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## Fish assemblages associated with *Cymodocea nodosa* and *Caulerpa prolifera* meadows in the shallow areas of the Mar Menor coastal lagoon

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### ABSTRACT

#### Fish assemblages associated with *Cymodocea nodosa* and *Caulerpa prolifera* meadows in the shallow areas of the Mar Menor coastal lagoon

The present study investigates several biological parameters of the fish assemblages, mainly juvenile fishes and adults of small sized species, associated with the seagrass *Cymodocea nodosa* and the macroalga *Caulerpa prolifera* in the shallow littoral areas of the Mar Menor coastal lagoon. Results showed that *C. nodosa* seagrass meadows have a much higher number of fish species and considerably greater fish abundance and biomass than *Ca. prolifera* meadows. Other community variables (diversity and evenness) did not show significant differences between both meadows.

**Key words:** Coastal lagoon, shallow habitats, juvenile fish, Mugilidae, Syngnathidae.

### RESUMEN

#### Comunidades de peces asociadas a praderas de *Cymodocea nodosa* y *Caulerpa prolifera* en las zonas someras de la laguna costera del Mar Menor

En el presente estudio se investigaron diversos parámetros biológicos de las comunidades de peces, principalmente peces juveniles y adultos de especies de talla pequeña, asociadas a las praderas de la fanerógama acuática *Cymodocea nodosa* y la macroalga *Caulerpa prolifera* en las zonas someras litorales de la laguna costera del Mar Menor. Los resultados mostraron que las praderas de *C. nodosa* presentaron un mayor número de especies y una mayor abundancia y biomasa de peces que las praderas de *Ca. prolifera*. Otras variables de la comunidad (diversidad y equitatividad) no mostraron diferencias significativas entre ambos tipos de praderas.

**Palabras clave:** Laguna costera, hábitats someros, peces juveniles, Mugilidae, Syngnathidae.

### INTRODUCTION

Coastal lagoons are usually among those marine habitats with highest biological productivity providing abundant food resources and functioning as nursery areas for marine fish populations (Pérez-Ruzafa *et al.*, 2004; Franco *et al.*, 2006; Ribeiro *et al.*, 2006). In addition, most lagoons are subjected to anthropogenic disturbances that lead to changes in the composition and distribution of flora and fauna species (Gamito *et al.*, 2005).

The Mar Menor is a hypersaline coastal lagoon located in a semiarid region in the south-east of the Iberian Peninsula. Since the 1970's it has suffered strong environmental changes following widening of the connecting channels that have caused a decrease in salinity from 50 ‰-52 ‰ to the present levels. Moreover, regular and intermittent watercourses flow into the lagoon, draining a large intensive agricultural area and leading to an important input of agrochemicals (Pérez-Ruzafa *et al.*, 2005). Its coastline is also

densely populated and affected by a variety of human activities (urban development, the construction of pleasure marinas, artificial beaches, etc.), although there are still some associated wetlands (industrial salt ponds and natural marshlands) that have an important ecological and natural value and which have been given national and international protection status (Martínez *et al.*, 2005). In addition, recent studies dealing with the Mar Menor coastal lagoon fish assemblages pointed to the importance of shallow littoral areas as nursery habitats for juvenile fish as well as adult individuals of small sized species (Oliva-Paterna *et al.*, 2006).

Environmental degradation has led to changes in the distribution of the benthic macrophytes of the lagoon. Before 1970, its bottom was covered principally by scattered meadows of *Cymodocea nodosa* (Ucria) Ascherson and *Zostera marina* Linnaeus (Pérez-Ruzafa *et al.*, 2005) sea grasses. At the present time, a dense monospecific meadow of the invasive macroalga *Caulerpa prolifera* (Forsskal) Lamouroux covers more than 80 % of the bottom, and *C. nodosa* is restricted to very small patches in the shallowest areas of the lagoon.

The spread of *Ca. prolifera* has created several negative effects on the sediment characteristics, such an increase in its organic matter content and low oxygen concentration, and the modification of fish assemblages in the lagoon (Lloret *et al.*, 2005; Pérez-Ruzafa *et al.*, 2005; Pérez-Ruzafa *et al.*, 2006).

Therefore, the aim of this work was to study the differences in several biological parameters of the fish assemblages, mainly juvenile fishes and adults of small species, between areas with homospecific meadows of *Caulerpa prolifera* and *Cymodocea nodosa* located in the shallow and littoral areas of the lagoon.

## MATERIALS AND METHODS

### Study area

The present study was carried out in the shallow littoral areas (maximum depth  $\leq 100$  cm) of the Mar Menor coastal lagoon. It is one of the largest

coastal lagoons in the Mediterranean region and Europe, with a surface area of 135 km<sup>2</sup>, an average depth of 4 m and it is separated from the Mediterranean Sea by a 22 km long sand bar with three narrow channels connecting it with the open sea. The lagoon shows a salinity range of 39 ‰–45 ‰ and the temperature varies from 10°C in winter to 32°C in summer.

Sampling sites are characterised by soft substrates (principally muddy and sandy bottoms) and isolated patches of submerged vegetation, mainly meadows of the seagrass *Cymodocea nodosa* and the macroalga *Caulerpa prolifera*.

### Sampling methods

The sampling was carried out on a seasonal basis, during the summer (July) and autumn (October) of 2003, and the winter (February) and spring (May) of 2004.

Samples were collected using a 10 m long beach seine (2 mm mesh size) in the shallow areas of the lagoon with homospecific meadows of *C. nodosa* and *Ca. prolifera*. The sampling unit (a haul) consisted of the area swept (160 m<sup>2</sup>) by the beach seine. We obtained a total of 44 sampling units during the study period, 26 in the *C. nodosa* meadows (8 in summer, 6 in autumn, 10 in winter and 2 in spring) and 19 in the *Ca. prolifera* meadows (8 in summer, 2 in autumn, 7 in winter and 2 in spring).

All fish collected per haul were preserved in 7 % formaldehyde, identified at species level in the laboratory according to Whitehead *et al.* (1986) and Arias & Drake (1990) and classified in relation to their vertical distribution adapted from Elliot & Dewailly (1995): (B) benthic and (EB) epibenthic species.

The total relative abundance, total relative biomass, benthic species relative abundance, benthic species relative biomass, epibenthic species relative abundance and epibenthic species relative biomass were determined for the fish assemblage at each sampling unit. These were respectively expressed as catch per unit of effort (CPUE) and biomass per unit of effort (BPUE):

CPUE = fish number/haul area covered (160 m<sup>2</sup>)

**Table 1.** Mean cover and volume ( $\pm$  S.E.) for *Cymodocea nodosa* and *Caulerpa prolifera* meadows during the study period. Cobertura y volumen promedio ( $\pm$  E.S.) de las praderas de *Cymodocea nodosa* y *Caulerpa prolifera* durante el periodo de estudio.

Season	<i>Cymodocea nodosa</i>		<i>Caulerpa prolifera</i>	
	Cover $\pm$ S.E.	Volume $\pm$ S.E.	Cover $\pm$ S.E.	Volume $\pm$ S.E.
Summer	75.00 $\pm$ 5.67	3.56 $\pm$ 0.22	48.75 $\pm$ 9.53	2.75 $\pm$ 0.28
Autumn	37.50 $\pm$ 10.39	1.42 $\pm$ 0.20	62.50 $\pm$ 17.50	2.00 $\pm$ 0.50
Winter	45.95 $\pm$ 8.21	2.20 $\pm$ 0.26	51.43 $\pm$ 7.05	2.29 $\pm$ 0.21
Spring	47.50 $\pm$ 12.50	2.00 $\pm$ 0	17.50 $\pm$ 3.54	2.00 $\pm$ 0

BPUE = fish biomass (g)/haul area covered (160 m<sup>2</sup>)

Each sampling unit was characterized by environmental variables related to submerged vegetation structure: submerged vegetation cover (%) and submerged vegetation volume. The assessment of these variables was made visually, the first recorded as the area percentage covered by submerged vegetation at each haul and the second as an ordinate categorical variable from 0 (low density of meadows) to 5 (high density of meadows).

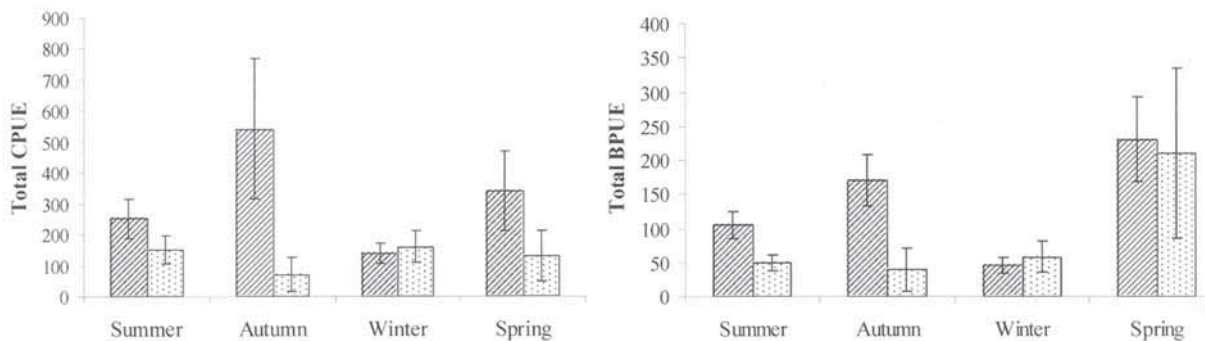
In addition, the species richness ( $S$ ), Shannon diversity ( $H' = -\sum P_i \ln(P_i)$ ) and Pielou's evenness ( $J' = H' / \ln S$ ), describing the structure of fish assemblage, were calculated for each sampling unit.

### Statistical analyses

Analysis of variance (one way ANOVA) was used to test differences in the cover and volume of the meadows.

A two-way factorial analysis of variance (ANOVA) was used to test for differences in the total CPUE, total BPUE, benthic species CPUE, benthic species BPUE, epibenthic species CPUE, epibenthic species BPUE, species richness, Shannon diversity and Pielou's evenness of the fish assemblages. The independent variables were vegetation species (*C. nodosa* and *Ca. prolifera*) and season (summer, autumn, winter and spring), both considered as fixed factors (Quinn & Keough 2002). Analysis was performed on the transformed data ( $\ln(x + 1)$ ) with significance level of  $P < 0.05$ .

The statistical analyses were performed using the SPSS<sup>®</sup> statistical package.

**Figure 1.** Mean relative abundance (CPUE  $\pm$  S.E.) and mean relative biomass (BPUE  $\pm$  S.E.) of all fish species over *Cymodocea nodosa* (▨) and *Caulerpa prolifera* (▩) meadows during the study period. Abundancia relativa promedio (CPUE  $\pm$  E.S.) y biomasa relativa promedio (BPUE  $\pm$  E.S.) del total de especies de peces en las praderas de *Cymodocea nodosa* (▨) y *Caulerpa prolifera* (▩) durante el periodo de estudio.

**Table 2.** List of families and species caught over *Cymodocea nodosa* and *Caulerpa prolifera* meadows in the Mar Menor coastal lagoon, mean relative abundance (CPUE), mean relative biomass (BPUE), and vertical distribution classification. *Listado de las familias y especies capturadas sobre las praderas de Cymodocea nodosa y Caulerpa prolifera en la laguna costera del Mar Menor, abundancia relativa promedio (CPUE), biomasa relativa promedio (BPUE), y clasificación en función de su distribución vertical.*

Family	Species	<i>Cymodocea nodosa</i>		<i>Caulerpa prolifera</i>		Vertical distribution
		CPUE	BPUE	CPUE	BPUE	
Anguillidae						
	<i>Anguilla anguilla</i>	0	0	0.05	0.68	B
Atherinidae						
	<i>Atherina boyeri</i>	30.65	13.00	28.26	16.30	EB
Bleniidae						
	<i>Lipophrys dalmatinus</i>	0.08	0.05	0.53	0.15	B
	<i>Salaria pavo</i>	4.19	5.45	5.00	4.22	B
Callionymidae						
	<i>Callionymus pusillus</i>	0.23	0.17	0	0	B
Cyprinodontidae						
	<i>Aphanius iberus</i>	19.00	4.10	1.21	0.26	EB
Gobiidae						
	<i>Pomatoschistus marmoratus</i>	53.77	17.38	38.63	7.28	B
	<i>Gobius cobitis</i>	1.62	4.86	0.79	1.53	B
	<i>Gobius paganellus</i>	0.19	0.30	0	0	B
	<i>Gobius niger</i>	0.89	1.90	0.16	0.62	B
Labridae						
	<i>Symphodus cinereus</i>	0.73	3.91	0.32	0.51	EB
Moronidae						
	<i>Dicentrarchus labrax</i>	0.15	0.02	0	0	EB
	<i>Dicentrarchus punctatus</i>	0.04	0.29	0.21	0.32	EB
Mugilidae						
	<i>Liza aurata</i>	58.19	20.01	29.42	13.91	EB
	<i>Liza saliens</i>	79.85	21.38	14.00	17.21	EB
	<i>Liza ramado</i>	0.38	0.35	0.58	0.10	EB
	<i>Chelon labrosus</i>	0.19	0.25	0	0	EB
	<i>Mugil cephalus</i>	3.96	0.60	0	0	EB
Soleidae						
	<i>Solea vulgaris</i>	0	0	0.05	0.12	B
Sparidae						
	<i>Diplodus puntazzo</i>	1.92	1.00	0.21	1.05	EB
	<i>Diplodus sargus</i>	1.50	0.09	0	0	EB
	<i>Sparus aurata</i>	3.50	0.86	20.58	3.16	EB
	<i>Sarpa salpa</i>	0.54	0.52	0	0	EB
Syngnathidae						
	<i>Hippocampus guttulatus</i>	0.08	0.03	0.05	0.02	EB
	<i>Syngnathus abaster</i>	19.89	5.30	4.16	0.83	EB
	<i>Syngnathus typhle</i>	0.15	0.20	0	0	EB
Epibenthic species		220.72	71.89	94.00	39.20	
Benthic species		60.97	30.11	46.4	14.31	
Total		281.69	102.00	140.4	53.51	
Total species		24		18		

## RESULTS

The seasonal fluctuation of the cover and volume of *Cymodocea nodosa* and *Caulerpa prolifera* meadows is shown in Table 1. In *C. prolifera* meadows, no significant differences were observed through the study period (ANOVA cover,  $F=1.518$ ,  $P=0.251$ ; ANOVA volume,  $F=1.229$ ,  $P=0.334$ ), although higher cover and volume were recorded in summer and autumn, respectively. On the other hand, *C. nodosa* showed significant seasonal differences (ANOVA cover,  $F=3.773$ ,  $P<0.05$ ; ANOVA volume,  $F=3.773$ ,  $P<0.001$ ). Higher cover and volume was recorded in summer and lower values in winter.

The overall fish species abundance and biomass were higher in the *C. nodosa* than *Ca. prolifera* meadows (Table 2), with significant differences in mean total CPUE and mean total BPUE between *C. nodosa* and *Ca. prolifera* meadows (Table 3 and Fig. 1). There was also a significant seasonal difference in mean total BPUE, which was higher during spring for both

meadow species (Table 3 and Fig. 1).

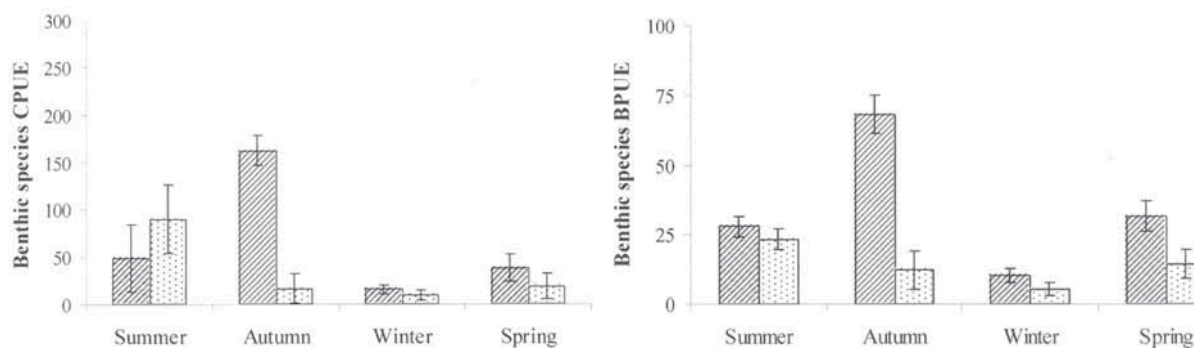
Overall abundance and biomass of the benthic species were higher in the *C. nodosa* than *Ca. prolifera* meadows (Table 2). Their mean CPUE and mean BPUE were also significantly higher in the *C. nodosa* meadows (Table 3 and Fig. 2).

There was also a significant seasonal variation in benthic species abundance and biomass, both being higher in the *C. nodosa* meadows in autumn and the *Ca. prolifera* meadows in summer (Table 3 and Fig. 2).

With regard to epibenthic species, the overall abundance and biomass were higher in the *C. nodosa* meadows (Table 2). Although no significant differences were obtained for mean epibenthic species BPUE, their mean CPUE was significantly higher in the *C. nodosa* than *Ca. prolifera* meadows (Table 3 and Fig. 3). In addition, there was a significant effect of season on mean epibenthic species BPUE (Table 3 and Fig. 2). Of note are the higher abundance and biomass of the mugilidae species *Liza aurata* and *L. saliens*, the syngnathidae

**Table 3.** Results of two-way ANOVA tests for differences between seasons and meadow species in total CPUE and BPUE, benthic species CPUE and BPUE, epibenthic species CPUE and BPUE, species richness (S), Shannon diversity ( $H'$ ) and Pielou's evenness ( $J'$ ). *Resultados del test ANOVA de dos vías empleado para testar las diferencias entre las estaciones del año y las especies de pradera en las CPUE y BPUE totales, CPUE y BPUE de las especies bentónicas, CPUE y BPUE de las especies epibentónicas, riqueza de especies (S), diversidad ( $H'$ ) y equitatividad ( $J'$ ).*

Effects	df	Total abundance		Total biomass		Benthic species abundance	
		F	P	F	P	F	P
Season	3	0.260	0.854	5.001	< 0.01	4.504	< 0.01
Meadow species	1	7.505	< 0.01	4.870	< 0.05	4.831	< 0.05
Season x Meadow species	3	1.994	0.132	1.800	0.164	2.431	0.081
Effects	df	Benthic species biomass		Epibenthic species abundance		Epibenthic species biomass	
		F	P	F	P	F	P
Season	3	8.85	< 0.001	0.824	0.489	3.464	< 0.05
Meadow species	1	5.387	< 0.05	6.026	< 0.05	2.804	0.102
Season x Meadow species	3	1.709	0.182	1.822	0.160	1.783	0.167
Effects	df	S		$H'$		$J'$	
		F	P	F	P	F	P
Season	3	3.341	< 0.05	2.347	0.089	0.854	0.474
Meadow species	1	11.177	< 0.01	0.439	0.512	0.444	0.509
Season x Meadow species	3	1.078	0.370	2.600	0.067	2.542	0.071



**Figure 2.** Mean relative abundance (CPUE  $\pm$  S.E.) and mean relative biomass (BPUE  $\pm$  S.E.) of benthic fish species over *Cymodocea nodosa* (▨) and *Caulerpa prolifera* (▩) meadows during the study period. *Abundancia relativa promedio* (CPUE  $\pm$  E.S.) y *biomasa relativa promedio* (BPUE  $\pm$  E.S.) de las especies de peces bentónicos en las praderas de *Cymodocea nodosa* (▨) y *Caulerpa prolifera* (▩) durante el periodo de estudio.

species *Syngnathus abaster* and the threatened cyprinodontidae species *Aphanius iberus* in the *C. nodosa* meadows, while *Sparus aurata* abundance and biomass were higher in the *Ca. prolifera* meadows (Table 2).

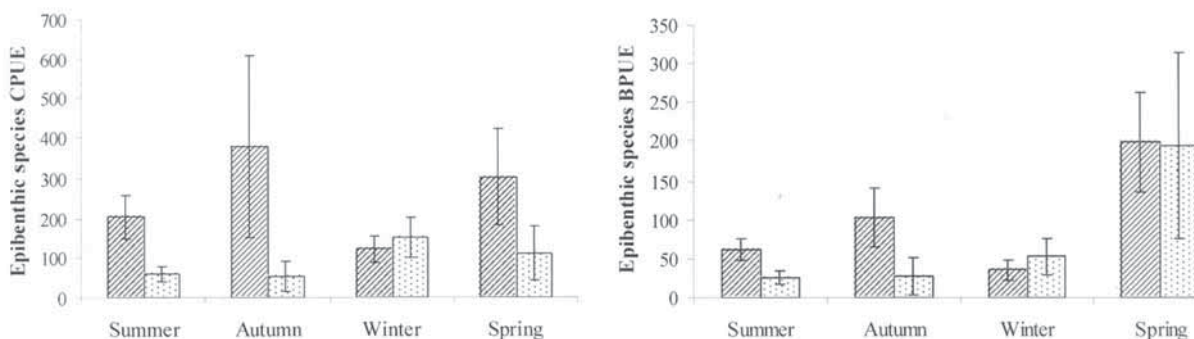
The total number of species and mean species richness were higher in the *C. nodosa* than in *Ca. prolifera* meadows (Tables 2 and 3). In addition, there was a significant effect of season on mean species richness; which was higher during spring in the *C. nodosa* and during autumn in the *Ca. prolifera* meadows (Table 3 and Fig. 4).

The Shannon diversity index ( $H'$ ) and Pielous' evenness ( $J'$ ) did not differ between meadow species and seasons (Table 3 and Fig. 4).

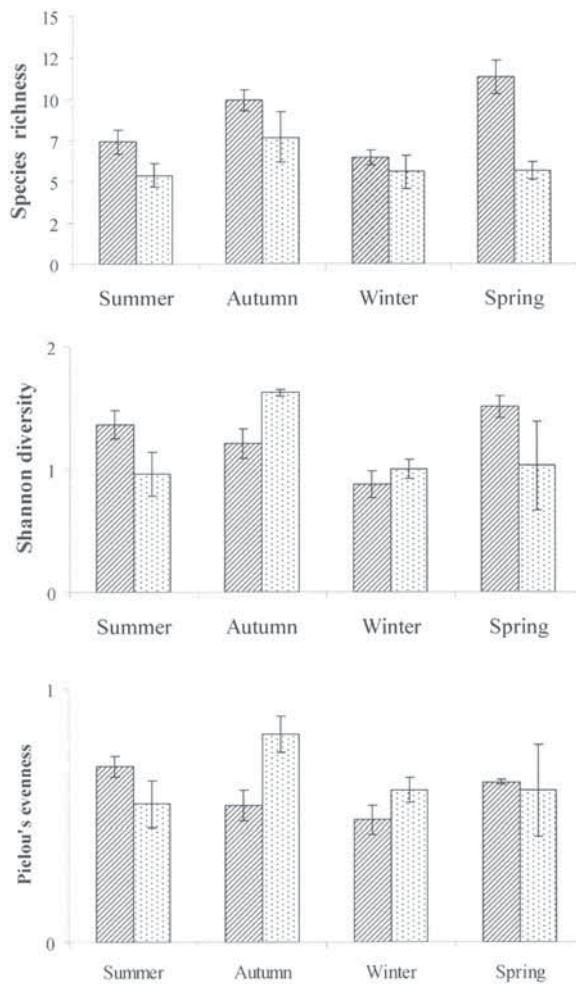
## DISCUSSION

Many studies world-wide have demonstrated that vegetated habitats often support a greater diversity and abundance of juvenile fish (Guidetti, 2000; Paterson & Whitfield, 2000; Lazzari *et al.*, 2003; Nakamura & Mitsuhiko, 2004; Ribeiro *et al.*, 2006). This pattern is due to the high structural complexity and productivity of vegetated systems that provide protection against predators and abundant food resources (i.e. higher invertebrate prey density) (Bell & Pollard, 1989).

The vegetated habitats sampled in the present study were undoubtedly important areas for fish assemblages, especially for juvenile fishes. A to-



**Figure 3.** Mean relative abundance (CPUE  $\pm$  S.E.) and mean relative biomass (BPUE  $\pm$  S.E.) of epibenthic fish species over *Cymodocea nodosa* (▨) and *Caulerpa prolifera* (▩) meadows during the study period. *Abundancia promedio* (CPUE  $\pm$  E.S.) y *biomasa promedio* (BPUE  $\pm$  E.S.) de especies de peces epibentónicos en las praderas de *Cymodocea nodosa* (▨) y *Caulerpa prolifera* (▩) durante el periodo de estudio.



**Figure 4.** Mean species richness ( $\pm$  S.E.), mean diversity, ( $\pm$  S.E.) and mean evenness ( $\pm$  S.E.) over *Cymodocea nodosa* (▨) and *Caulerpa prolifera* (▩) meadows during the study period. *Riqueza de especies promedio* ( $\pm$  E.S.), *diversidad promedio* ( $\pm$  E.S.) y *equitatividad promedio* ( $\pm$  E.S.) en las praderas de *Cymodocea nodosa* (▨) y *Caulerpa prolifera* (▩) durante el periodo de estudio.

tal of 26 fish species were recorded in the vegetated shallow areas of the Mar Menor during the study period, which represents 58 % of the fish species cited in the shallow littoral areas of the lagoon (Oliva-Paterna *et al.*, 2006). Moreover, 73 % of the species caught are among the species that form the main targets for commercial fisheries in the lagoon and adjacent coastal areas, or represent species of conservation interest.

In addition, we demonstrated that the fish assemblage in the *C. nodosa* seagrass meadows

has a much higher number of species and considerably greater fish abundance and biomass than *Ca. prolifera* meadows. These results suggest that *C. nodosa* meadows offered better conditions for the settlement of juvenile and adult fishes, probably due to differences in the structural complexity and food availability between seagrass and macroalgal habitats.

It is well documented that *Caulerpa* species produce repulsive and toxic secondary metabolites, like caulerpenine, against grazer and epiphytic organisms (Sánchez-Moyano *et al.*, 2001; Jung *et al.*, 2002; Davis *et al.*, 2005). In addition, the settlement of dense *Ca. prolifera* meadows produces important and negative changes in the sediment characteristics through the accumulation of organic matter and the later appearance of anoxic conditions and the production of toxic acid volatile sulphides (Lloret *et al.*, 2005; Pérez-Ruzafa *et al.*, 2005). Despite such negative effects, several studies have demonstrated that *Ca. prolifera* meadows support substantial invertebrate macrofaunal communities although such communities are not as rich and structured as in the seagrass meadows (Sánchez-Moyano *et al.*, 2001; Rueda & Salas, 2003; López *et al.*, 2006).

On the other hand, some authors remarked on the importance of *C. nodosa* seagrass with regard to its higher abundance and diversity of invertebrate fauna (Sánchez-Jerez *et al.*, 1999; Marín-Guirao *et al.*, 2005).

It is possible that, due to the higher density of *Ca. prolifera* meadows compared with the scarce seagrass meadows of *C. nodosa*, fish may not be able to obtain food so successfully; in addition, the availability of space for fish may be reduced. This hypothesis is consistent with the conclusions presented by several authors comparing other seagrass species, who observed differences in fish abundance and species composition related with changes in the structural architecture of the seagrass (Guidetti, 2000; Guidetti & Bussotti, 2000; MacArthur & Hyndes, 2001; Hyndes *et al.*, 2003).

It is interesting to note the differences observed in the abundance and biomass of *Aphanius iberus*. This endangered species shows preference for vegetated habitats which are very important for its reproduction and feeding

(Oliva-Paterna *et al.*, 2006). The results obtained highlight that *C. nodosa* seagrass meadows offered much more favourable conditions for the settlement of *A. iberus*.

In the same way, patterns in habitat preferences of syngnathidae species, like *S. abaster*, are related with their morphology and foraging strategy (Kendrick & Hyndes, 2003; Curtis & Vincent, 2005). Our results suggest that *S. abaster* is morphologically better adapted to the sparse and narrower leaves of *C. nodosa* since its abundance and biomass were higher in this seagrass species.

It is to note the higher abundance and biomass of *Liza aurata* and *L. saliens* in the *C. nodosa* than in *Ca. prolifera* meadows. This situation was probably related with their foraging strategy, which consists of foraging on detritus and benthic invertebrates (Fernández-Delgado *et al.*, 2000; Verdiell-Cubedo *et al.*, 2007). The higher density of the *Caulerpa* meadow and its negative effects on the sediment characteristics could negatively affect the foraging effectiveness of these Mugilidae species. In fact, the spread of *Ca. prolifera* has been considered one of the causes of the strong reduction in Mugilidae fisheries in the Mar Menor coastal lagoon (Pérez-Ruzafa & Marcos, 1987).

Finally, the seasonal differences observed for the mean cover and volume of the *C. nodosa* and *Ca. prolifera* meadows seems to be consistent with the typical dynamics of these species, which strongly respond to seasonal forces (Terrados & Ros, 1992; Sánchez-Moyano *et al.*, 2001; Agostini *et al.*, 2003). In this sense, the significant seasonal variations of the benthic fish fauna (CPUE and BPUE), epibenthic species BPUE and species richness could be affected by the marked annual dynamics of the above-ground compartment of such meadow species (Tuya *et al.*, 2006), apart from the seasonality of the breeding and juvenile fish recruitment periods.

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