Seasonal variation of a molluscan assemblage living in a *Caulerpa prolifera* meadow within the inner Bay of Cádiz (SW Spain)

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Abstract

The molluscan macrofauna living in shallow muddy bottoms with the green algae *Caulerpa prolifera* was studied monthly between February 1994 and January 1996 in the inner Bay of Cádiz (SW Spain). The molluscan assemblage followed a similar pattern over the 2 years, displaying seasonal trends in species richness, abundance and structure. During the autumn and winter months, a decrease in abundance, species richness and diversity and an increase in evenness occurred. During the spring and summer months, the molluscan assemblage was characterised by an increase in species richness, abundance and diversity. These seasonal trends were supported statistically by the presence of significantly different groupings of seasonal samples in multivariate analyses.

Despite human impacts in the bay (e.g. aquaculture activities, sewage), the presence of repetitive seasonal trends, based on the qualitative and quantitative data, indicates the stability of the molluscan assemblage over 2 years. Benthic characteristics from the inner Bay of Cádiz, such as shallow soft bottoms with the presence of macrophytes and current dynamics, seem to be key factors influencing the composition and seasonality of this molluscan assemblage.

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1. Introduction

The meeting of different biogeographical regions, as documented in previous faunistic lists, points to the importance of southern Spain for the European marine diversity of molluscs (Rueda, Salas, & Gofas, 2000; Salas, 1996; Van Aartsen, Menkhorst, & Gittenberger, 1984). Molluscan assemblages have been studied from Mediterranean coastal waters of southeastern Spain, in soft bottoms (Luque, 1986; Rueda, Fernández-Casado, Salas, & Gofás, 2001; Salas, personal communication; Salas, 1996; Van Aartsen et al., 1984), bioclastic bottoms (Rueda et al., 2000), seagrass beds (Hergueta, personal communication; Templado, 1984), intertidal and subtidal rocky shores (García-Gómez, 1983; Salas & Luque, 1986; Sánchez-Moyano, Estacio, García-Adiego, & García-Gómez, 2000), calcareous algal formations (Hergueta & Salas, 1987; Salas & Hergueta, 1986) and red coral bottoms (Salas & Sierra, 1986; Templado et al., 1986). By contrast, information on molluscan assemblages of the Atlantic coasts of southern Spain is scarce (Rueda et al., 2001), though there have been general studies of benthic communities (Arias, 1976; Del Vals, Conradi, García-Adiego, Forja, & Gómez-Parra, 1998; Rodríguez & Vieitez, 1992; Templado et al., 1993). In most of these previous studies there has been no temporal investigation of the molluscan assemblages, therefore changes in composition and structure over time remain poorly documented.

In southern Spain, certain habitats of the Mediterranean coasts, such as calcareous algal formations (Salas & Hergueta, 1986) or seagrass beds (Hergueta, personal communication) are known for seasonal changes of molluscan assemblages. In those habitats, seasonal changes in faunistic composition and structure of the assemblage were related to seasonal variations of the
vegetated component of the seabed. The available data on temporal and/or seasonal studies of molluscan assemblages from the Atlantic coasts of southern Spain remain very poor, particularly in shallow waters (Arias & Drake, 1994). This type of study is therefore necessary to understand the dynamics of the benthic communities and their relationships with seasonal environmental changes or the effects on time of anthropogenic disturbances.

The Bay of Cádiz (SW Spain) is an interesting area for the study of spatial and temporal dynamics of benthic communities, as it is located in the Atlantic Ocean, close to the Mediterranean Sea and to northern Africa, which implies the confluence of fauna from different biogeographical regions (Rueda et al., 2001). A second interesting feature of this bay is the presence of different habitats such as seagrass beds, soft and rocky bottoms and salt marshes where aquaculture activities occur. Arias (1976) studied the benthic communities of this bay and included some general information about the species of molluscs. Seasonality of the macrobenthos, including molluscs, and their productivity have been recently studied in some shallow lagoons (depth between 0.4 and 2 m) related to aquaculture activities (Arias & Drake, 1994; Drake & Arias, 1997). The distribution and growth of the Hydrobia species from these shallow lagoons have been studied temporally, displaying seasonal trends (Drake & Arias, 1995). Information about temporal variation of benthic communities of deeper subtidal habitats of the bay is needed for a better management of the Bay of Cádiz, which is a protected natural park.

Rueda et al. (2001) described the seasonal changes of a molluscan assemblage living in shallow sandy bottoms with macrophytes in the outer part of the bay (depth between 3 and 6 m). The assemblage displayed seasonal trends in species composition, however, its structure was more influenced by recruitment events of bivalves, favoured by oceanic currents, rather than seasons.

The aim of the present study is to characterise the composition and structure of a molluscan assemblage living in shallow muddy bottoms with the presence of the algae Caulerpa prolifera, within the inner Bay of Cádiz. This shallower part of the bay is less influenced by oceanic currents than the outer part, however, it is contiguous to several aquaculture lagoon areas, where seasonal trends of their benthic assemblages have been observed (Arias & Drake, 1994). The inner part of the Bay of Cádiz receives a large quantity of fine sediments from the aquaculture lagoon area, accumulated at an average of 0.52 cm per year (Muñoz-Pérez & Sánchez-Lamadrid, 1994). This high sedimentation has favoured the presence of muddy bottoms in the inner bay where dense C. prolifera meadows are well established. The shallow depth of the sampling area (between 1 and 3 m) and the presence of macrophytes may indicate that clear seasonal trends in species composition, as well as in the structure of the assemblage, will occur, despite the influence of human activities in the area.

2. Material and methods

2.1. Area of study

The Bay of Cádiz (SW Spain; 36°23′–36°37′N and 6°09′–6°21′W) is a shallow ecosystem, which is largely used for aquaculture activities in the intertidal salt marshes and lagoonal areas (Fig. 1). The bay is subdivided into two basins, a shallower basin (inner bay), with a maximum depth of 11 m, and a deeper basin (outer bay) with a maximum depth of 17 m. The water temperature from the bay shows a seasonal trend with high values in August (24–26°C) and low values in December (12°C). The mean salinity values (practical salinity units) in the inner bay range from 32 in some autumn and winter months (wet season) to ca. 42 in summer (dry season). A progressive increase of the concentration of organic matter in the sediments of the bay has been recorded over time (Blasco, Gómez-Parrá, Frutos, & Establizer, 1987), as a result of aquaculture activities and the polluted effluents of a population of approximately 400,000 inhabitants. A progressive enhancement in chlorophyll a concentration in the bay has also been detected in the water column (Establizer, Blasco, Lubian, & Gómez-Parrá, 1990).

2.2. Collection of samples

Samples were collected every month from a subtidal bottom, (36°29′N; 6°15′W) with a water depth between 1 and 3.3 m (tidal variation), containing a dense bed of the green algae Caulerpa prolifera. This macrophyte shows a seasonal pattern of growth with a peak in the summer months (Sánchez-Moyano, Estacio, García-Adiego, & García-Gómez, 2001). The sediment of the sampling site was composed mainly of fine sand (38.8%) and mud (20%). In the inner bay, the organic carbon content of the sediment is generally higher than in the outer bay, with values oscillating between 1.97 and 5.18%, and normally higher than 3%.

One monthly sample was collected from February 1994 to January 1996, except in December 1995 due to unfavourable weather. Samples were obtained from a fishing boat by towing a semicircular dredge (width 1 m), with a 1 cm mesh inner bag, for 10 min at a constant speed of 1 knot. The dredged area for each monthly sample was approximately 300 m². This sampling area represents more than three times the minimum area for a correct estimation of the species richness of molluscs living in this particular habitat (Salas, personal communication). The sampled area was of this size in order to collect other
groups of mobile organisms (e.g. crustaceans) for concurrent studies. No replication of the samples was considered. Samples were sieved on different mesh sizes (10, 5, and 3 mm) and both epifauna and infauna were collected. The smaller fractions were sorted using a stereo-microscope. Molluscs were separated from the other macrobenthos, fixed in formaldehyde 10% and finally preserved in neutralised alcohol 70%. All fractions were sorted quantitatively over the 2 years and all mollusc individuals were identified and measured.

2.3. Data analysis

Dominance ($D$) (relative abundance of a particular species within the sample expressed as percentage) and frequency ($F$) (calculated as the percentage of monthly samples in which a particular species is present over the 2 years) were calculated for each monthly sample and for the total collected over the 2 years. The following basic and derived parameters were also calculated on each sample: total abundance (individuals per sample), number of species, percentage of juveniles (number of juveniles of a particular species within the monthly sample expressed as percentage), diversity of Shannon–Wiener ($H'$) (Krebs, 1989) and evenness index ($J$) (Pielou, 1969).

Seasonal and annual similarities/dissimilarities of the composition and structure of the assemblage were analysed by multivariate methods, using group-average sorting classification and non-metric multidimensional scaling (MDS) ordination with the Bray–Curtis similarity measure (Clarke, 1993). Both sorting classifications and
MDS ordinations were calculated: (1) qualitatively based on the presence or absence of species, and (2) quantitatively using fourth root transformed abundance data. Molluscan assemblages from the different monthly samples were compared statistically using an analysis of similarities (ANOSIM). Multivariate analyses were performed using the PRIMER package from Plymouth Marine Laboratory, UK.

3. Results

3.1. Composition of the molluscan assemblage

A total of 6003 individuals, belonging to 26 species, were collected and identified over the 2 years (Table 1). The assemblage was dominated in terms of number of species (65%) by gastropods, with 14 species of prosobranchs and three opistobranchs. The family Nassariidae (four species) and the family Rissoidae (three species) were the most abundant in terms of number of species. Gastropods also showed higher abundance and dominance values in comparison with the other classes of molluscs, with 70.9% of the total number of individuals collected. Bivalves were represented by only nine species, and showed lower abundance compared with gastropods. The Cephalopoda group was not abundant in the samples (Table 1).

Only seven species showed Dominance values ($D$) higher than 1% and, of these, the trochid *Jujubinus striatus* corresponded to the 30.1% of the total (Table 1). Other dominant species were the gastropods *Tricola tenuis*, *Pusillina marginata*, *Calliostoma* sp., *Rissoa membranacea* and the bivalves *Corbula gibba* and *Parvicardium exiguum*. In general, the values of $D$ were higher for gastropods than for bivalves.

The species occurring most frequently in time ($F > 75\%$) were mainly gastropods, such as *Calliostoma* sp., *Jujubinus striatus*, *Tricola pullus*, *Rissoa membranacea*, *Pusillina radiata* and *Nassarius incrassatus* (Table 1). A total of nine species, including *Nassarius vaucherii*, *Abra alba*, *Venerupis aurea* or *Pandora inaequivalvis*, had $F$ values lower than 10%.

3.2. Seasonal variation of the molluscan assemblage

The abundance of molluscs was higher in the summer months of the first year (maximum 1840 individuals in July 1994) than in the second year (up to 758 individuals per monthly sample in September 1995) (Fig. 2, Table 1). This was influenced by high juvenile densities of the bivalve *Corbula gibba*, during July and August of 1994. This bivalve, however, displayed a low $F$ value (30.4%) (Table 1) indicating its lower presence in this assemblage. In both years, similar abundance trends were observed for the remainder of the species from the assemblage (without *C. gibba*), with higher values in the spring and summer months (Mean = 408 ind. sample$^{-1}$) than in the autumn and winter months (Mean = 108 ind. sample$^{-1}$) (Fig. 2).

Most species increased in abundance in the spring and summer months (Table 1), due to recruitment. In both years, the abundance of juveniles represented between 20 and 40% of the total abundance of molluscs in those months (Fig. 3). The recruitment of different species, such as the trochids *Calliostoma* sp. (from June to August) and *Jujubinus striatus* (from April to August) or the rissoids *Rissoa membranacea* (from April to September) and *Pusillina marginata* (from March to September), was similar in both years. A similar trend was also found in both years for the epifaunal bivalve *Parvicardium exiguum* (from April to July). Other species, such as *Corbula gibba* or *Ostrea sp.* were generally represented in this assemblage by juvenile stages (<5 mm) in the summer months. The peaks of abundance were thus related to an increase in juveniles due to similar recruitment in both years.

Species richness followed a similar trend in both years (Fig. 4), with high values in the spring and summer months (11 spp. ± 2; Mean ± SD) and low values in the autumn and winter periods (6 spp. ± 2). The presence of the opistobranchs *Bulla striata* or *Haminoea* sp., as well as juveniles of some bivalves, such as *Ostrea stentina*, *Venerupis aurea* or *Abra alba* only occurred in the summer months (Table 1).

Diversity values of Shannon–Wiener index ($H'$) displayed similar trends in both years (Fig. 4). The highest values of $H'$ were registered in the spring and summer months in both years (2.3 ± 0.5) and the lowest values were registered in the autumn and winter months (1.7 ± 0.4). The evenness ($J$) (Fig. 5) followed a similar trend in both years with low values in the spring and summer months (0.67 ± 0.15), and high values in the autumn and winter months (0.75 ± 0.16), with a decrease during the autumn of 1995 (values between 0.4 and 0.6). This decrease in evenness was a consequence of the increase in abundance of trochids such as *Calliostoma* sp. and *Jujubinus striatus* during the autumn of 1995 (Table 1). The temporal trend in evenness was generally opposite to that observed for the diversity and species richness.

3.3. Seasonal and inter-annual variability of the assemblage

Seasonal groupings of samples were obtained in both the sorting classification and the MDS based on qualitative data (presence/absence). The summer and spring samples (warm season) from both years were dissimilar to the autumn and winter samples (cold season) in the MDS ordination plot (Fig. 6A). The spring samples from both years were grouped together
Table 1
Monthly abundance of the species collected from February 1994 to January 1996

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<tr>
<td><strong>Gastropods</strong></td>
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<tr>
<td>Calliostoma sp.</td>
<td>6</td>
<td>2</td>
<td>12</td>
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<tr>
<td>Jujubinus striatus</td>
<td>16</td>
<td>28</td>
<td>8</td>
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<td>Tricoliella tenuis</td>
<td>1</td>
<td>9</td>
<td>3</td>
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<td>Rissoa membranacea</td>
<td>7</td>
<td>5</td>
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<tr>
<td>Rissoa similis</td>
<td>2</td>
<td>7</td>
<td>3</td>
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<tr>
<td>Pusillina marginata</td>
<td>5</td>
<td>6</td>
<td>18</td>
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<td>Bittium reticulatum</td>
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<td>Cerithiopsis minima</td>
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<td>Nassarius incrassatus</td>
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<td>Nassarius pygmaeus</td>
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<td>Nassarius reticulatus</td>
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<td>Nassarius vaucheri</td>
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<td>Odostomia unidentata</td>
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<td>Chrysalida terebellum</td>
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<td>Bulla striata</td>
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<td>Haminoea sp.</td>
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<tr>
<td>Dendrodoris sp.</td>
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<td><strong>Bivalves</strong></td>
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<td>Musculus costulatus</td>
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<td>Ostreola stentina</td>
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<td>Loripes lacteus</td>
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<td>Parvicardium exiguum</td>
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<td>4</td>
<td>6</td>
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<td>Abra alba</td>
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<td>Veneria aurea</td>
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<tr>
<td>Corbula gibba</td>
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<td>812</td>
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<td>Pandora inaequivalvis</td>
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<tr>
<td><strong>Cephalopods</strong></td>
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<tr>
<td>Sepia sp.</td>
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<td><strong>Total abundance</strong></td>
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N', total abundance (number for 2 years); D, dominance (%); F, frequency (%). Winter samples from January (J) to March (M); spring samples from April (A) to June (J); summer samples from July (J) to September (S) and autumn samples from October (O) to December (D).
with the summer samples from both years. Samples from both winter periods were located between autumn samples. No significant qualitative differences were found between the assemblages for the 2 years (one-way ANOSIM: Factor year, \( p = 0.26 \)), the two autumn–winter periods (one-way ANOSIM: Factor cold season 1 vs cold season 2, \( p = 0.169 \)), or the two spring–summer periods (one-way ANOSIM: Qualitative, Factor warm season 1 vs warm season 2, \( p = 0.331 \)). Assemblages from the spring and summer months from both years were significantly different to those from the autumn and winter months of the same year (one-way ANOSIM: Factor warm season 1 vs cold season 1, \( p < 0.005 \); Factor warm season 2 vs cold season 2, \( p < 0.005 \) or contiguous years (one-way ANOSIM: Qualitative, Factor warm season 1 vs cold season 2, \( p < 0.005 \); Factor warm season 2 vs cold season 1, \( p < 0.005 \)).

In the quantitative MDS ordination plot (Fig. 6B), the monthly samples were also grouped according to season. The autumn and winter samples were also located at different sides of the MDS ordination plot to the spring and summer months. No significant quantitative differences were found between the assemblages for the 2 years (one-way ANOSIM: Factor year,
$p = 0.568$), the two autumn–winter periods (one-way ANOSIM: Factor cold season 1 vs cold season 2, $p = 0.504$), or the two spring–summer periods (one-way ANOSIM: Factor warm season 1 vs warm season 2, $p = 0.348$). Assemblages from the spring and summer months from both years were, however, significantly different to those from the autumn and winter months of the same year (one-way ANOSIM: Factor warm season 1 vs cold season 1, $p < 0.005$; Factor warm season 2 vs cold season 2, $p < 0.005$) or contiguous years (one-way ANOSIM: Factor warm season 1 vs cold season 2, $p < 0.005$; Factor warm season 2 vs cold season 1, $p < 0.005$). Both the presence/absence of species and their abundance thus displayed a very clear seasonal trend that was similar over the 2 years.

4. Discussion

4.1. Faunistic composition

The bulk of the molluscan species listed in this study are representative of the broader Lusitanian region and are similar to a previous study in the outer part of this bay (Rueda et al., 2001). Some of the molluscan species, inhabiting these muddy bottoms with the presence of the green algae Caulerpa prolifera, are also associated with seagrass species such as Zostera marina, Zostera noltii and Cymodocea nodosa. The presence of seagrass meadows (e.g. Z. noltii in the outer bay and few small beds of C. noda in the lagoonal system of the inner bay) influences the faunistic composition of the assemblages living in C. prolifera. Of the recorded species, Tricola tenuis and Rissoa membranacea are generally found on the seagrasses Z. marina or C. nodosa (Gofas, personal communication), whereas Jujubinus striatus, with a strong preference for these seagrasses, is also frequent and abundant in bottoms with C. prolifera (Rueda et al., 2001; Sánchez-Moyano et al., 2001). In general, this molluscan assemblage is similar to that observed in other closed and shallow bays of the Mediterranean coasts, containing seagrass and seaweed beds (Dantart, Frechilla, & Ballesteros, 1990; Murillo & Talavera, 1983). On the Atlantic littoral of France, the molluscan fauna of similar lagoonal areas is characterised by fewer species than in the Mediterranean Sea, with dominance of a few species displaying certain heterogeneity of abundances and biomass (Labourg & Desprez, 1997).

The fauna from tropical and temperate waters of Western Africa is represented in the soft bottoms of the outer Bay of Cádiz by Nassarius elatus and some bivalves such as Macoma melo and Eastonia rugosa (Rueda et al., 2001). Populations of other subtropical species from the Atlantic coasts of Africa have been described recently in different coastal habitats of the southern Iberian Peninsula (Rueda & Gofas, 1999; Rueda & Salas, 1998; Rueda et al., 2000). No species from tropical or
temperate Western Africa has been found in the studied assemblage of the inner bay. The absence of this faunal component could be explained by a lower level of oceanic influence in this part of the bay (Alvarez et al., 1999), which could affect the larval settlement of species from similar habitats around the area. Moreover, the inner bay of Cádiz stands rather isolated from other similar lagoonal ecosystems. To the west, it is separated from the shallow lagoons of the Algarve coast by the mouth of the Guadalquivir river area. To the east, the Mediterranean lagoons (e.g. Nador in Northern Morocco, Mar Menor in SE Spain) are remote and separated by a long stretch of rocky coast.

In this assemblage, gastropods were the dominant group both in terms of number of species and individuals. The dominance of gastropod species, compared with bivalves, could be favoured by their direct development, the hydrodynamics of this shallower part of the bay of Cádiz (e.g. less oceanic influence) (Alvarez et al., 1999), sediment characteristics (e.g. organic carbon content in the sediment), and the dense vegetated cover of Caulerpa prolifera. The presence of benthic vegetation (e.g. seagrasses, seaweeds) may benefit the presence of high species richness with large and stable populations of dominant species (e.g. trochids, rissoids) within this zone of a lagoonal habitat, despite the presence of unvegetated muddy bottoms which usually support lower species richness (Salas, personal communication).

The dominance of gastropods in the inner Bay of Cádiz is particularly notable when comparing this assemblage with that of the outer bay (Rueda et al., 2001). The recruitment events of some bivalves, such as Corbula gibba, Venerupis aurea or Pandora inaequivalvis, did not develop populations in the inner bay, while juveniles of the same species developed large populations in the outer bay (Rueda et al., 2001) during the same studied period. In benthic habitats, sediments with high organic load generally result in increase of abundance, biomass, and production of fauna, except under anaerobic conditions (Buchanan and Moore, 1986). The large sediment-retention capacity of the stolons of Caulerpa prolifera results in an organic enrichment of the sediments (Sánchez-Moyano et al. 2001). The dense algal cover of C. prolifera can have an indirect negative effect on the infauna, especially bivalves, because of the promotion of anoxic conditions in the sediments (Sánchez-Moyano et al., 2001; Sundbäck, Jönsson, Nilson, & Lindström, 1990). In soft bottoms with C. prolifera, the epifauna (e.g. gastropods) seem to be favoured over the infaunal bivalves due to changes in the vegetated surfaces (e.g. fronds growth, increment of fronds density) and the organic enrichment of the sediments.

The abundant and frequent gastropod Calliostoma sp. could not be identified to species, as the species of this genus are problematic in the area of transition between the Mediterranean Sea and the Atlantic Ocean. The Atlantic forms usually have a heavier sculpture of spiral cords than Mediterranean ones, and this variation of sculptures obscures the delimitation of the species. This species is close to the Mediterranean species Calliostoma conulus, but it possesses heavier ribs. A similar species has been found living in bioclastic bottoms (18–30 m depth) in the Straits of Gibraltar and was named as Calliostoma sp. 1 (Rueda et al., 2000). A taxonomic revision of the species of the genus Calliostoma is needed in the Straits of Gibraltar area. In the present study, the species is named Calliostoma sp. for concordance with other studies on mollusc assemblages of the area.

4.2. Seasonal changes in the assemblage over 2 years

The molluscan composition and structure followed a seasonal trend, similar to that observed in molluscan assemblages from other vegetated habitats in southern Spain, such as shallow soft bottoms with macroalgae (Dantart et al., 1990; Rueda et al., 2001), calcareous algal formations (Salas & Hergueta, 1986) or seagrass beds (Hergueta, personal communication). The presence of vegetation on soft bottoms causes better stabilisation of the sediments and greater accumulation of organic matter compared with unvegetated seabeds. This results in significantly higher animal richness, abundance and biomass in vegetated habitats in temperate and cold areas (Boström & Bonsdorff, 1997; Edgar, Shaw, Watson, & Hammond, 1994). Generally, juveniles or adults are sheltered in vegetated bottoms, diminishing the risk of being re-suspended and transported away (Olafsson, Peterson, & Ambrose, 1994) or predated (Irlandi, 1994). The presence of the dense algal layer of Caulerpa prolifera may reduce the inter-annual variability of the assemblage because of the survival of most juveniles, especially of the dominant gastropod species. Moreover, the increase of food available (e.g. organic matter due to sediment-retention) for juveniles could represent a key factor in the population dynamics of some gastropod species and of the entire assemblage (Sánchez-Moyano et al., 2001).

High abundance and species richness values occurred in the spring and summer months, when the algae Caulerpa prolifera displays maximum frond densities and biomass in southern Spain, as found in the Bay of Algeciras (Sánchez-Moyano et al., 2001). Similar trends of high abundance of molluscs associated with the biomass or shoot/frond density of seagrass and seaweed beds have been found in studies of molluscan assemblages of vegetated bottoms off Southern Spain (Hergueta, personal communication; Rueda et al., 2001; Salas & Hergueta, 1986; Sánchez-Moyano et al., 2001). In spring and summer months, an increase in abundance or in number of species has been generally related to the recruitment events. The increase of the availability of microhabitats (e.g. higher fronds density, epiphytes)
may also support the presence of higher numbers of species and abundances as found in benthic assemblages of heterogeneous sediment types (Dewarumex, Davout, Sanvicente Anorve, & Frontier, 1992; Frontier & Pichod-Viale, 1991).

A repetitive seasonality in species composition and abundance was found in both years. Abundance and recruitment events, as well as diversity and evenness were very similar in the same months of consecutive years. In general, no year to year differences occurred in the recruitment of gastropods with direct development, the most dominant and frequent molluscan class of this habitat. Conversely, in the outer Bay of Cádiz, interannual similarities of the molluscan assemblage from vegetated soft bottoms were based only on the species presence/absence but not on their abundance (Rueda et al., 2001). In that assemblage, recruitment of bivalves played a significant role during 1995, influenced by the presence of high densities of the filter feeder bivalve Corbula gibba. The presence of large populations of bivalves may result in adult–larval interactions, causing reductions in larval recruitment of up to 40% (Andre & Rosenberg, 1991). In the inner part of the bay, dense populations of bivalves such as C. gibba did not develop successfully, despite the high abundance of juveniles in the summer recruitment of 1994. The unsuccessful development of bivalve populations in this part of the bay could be related to the higher organic loads of the sediment and the dense algae cover, which can promote anoxic conditions of the sediments and affect adversely some infaunal species such as bivalves (Sánchez-Moyano et al., 2001).

For the same period of study, a seasonal trend in both years was observed for the community of decapod crustaceans in the outer bay (López de la Rosa, García-Raso, & Rodríguez, 2002), whereas the decapod assemblage remained stable in the inner and shallower part of the bay (López de la Rosa, personal communication).

5. Conclusions

The molluscan assemblage of Caulerpa prolifera beds within this area of southern Spain shows a relatively higher species richness than similar habitats of other semiclosed and muddy lagoonal areas from European coasts. The seasonal trends observed in the molluscan assemblage seem to follow the vegetative cycle of the algae C. prolifera. The absence of year to year variability in this study may indicate a general stability of the molluscan assemblage.

The intense aquaculture activities in the saltmarsh zone of the bay, together with the affluence of the town of Cádiz, give rise to deposition of fine sediments in the inner bay (ca. 0.52 cm yr$^{-1}$) and, consequently, to eutrophication of this basin. In the absence of rich and structured seagrass meadows in the inner bay, the dense beds of C. prolifera may stabilise the year to year variations of the molluscan assemblages by retaining the sediment with high organic matter content and developing heterogeneous microhabitats for the epifauna (e.g. gastropods).

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