The ecology of rafting in the marine environment -I. The floating substrata. *Oceanography and Marine Biology: An Annual Review*, 4: 181-264.

THIEL, M. & GUTTOW, L. 2005b. The ecology of rafting in the marine enviroment -II. The rafting organisms and community. *Oceanography and Marine Biology: An Annual Review*, 43: 279-418.

VÁZQUEZ-LUIS, M., SÁNCHEZ-JEREZ, P. & BAYLE-SEMPERE, J. T. 2008. Changes in amphipod (Crustacea) assemblages associated with shallow-water algal habitats invaded by *Caulerpa racemosa* var. *cylindracea* in the western Mediterranean Sea. *Marine Environmental Research,* 65: 416-426.

— 2009. Comparison between amphipod assemblages associated with Caulerpa racemosa var. cylindracea and those of other Mediterranen habitats on soft substrate. *Estuarine Coastal and Shelf Science,* 84: 161-170.

VIEJO, R. M. 1999. Mobile epifauna inhabiting the invasive *Sargassum muticum* and two local seaweeds in northern Spain. *Aquatic Botany*, 64: 131-141.