CHANGES ON MACROBENTHIC FAUNA OF A MEDITERRANEAN SALT MARSH (EMPORDÀ WETLANDS, NE IBERIAN PENINSULA) AFTER A SEVERE DROUGHT, WITH SPECIAL EMPHASIS ON THE *COROPHIUM ORIENTALE* POPULATION

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PERMANENT WATERS
ZOOBENTHOS
COMMUNITY STRUCTURE
COROPHIUM
POPULATION DYNAMICS
LENGTH-CLASSES
SEX RATIO
SALT MARSHES

ABSTRACT. – Monthly samples of macrobenthic fauna (> 1 mm) were collected during two hydroperiods (from November 1997 to July 1998 and from November 1998 to July 1999) from permanent waters of the Empordà salt marshes (NE Iberian Peninsula). During the summer of 1998, a severe drought took place at the sampling site. A significantly higher diversity was found after the severe drought, caused by a decrease of the dominant taxa (*Nereis diversicolor* and *Corophium orientale*) and the appearance of taxa which were not found before, such as Ephydridae species. Before the severe drought, the macrobenthic community was dominated by the Mediterranean endemic amphipod *Corophium orientale*, which almost disappeared after the severe drought. The decrease of the population of *Corophium orientale* coincided with an increase of more opportunistic taxa, such as some *Paranais* sp. and *Streblospio shrubsolii*. The population of *C. orientale* had three abundance peaks (more than 6000 ind·m^{-2}) during the first hydroperiod, before the severe drought, and none of such magnitude during the second hydroperiod. In contrast, the severe drought did not imply differences in sex ratio dominance, which was dominated by females both before and after the severe drought in the bigger length-classes and in most of the sampled dates. Moreover, no body size differences were detected before and after the severe drought.

INTRODUCTION

Droughts are considered as one of the most important disturbances in aquatic systems, especially in dry climates, which act as 'ramp disturbances' (Angeler & Rodrigo 2004). The role of droughts is very complex, and they can be divided in different types of disturbances depending on their intensity and duration. Thus, more predictable droughts generate a different response of the communities than less predictable ones (Resh *et al.* 1988, Humphries & Baldwin 2003). Some of the changes produced by these less predictable droughts are not immediate, such those affecting some biological traits (e.g., recruitment) and, in consequence, the population dynamics of the following year might be altered (Boulton 2003).

In Mediterranean wetlands, with marked daily and seasonal variations of physical and chemical parameters, only a small number of highly adaptable macroinvertebrate species can survive and grow (Guelorget & Perthuisot 1983, Victor & Victor 1997, Mistri *et al.* 2001, Kevrekidis 2004a, Reizopoulou & Nicolaidou 2004). In Empordà salt marshes, benthic communities are mainly composed of euryhaline taxa adapted to fluctuating environments, though the degree of adaptation is related to the water regime (Gascón *et al.* 2005). It has been reported that a drought event in highly eutrophic waters can exert deleterious effects in wetlands, including deterioration of water quality, hypoxia and high water temperatures, which become worse as droughts persist (Angeler *et al.* 2002). As a consequence, benthic communities of permanent waters, which are more sensitive to anoxia than those of temporary waters (Gascón *et al.* 2005), are expected to be more sensitive to drastic environmental changes, such as those occurring during an exceptional drought event. Thus, in Mediterranean wetlands, seasonal droughts (predictable disturbances) favour eurytopic fauna, whereas severe drought (less predictable disturbances) might have a very different effect on the community structure and population dynamics.

In this context Mediterranean wetlands, which are characterised by a highly fluctuating hydrological pattern, are ideal sites to develop research on disturbance ecology (Mitsch & Gosselink 1993). The Empordà salt marshes have a complex hydrology with extremely variable meteorological conditions, characterised by the occurrence of various hydrological disturbances, such as winter floods and summer droughts (Quintana 2002a). The effects of sudden floods have been studied both on planktonic (e.g. Quintana 2002b) and benthic organisms (e.g. Boulton *et al.* 1992) and the importance of periodical drying on temporary systems has been pointed out in several works (e.g. Collinson *et al.* 1995, Everard 1996), but the effects of exceptional severe droughts, mainly in permanent systems, have been more neglected.

Corophium orientale Schellenberg, 1928 is a Mediterranean endemic species, which has been reported from several sites of the eastern Mediterranean (Myers 1982, Kevrekidis 2005). This species has also been cited in the Atlantic coast of the southern Iberian Peninsula (Dexter 1992, Calvário 1995, Cuesta *et al.* 1996, Baldó *et al.* 2001) but, as far as we know, in the Mediterranean coast of the Iberian Peninsula, their presence was only recorded in Algeciras Bay, close to the Atlantic Ocean (Conradi & López-González 1999). Although *Corophium volutator* (Pallas) has been cited on Ebre delta (Chinchilla & Comín 1977), no evidence of its presence was found in a recent study covering littoral coastal lagoons of Catalonia (Boix *et al.* 2004), not even where it was previously cited. Besides, according to the figures of Chinchilla & Comín (1977) the urosoma 2 corresponds to *C. orientale*, not to *C. volutator*. These observations provide support to Myers (1982), who questioned the presence of *C. voluta - tor* in the Mediterranean. In Empordà salt marshes, *C. orientale* is the dominant macrobenthic species found in permanent waters. *Corophium orientale* is very euryhaline and is common in lagoons and brackish environments of the Mediterranean Sea (Kevrekidis 2005 and references therein), but a dramatic decrease of its abundance was reported after the environmental changes which occurred following a heavy eutrophic episode (Tagliapietra *et al.* 1998). Additionally, the lack of strategies of this species to survive dry periods (Wiggins *et al.* 1980) renders the study of the effects of severe droughts on a non adapted population particularly interesting.

Due to the singularity of *C. orientale* as a Mediterranean endemic species, and the interest to study the drought effects on a macrobenthic Mediterranean community, the aims of the present study are: (1) to describe changes on the macrobenthic fauna of a permanent basin after a severe drought; and (2) to analyse the changes on population parameters of *C. orientale* before and after the severe drought.

MATERIAL AND METHODS

The study was undertaken at a permanent water basin of the Empordà salt marshes (Fig. 1), during two hydroperiods (from November 1997 to July 1999). These salt marshes are free from tidal influence. The hydrology is characterised by sudden and irregular flooding (caused by rainfall, inputs from rivers or channels, and sea storms), followed by dry periods, when most of the basins become isolated and gradually dry out (Quintana 2002a). Subterranean circulation of fresh and salt water is very prominent due to the abundance of sand deposits in the surface aquifer (Bach 1990).

The basin under study is the only one with permanent brackish shallow waters in the salt marshes of the integral reserve of the Empordà Wetlands Natural Park. It is a depression located between sand bars where water accumulates permanently, and
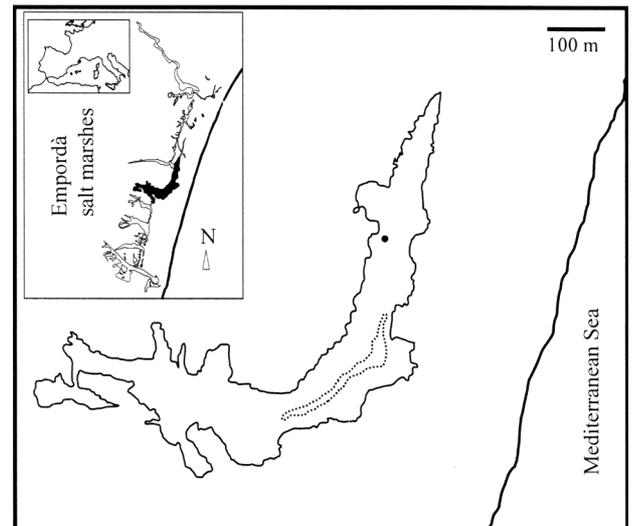

Fig. 1. – Map of the study site, indicating the basin under study (black), the sampling site (point), and the limit of the remaining water during summer (discontinuous line).

has a substrate dominated by sand particles (90.5%). The basin is very flat and without macrophytes during the study period. There is no direct surface communication with the sea, except under exceptional situations during strong sea storms. It has an extension of 8.7 ha, and its depth varies greatly depending on the flood regime, but is usually below 1.5 m. Generally, during the summer, the flooded surface decreases but always retains some water in the deepest part.

A severe drought occurred in Empordà salt marshes during the summer of 1998, which consisted in a drastic reduction of the remaining flooded surface during the summer months (Fig. 1). Thus, two hydroperiods were discriminated: the first one (from November 1997 to July 1998) occurred before the severe drought and the second one (from November 1998 to July 1999) after the severe drought. Note that the effects of droughts need to be evaluated during the following hydrological cycle, because some of them generate a lag in response time on the community (Boulton 2003).

Meteorological data (monthly total precipitation, days of rain per month, and atmospheric temperature) were supplied by the Natural Park meteorological station, while potential evaporation values and rain per day was obtained from the nearby meteorological station of l'Estartit. Conductivity and water depth was monthly measured *in situ*. Monthly samples of macrobenthic fauna, consisting of four replicates, were obtained with an Ekman grab (225 cm^2) at approximately 20 m off the littoral, in an area which dries out every summer. Samples were taken until the sampling site dried out. Organisms were sorted alive from the sediment using a 1 mm-mesh size sieve and preserved in 4% formalin until taxonomic identification. The total number of individuals on a sampled date was estimated as the mean abundance of the four replicates. Three community parameters were calculated for each sample to describe benthic community changes. Shannon diversity and evenness were obtained using base-two logarithm (Pielou 1969), and specific richness was

Table I. – Macrobenthic fauna collected during the study. Mean abundance (individuals·m^{-2}) ± standard error for each hydroperiod, and the code used for each taxa, are shown. In bold, species considered in the CA which were captured in more than 3 samples.

		Hydroperiod	
		1997-1998	1998-1999
Taxa			
Corophium orientale	**COOR**	**3772.8 ± 903.4**	**177.8 ± 113.4**
Nereis diversicolor	**NEDI**	**742.8 ± 299.3**	**306.9 ± 150.4**
Chironomus gr. salinarius	**CHSA**	**214.8 ± 180.2**	**23.6 ± 13.2**
Streblospio shrubsolii	**STSH**	**98.8 ± 69.6**	**341.7 ± 141.6**
Gammarus aequicauda	**GAAE**	**30.9 ± 25.8**	**2.8 ± 1.8**
Lekanesphaera hookeri	**LEHO**	**16.0 ± 8.1**	**2.8 ± 1.8**
Chloropidae undet.	FCHL	4.9 ± 4.9	11.1 ± 9.6
Pomatoschistus microps	POMI	2.5 ± 2.5	0
Paranais sp.	**GPAR**	**1.2 ± 1.2**	**131.9 ± 80.5**
Nais sp.	GNAI	0	12.5 ± 11.0
Scatella sp.1	GSC1	0	102.8 ± 101.2
Scatella sp.2	GSC2	0	20.8 ± 17.9
Halocladius varians	HAVA	0	15.3 ± 8.6
Leptocheirus pilosus	LEPI	0	2.8 ± 2.8
Hydrobia acuta	OGAS	0	4.2 ± 4.2
Parhyale eburnea	PAEB	0	1.4 ± 1.4
Polydora cornuta	POCO	0	2.8 ±1.8

calculated using the taxonomic resolution which appears on Table I.

The size of *Corophium orientale* was estimated by measuring the length of the animal (from the tip of the rostrum to the base of the telson) to the nearest 0.1 mm (under a stereomicroscope fitted with an eye-piece micrometer). Sex distinction has been reported as problematic below 2.75 mm (Kevrekidis 2005), so we considered individuals below 2.8 mm as juveniles. Animals larger than or equal to 2.8 mm were sexed according to the sexual dimorphism of the second antennae (Myers 1982). Females with eggs or embryos were labelled as gravid females. Following Kevrekidis (2005), individuals were grouped in length-classes with an interval of 0.5 mm. Small individuals may be underestimated since the mesh size was 1 mm, and as a consequence recruitment may also be underestimated in these low length-classes.

Pearson correlations were carried out to identify possible relationships between *C. orientale* abundance and some environmental variables (water depth, temperature and salinity). To determine interannual differences in physical and chemical characteristics and in benthic community parameters, t-Student tests were performed since assumptions of parametric statistics were accomplished. Chi square was used to test if sex ratio was significantly different to a 1:1 proportion among months and length-classes. Since abundances (logarithmic transformed using base 10) had variance homogeneity, abundance differences were analysed by means of a Two Way ANOVA, using hydroperiod and length-classes as factors. On the other hand, differences between sex sizes of corresponding periods (e.g. June 1998 *vs* June 1999) were analysed using t Student tests. However, only two months (June and July) had enough data (more than 2 individuals in each date) to carry out this comparison.

A Correspondence Analysis (CA) was carried out to identify the variability of the macrobenthic community. This type of analysis is appropriate when species abundance is used, and when a unimodal relationship of the correlated variables is to be expected (Jongman *et al.* 1995). Because rare species can have a strong effect on unimodal methods (ter Braak & Šmilauer 1998), we did not consider those species of macrobenthos found in less than 4 samples of the 17 under analysis (20% occurrence).

RESULTS

During the study period, water temperature increased gradually in both hydroperiods. In contrast, water salinity and water depth showed different temporal patterns between hydroperiods (Fig. 2). Although meteorological
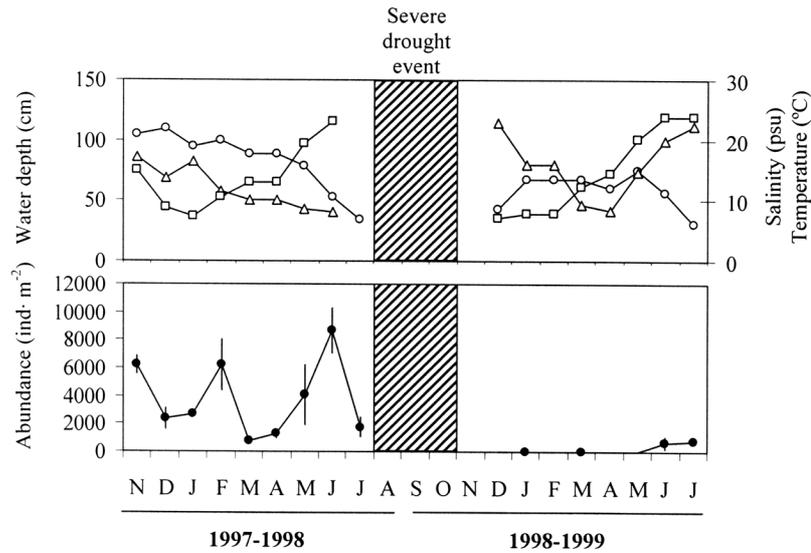
Fig. 2. – Monthly water depth values (open circles), water salinity values (open triangles), and water temperature values (open squares) in the upper graph, and monthly abundances (mean ±standard error) of *C. orientale* in the bottom graph. The severe drought event is also indicated.

data measured during hydroperiods, as well as water salinity and temperature, did not show significant differences between them, basin water depth had significantly different values for the first hydroperiod (Table II). Moreover, significant higher evaporation ($t_{107.091}$ = -4.179; $p < 0.001$) and lower rain per day (Fig. 3) were measured during the severe drought (summer of 1998) than during the previous summer. Differences before and after the severe drought were detected on benthic community parameters (Table III, top): Shannon diversity (t_{14} = -3.51; $p = 0.003$), evenness (t_{14} = -2.28; $p = 0.039$), and total number of individuals (t_{14} = 3.313; $p = 0.008$) were significantly higher after the severe drought. In contrast, no significant differences were found in richness data. Finally, the correspondence analysis showed that the main benthic variability, the one related to the first axis (43.5 %), was associated with the different hydroperiods (Fig. 4). The most abundant taxa were also different for each hydroperiod. The first hydroperiod was characterised by the dominance of *Corophium orientale*, followed by *Nereis diver* -
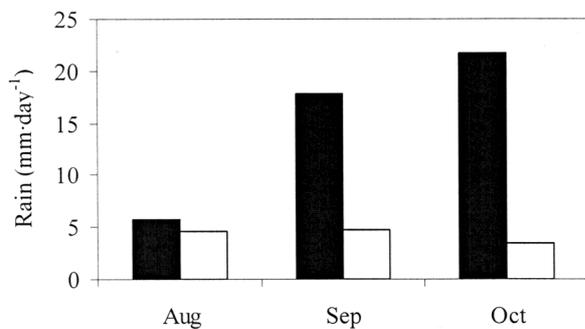
sicolor Müller, 1776 and *Chironomus* gr. *salinarius*. Other less abundant taxa, such as *Streblospio shrubsolii* (Buchanan, 1890), *Gammarus aequicauda* (Martynov,
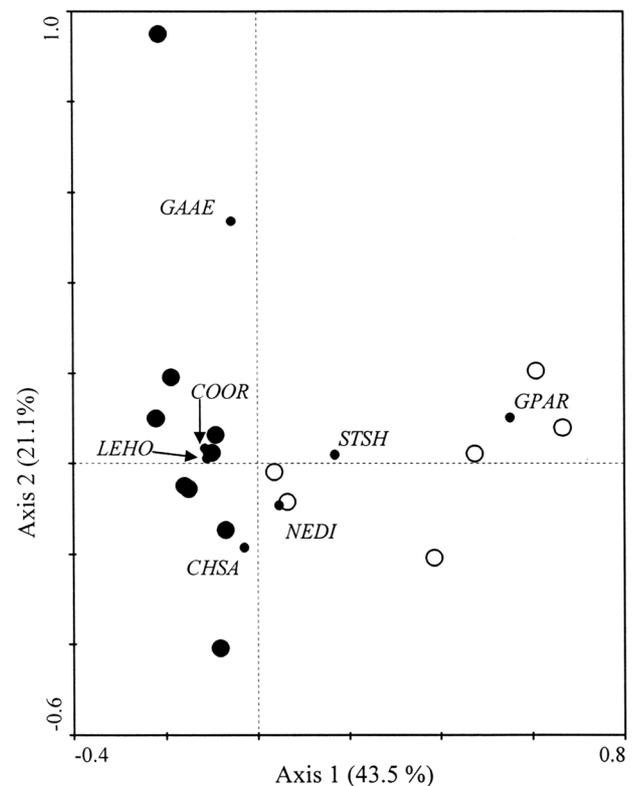

Fig. 4. – Sample (circles) and species (points) position on the space created by the first two axes of the correspondence analysis. Solid circles correspond to the first hydroperiod and open circles to the second hydroperiod. For correspondence between code and species names see Table I.

Fig. 3. – Rain per day for each summer period: 1997 (solid bar), and 1998 (open bar).

Table II. – Mean ± standard error and, in brackets, minimum and maximum values of monthly total precipitation, days of rain per month, and basin water depth for each hydroperiod, atmospheric temperature, water temperature, and salinity. Significant results at a confidence level of 95% are indicated in bold.

	Hydroperiod		
	1997-1998	1998-1999	t-test
Monthly total precipitation (mm)	41.52 ± 10.25 (2.8-103.8)	38.15 ± 7.82 (1.4-93.1)	$t_{19} = 0.264$
Monthly days of rain	7.20 ± 1.31 (2-15)	7.91 ± 0.74 (4-12)	$t_{19} = -0.481$
Atmosphere temperature (ºC)	15.39 ± 1.95 (9.40-24.67)	14.83 ± 1.62 (8.72-23.90)	$t_{19} = 0.220$
Basin water depth (cm)	**83.39 ± 8.25** **(0-109.42)**	**58.56 ± 5.27** **(0-75.5)**	$t_{15} = 2.46$
Water temperature (ºC)	13.75 ± 1.86 (7.35-23.00)	14.77 ± 2.51 (7.23-23.90)	$t_{14} = -0.32$
Salinity (psu)	11.95 ± 1.22 (8.10-17.22)	16.14 ± 1.94 (8.27-22.87)	$t_{14} = -1.83$

	Hydroperiod	
	1997-1998	1998-1999
Benthic assemblage parameters		
Shannon diversity (bits)	0.79 ± 0.14	1.68 ± 0.22
Evenness	0.40 ± 0.09	0.66 ± 0.06
Specific richness (nº of taxa)	4.22 ± 0.36	6.00 ± 0.87
Total abundance (ind · m^{-2})	4885 ± 1028	1327 ± 311

Table III. – Top, Macrobenthic assemblage parameters (Mean ± standard error) for each hydroperiod. Bottom, Comparative of body length in mm (mean ± standard error, and in brackets number of individuals) for each sex and hydroperiod. Month with enough data to carry out the comparison (minimum more than 2 individuals) are shown.

		Hydroperiod		
		1997-1998	1998-1999	
June				*t-Student* test
	Males	3.91 ± 0.62 (28)	3.47 ± 0.37 (9)	$t_{35} = 2.081; p = 0.051$
	Females	3.95 ± 0.88 (43)	3.74 ± 0.79 (23)	$t_{64} = 0.933; p = 0.354$
July				
	Males	3.37 ± 0.43 (19)	3.85 ± 0.56 (18)	$t_{35} = -2.921; p = 0.006$
	Females	3.65 ± 0.58 (35)	4.56 ± 0.82 (38)	$t_{71} = -5.430; p < 0.001$

1931) and *Lekanesphaera hookeri* (Leach, 1814), were also characteristic of this hydroperiod. In contrast, after the severe drought, macrobenthic fauna was dominated by taxa which had low abundances during the first hydroperiod, as *Streblospio shrubsolii* and *Paranais* sp. Also characteristic of this second hydroperiod was the presence of new taxa not found during the first one, such as *Halocladius varians* (Staeger, 1839), *Hydrobia acuta* (Draparnaud, 1805) and *Scatella* spp. While *H. varians*

was found from the middle to the final part of the hydroperiod, *H. acuta* and *Scatella* spp. were found at the beginning of the hydroperiod associated with algal mats. On the other hand, the abundance of the dominant taxa before the severe drought was lower after this event, especially the abundance of *C. orientale*, which was reduced about 20 times (Table I).

During the first hydroperiod, three peaks of *C. orientale* abundance were detected (Fig. 2): the first one in
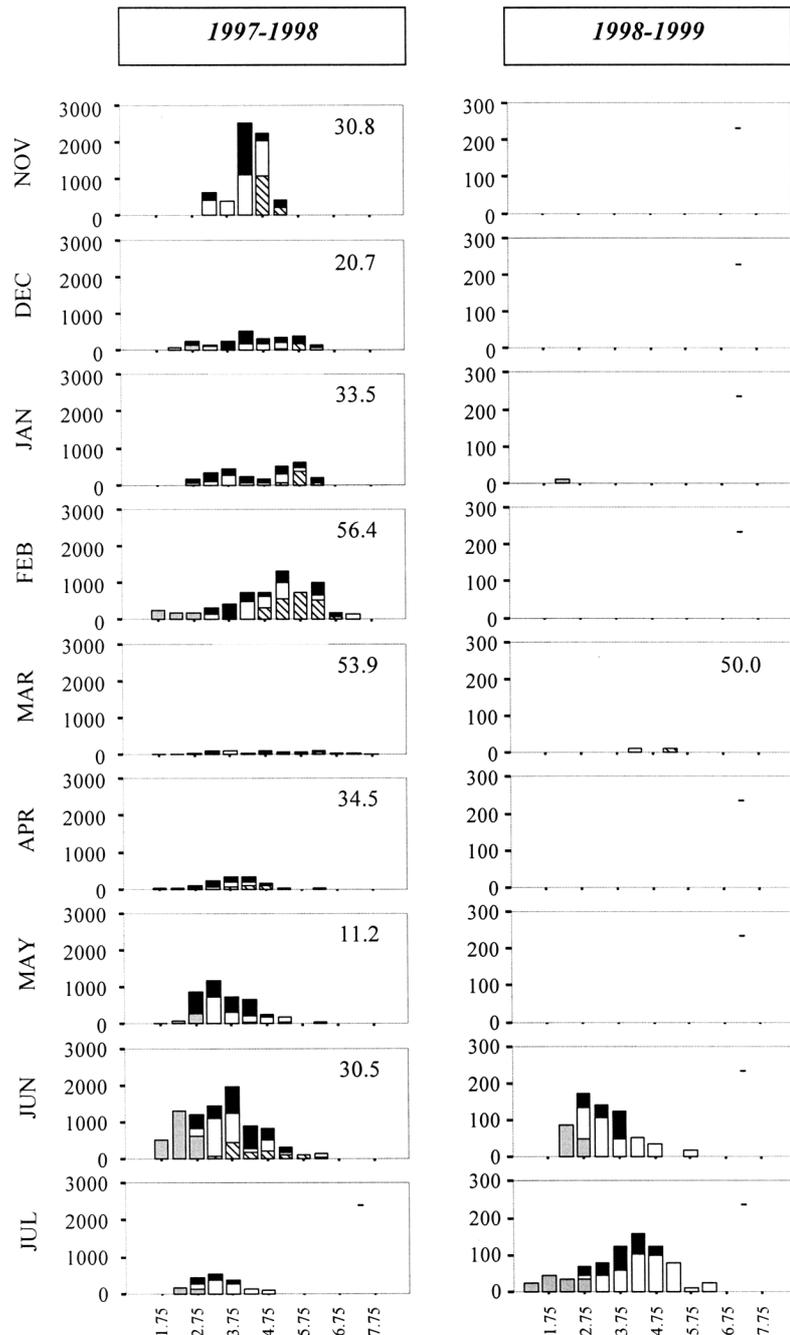

Fig. 5. – Monthly length-frequency histograms of *C. orientale*, showing males (black), non-gravid females (white), gravid females (grated pattern) and juveniles (shaded). Length-classes of animals (mm) are shown on the x-axis, and density (ind·m⁻²) on the y-axis. Numbers inside the graphs indicate percentage of gravid females among total female abundance. The absence of gravid females is indicated with a hyphen (-).
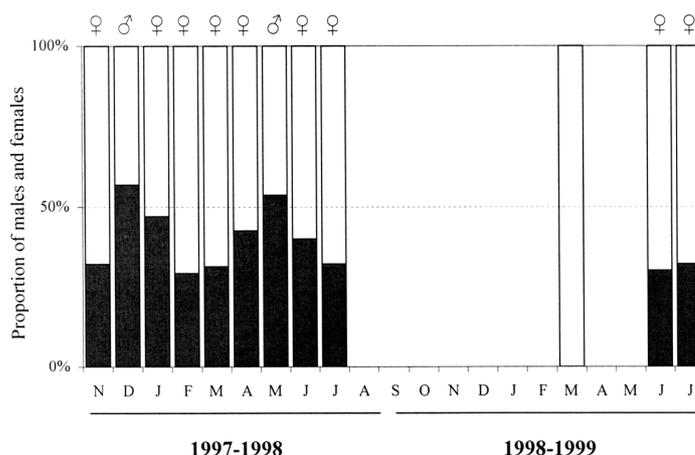
Fig. 6. – Sex ratio (males: females) by month. Sex ratios significantly different from 1:1 ($p < 0.05$) are indicated with the symbol of the dominant sex. The proportion of males (black) and females (white) is shown.

middle autumn (November, with 6200 ind·m^{-2}), the second one in middle winter (February, with 6244 ind·m^{-2}), and the third one in late spring (June, with 8655 ind·m^{-2}). No significant correlation between water depth, salinity, temperature, and *C. orientale* abundance was found (Fig. 2). The structure of the population during these peaks of abundance was different in the distinct periods (Fig. 5). In November, the oversummering population of *C. orientale* had a small range of length classes, with only 5 length-classes represented, and was dominated by individuals from 4 to 5 mm. In contrast, in February and June the number of length-classes was at least double. However, the dominant length-classes were different between February and June. While in February the population was dominated by bigger length-classes (from 4.5 to 6.5 mm), in June it was dominated by smaller ones, most of them corresponding to juvenile forms (from 1.5 to 4 mm). After the severe drought, and until the beginning of summer (June and July), the *C. orientale* population had almost disappeared. Despite the fact that in these two months the abundance was always low (under 1000 ind·m^{-2}), a wide range of length-classes was still found (Fig. 5). Moreover, the abundance of *C. orientale* was significantly different before and after the severe drought ($F_{1,171} = 11.78$; $p = 0.001$), but was not significantly different either among length-classes or among length classes x hydroperiod interaction.

Only in the last month of the hydroperiods (July) significant differences were found on *Corophium* body length before and after the severe drought. The body length of *C. orientale* was significantly larger after the severe drought for both females and males (Table III, bottom). The *Corophium* population of July 1999 was composed of individuals of higher length-classes, while in July 1998 the population was decreasing in number and in body sizes (Fig. 5). However, all the largest individuals were found during the first hydroperiod: the largest female, male, and gravid female, captured during the first hydroperiod, measured 7.8, 6.7 and 7.5 mm, respectively.

During the second hydroperiod the largest female and male measured 6.3 and 4.8 mm respectively, and only a gravid female was captured which measured 5.3 mm.

Although there were gravid females throughout the first hydroperiod, a peak was observed in February and March (Fig. 5), when more than half of the females were gravid. Two main recruitment periods were detected: one in February, and a second one in June. The recruitment periods coincided with an increase of the proportion of gravid females observed in both months (February and June). The population of *C. orientale* was sex-biased in time (Fig. 6). Only 11 months had enough individuals to enable calculating the sex ratio, 9 being dominated by females. In addition, length-classes bigger than 4.5 were

Table IV. – Number of males and females (ind.m^{-2}) in each length-class. Chi square was used to test if sex ratio was significantly different to a 1:1 proportion among length-classes. Significant higher values are shown in bold.

Length-class (mm)	Number of	
	males	females
(1.00-1.50)	-	-
(1.51-2.00)	-	-
(2.01-2.50)	-	-
(2.51-3.00)	**4975**	2141
(3.01-3.50)	6265	**11022**
(3.51-4.00)	7591	**9997**
(4.01-4.50)	**9380**	7560
(4.51-5.00)	2947	**10191**
(5.01-5.50)	2365	**5602**
(5.51-6.00)	891	**3456**
(6.01-6.50)	1091	**2906**
(6.51-7.00)	231	264
(7.01-7.50)	0	511
(7.51-8.00)	0	44

dominated by females, except for the 6.5 to 7.0 mm class, in which no sex was dominant (Table IV).

DISCUSSION

Macrobenthic assemblage

All atmospheric and water parameters considered in this study, except water column depth, were not significantly different between hydroperiods. Thus, the changes on the macrobenthic fauna from one hydroperiod to the other may be mainly attributed to the severe drought occurred in the summer of 1998 and not to an immediate response to salinity fluctuations or temperature values. The severe drought affected both relative abundances and the taxonomic composition of macrobenthic fauna and, as a consequence, its diversity values. In accordance to this, in lotic systems a drought period has similar community responses: a reduction of macrobenthic densities and a decrease of the relative abundance of the more abundant species (Boulton *et al.* 1992). Additionally, low macroinvertebrate abundances during the hydroperiods with lower water column depth have also been observed in lentic systems of temperate climatic areas (Leeper & Taylor 1998), as is the case in our study. A decrease in diversity values has been reported in a Mediterranean coastal lagoon coinciding with its partial drying out (Kevrekidis *et al.* 2000). In contrast, in our study, diversity increased after the severe drought. However, in the cited study diversity was calculated during the severe drought, when only 1/5 of the lagoon had water, and in our case the diversity values corresponded to a period of 11 months after the severe drought, when the benthic fauna was under a recovering process.

The increase in diversity at our site was due to an increase of evenness, because after the severe drought a reduction in the abundance of the dominant taxa (*Corophium orientale* and *Nereis diversicolor*), which are poorly adapted to survive dessiccation (Wiggins *et al.* 1980), was observed. Moreover, changes in the structure of the macrobenthic community after the severe drought were also shown by changes of the dominant taxa which had different life strategies. For instance, after the severe drought and until the reappearance of *C. orientale* at the end of the hydroperiod, the dominant taxa were small polychaeta and oligochaeta, which are described as opportunistic taxa (e.g. Kube & Powilleit 1997, Löhlein 1999). This succession pattern is similar to that observed in a Mediterranean lagoon after an eutrophic crisis (Tagliapietra *et al.* 1998).

In summary, although Mediterranean fauna of coastal lagoons is adapted to highly fluctuating environmental conditions (Guelorget & Perthuisot 1983), severe droughts have drastic effects on population dynamics and community structure in permanent waters. Benthic communities of these systems are characterised by a high dominance (e.g. Arias & Drake 1994) and, as a consequence, this type of disturbances causes a decrease of the dominant species and an increase in community diversity.

Corophium orientale population

The density peaks of the *C. orientale* population before the severe drought was comparable to those of this species in an eastern Mediterranean population observed at the shallower innermost part of Monolimni Lagoon (Kevrekidis 2005). Two of the three density peaks observed at the Empordà salt marshes were coincident with the recruitment periods (February and June of 1998), while the November peak was explained by the oversummer remaining population. The relation between abundance peaks and recruitment periods was also found in the innermost part of the Monolimni lagoon (Kevrekidis 2005). Low salinity and temperature have been related to low abundance in other *Corophium* species populations, probably causing mortality and/or emigration. The minimum salinity and temperature values registered at the study site were higher than those reported to be problematic for *Corophium* populations' subsistence (Kevrekidis 2004b and references therein). Hence, abundance fluctuations of *C. orientale* in Empordà salt marshes could be explained by their life cycle, since no relation has been found among abundance fluctuations and some water parameter fluctuations (as temperature, salinity or water depth). However, another possible cause for the decrease of the *Corophium* population is that oversummering individuals undergo environmental stress due to high reduction of water surface, since *Corophium* species are known to be sensitive to hypoxia and sulphide episodes (Gamenick *et al.* 1996).

The severe drought had not an influence on the *C. orientale* sex ratio, since females were the dominant sex in time and in length-classes. The female dominance is in accordance with existing data on *C. orientale* (Kevrekidis 2005), which, similarly to our observations, also showed that after 6.75 mm all individuals were females. The breeding peaks of *C. orientale* in Empordà wetlands and Monolimni Lagoon are not coincident. Moreover, in the salt marshes of Empordà wetlands the percentage of breeding females is higher than at Monolimni Lagoon, where the highest number of gravid females was at most 20% of total females. The highest breeding magnitude observed in Empordà salt marshes could be explained by the fact that at Monolimni Lagoon salinity values are lower, varying between 0.3 and 5.6 psu, while in Empordà salt marshes varied between 8.1 and 17.2 psu. This will be in accordance with a negative effect of low salinity values on the magnitude of breeding (Kevrekidis 2005). On the other hand, the number of cohorts of *C. orientale* observed during the first hydroperiod is similar to those observed at the innermost part of Monolimni

Lagoon, which is not surprising due to their similar latitudinal situation (aprox. 42° N in Empordà salt marshes and 41° N in Monolimni lagoon), and to their similar water temperature (mean water temperature from February to June: 15.8 ℃ in Empordà salt marshes and 14.6 ℃ in Monolimni lagoon). It is worth pointing out that, coinciding with higher salinity values, sizes of males, females and gravid females are smaller than those of Monolimni Lagoon. This is in accordance with the negative relationship found between other crustacean species body size and salinity (e.g. Dana *et al.* 1993)

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