MESOZOOPLANKTON COMMUNITY STRUCTURE DURING SUMMER MONTHS IN THE BAY OF CÁDIZ

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ABSTRACT

Mesozooplankton organisms (>250 µm) were sampled at two stations (inner and outer Bay) in the Bay of Cádiz between May and July 2008. Samples were analysed by means of a semi-automated technique in order to give a preliminary view of the mesoozooplankton community structure in the Bay, based on taxonomic diversity and biomass distribution among size classes. The abundance of organisms increased from May to July in accordance with the increase in temperature and Chlorophyll *a* (Chl*a*) concentrations. Abundances were higher in

the outer Bay station, where Chl*a* concentrations are greater and the water column is more stable. The community changed from being meroplankton- to holoplankton-based due to an increase of Calanoida and especially Cladocera individuals (mainly *Penilia avirostris*), which are known to peak acutely in the summer. The analysis of Normalised Biomass-Size spectra revealed fairly steep slopes (average -1.3) and relatively high departures from steady state (r^2 = 0.8 – 0.94), expectable in a coastal system such as the Bay of Cádiz were disturbance factors are introduced from benthic and tidal processes, together with anthropogenic pressure.

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INTRODUCTION

The growing consciousness on the role of coastal areas in global CO_2 budgets has lead scientists to initiate diverse research programmes covering various issues (Siefert and Plattner, 2004). Much discussion has awoken around the controversy on whether these ecosystems are acting as sources or sinks of the greenhouse gas. In this context, the present study is part of the 2007 Excellence Projects Call, held by the Andalusian regional
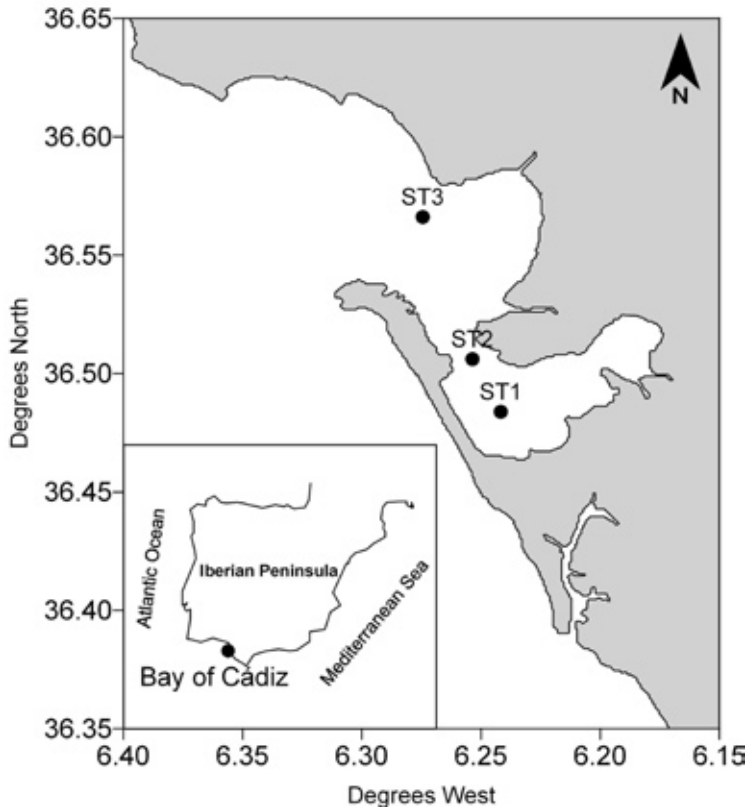
Figure 1: *Map of the area of study and sampling stations.*

government (Junta de Andalucía) named Project Bahía, which aims to elucidate the overall carbon budget of the Bay of Cádiz and to start off a continuous data series which will provide valuable information about the ecosystem state and evolution. The high diversity and eco-sociological interest of the Bay of Cádiz (declared Natural Park in 1989, birds protected area-Zona de Especial Protección para las Aves (ZEPA)- in 1993, protected area under Ramsar Convention in 2002), as well as its situation near the connection of the Atlantic Ocean and the Mediterranean Sea are reasons why the study of carbon balances here are important as a reference-system when comparing with similar coastal ecosystems and semi-enclosed bays in mid-

latitude coasts. The great biological productivity of the Bay (Muñoz-Pérez and Sánchez-Lamadrid, 1994) highlights the need of considering the function of planktonic communities and their dynamics within the pelagic system together with physical and environmental variables in order to obtain an integrative approach for the study of the overall carbon budget. Indeed, linking physic-chemical variables to zooplankton community dynamics was one of the great goals of GLOBEC (GLOBEC, 1997; Alcaraz *et al*., 2007). The key role performed by zooplankton species in transferring biomass from autotrophic organisms towards higher trophic levels as well as their influence in vertical particle fluxes make zooplankton studies indispensible in marine

ecological and biogeochemical research (Banse, 1995). Plankton are drifting, short-lived and non-exploitable organisms (with the exception of some aquaculture-targeted phytoplankton species), thus environmental changes are well and rapidly reflected on them. Hence, building planktonic community data series yields valuable proxies for climate change evidence (Hays *et al*., 2005).

Much effort has been invested in zooplankton dynamics studies and our knowledge has evolved considerably, but facts such as undersampling, time-consuming analysis and low spatial-temporal resolution remain a drawback (Grosjean *et al*., 2004), although the latter has been relatively solved with new sampling devices such as the Longhurst-Hardy Plankton Recorder (Longhurst *et al*., 1966) or the Video Plankton Recorder (Davis *et al*., 1992). Counting, identifying and measuring the size of zooplankton organisms are still tasks of crucial importance which unfortunately entail large efforts in time and previous taxonomic classification experience (Grosjean *et al*., 2004). The need to overcome this problem has led oceanographers and planktologists to develop automated methods based on image analysis (Rolke and Lenz, 1984). Although the effectiveness of plankton-imaging systems has been corroborated reporting accuracy levels up to 70-80% with 10-20 taxonomic classes (Benfield *et al*., 2007), it must be noted that these systems need good image-acquisition tools which often lead to high-resolution images. This increases the computer power requirements and, in most cases, does not allow identification to the species level. Nevertheless, these techniques have significantly reduced the sample-processing time and are especially useful regarding biomass estimates, as they do not involve the destruction of the samples by incineration or similar (Alcaraz *et al*., 2003).

In coastal ecosystems different taxa have been shown to be more or less abundant according to factors such as temperature, salinity, chlorophyll, nutrients and turbulence (Calbet *et al*., 2001; Lawrence *et al*.,

2004; Alcaraz *et al*., 2007), and throughout seasons (Fernández de Puelles *et al*., 2003; Isinibilir *et al*., 2008). Seasonal variability is especially distinctive for meroplankton species which only occur in certain parts of the year, when the environmental conditions are adequate for their development. As well, taking advantage of hydrodynamics is the strategy of many meroplankters, e.g. decapods that use tidal currents as a larval dispersion and recruitment method (Pineda, 2000). In our case of study, neighbouring areas such as the Gulf of Cádiz, Strait of Gibraltar and Mar de Alborán have been targeted in past studies concerning phytoplankton, bacterioplankton and especially ichthyoplankton due to the importance of fish landings in this area. Mesozooplankton has been well studied in Mar de Alborán, the Strait of Gibraltar and more scarcely in the Gulf of Cádiz. Within the Gulf, the Bay of Cádiz's planktonic communities have been previously studied by Yúfera *et al*. (1984) who provided preliminary results on the zooplankton community composition within salt ponds of the marshes in the Bay, while González-Gordillo (1999), González-Gordillo and Rodríguez (2003) and González-Gordillo *et al*. (2003) presented comprehensive information on decapod larvae distribution and its assemblages' ecology in the Bay and surrounding areas.

Surprisingly, the whole mesozooplanktonic community has not been sought in any previous studies of this system and therefore the aim of this work is to give a first estimation of the zooplankton community structure in the Bay of Cádiz. In our study, organisms are analysed by means of a semi-automated technique and the community structure is discussed based on taxonomic differences and biomass variability among size classes, in the frame of environmental factors variability, such as temperature, salinity, Chl*a* and nutrients. The project's perpetual monitoring-programme will provide a precious data series which will inform how climate change is affecting the structure of planktonic communities and the Bay's ecosystem as a whole.
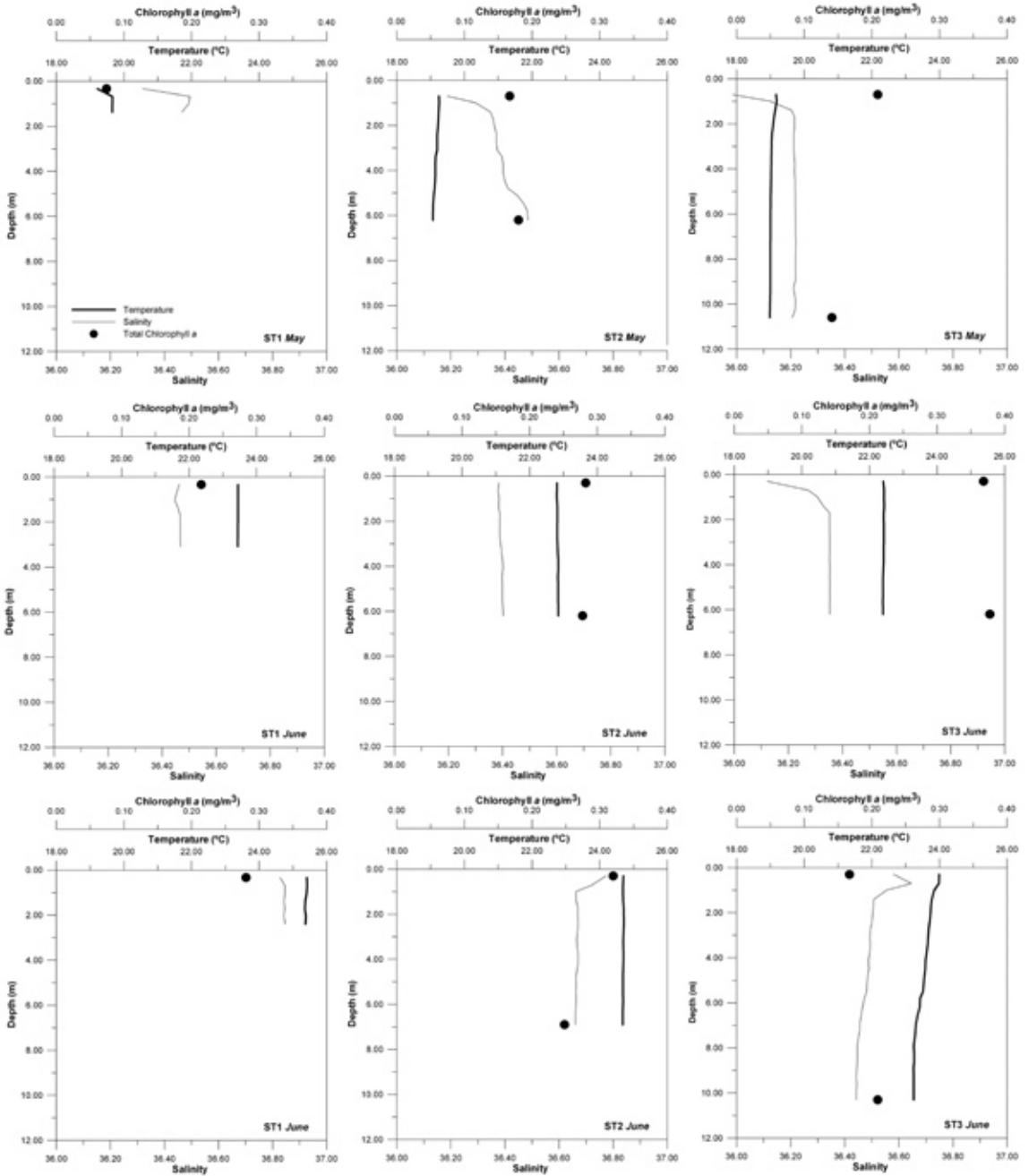
Figure 2:
Temperature, salinity and total Chl*a profiles for ST1, ST2 and ST3 between May and July 2008.*

METHODS

Study site

The Bay of Cádiz is a shallow water coastal ecosystem in the SW of Spain composed of two basins (inner and outer bays) connected by a narrow navigation channel (figure 1). The area is subjected to a semidiurnal tidal regime which exerts great control on the ecosystem, providing water renewal rates of 30% during neap tides and 75% during springs (Álvarez *et al.*, 1999). The vast extensions of intertidal zones and salt marshes surrounding the area produce nutrient and organic matter loading which together with the favourable light and temperature conditions make the Bay of Cádiz a productive ecosystem which houses a great variety of algae, seagrasses, as well as an important hatchery role for many fish and crustacean species (González-Gordillo and Rodríguez, 2003). Sampling was performed in the Bay of Cádiz at three stations in 3 cruises between May and July 2008 (12th May, 16th June and 1st July, correspondingly). Station 1 corresponds to the inner bay, station 2 is located in the narrow channel which connects both bays and station 3 corresponds to the outer bay (these stations will be referred to as ST1, ST2 and ST3 hereinafter).

Sampling procedures and seawater analysis

At each station temperature, salinity and fluorescence data were obtained with a SeaBird25 CTD making vertical profiles from surface to bottom. Transects were performed sailing from ST3 to ST1 logging surface fluorescence, temperature and salinity data each second at a mean speed of 6 knots. Seawater samples for nutrients and Chl*a* analysis were taken with a Niskin bottle from the bottom and surface of the water column (depth varied depending on the tide height and station). Zooplankton was collected performing double-oblique tows at ST1 and ST3 with a Bongo net fitted with 250 μm mesh and equipped with an analogical flowmeter. The mean volume filtered was 59.3 m³, ranging between 27.4 and 74.6 m³. The net was rinsed gently and then samples were transferred into 500 ml containers and finally preserved adding buffered formalin to a final concentration of 4%. Total Chl*a* concentrations were obtained after filtering 250 ml on Whatman glass fibre filters (GF/F) and analysing them by means of a Turner fluorimeter. Seawater samples were analysed for nitrate, nitrite, phosphate and silicate with a segmented flow San⁺⁺ Skalar Autonalyser, following the automated methods described by Grasshoff *et al.* (1983).

Counting and measuring zooplankton

Identification, counting and size measurements of zooplanktonic organisms were made by means of the Plankton Visual Analyzer (Boyra *et al.*, 2005; PVA, 2005), a free plankton-imaging software available from AZTI's website (www.azti.es). The software was used in its *Visual Mode*, which allows the user to extract individual size data from each of the organisms in a digital image. Before being processed, samples were concentrated and dyed with Rose Bengal for 24 hours to enhance contrast between the organisms and the background. Then they were filtered through 1000, 500 and 250 μm sieves and divided into 3 size fractions, namely >1000 μm, <1000 and >500 μm, <500 and >250 μm. Subsequently, each fraction was subsampled with 10 ml automatic pipette. Depending on the density of organisms in each fraction 4 to 8 subsamples were performed. Each subsample was placed in a Petri dish and previewed under a stereomicroscope with the purpose of removing any particles and separating organisms forming tangles as these could be mistakenly recognised by the PVA as a candidates. Also, any overlaps or image-cuttings were avoided (e.g. organisms at the edge of the dish), preventing problems which could hinder the accuracy of our data. After this pre-treatment, digital images were obtained using a regular scanner. Different resolutions were used according to the size fraction which was being scanned, commonly we used 1200 ppi for the >1000 μm fraction, 1800 ppi for the fraction corresponding to sizes between <1000 and >500 μm, and 2000 ppi for <500 and >250 μm one. The last fraction occasionally needed 2400 ppi.
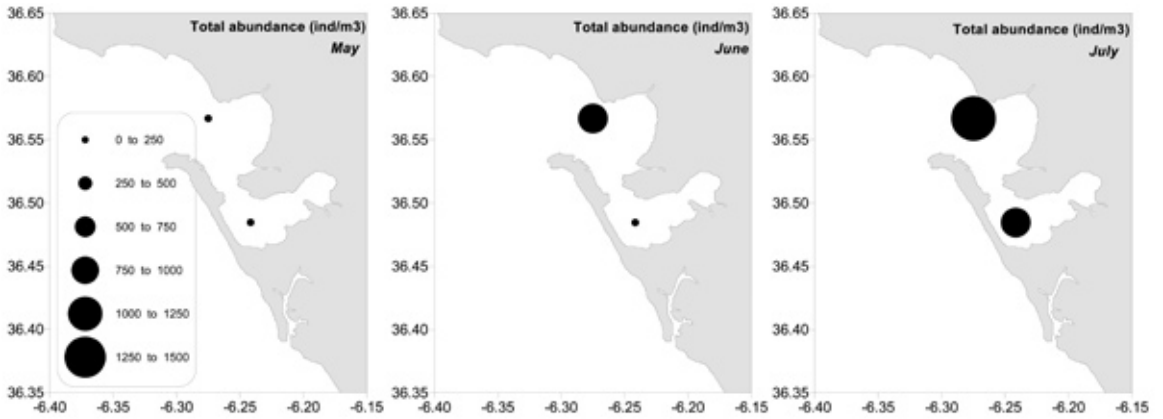
Figure 3:
Total abundance variability (ind/m³) among stations between May and July 2008.

Before processing, the parameters of the PVA were set according to the size and resolution of each image acquired. The PVA recognises each organism by searching sufficiently contrasting bodies within a size range set by the user, i.e. minimum and maximum pixels to be recognised as a candidate. Thus, the number of pixels per mm needs to be changed consistently with images' resolution. After these settings, the image was imported and processed, classifying organisms in the main (most abundant) taxonomic groups: Copepoda (namely Calanoida, Cyclopoida and Harpacticoida), Cladocera, Appendicularia, Cirripedia (only larvae), Ostracoda, Decapoda (zoeal stages of Brachyura, Anomura and Caridea), Siphonophora, Euphasiacea, Mysidacea, Chaetognata, Hydromedusae, Amphipoda and Ascidiacea. Taxa abundance and individual Equivalent Spherical Diameter (ESD) were obtained from each image.
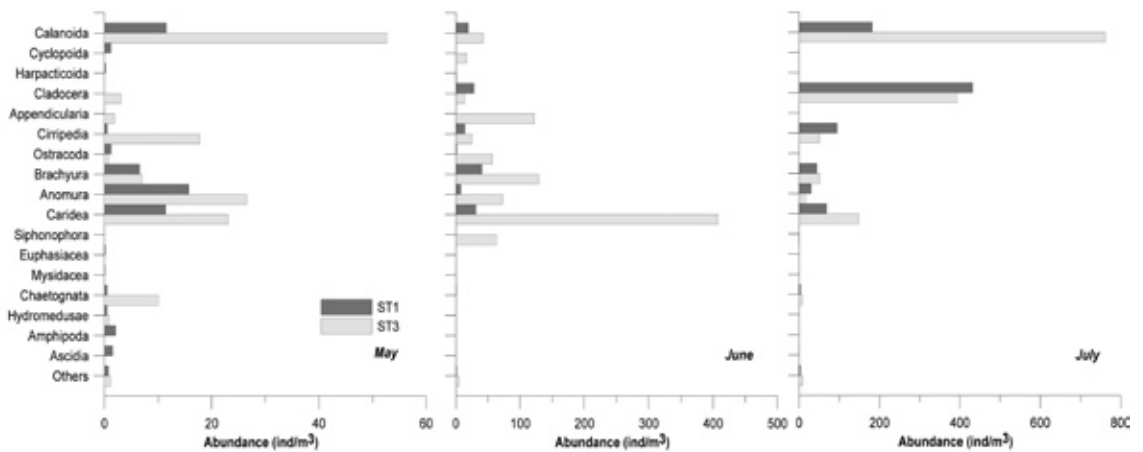

Figure 4:
Taxa abundance (ind/m³) recorded between May and July 2008. Please note the different scales used for each graph.

Data

Biomass analysis

Individual ESD of mesozooplankton was used to calculate biovolume from the volume of a sphere with r = ESD/2. The biomass of crustaceans was determined by the biovolume-to-carbon conversion factor provided by Alcaraz *et al.* (2003), while gelatinous mesozooplankton biomass was calculated with that of Parsons *et al.* (1984). Biomass and biovolume values were used to build Normalised-Biomass Size Spectra (NBSS), confronting mean biomass (mg C/m^3) and biovolume intervals (mm^3), ranging from the smallest to the biggest organism found in the sample set. NBSS (Platt and Denman, 1978) were constructed plotting the biomass in a specific size class (as biovolume) divided by the amplitude of each interval (normalised biomass) versus biovolume, on a double logarithmic scale:

$$\log(B_m / \Delta m) = \log a + b \log m$$

where B_m is the total biomass per size class m (in mg C/m^3), a and b are constants, and m is the size class interval (in mm^3). Results are discussed based on the slope (b), y-intercept (a) and determination coefficient (r^2) yielded by the linear fit of the spectra.

Indices

The next indices were calculated for each sample, using the equations shown below. As our samples were classified as general groups (see Methods), these have been used as taxonomic units for the application of the different indices. Margalef's species richness index (d):

$$d = \frac{S-1}{\log N}$$

where S is the total number of groups and N the total number of organisms. Shannon-Wiener diversity index (H'):

$$H' = -\sum p_i \log p_i$$

where p_i is the relative abundance of each group, calculated as the proportion of individuals of a given group to the total number of individuals in the community (n_i/N). Pielou's evenness index (J') responds to the next expression:

$$J' = \frac{H'}{\log S}$$

and Simpson's dominance index (D%) was calculated as:

$$1 - \lambda' = 1 - \sum \frac{n_i(n_{i-1})}{N(N-1)}$$

Constancy (C%) was calculated from the number of times a group appears in a station related to the total number of samples taken at that station.

RESULTS

Hydrography

The CTD profiles (figure 2) showed a considerable homogeneity in the shallow and tidally-mixed Bay of Cádiz, evident for both temperature and salinity with some exceptions. The more saline character of the inner bay waters can be noticed (due to the acute evaporation in the inner bay related to low depths and intense sunlight year round). Total Chl*a* concentrations were similar between surface and bottom waters throughout the sampling period, though increasing from the inner to the outer bay, and from May to July.

Taxa spatial and temporal variability

Throughout the study period the total abundance of sampled organisms (ind/m^3) increased in both the inner and outer Bay stations. The overall abundance distribution (sum of all mesozooplankton organisms) at ST1 and ST3 (figure 3) reported similar values in May whereas an augment in ST3 in relation to ST1 occurred in June, being even more acute in July. By taxa (figure 4), the abundance of organisms was always higher in the outer bay (ST3) than in the inner ST1 with some exceptions in May and June
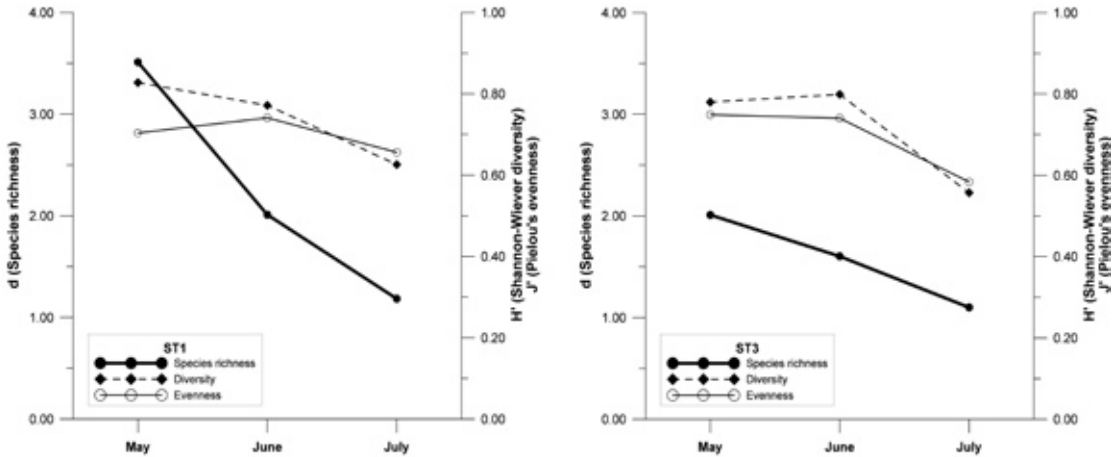
Figure 5:
Species richness (d), Shannon-Wiener diversity index (H') and Pielou's evenness (J') evolution at ST1 and ST3 throughout the study period.

(see figure 4) and especially in July, when Cladocera, Cirripedia and Anomura individuals in the inner bay outnumbered those of the outer bay. Nevertheless, taxa abundance spatial variability was not found to be statistically significant.

Among months, the lowest abundances were recorded in May. The most abundant taxa then were copepods from the order Calanoida (52.7 ind/m³) at ST3, followed by Anomura and Caridea (26.52 and 23.07 ind/m³, respectively). The highest abundance in May for inner ST1 was that of Caridea (11.42 ind/m³). Below that abundance, all the rest of taxa considered in this study were witnessed with the exception of Siphonophora. Interestingly, the taxa Appendicularia, Euphasiacea, Mysidacea and Amphipoda, which appeared in this first survey were not recorded again, neither in June nor in
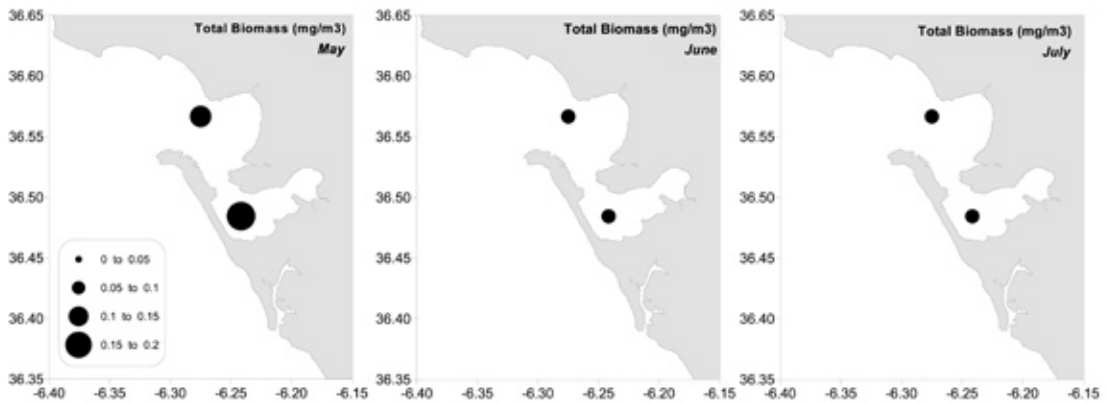

Figure 6:
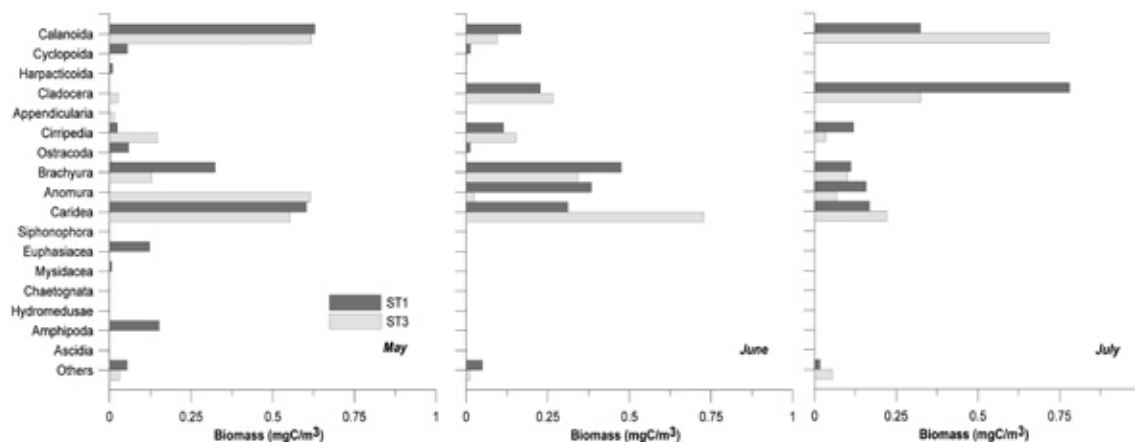*Total biomass variability (mg C/m³) among stations between May and July 2008.*

Figure 7:
Biomass distribution (mg C/m³) among functional groups for both stations between May and July 2008 (sum of all size fractions).

July. In June the groups Calanoida, Cyclopoida, Cirripedia, Brachyura, Anomura and Caridea were present at both stations, being more abundant in the outermost ST3. A remarkably great abundance of Caridea in ST3 was observed, reaching 407.3 ind/m³. July was dominated by the presence of copepods from the order Calanoida with 761.79 ind/m³ at ST3. The abundance of Cladocera increased to a great extent in comparison to previous surveys, reaching a maximum of 432 ind/m³ at the inner station ST1 and 393.35 ind/m³ at the outer one. Temporal abundance variability was demonstrated for Cladocera, Cirripedia and Hydromedusae, all p<0.005. Gathering all three sampling months (table 1), the most dominant taxon at ST1 was Cladocera (43.46 D%), followed by Calanoida, Caridea and Cirripedia (as >10 D% taxa). A 100% constancy was reached by Calanoida, Cirripedia, Brachyura, Anomura, Caridea and Chaetognata. At ST3, Calanoida were dominant (33.74 D%), closely followed by Caridea (22.76 D%). Cladocera also made up a considerable part of the mesozooplanktonic community in these months, with a dominance percentages >10%. A 100% constancy was achieved by Calanoida, Cladocera, Cirripedia, Brachyura, Anomura and Caridea.

The Holoplankton/Meroplankton ratio temporal evolution was calculated, resulting in a holoplanktonic dominance from May to June (0.81 and 0.50, respectively), which shifted in July to a predominantly meroplanktonic community (3.53). A general decrease in diversity was observed between May and July for both stations and linked to a drop in groups richness, though a slight increase in diversity occurred at ST3 in June (figure 5). Evenness maintained similar values from May to July in ST1, being more variable in ST3 where a small increase was followed by an acute decrease attributable to the augment of calanoids and cladocerans over the rest of taxa.

Biomass variability and distribution among size classes

Comparing the spatial distribution of total biomass (figure 6) to that of abundance (figure 3) it can be clearly seen that these two variables did not evolve in the same manner. The greater biomasses were found in May, when the lowest abundances occurred. This was caused by the presence of bigger organisms such as large brachyuran zoeas and anomurans, with
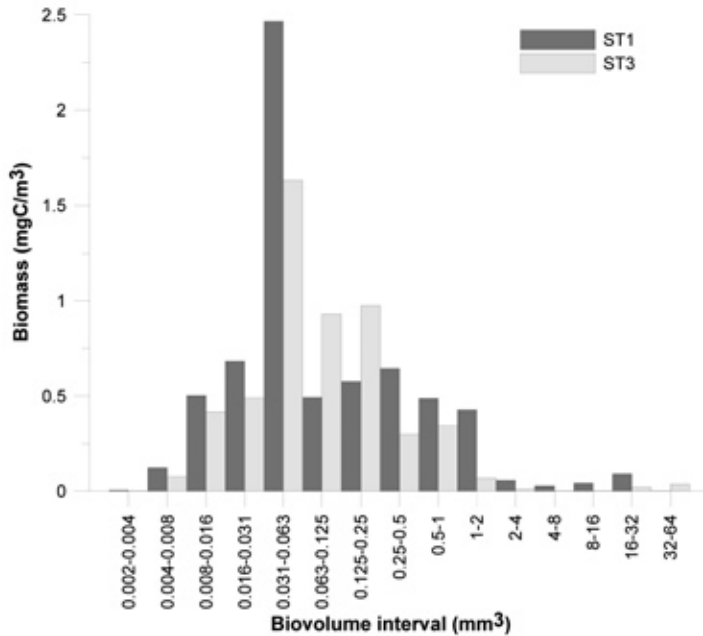
Figure 8:
Biomass distribution among size classes at both stations throughout the study sampling period.

large biovolumes and low abundances of smaller holoplankters. In June and July, albeit abundances were not equal, biomasses maintained similar values among stations, meaning that mean biovolumes were minor due to the increased abundance of cladocerans and small calanoid copepods. The biomass provided by each taxon during the sampling period is shown in figure 7. In May, though the abundance of calanoid copepods was much higher at ST3 (figure 4), biomass was almost equal, it follows then that calanoid copepods from ST1 were more voluminous. This pattern in Calanoida biomass was observed in June too, though with much lower values. Their biomass increased again in July especially that of ST3, this time corresponding to a greater abundance.

Cladocerans' biomass increased greatly during the sampling period, consistently with their abundance rather than with their size (biovolume), which was always similar (data not shown).

Cirripedia maintained similar abundances across months with only lower values at ST1 in May and ST3 in July due to lower abundance. The increase of biomass and steadiness in Brachyura abundance reflects their enlargement in size from May to June. Interestingly, this group increased in abundance in July maintaining similar biomass values. Anomura presented great differences between the inner and outer Bay biomass values in May (ST1 ones were so small that cannot even be noticed in the graph due to scale range). Their greatest biomasses occurred in June, being greater at ST1 and almost equal for both stations in July. The biomass of Caridea decreased from May to July, though a remarkable peak occurred at ST3 in June, related to a greater abundance (figure 4).

Concerning size classes, the mesh size used (250 μm) selects organisms with ESDs over that size. This selectivity should avoid the presence of smaller
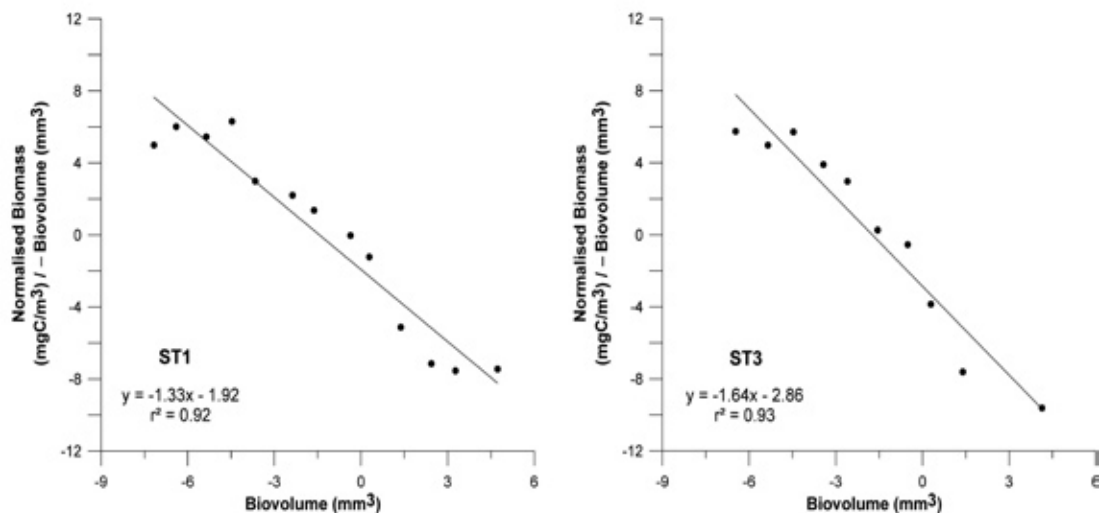
Figure 9:
NBSS representation for ST1 and ST3 (sum of May, June and July).

individuals but in our study their biomass appeared have similar values than the bigger zooplankters at the right hand side of the distribution (figure 8). This was due to the recurrence of "zooplankton tangles" (i.e. groups of attached organisms together with seagrass portions and other rests of organic matter), and also the abundance and biomass of these small organisms might be undersampled. The NBSS results are presented in table 2 (temporal variability among stations) and the overall spectra (average of all months) are plotted in figure 9. A greater temporal variability in slope was observed at ST3, as well as lower determinations coefficients in comparison with ST1. The over-time spectra for both stations though revealed similar departures from steady state (r^2). Smaller undersampled classes were removed (0.002 to 0.008 mm^3) and thus do not appear in the spectra. A steeper slope was computed for ST3, as well as the absence of some size classes which instead were present at ST1.

DISCUSSION

Taxonomic distribution

Plankton community structure studies are usually based on at least one-year data series. Although a three-month survey might not be sufficiently representative, the present work provides a first characterisation of the mesozooplankton community and its structure in the Bay of Cádiz, based on predominant groups. The image-analysis software employed offered an easy and rapid way to identify, count and measure zooplanktonic organisms, although it did not permit identification to the species level with common resolutions. Nevertheless, when necessary, previous observation under the stereomicroscope and pictures permitted the observation of some characteristic taxa which varied in space and time according to hydrographic features. The spatial significant differences in temperature support the variability

Table 1:
Total abundance (N, ind/m³), dominance index (D%) and constancy index (C%) for stations 1 and 3 throughout the study period.

Taxa	ST1			ST3		
	N	D%	C%	N	D%	C%
Calanoida	212.99	20.12	100.00	857.34	33.74	100.00
Cyclopoida	1.33	0.13	66.67	16.57	0.65	33.33
Harpacticoida	0.20	0.02	33.33	1.14	0.04	33.33
Cladocera	460.18	43.46	66.67	410.15	16.14	100.00
Appendicularia	0.00	0.00	0.00	124.10	4.88	66.67
Cirripedia	109.63	10.35	100.00	93.42	3.68	100.00
Ostracoda	2.77	0.26	66.67	57.38	2.26	66.67
Brachyura	91.79	8.67	100.00	187.81	7.39	100.00
Anomura	53.65	5.07	100.00	115.76	4.56	100.00
Caridea	111.03	10.49	100.00	578.33	22.76	100.00
Siphonophora	0.00	0.00	0.00	64.72	2.55	66.67
Euphasiacea	0.15	0.01	33.33	0.00	0.00	0.00
Mysidacea	0.08	0.01	33.33	0.00	0.00	0.00
Chaetognata	5.08	0.48	100.00	18.89	0.74	66.67
Hydromedusae	0.51	0.05	66.67	0.85	0.03	33.33
Amphipoda	2.08	0.20	33.33	0.00	0.00	0.00
Ascidiacea	1.83	0.17	66.67	0.00	0.00	0.00
Others	5.55	0.52	100.00	14.71	0.58	100.00

of abundance and taxonomic composition of zooplankton found, together with the increasing Chl*a* concentrations occurred from the inner to the outer bay. Overall zooplankton abundance increased from May to July. The reduced abundance of zooplankters in May is not only attributable to colder temperatures, but also to the remarked presence of ctenophores which may have been feeding on them actively. In addition, surface circulation patterns of tidal currents in the Bay of Cádiz (figure 7 in González-Gordillo and Rodríguez, 2003) probably play an important role on zooplankton distribution. In particular they

Table 1:
Total abundance (N, ind/m^3), dominance index (D%) and constancy index (C%) for stations 1 and 3 throughout the study period.

Sample	Slope	y-intercept	r^2
ST1 May	-1.39	-2.85	0.91
ST1 June	-1.38	-3.82	0.94
ST1 July	-1.28	-3.58	0.88
ST1 average	-1.33	-1.92	0.92
ST3 May	-0.87	-0.99	0.88
ST3 June	-1.57	-3.35	0.80
ST3 July	-1.23	-3.48	0.90
ST3 average	-1.64	-2.86	0.93

might be responsible for the greater abundances found in the outermost ST3 as the ebb flow passes by the area where ST3 is located and has a lower hydrodynamic activity and therefore houses warmer waters which are preferable for the development of most coastal zooplankton species. Moreover, Chl*a* concentrations are greater in the outer bay than in the inner one where high turbidity levels might be hindering photosynthesis and consequently reducing autotrophic biomass.

Besides the short sampling period, sampling between May and July permitted us to witness the change from a meroplankton-based community to a holoplankton-based one. Meroplankters maintained similar abundances in June and July, therefore the ratio shift occurred in accordance with an augment of Calanoida and Cladocera species, rather than with a drawdown of meroplankton. This agrees with González-Gordillo and Rodríguez (2003) investigations, in which they found several peaks of meroplankton between spring and summer, up to August when the

environmental conditions are favourable for their development. Indeed, meroplankters found in this study (Cirripedia, Anomura, Caridea and Brachyura) showed a 100% constancy at both stations throughout the sampling period. From this we conclude that meroplankters make up a significant part of the zooplankton community in the Bay of Cádiz in the spring-summer period. Certainly, large abundances were found before (Rodríguez *et al*., 1997; Drake *et al*., 1998) and related to the absence of temperature and salinity abrupt changes in the Bay and associated to the semidiurnal regime and its high water renewal rates (Álvarez *et al*., 1999), which enhances the successful development of these species. The density of meroplankton species was greater in ST3 than in ST1, with the exception of Cirripedia and Anomura which were more abundant in the inner Bay. The remarkable abundance of Caridea at ST3 in June decreases towards July coinciding with the inter-spawning period of *Philocheras* (the most representative caridean taxon for this time in Cádiz Bay) and the shift of these species from planktonic

to benthic life (González-Gordillo and Rodríguez, 2003). The drop of Anomura biomass from May to July is clearly identified with a decrease in size. Individuals in May were voluminous (mean of 0.65 mm^3) and mixed with smaller ones, meaning various developmental stages are coexisting as this taxon peaks along all summer. In spring-summer months, the overall holoplankton taxa composition in the Bay is shared with that of the Gulf of Cádiz (Mafalda *et al*., 2007), though some groups found over the shelf are scarce here. The absence of gelatinous groups such as doliolids and siphonophores may be an advantage for copepods which are usually heavily preyed on by them.

Zooplankton species usually present a developing delay with respect to phytoplankton. Spring phytoplankton bloom typically occurs in April-May in the Bay of Cádiz (Establier *et al*., 1990) and therefore copepods (and other taxa) present higher abundances in June and July. The dominant copepods from the order Calanoida were more abundant at ST3 where Chl*a* concentrations are greater. The absence of cyclopoids could be attributable to the inappropriate selectivity of the size mesh used (250 μm), as many of these species, such as *Oithona* sp. for instance, are smaller and important in coastal areas (Calbet *et al*., 2001). Calanoids were always more abundant at ST3 where the salinity was slightly lower due to the discharge of the Guadalete river (which is reduced, but not negligible), and always lower in comparison to the low depths of the inner bay. The calanoid group was mainly composed of *Acartia* and *Paracalanus* species known for being sensitive to salinity (Lawrence *et al*., 2004). Short-term seasonality is obvious as the total abundance of organisms increases with temperature from May to July. In particular, the cladoceran *Penilia avirostris*, known for presenting abundant blooms due to their rapid parthenogenetic reproduction, are habitually used as a biological indicator of warmer waters. These cladocerans abounded in the Bay of Cádiz in July as it occurs in other parts of the south-Iberian and Mediterranean Seas (Calbet *et al*., 2001; Mafalda

et al., 2007). The temperature increase may have been responsible for the absence of Chaetognata in June and July, as this rather oceanic taxon prefers colder waters.

Biomass distribution

The flow of biomass occurs through size-dependent processes in trophic food webs, therefore the distribution of biomass among size classes follows regular patterns (Sheldon *et al*., 1972) that are superimposed on species diversity. Thus, the construction of NBSS yields an easy way to aggregate and compare the large amounts of individualised information given by imaging systems, as size and biomass are properties present upon all taxa (Parsons, 1969). In this sense, the use of this type of spectra provides a comparative approach for planktonic community structure analysis regardless of taxonomic differences between organisms (Quiñones *et al*., 2003). The analysis of the NBSS constructed for ST1 and ST3 demonstrated differences among them, based on the distribution of biomass among size classes rather than on taxonomic composition. The greater abundance of organisms at ST3 is reflected in the larger y-axis intercept of its NBSS, as this is indicative of abundance. As well, disturbances external to the pelagic system such as benthic and near-shore interactions are reflected in the NBSS as departs from steady state and thus variation around the linear trend is found (Sprules and Manawar, 1986).

The Bay of Cádiz is subject to a great variability due to hydrodynamic activity and anthropogenic pressure, together with considerable local recreational fishery which might act as a slope-increasing factor, due to the elimination of organisms with greater biovolumes (i.e. fish). Another indicative of disturbance are the high slopes found (over -1.30 in most cases). These slopes indicate irregularities in the distribution of biomass among size classes. Indeed, the greatest biomass values were found in the class 0.031 – 0.063 mm^3 (figure 8, whilst biomass values in classes from 1 to 64 mm^3 were much lower, giving steeper slopes.

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