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Characterisation of the nursery areas for YOY Sparidae fish species in a Mediterranean coastal lagoon (SE Iberian Peninsula)

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Resumen

Caracterización de las zonas de alevinaje de los juveniles de espáridos en una laguna costera Mediterránea (SE Península Ibérica).

El presente trabajo investiga la variación espacial de la abundancia total de juveniles de la familia Sparidae (*Sparus aurata, Sarpa salpa, Diplodus puntazzo* and *D. sargus sargus*) entre 13 localidades de muestreo situadas en las zonas someras litorales de la laguna costera del Mar Menor. El análisis de regresión múltiple mostró que tanto el volumen como el recubrimiento de la vegetación subacuática afectaron de forma positiva a la abundancia de juveniles de espáridos. Este patrón parece estar relacionado con el grado de alteración de la orilla ya que aquellas localidades con presencia de playas artificiales presentaron un escaso desarrollo de las praderas de vegetación sumergida y, por tanto, una menor abundancia de juveniles de espáridos.

Palabras clave: Mar Menor, Zonas someras, Peces juveniles, Vegetación sumergida, Perturbaciones antropogénicas

Abstract

The present study investigates the spatial variation in the total abundance of YOY Sparidae fish species (*Sparus aurata, Sarpa salpa, Diplodus puntazzo* and *D. sargus sargus*) between 13 sampling sites located in littoral and shallow areas of the Mar Menor coastal lagoon. A stepwise multiple regression model indicated that submerged vegetation volume and submerged vegetation cover had a positive effect and accounted for most of the variation in YOY Sparidae abundance between sampling sites. This abundance pattern also seemed to be related with the shoreline development, the more altered and artificial beaches (due to anthropogenic disturbances) presenting scarce submerged vegetation development with a corresponding low abundance of YOY Sparidae fish species.

Key words: Mar Menor, Shallow areas, Juvenile fish, Submerged vegetation, Anthropogenic disturbances

Introduction

Shallow inshore habitats of coastal lagoons and estuaries have demonstrated their value as fish nursery habitats (Malavasi et al. 2004, Franco et al. 2006, Ribeiro et al. 2006). Information on the habitat requirements of young-of-the-year fish (YOY; Fish produced from the current year's spawnings) in these

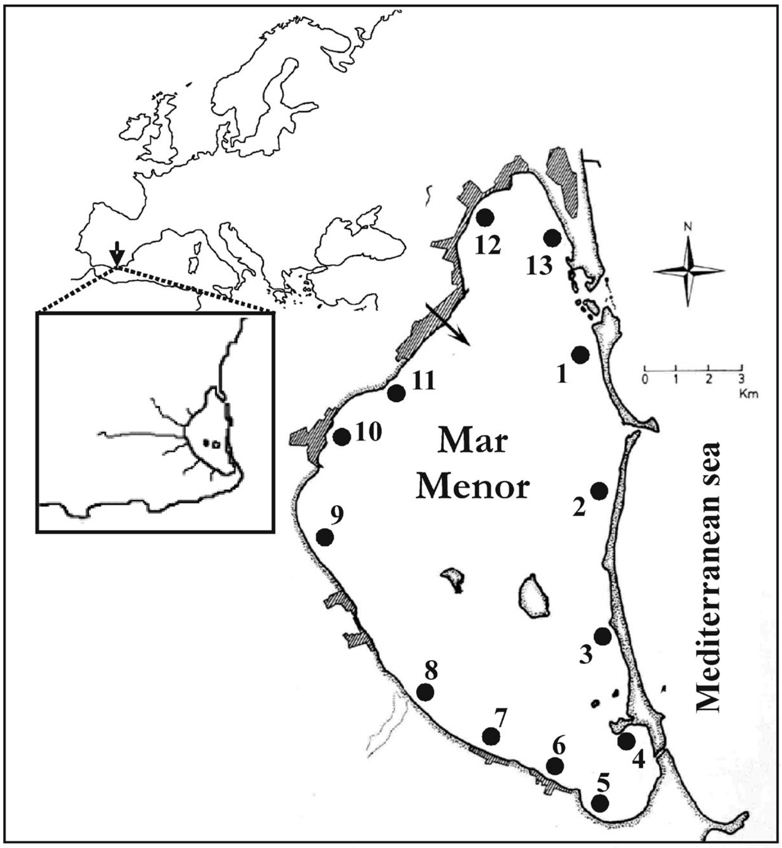

Figure 1. Map of the Mar Menor coastal lagoon and location of sampling sites.
Figura 1. Mapa de la laguna costera del Mar Menor y situación de las localidades de muestreo.

areas is important because it provides a valuable tool for management and conservation of these valuable habitats which are essential for marine fish populations (Langton et al. 1996).

The Mar Menor is a hypersaline coastal lagoon located in a semiarid region in the south-east of the Iberian Peninsula (Fig. 1). It is one of the largest coastal lagoons in the Mediterranean region and Europe, with a surface area of 135 km^2 and an average depth of 4 m. It is separated from the Mediterranean Sea by a 22 km-long sand strip 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 ºC in winter to 32 ºC in summer. Its bottom is principally covered by dense meadows of the invasive macroalga *Caulerpa prolifera*, although shallow areas are covered by meadows of *Cymodocea nodosa* (Pérez-Ruzafa et al. 2005).

Since the 1970's the Mar Menor has suffered severe 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 (Velasco et al. 2006). 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 international and national protection status (Martínez et al. 2005).

The lagoon supports important commercial fisheries, principally of Sparidae, Mugilidae and Atherinidae species (Andreu-Soler et al. 2003, Pérez-Ruzafa et al. 2004). Its shallow zones provide important nursery habitats for YOY fish species, including those that form the main targets for commercial fisheries. Sparidae represents the most diverse family, and include a total of nine species: *Sparus aurata*, *Diplodus sargus sargus*, *Diplodus puntazzo*, *Diplodus vulgaris*, *Diplodus annularis*, *Diplodus cervinus*, *Boops boops* and *Sarpa salpa*, all of commercial interest (Oliva-Paterna et al. 2003, 2006).

The study of shallow littoral areas of coastal lagoons and estuaries as YOY recruitment and refuge grounds for fishery species is an important objective for management programmes and fisheries enhancement (Pihl et al. 2002).

Therefore, the aim of this work was 1) to examine the spatial differences in the abundance of YOY Sparidae fish species between sampling sites located in littoral and shallow areas of the Mar Menor coastal lagoon and 2) to establish the relationship between such abundance and several environmental (physico-chemical and biological) variables.

Materials and methods

Study area

The catches were carried out during April 2004, when YOY fish of Sparidae species were abundant in the shallow areas of the lagoon (unpublished data). A total of 13 sampling sites were selected in the littoral and shallow areas (maximum depth ≤ 1 m) of the lagoon (Fig. 1). The bottoms are characterised by soft substrates (principally muddy and sandy bottoms) and isolated patches of submerged vegetation (meadows of *Cymodocea nodosa* and mixed meadows of *Cymodocea nodosa*-*Caulerpa prolifera*).

Sampling methods

Fish samples were collected using a 10 m-long bag seine net and 2 mm mesh size which allowed the collection of juvenile fishes. We collected three to six replicates at each sampling site by adjacent 20 m reaches of shoreline at each site. In each reach, the bag seine was hauled offshore parallel to the shoreline in water < 1.0 m deep for the length of the reach. The area covered by each haul was approximately 160 m^2 (minimum hauled area per sampling site = 480 m^2), with a total number of 57 samples taken.

Sparidae fish species were determined according to Arias & Drake (1990) and specimens were measured (total length, LT; standard length, LS) to the nearest 0.1 mm. The abundance of YOY Sparidae fish at each sampling site was expressed as catch per unit effort (CPUE):

$$\text{CPUE} = \text{fish number / haul area covered } (160\ m^2)$$

Each sampling site was characterized by seven environmental variables and indices (quantified in each reach of every sampling site) related to water quality (weekly mean values) and habitat structure: water temperature (ºC), water salinity (Practical Salinity Scale), depth (cm), submerged vegetation cover (%), submerged vegetation volume, substrate size and substrate heterogeneity (Table 1).

The assessment of submerged vegetation cover and submerged vegetation volume was made visually, the first recorded as the area percentage covered by

Sampling site	Abundance of Sparidae (CPUE)	Water temperature (ºC)	Salinity	Submerged vegetation cover (%)	Submerged vegetation volume	Depth (cm)	SS	SH
1 (Las Encañizadas)	48.33	21.98	38.37	38.33	1.67	44	2.12	0.35
2 (Tomás Maestre)	4.66	21.67	38.53	0.00	0.00	52	2.07	0.25
3 (Los Alíseos)	4.67	21.51	38.38	3.33	0.33	40	2.17	0.46
4 (Isla del Ciervo)	7.17	20.09	38.36	5.83	0.50	30	2.25	0.50
5 (Playa del Arsenal)	29.83	20.71	37.37	10.83	0.67	48	2.17	0.43
6 (Mar de Cristal)	15.67	19.08	38.38	0.00	0.00	49	2.05	0.39
7 (Los Nietos)	0.00	18.84	38.56	0.00	0.00	47	1.98	0.64
8 (Lo Poyo)	32.67	21.13	38.42	10.00	0.83	39	1.82	0.69
9 (El Carmolí)	14.67	17.16	32.96	8.33	1.00	30	1.95	0.82
10 (Los Alcázares)	0.00	16.59	38.83	3.33	0.33	73	2.28	0.72
11 (La Hita)	5.75	16.48	38.14	10.00	0.75	29	1.95	0.70
12 (Lo Pagán)	26.5	16.14	37.97	2.50	0.33	48	2.03	0.35
13 (Salinas de San Pedro)	96.5	17.78	38.58	37.50	2.00	36	2.13	0.85

Table 1. Abundance of the YOY Sparidae fish species (number of individuals/160 m^2) and environmental variables in each sampling site of the Mar Menor coastal lagoon. Submerged vegetation volume varies from 0 (low density) to 5 (high density); SS = Substrate size (mean value); SH = Substrate heterogeneity (mean value).

Tabla 1. Abundancia de juveniles de espáridos y variables ambientales en cada una de las localidades de muestreo en la laguna costera del Mar Menor. El volumen de la vegetación subacuática varía de 0 (densidad baja) hasta 5 (densidad alta); SS = Granulometría del sustrato (valor promedio); SH = Heterogeneidad del sustrato (valor promedio).

submerged vegetation at each reach and the second as an ordinate categorical variable from 0 (low density of meadows) to 5 (high density of meadows). Substrate was classified according to Bain (1999) [mud (1), sand (2), gravel (3), pebble (4) and boulder (5)] and the substrate size (SS; average in each sampling site) and substrate heterogeneity (SH, standard deviation in each sampling site) were assessed by making at least 10 visual designations in each reach.

Statistical analysis

To explore patterns of association among the environmental variables of the 13 sampling sites, a principal components analysis (PCA) was applied to the correlation matrix. A varimax rotation of the resulting matrix was performed (Visauta-Vinacua 1997).

Differences in Sparidae abundance (log-transformed data) between sampling sites were tested by ANOVA test.

A stepwise multiple regression analysis was performed to determine the amount of variation in Sparidae abundance (log-transformed data) associated with environmental variables (log-transformed data). The bivariate relationships between environmental variables was analysed using Pearson' s correlation.

Statistical analyses were performed with the SPSS® software package and a *P*-value of < 0.05 was considered statistically significant.

Results

During the sampling period, YOY fish of four Sparidae species were captured: *Sparus aurata*, *Diplodus sargus sargus*, *Diplodus puntazzo* and *Sarpa salpa*. The size frequency distribution for all these species is shown in Fig. 2.

The first two factors extracted by PCA explained 62.3 % of the total variance (component 1, 40.8 %; component 2, 21.7 %). Fig. 3a leads to the following conclusions: there was a high level of association between the first component and submerged vegetation (cover and volume). Secondly, substrate size and water temperature were strongly associated with component 2.

Fig. 3b shows the location of sampling sites according to PCA values. It is worth pointing out that component 1 constituted a gradient running from sampling sites with scarce to well developed meadows of submerged vegetation. The sampling sites located in the left part of the diagram (negative PCA scores) were clearly characterized by low submerged vegetation volume and cover (unvegetated sandy bottoms). On the other hand, the sampling sites located in the oposite direction (positive PCA scores) showed a well-developed submerged vegetation both as regards volume and cover.

Analysis of Sparidae abundance showed that there were significant differences (ANOVA test, $F = 5.77$, $P = 0.035$) between sampling sites with scarce developed meadows of submerged vegetation (mean

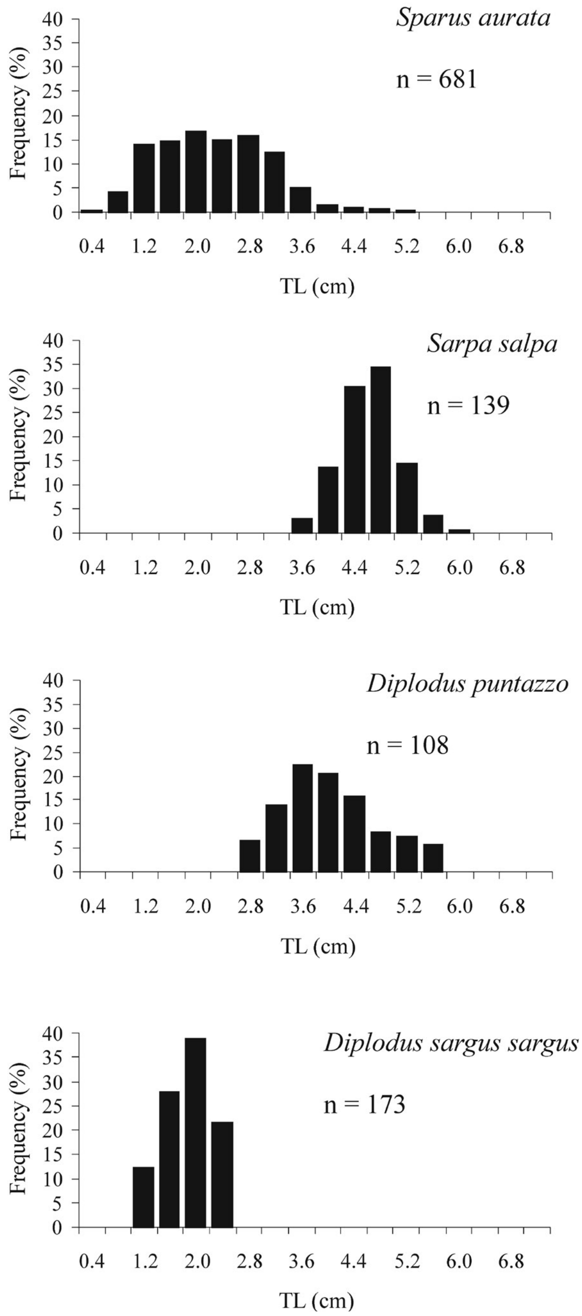

Figure 2. Size frequency distributions for YOY Sparidae fish species captured in the shallow areas of the Mar Menor coastal lagoon.
Figura 2. Distribución de frecuencias por tallas de los juveniles de las especies de espáridos capturadas en las zonas someras de la laguna costera del Mar Menor.

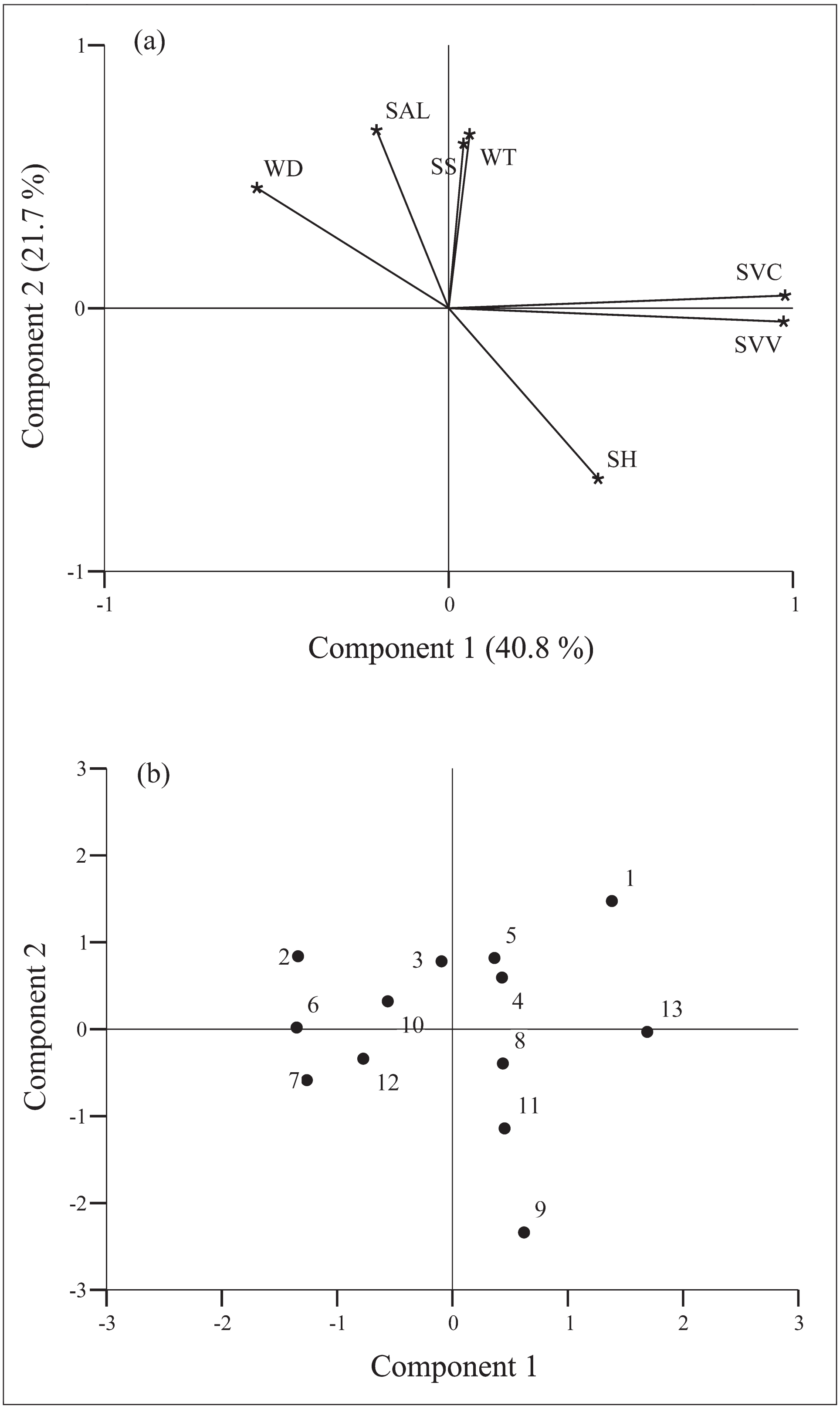

Figure 3. Results of the principal component analysis (PCA): (a) Environmental variables (b) Location of sampling sites according to PCA scores. WT = water temperature; SAL = salinity; SVC = submerged vegetation cover; SVV = submerged vegetation volume; WD = water depth; SS = substrate size; SH = substrate heterogeneity.

Figura 3. Resultados del análisis de componentes principales (ACP): (a) Variables ambientales (b) Situación de las localidades de muestreo de acuerdo con las puntuaciones obtenidas en el ACP. WT = temperatura del agua; SAL = salinidad; SVC = cobertura de la vegetación subacuática; SVV = volumen de la vegetación subacuática; WD = profundidad; SS = granulometría del sustrato; SH = heterogeneidad del sustrato.

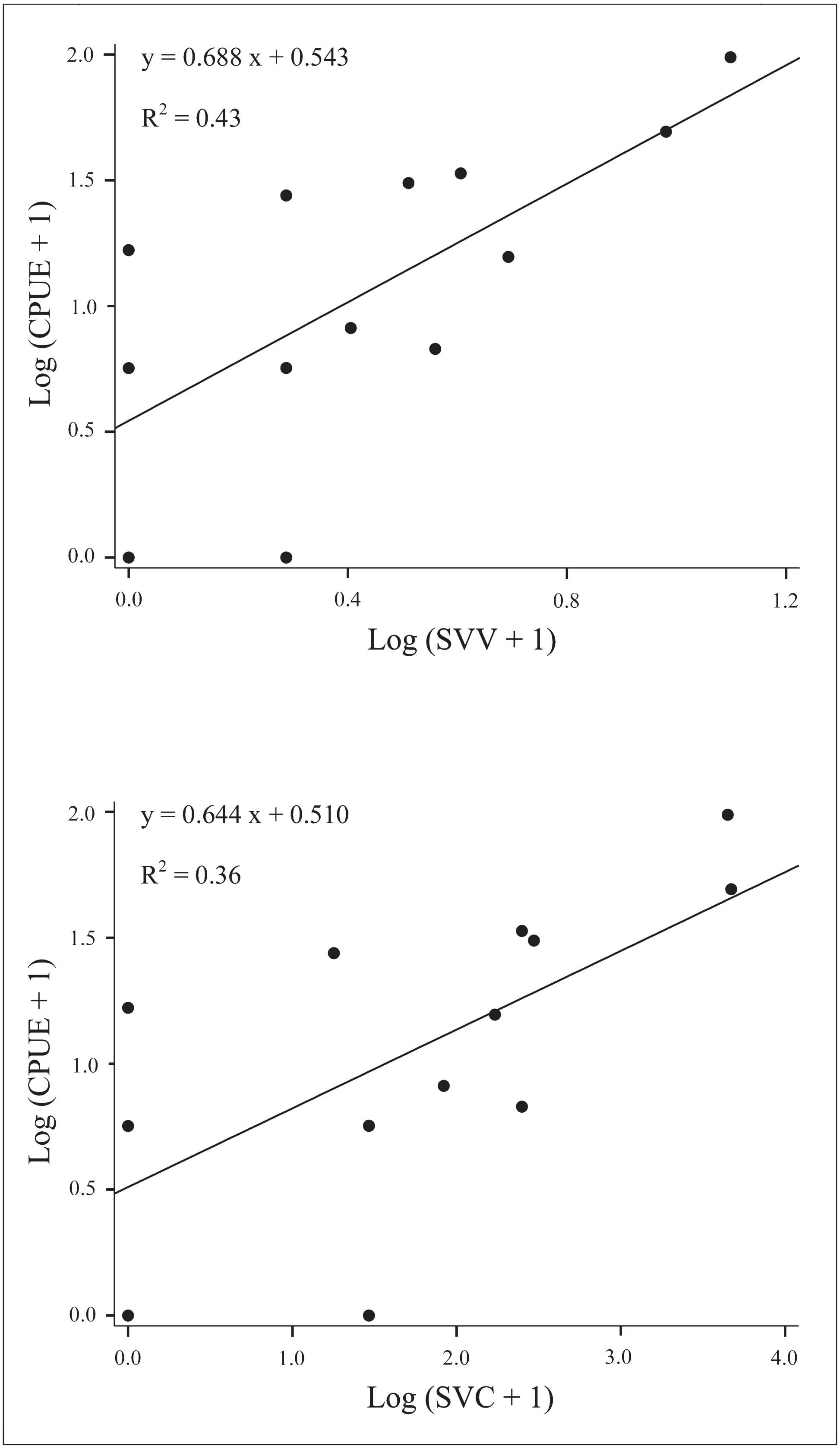

Figure 4. Relationship between abundance of YOY Sparidae fish species with the submerged vegetation volume (a) and submerged vegetation cover (b) in the Mar Menor coastal lagoon. Log-transformed data.

Figura 4. Relación entre la abundancia de juveniles de espáridos y el volumen (a) y recubrimiento (b) de la vegetación subacuática en la laguna costera del Mar Menor. Datos transformados logarítmicamente.

abundance ± S.E. = 8.58 ± 4.28 CPUE) and those with well developed meadows (mean abundance ± S.E. = 33.6 ± 11.97 CPUE).

The bivariate relationships between abundance of YOY Sparidae and submerged vegetation parameters are shown in Fig. 4. The first stepwise multiple regression model indicated that submerged vegetation volume accounted for most of the variation in YOY Sparidae abundance between sampling sites (adjusted $R^2 = 0.43$; $F = 9.902$; $P = 0.009$), the effect being positive. However, due to the great weight of this variable in the model (no other independent variable was selected) and because submerged vegetation volume showed a significant correlation with submerged vegetation cover (Pearson's correlation coefficient = 0.933; $P < 0.001$), we perfomed a second stepwise multiple regression model without the submerged vegetation volume variable. This second model indicated that vegetation cover is also an important variable for explaining the variation in YOY Sparidae abundance between sampling sites (adjusted $R^2 = 0.36$; $F = 7.805$; $P = 0.017$).

Discussion

The results obtained show that YOY Sparidae fish abundance was greater in the sampling sites with well-developed meadows of submerged vegetation. Some authors have remarked on the importance of vegetated shallow areas for juvenile marine fishes (Paterson & Whitfield 2000, Lazzari et al. 2003, Nakamura & Mitsuhiko 2004). In a study of southern African estuaries, Paterson & Whitfield (2000), showed that Sparidae juveniles were the most abundant fish in the eelgrass habitats of *Zostera*. Mistri et al. (2000) in a Mediterranean lagoon (Italy) demonstrated the importance of vegetated habitats for the abundance of marine macroinvertebrates, an animal group which is the main prey resource for the YOY Sparidae fish species (Arias & Drake 1990, Malavasi et al. 2004), so it is probable that they can obtain abundant food resources in these vegetated habitats. In addition, numerous field and laboratory experiments have shown that seagrasses provide effective refuge from predators due to the increase in habitat structure and complexity (Turner et al. 1999, Peterson et al. 2001).

Previous studies in the Mediterranean Sea (Harmelin-Vivien et al. 1995) noted that the habitat requirements of Sparidae juveniles were related to the presence of seagrass beds of *Posidonia oceanica* and a heterogeneus substrate. In addition, Ribeiro et al. (2006) demonstrated the importance of vegetated habitats (patches of the seagrass *Cymodocea nodosa*) in the recruitment of YOY Sparidae in an Atlantic coastal lagoon. In the Mar Menor, areas with well-developed submerged vegetation meadows are mainly associated with the adjacent lagoon wetlands (Las Encañizadas, Lo Poyo, El Carmolí, La Hita and Salinas de San Pedro) that still show an important degree of naturalness. In this sense, the seagrass *Cymodocea nodosa* forms several extensive patches of submerged vegetation in these shallow areas of the lagoon.

In contrast, the sampling sites with lower values of YOY Sparidae abundance showed scarce cover and low volume of submerged vegetation and are associated with littoral urbanized areas (altered and artificial shoreline). This situation was probably due to intensive beach cleaning operations and the use of new sand to maintain these artificial sandy beaches, leading to a homogeneous substrate (bottoms mainly formed by sand) and the burying and uprooting of submerged vegetation. Pérez-Ruzafa et al. (2006) showed that coastal works (dredging and pumping of sand to create artificial beaches and the installation of artificial rocky structures) in the Mar Menor littoral areas, have a negative impact on distribution and abundance of the benthic fish fauna. In this sense, such degradation of habitat structure and heterogeneity causes the loss of feeding and nursery areas for a variety of marine fish species, including those of commercial interest (Turner et al. 1999)

The Mar Menor lagoon system has been affected by large-scale anthropogenic disturbances, mainly related with the substantial development of intensively irrigated agriculture and the increase in population and shoreline urbanization. These impacts have a direct influence on the environment and food resources, and on the distribution and abundance of the fish species present in the lagoon (Pérez-Ruzafa et al. 1991, Pérez-Ruzafa et al. 2006). Although maintenance of artificial beaches has become a tourist necessity in the study area, sustainable management requires information on the functioning of the ecosystems concerned, especially an understanding of how vulnerable particular habitats, communities and species are to different anthropogenic coastal activities (Hiscok 1997, Turner et al. 1999).

In conclusion, the results obtained showed that abundance of YOY Sparidae fish species in the shallow and littoral areas of the Mar Menor coastal lagoon are positively correlated with the presence of well-developed meadows of submerged vegetation. Furthermore, this abundance pattern seems to be related with the shoreline development, the more altered and artificial beaches (due to anthropogenic disturbances) showing poor submerged vegetation development and correspondingly low abundance of YOY Sparidae fish species.

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