Migrant YoY and resident short-lived fish species in the shallow bottoms of the Mar Menor (SE Iberian Peninsula): shoreline development effects.

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INTRODUCTION

Shallow littoral habitats of coastal lagoons and estuaries play an important role and have great value for fish communities as spawning, nursery and feeding areas and even as essential habitats for threatened fish species (Franco et al., 20006; Ribeiro et al., 2006). Significant anthropogenic coastal stressor in these areas is shoreline development that can directly affect aquatic communities through the modification of intertidal and subtidal habitats, increases in nutrients inputs, loss of allocthanous material, increased recreational use and a loss of natural erosion control (Seitz et al. 2006; Bilkovic & Roggero, 2008).

The Mar Menor is a hypersaline coastal lagoon located in a semiarid region in the south-east of the Iberian Peninsula (Figure 1). Its coastline is densely populated and affected by a variety of human activities (urban development, construction and maintenance of artificial beaches, etc.), although there are still some associated wetlands (natural marshlands) that have an important ecological and natural value and which have been given international and national protection status (Conesa & Jiménez-Cárceles 2007).

Liza aurata, *L. saliens* and *Sparus aurata* are among the most important migrant species (= non-resident) that recruit into the lagoon. As a resident species, *Aphanius iberus*, *Syngnathus abaster*, *Pomatochistus marmoratus* and *Atherina boyeri* are the most abundant short-lived fish species on the shallow littoral areas of the Mar Menor.

The aim of this work was to asses wether there was a significant difference in abundance of such a species and habitat variables between shallow littoral habitats adjacent to two types of shoreline condition in the Mar Menor: 1) natural marshland and 2) developed shoreline.

MATERIALS & METHODS

The sampling was carried out during four sampling periods, July 2002 and 2003 (summer) and February 2003 and 2004 (winter). Samples were collected using a 10 m long beach seine which allowed the capture of YoY (Young-of-the-Year) and adults of short-lived fish species. We collected three to six replicates within sampling period at each of the 6 sampling sites, 3 in natural marshlands and 3 in developed areas (recreational beaches) (Figure 1).

Moreover, each sampling site was characterized by five environmental variables related to habitat structure: water depth (cm), submerged vegetation cover (%), submerged vegetation volume, substrate size and substrate heterogeneity. The assessment of submerged vegetation cover and volume was made visually, the first recorded as the area percentage covered by 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.

Two-way factorial analysis of variance (ANOVA) was used to test for differences on each fish species abundance, total abundance of migrant fish species and total abundance of resident fish species between shoreline types and seasons. Both independent variables were considered as fixed factors. Data were transformed to ln (x + 1) in order to reduce the heterocedasticity of the data.

To characterize both shoreline types a PCA was applied to the correlation matrix of species abundance. Only components with eigenvalues larger than 1 were interpreted. One-way ANOVA was used to test for differences in PCA scores between shoreline types.

The effect of shoreline condition on environmental variables was assessed through Mann-Whitney test.

Figure 1. Geographical location of the Mar Menor coastal lagoon and location of the sampling sites with different shoreline condition. Natural shoreline Developed shoreline

RESULTS

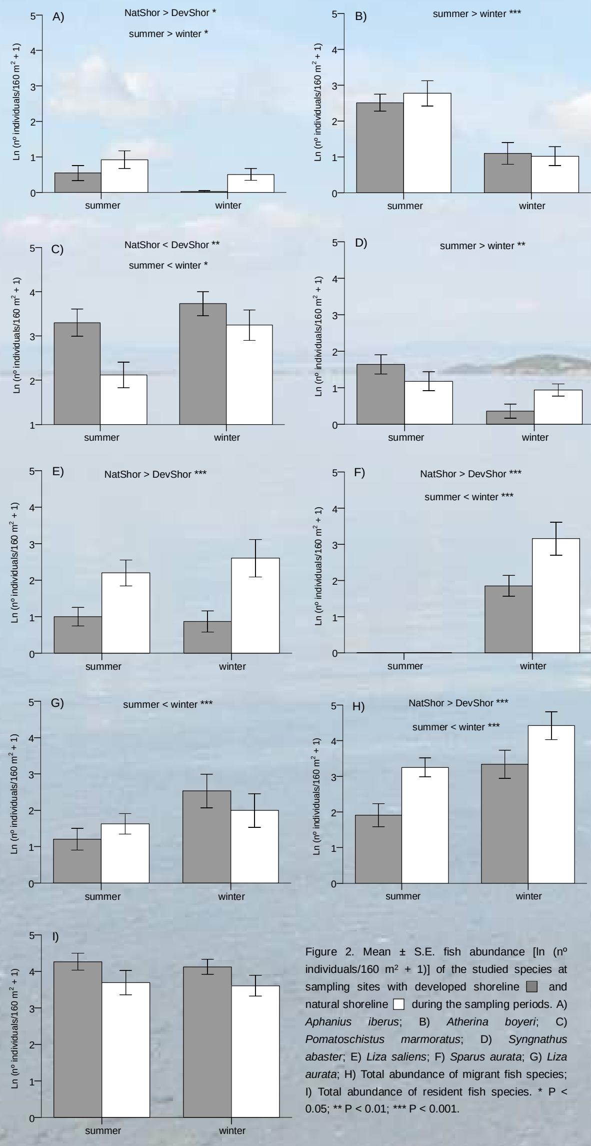

Figure 2. Mean ± S.E. fish abundance [ln (nº individuals/160 m² + 1)] of the studied species at sampling sites with developed shoreline and natural shoreline during the sampling periods. A) *Aphanius iberus*; B) *Atherina boyeri*; C) *Pomatoschistus marmoratus*; D) *Syngnathus abaster*; E) *Liza saliens*; F) *Sparus aurata*; G) *Liza aurata*; H) Total abundance of migrant fish species; I) Total abundance of resident fish species. * P < 0.05; ** P < 0.01; *** P < 0.001.

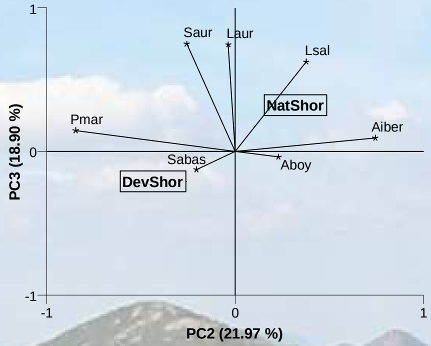

Figure 3. Projection of the loadings of the different fish species on the space formed by PC2 and PC3 and centroids of sampling sites corresponding to natural (NatShor) or developed shorelines (DevShor). Aiber, *Aphanius iberus*; Pmar, *Pomatoschistus marmoratus*; Sabas, *Syngnathus abaster*; Aboy, *Atherina boyeri*; Saur, *Sparus aurata*; Laur, *Liza aurata*; Lsal, *Liza saliens*.

There were significant differences in fish species abundance between shoreline types for *A. iberus*, *L. saliens*, *S. aurata* and *P. marmoratus*. The first three species were more abundant in sampling sites with natural shoreline while *P. marmoratus* was more abundant in developed shorelines (Figure 2). Total abundance of migrant fish species was significantly higher in natural shorelines (Figure 2). There were no such differences for abundance of *A. boyeri* (P = 0.76), abundance of *L. aurata* (P = 0.88) and total abundance of resident fish species (P = 0.06) (Figure 2).

As regards seasonal variation in abundance there were significant differences for all species except for *L. saliens* (P = 0.70). The abundance of *A. iberus*, *A. boyeri* and *S. abaster* were higher during summer and the rest of species were more abundant during winter (Figure 2). The total abundance of migrant fish species was significantly higher during winter but total abundance of resident fish species did not show seasonal differences (P = 0.68) (Figure 2).

The habitat x season interaction was only significant for *S. abaster* abundance which showed higher values in undeveloped shorelines during winter (P < 0.05) (Figure 2).

The PCA produced three principal components (PCs) with eigenvalues > 1 that explained 68.81 % of the total variance (PC1, 27.95%; PC2, 21.97%; PC3, 19.90%). PC1 scores did not differ between shoreline types but PC2 and PC3 scores showed significant differences (ANOVA, PC1 P = 0.92; PC2 P < 0.01; PC3 P < 0.05). PC2 was related with the resident fish species abundance, being *P. marmoratus* abundance related to negative scores and *A. iberus* abundance with positive scores (Figure 3). PC3 represented a gradient running from low to high values of migrant fish species abundance (Figure 3). Hence, natural shorelines were characterized by high migrant fish species abundance and high *A. iberus* abundance, while developed shorelines were characterized by high *P. marmoratus* abundance and low abundance of migrant fish species (Figure 3).

Mann-Whitney test showed significant differences for all environmental variables between shoreline types. Water depth and substrate size were higher in developed shorelines (P < 0.001; P < 0.001, respectively) while submerged vegetation cover and volume and substrate heterogeneity were higher in natural shorelines (P < 0.001; P < 0.001, P < 0.001, respectively) (Table 1).

Table 1. Mean ± S.E. of the measured environmental variables at each shoreline types during the study period in the shallow areas of the Mar Menor coastal lagoon.

	Shoreline type	
Environmental variables	Natural shoreline	Developed shoreline
Depth (cm)	31.3 ± 0.8	48.9 ± 1.2
Submerged vegetation cover (%)	27.4 ± 1.7	15.0 ± 1.6
Submerged vegetation volume	1.8 ± 0.08	1.2 ± 0.8
Substrate size	1.73 ± 0.02	2.14 ± 0.03
Substrate heterogeneity	0.62 ± 0.01	0.55 ± 0.02

DISCUSSION

Results obtained show that abundance of several fish species differed between shoreline types, this situation was probably due to differences in the habitat structure and changes in allocthanous inputs. The resident species *P. marmoratus* was more abundant in the shallow habitats adjacent to developed shorelines, such habitats show deeeper bottoms mainly formed by sand and scarce cover and low volume of submerged vegetation (recreational beaches), which conform the typical habitat of this species (Verdiell-Cubedo et al. 2008). In contrast, *A. iberus* abundance was higher in habitats associated with natural marshlands, which showed shallow muddy bottoms and higher cover and volume of submerged vegetation in the form of *Cymodocea nodosa* and *Ruppia cirrhosa* meadows and algal mats of *Enteromorpha* sp. and *Chaetomorpha* sp. In this sense, Oliva-Paterna (2006) showed that such wetlands (Lo Poyo, El Carmolí and La Hita) and the associated littoral habitats constituted very important areas for this threatened fish species. In a similar way, the higher abundance of the pipefish *S. abaster*, a typical inhabitant of seagrass beds, along undeveloped shorelines during winter could be related to the spatio-temporal dynamics of submerged vegetation, since submerged vegetation cover showed very low values during winter in developed shorelines (< 6 %) while the former showed relatively high cover values (> 23 %).

Total abundance of migrant fish species showed higher values along undeveloped shorelines mainly due to *S. aurata* and *L. saliens* species. In addition, migrant fish species abundance was higher during winter. This situation was probably due to the presence of abundant food resources since such littoral areas show high productivity and receive important inputs of organic debris via freshwater currents coinciding with the rainy season (autumn-spring) in the study area (Velasco et al. 2006; Álvarez-Rogel et al. 2007). Therefore, shallow habitats adjacent to natural marshlands could be considered important nursery and feeding habitats for these migrant fish species.

In conclusion, we suggest that developed shorelines have negative impacts on habitat structure through the loss of habitat complexity and refuge, and changes or reduction in the productivity and allocthanous inputs of carbon from terrestrial systems.

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