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David Verdiell-Cubedo [a] , Francisco J. Oliva-Paterna [a] , Ana Ruiz-Navarro [a] & Mar Torralva [a]

[a] Departamento de Zoología y Antropología Física , Universidad de Murcia , Murcia , Spain

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ORIGINAL ARTICLE

Assessing the nursery role for marine fish species in a hypersaline coastal lagoon (Mar Menor, Mediterranean Sea)

DAVID VERDIELL-CUBEDO*, FRANCISCO J. OLIVA-PATERNA, ANA RUIZ-NAVARRO & MAR TORRALVA

Departamento de Zoología y Antropología Física, Universidad de Murcia, Murcia, Spain

Abstract
The shallow inshore areas of coastal lagoons function as nursery grounds for the early life stages of marine fish. Multi-species approaches and the assessment of several population variables are of great value in studies focused upon the ecological importance of estuarine systems as fish nursery areas. Therefore, the objective of this study was to analyse the spatial differences in the abundance, biomass, growth and condition indexes of juveniles from three marine species: *Sparus aurata*, *Liza aurata* and *Liza ramada*, in order to assess the nursery role of the Mar Menor coastal lagoon for these species. Results showed high spatial variability of the studied variables, with higher abundance and biomass values at those sites closest to the inlet connecting the lagoon with the Mediterranean Sea. Moreover, there were significant relationships between the growth and condition of the fish with hydrographical circulation patterns within the lagoon, indicating the suitability of the Mar Menor as a nursery area for the three studied fish species.

Key words: *coastal lagoon, juvenile fish, growth, condition,* Liza *spp.,* Sparus aurata

Introduction

The shallow inshore areas of coastal lagoons and estuaries are usually among those marine habitats with the highest biological productivity (Day et al. 1989), that provide suitable habitats for numerous fish species and function as nursery grounds for the early life stages of marine fish (Elliott et al. 2007). These environments provide abundant food resources (e.g. a high abundance of invertebrates) and possess favourable habitat conditions (e.g. temperature, hydrodynamics, refuge) that enhance fish growth and survival (Baldó & Drake 2002; Attrill & Power 2004; Franco et al. 2006; França et al. 2009).

The inward migration or recruitment timing of juveniles and larvae in these systems greatly depends upon the length of the adult spawning season and marine hydrodynamics (Martinho et al. 2009; Ramos et al. 2010). Thus, juveniles of the same species may enter the estuarine systems at different times of the year constituting different size groups or cohorts that differ in growth and condition (Fonseca et al. 2006; Vasconcelos et al. 2009).

Individuals with greater condition values benefit from increased growth rates and survival probability and, therefore, would be more likely to replenish the adult stock (Hoey & McCormick 2004; Morgan 2004; Grorud-Colvert & Sponaugle 2006). Hence, it is of great importance to determine the relevance of increased juvenile condition and growth in estuarine systems in order to assess their overall nursery role for marine fish species.

In general, most research on these habitats has focused on spatial and temporal differences in abundance and biomass in order to evaluate their importance as nursery grounds for fish species, but few have used additional population variables such as growth or condition (e.g. Sogard 1992; Vasconcelos et al. 2009; Franco et al. 2010). Thus, there is a need to broaden our knowledge concerning the ecological importance of nurseries via integrated studies that combine fish abundance and distribution data with juvenile growth and condition indices.

In terms of abundance and species richness, Mugilidae and Sparidae are important families

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*Correspondence: David Verdiell-Cubedo, Departamento de Zoología y Antropología Física, Universidad de Murcia, 30100 Murcia, Spain. E-mail: verdiell@um.es

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among the estuarine system fish communities in temperate areas (Elliott et al. 2007). In the Mediterranean Sea, several species of these families undertake reproductive seaward migrations (Katselis et al. 2003), and their juvenile stages recruit into estuarine systems at different times of the year to feed and find shelter until they reach sexual maturity (Koutrakis 2004; Koutrakis et al. 2005; Maci & Basset 2009).

The purpose of the present study was to first analyse the spatial differences in the abundance and biomass of juvenile individuals (0+, fish produced from the current year's spawnings) from three marine fish species of ecological and commercial interest: the sparid *Sparus aurata* (Linnaeus, 1758) and the mullet *Liza aurata* (Risso, 1810) and *Liza ramada* (Risso, 1827), in the Mar Menor coastal lagoon. These fish species are among the most abundant marine migrants that colonize Mar Menor in their juvenile stages (Verdiell-Cubedo et al. 2013). Second, their growth and condition was evaluated based on the determination of population size structure (length-frequency-based method) and a morphometric index (ANCOVA-adjusted weights), respectively. Additionally, the general nursery role of the lagoon for these species was investigated by studying the relationships between these population variables and the proximity to the Las Encañizadas inlet, which was assumed to be the main inward migration route for juvenile fishes of marine migrant species. Considering that nursery areas significantly contribute to enhance growth and condition of the early life stages of marine fish, we hypothesized that juveniles of these species would exhibit higher condition and growth values at sites farthest from the Las Encañizadas inlet, as they could benefit by spending more time in the favourable lagoon environment.

Material and methods

Study area

The Mar Menor is a hypersaline coastal lagoon located in a semiarid region of the southeastern Iberian Peninsula. It is one of the largest coastal lagoons in the Mediterranean Sea, with a surface area of 135 km^2 and an average depth of 3.6 m. The lagoon is separated from the Mediterranean Sea by a 22-km long sand bar, known as La Manga, with three inlets connecting it with the open sea, from north to south: Las Encañizadas, El Estacio and Marchamalo (Figure 1). Las Encañizadas inlet is the natural communication point of the lagoon with the open sea. It is 1.5 km wide and presents salt marsh characteristics, with several narrow channels and extensive shallow areas with muddy bottoms and small patches of submerged vegetation, mainly *Ruppia cirrhosa* (Petagna) Grande and *Cymodocea nodosa* (Ucria) Ascherson. El Estacio and Marchamalo inlets are artificial channels that have been enlarged for navigation purposes and are periodically dredged. They present a greater depth (e.g. 5 m depth of El Estacio channel) and strong currents (Pérez-Ruzafa et al. 2005).

Water temperature shows a regular seasonal cycle, with maximum records registered in August (30.0°C) and minimum in February (11.2°C). Salinity shows heterogeneous spatial and temporal distribution depending on season, rainfall, runoff and Mediterranean influence through the inlets, with a minimum of 38.1 and a maximum of 51. Several ephemeral watercourses flow into the lagoon, most of them discharging with a sporadic and torrential rainfall regime. An exception is the El Albujon watercourse, the main collector in the drainage basin, which, due to changes in agricultural practises and related phreatic rising, maintains a regular but low flux of water of around 0.02 $m^3\ s^{-1}$. The lagoon's hydrodynamics are driven by the wind, generating an anti-clockwise circulatory pattern comprising three main gyres and dominant currents from north to south along the internal coast of the lagoon (Pérez-Ruzafa et al. 2004, 2005).

The shallow littoral areas (maximum depth <1 m) of the lagoon are mainly characterized by soft substrates (muddy and sandy bottoms) and isolated patches of submerged vegetation, and maintain a diverse fish community (Oliva-Paterna et al. 2006; Verdiell-Cubedo et al. 2013).

Sampling methods

Fish samples were collected using a 10-m long beach-seine net (2 mm mesh size), which allowed the capture of juvenile fishes and adults of small-sized species, at a total of 16 sampling sites located along the littoral shallow areas of the lagoon (Figure 1). Six replicates were collected at each sampling site by hauling along 20-m reaches of shoreline at each replicate. The area covered by each haul was approximately 160 m^2 (total hauled area per sampling site $=960\ m^2$). In some sites, additional hauls were performed in order to increase the sample to study condition and growth variables, although they were not computed for species abundance and biomass variables. In the Mar Menor lagoon, *Liza aurata*'s recruitment period starts in October–November while that of *Sparus aurata* starts during January–February and *L. ramada* during February–March (unpublished data). The inshore migration of each species in the Mar Menor followed similar temporal patterns with regard to other estuarine systems of the Mediterranean Sea and the Atlantic coast of the Iberian Peninsula (Arias & Drake 1990; Koutrakis 2004). Captures were

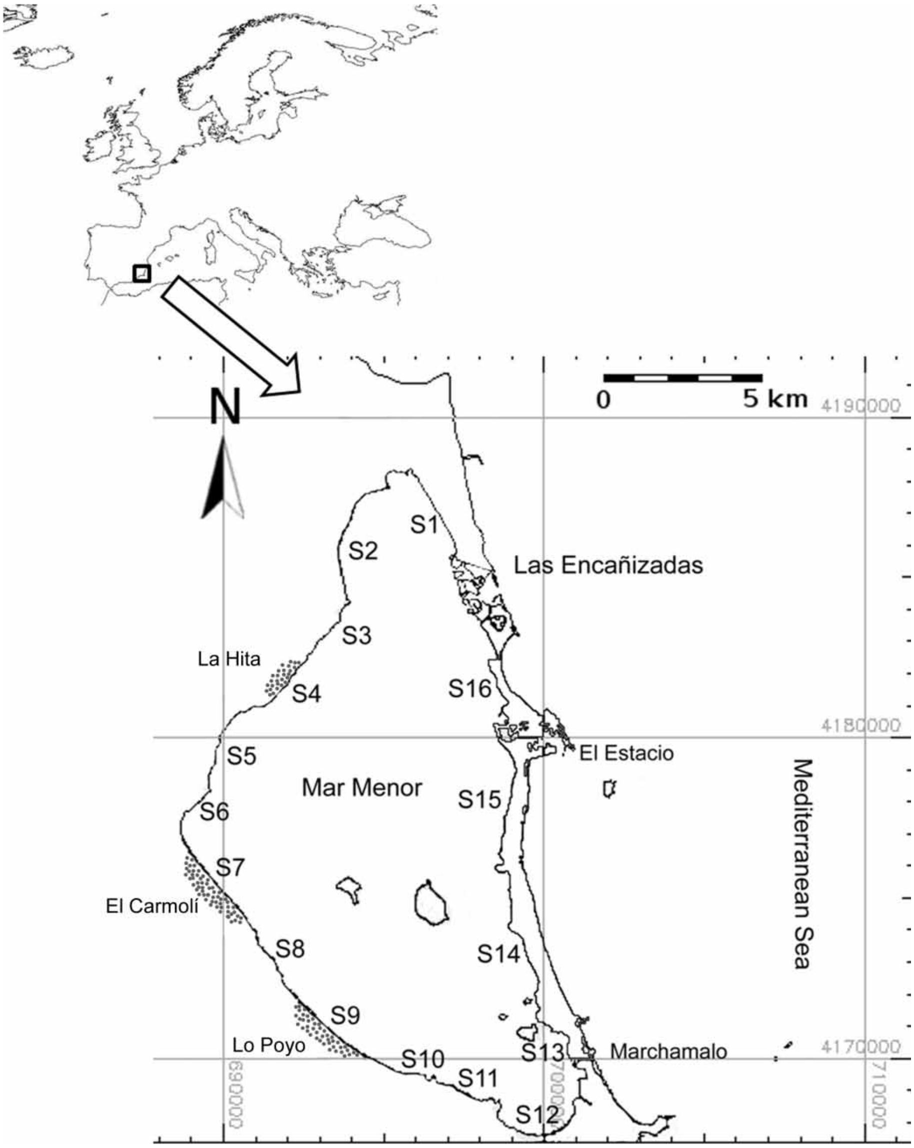

Figure 1. Location of the Mar Menor coastal lagoon and distribution of sampling sites. The main inlets and salt marsh areas (grey dots) are indicated.

conducted during February 2003 for *L. aurata* and *L. ramada* and during April 2004 for *S. aurata*.

After being anaesthetized, the fish were preserved in a 10% buffered formalin solution and identified at species level in the laboratory. A random subsample of individuals for each species at each sampling site was measured for total length (TL, ±1 mm) and weighed for total weight (TW, ±0.01g).

The species abundance and biomass at each sampling site was recorded and expressed as number of individuals per 100 m^2 and grams of fish biomass per 100 m^2, respectively.

Data analyses

Data on the juvenile length of each fish species were arranged in frequency distributions of 2 mm increments. Cohorts were determined for each fish species both from all data and separately for each sampling site, using FiSAT II software (FAO ICLARM Stock Assessment Tools ver. 1.2.0). First, following the length-frequency-based method described by Bhattacharya (1967), size groups presumed to represent cohorts in the length-frequency samples were identified. Second, the normally distributed components (NORMSEP subroutine) were separated, where the separation index (SI) was >2 to provide meaningfully separated groups (Gayanilo et al. 1988). Thus, cohort mean TL was compared between sampling sites as a measure of fish growth.

Fish condition was studied by analysing length–weight relationships. The adjustment for size variation in the data by regression-related techniques has been successfully used with an analysis of covariance

Table I. Abundance (ind. 100 m $^{-2}$) and biomass (g 100 m $^{-2}$) of each species at each sampling site (mean value ± 1 SE), in the shallow areas of the Mar Menor.

	Sparus aurata (April 2004)		*Liza aurata* (February 2003)		*Liza ramada* (February 2003)	
Sampling site	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
S1San Pedro	53.8 ± 24.4	16.3 ± 3.7	43.4 ± 16.6	10.8 ± 4.2	0.8 ± 0.5	0.1 ± 0.1
S2 Lo Pagán	15.3 ± 6.3	6.6 ± 2.5	58.5 ± 40.3	15.8 ± 11.3	2.2 ± 2.2	0.2 ± 0.2
S3 Casablanca	–	–	33.8 ± 15.1	13.4 ± 5.9	17.3 ± 11.0	1.7 ± 1.1
S4 La Hita	3.6 ± 3.6	1.2 ± 1.2	31.9 ± 17.9	5.7 ± 3.4	18.3 ± 7.7	2.1 ± 0.9
S5 Los Alcázares	0	0	8.5 ± 4.5	3.2 ± 2.0	0	0
S6 Cartagonovo	–	–	0	0	1.5 ± 1.2	0.2 ± 0.2
S7 El Carmolí	8.8 ± 3.6	4.4 ± 1.7	4.0 ± 3.7	1.0 ± 3.9	0.2 ± 0.2	0.2 ± 0.2
S8 Punta Brava	0.6 ± 0.6	0.5 ± 0.5	17.3 ± 9.6	6.8 ± 3.9	8.8 ± 5.6	0.1 ± 0.1
S9 Lo Poyo	17.5 ± 8.3	16.6 ± 8.2	0.7 ± 0.4	0.2 ± 0.1	0.4 ± 0.4	0.4 ± 0.4
S10 Los Nietos	0	0	17.9 ± 13.9	17.4 ± 7.0	10.9 ± 4.4	1.5 ± 1.1
S11 Las Lomas	8.5 ± 2.3	4.8 ± 2.1	34.1 ± 23.3	11.0 ± 7.3	28.1 ± 14.5	3.1 ± 1.6
S12 Playa Arsenal	9.7 ± 4.6	5.2 ± 2.4	49.2 ± 32.6	7.7 ± 4.8	8.4 ± 7.0	0.8 ± 0.6
S13 El Vivero	4.2 ± 5.8	1.6 ± 1.1	30.7 ± 20.4	8.4 ± 4.0	5.5 ± 5.5	0.5 ± 0.5
S14 Los Alíseos	0	0	0.7 ± 0.3	0.3 ± 0.1	0	0
S15 Tomás Maestre	0	0	30.8 ± 15.2	11.0 ± 5.5	0.3 ± 0.3	0.1 ± 0.1
S16 La Chanta	0	0	66.0 ± 33.1	26.6 ± 11.1	0.7 ± 0.5	3.0 ± 2.2

(ANCOVA) for several fish species (e.g. Verdiell-Cubedo et al. 2006; Ruiz-Navarro et al. 2011, among others). ANCOVA has several advantages over traditional condition indices such as relative condition factor and Fulton's condition factor (see review in García-Berthou & Moreno-Amich 1993). The analysis was conducted on weight (dependent variable) and length (covariate) variables, which were each log-transformed ($\log_{10}$) to ensure linearity. The homogeneity of slopes of dependent–covariate relationships was tested with the ANCOVA model design which included the pooled covariate-factor interaction. Estimated marginal (or adjusted) means in ANCOVA, which are the means of values of the response variable (weight) adjusted for effects of the covariate (size-adjusted means), were used to describe condition variation among sampling sites, testing differences with ANOVA (Bonferroni post-hoc tests). The non-significant interactions were removed from the models to increase the statistical power of the remaining sources.

The distance from Las Encañizadas inlet to each sampling site was measured as curves following the distance along the internal shoreline of the lagoon (km), according to the general circulatory pattern of currents from north to south (see Pérez-Ruzafa et al. 2004), using the ArcView GIS 3.2® software. Las Encañizadas inlet was considered as the principal inward migration route for juveniles due to its natural characteristics when compared to other inlets in the lagoon that have been strongly modified; a factor that could hinder the entrance of juveniles, as has been demonstrated in other areas (Katselis et al. 2003).

Linear, quadratic and logistic regressions were performed to describe the best-fitted relationship

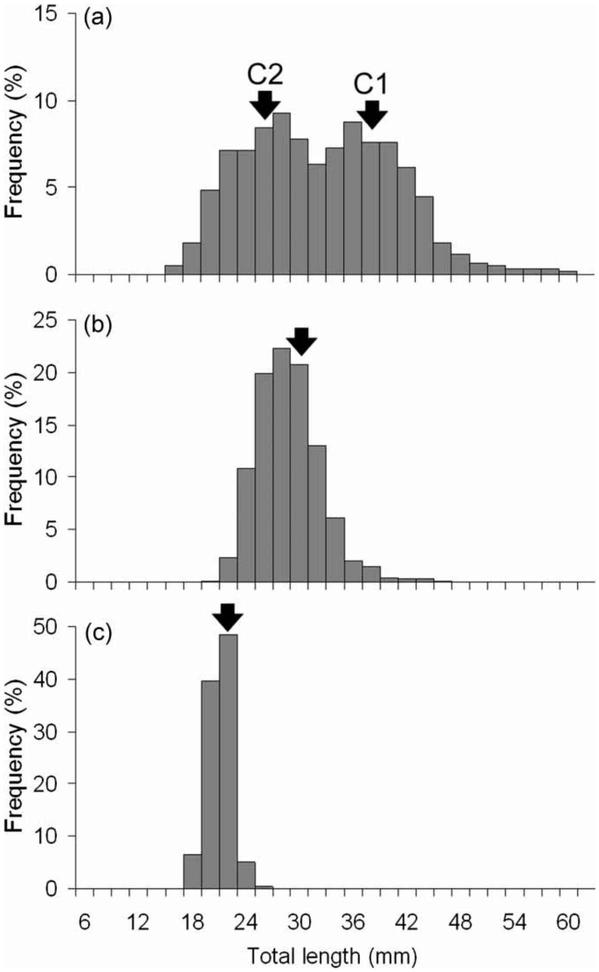

Figure 2. Size frequency distributions (total length, mm) for: (a) *Sparus aurata* (April 2004), (b) *Liza aurata* (February 2003) and (c) *Liza ramada* (February 2003). Arrows indicate cohort mean total length for each species. C1 and C2 distinguish the two cohorts recognized for *S. aurata*.

between abundance, biomass, cohort mean TL, the condition of each species and distance from Las Encañizadas inlet.

Statistical analyses were performed using the SPSS® package (version 15.0).

Results

Abundance and biomass values for each fish species at each sampling site are shown in Table I. During the study period, *Liza aurata* was the dominant species with a mean abundance and biomass of 26.1 ind. 100 m^{-2} and 8.3 g 100 m^{-2}, respectively. The second most significant species was *Sparus aurata*, which showed a mean abundance of 7.7 ind. 100 m^{-2} and mean biomass of 3.8 g 100 m^{-2}. *Liza ramada* presented a mean abundance of 5.9 ind. 100 m^{-2} and mean biomass of 0.8 g 100 m^{-2}.

In regards to spatial abundance and biomass patterns *S. aurata* reached the highest values at S1, with 53.8 ind. 100 m^{-2} and 16.3 g 100 m^{-2}, respectively (Table I). *Liza aurata* showed maximum abundance and biomass values at S16 (66.0 ind. 100 m^{-2} and 26.6 g 100 m^{-2}, respectively) and S2 (58.5 ind. 100 m^{-2} and 15.8 g 100 m^{-2}, respectively) (Table I). Higher abundance and biomass of *L. ramada* were recorded at S11, with 28.1 ind. 100 m^{-2} and 3.1 g 100 m^{-2}, respectively, and S4 (18.3 ind. 100 m^{-2} and 2.1 g 100 m^{-2}, respectively). The high biomass values obtained for this species at S16 were due to the capture of a large individual of about 80 mm in TL (4.2 g TW) (Table I), which was removed for subsequent analyses.

A total of 606 juveniles of *S. aurata*, 1471 juveniles of *L. aurata* and 497 juveniles of *L. ramada* were measured and weighed. Sampled *S. aurata* ranged 16–61 mm in TL and the mean TL was 29 mm. The mean TL of *L. aurata* was 29 mm (range 21–46 mm) and *L. ramada* was 22 mm (range 18–26 mm).

The analysis identified two cohorts for *S. aurata* during April 2004 (SI = 3.71): the younger cohort C2 (mean TL = 23.0 ± 3.0 mm, $n = 172$) and the older cohort C1 (mean TL = 37.4 ± 4.8 mm, $n = 330$) (Figure 2). *Liza aurata* and *L. ramada* only showed a single cohort in February 2003, with mean TL of 28.8 ± 3.6 mm and 21.1 ± 1.4 mm, respectively (Figure 2). The cohort mean TL recognized for each species at each site are shown in Table II. *Sparus aurata* presented two simultaneous cohorts at the S1, S2 and S13 sampling sites (Table II). However, for regression analysis, only specimens from the older cohort (C1) were considered. Thus, there was a high spatial variability of cohort mean TL for all species, with *S. aurata* showing lower values at S4 (29.3 mm) and higher at S9 (40.5 mm) (Table II). *Liza aurata* had lower cohort mean TL at S10 (26.8 mm), S1 and S11 (27.4 mm for both sites) and higher at S15 (31.0 mm) and S16 (31.5 mm) (Table II). The lowest cohort mean TL for *L. ramada* was 20.6 mm at S12 and the highest was 21.6 mm at S8 (Table II).

With regard to fish condition, all species displayed significant differences among sampling sites

Table II. Cohorts identified for each species at each sampling site in the shallow areas of the Mar Menor. The separation index (SI) must be greater than 2 to provide meaningful separated groups. Cohort mean total lengths (TL, mm) are given (±SD). n, number of individuals.

	Sparus aurata (April 2004)			*Liza aurata* (February 2003)			*Liza ramada* (February 2003)		
Sampling site	TL	SI	n	TL	SI	n	TL	SI	n
S1 San Pedro	22.9±3.6	–	77	27.4±2.3	–	153			
	38.5±9.2	2.44	39						
S2 Lo Pagán	25.5±2.7	–	48	27.5±3.2	–	148	21.1±1.3	–	21
	36.1±2.8	2.36	31						
S3 Casablanca				29.2±2.4	–	96	21.5±1.5	–	75
S4 La Hita	29.3±5.5	–	58	28.8±2.8	–	116	21.3±1.3	–	82
S5 Los Alcázares	31.7±4.6	–	21						
S6 Cartagonovo									
S7 El Carmolí	31.0±6.3	–	42						
S8 Punta Brava	36.7±3.5	–	27	28.1±3.0	–	123	21.6±1.3	–	42
S9 Lo Poyo	40.5±3.1	–	73						
S10 Los Nietos				26.8±2.5	–	83	21.1±1.5	–	63
S11 Las Lomas	35.0±6.9	–	49	27.4±2.8	–	109	20.8±1.4	–	125
S12 Playa Arsenal	34.5±4.2	–	54	28.0±2.7	–	114	20.6±1.3	–	49
S13 El Vivero	21.5±1.8	–	22	30.3±3.5	–	146	20.9±3.5	–	40
	36.8±5.7	4.08	22						
S14 Los Alíseos									
S15 Tomás Maestre				31.0±3.2	–	191			
S16 La Chanta				31.5±3.9	–	213			

Table III. Results of ANCOVA analyses of the TL–TW relationships for each species. Total length (TL) is the covariate. C1: cohort 1, C2: cohort 2.

	Sparus aurata (C1, April 2004)			*Sparus aurata* (C2, April 2004)		
	F	d.f.	*P*	*F*	d.f.	*P*
Covariate-factor interaction						
TL	11,642.51	1, 432	<0.001	84.34	1, 90	<0.001
Sampling site	1.33	9, 432	0.207	3.42	2, 90	<0.05
TL × sampling site	1.34	9, 432	0.212	3.39	2, 90	<0.05
No interaction						
TL	16,375.99	1, 441	<0.001	–	–	–
Sampling site	9.05	9, 441	<0.001	–	–	–

	Liza aurata (February 2003)			*Liza ramada* (February 2003)		
Covariate-factor interaction						
TL	22,893.88	1, 1449	<0.001	1572.85	1, 481	<0.001
Sampling site	3.75	10, 1449	<0.001	0.87	7, 481	0.528
TL × sampling site	3.73	1, 1449	<0.001	0.84	7, 481	0.555
No interaction						
TL	–	–	–	2031.49	1, 488	<0.001
Sampling site	–	–	–	22.22	7, 488	<0.001

(Table III). *Sparus aurata*'s condition (cohort C1) was highest at S8 (2.81 ± 0.005 logTW) and lowest at S4 (2.75 ± 0.005 logTW). In addition, cohort C 2 of *S. aurata* showed the highest values at S2 (2.18 ± 0.03 logTW) (Figure 3). It is noticeable that, when comparing mean condition values for cohort C1 between the S1–S7 and S8–S13 sampling sites, there were significant differences ($F = 45.65$, $P < 0.001$) with higher condition values at the S8–S13 sampling sites (2.79 ± 0.01 logTW) compared to S1–S7 (2.76 ± 0.01 logTW) (Figure 3).

Condition of *L. aurata* was higher at S16 (2.37 ± 0.002 logTW) and lower at S4 (2.29 ± 0.04 logTW), whereas *L. ramada* showed the highest condition value at S11 (1.95 ± 0.004 logTW) and lowest at S4 (1.89 ± 0.004 logTW) (Figure 3).

Regression analyses revealed a significant logarithmic relationship between *S. aurata* abundance

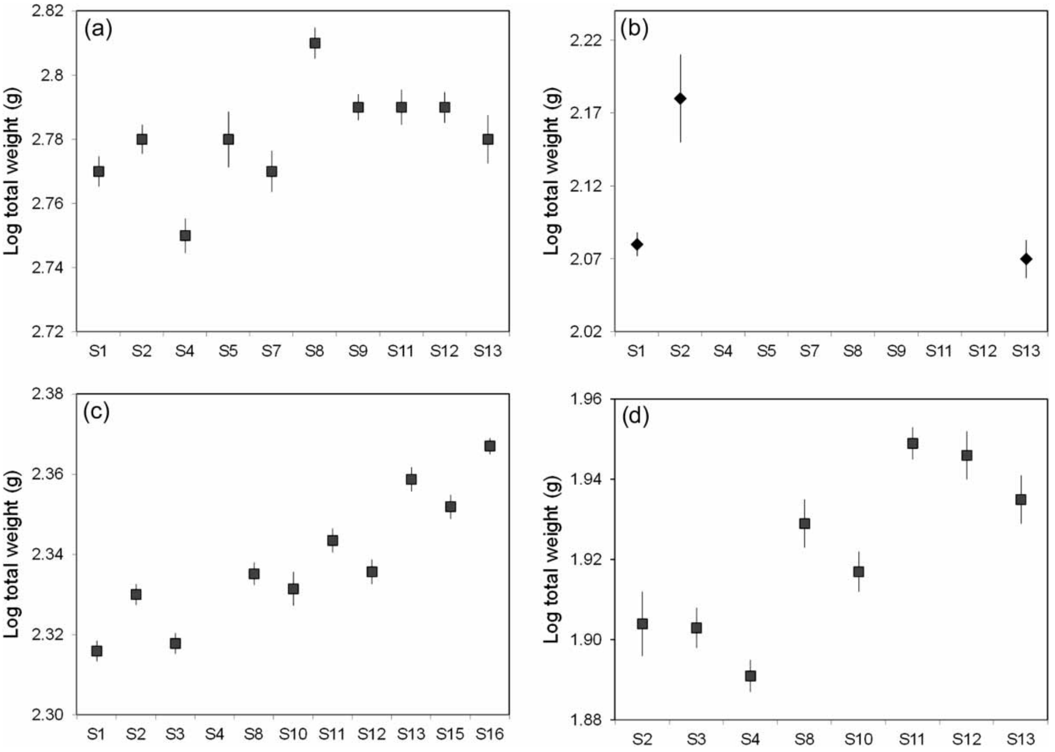

Figure 3. Comparison of fish condition with size-adjusted means (log total weight ± 1 SE) among sampling sites for: (a) *Sparus aurata* (cohort C1, April 2004), (b) *Sparus aurata* (cohort C2, April 2004), (c) *Liza aurata* (February 2003) and (d) *Liza ramada* (February 2003).

($F = 16.14$, $P = 0.002$) and distance from the Las Encañizadas inlet, with higher values at site S1 (Figure 4). *Liza aurata* abundance and biomass showed a parabolic trend ($F = 6.25$, $P = 0.013$; $F = 7.05$, $P = 0.008$, respectively), with higher values nearest to Las Encañizadas (Figure 5). Condition and mean cohort TL of *L. aurata* displayed significant linear relationships with distance from Las Encañizadas ($F = 17.32$, $P = 0.002$; $F = 6.87$, $P = 0.028$, respectively) (Figure 5). Finally, the condition of *L. ramada* showed a significant linear relationship ($F = 16.18$, $P = 0.007$) (Figure 6).

Discussion

Multi-species approaches and the assessment of several population variables are of great value in studies focusing upon the ecological importance of estuarine systems as fish nursery areas (Vasconcelos et al. 2009; Franco et al. 2010). Overall, these results highlight the potential value of the Mar Menor lagoon as a nursery for the studied fish species. When compared to other estuarine systems, the mean abundance values obtained in this study were equal or higher than those reported from other studies (Koutrakis 2004; Koutrakis et al. 2005; Franco et al. 2006; França et al. 2009) (see Table IV). However, although these results are indicative of the important nursery role of the Mar Menor, they must be considered carefully, as they could have been affected by differences in the efficiency of the sampling methods and/or sampling periods (Franco et al. 2012). The lower abundance values obtained for *Liza ramada* in comparison with the other two species could be due to its habitat preferences, as this species prefers waters low in salinity (Koutrakis 2004), or to the fact that the sampling period coincides with the initial recruitment phase of this species in the Mar Menor.

Results regarding spatial differences in the abundance and biomass of the different species reflected a general pattern of increased captures in sampling sites close to Las Encañizadas inlet (mainly S1 and S2 sites). These results coincide with those of Franco et al. (2006) from the Venice coastal lagoon, where the northern sub-basin of the lagoon supported higher captures of marine migrant juveniles mainly due to the influence of the Lido inlet, which favoured the entrance of juveniles of marine fish species. Hence, these results suggest that these sites function as important settlement areas for juveniles at the initial stages of the lagoon colonization process. In fact, the cohort mean TL and condition

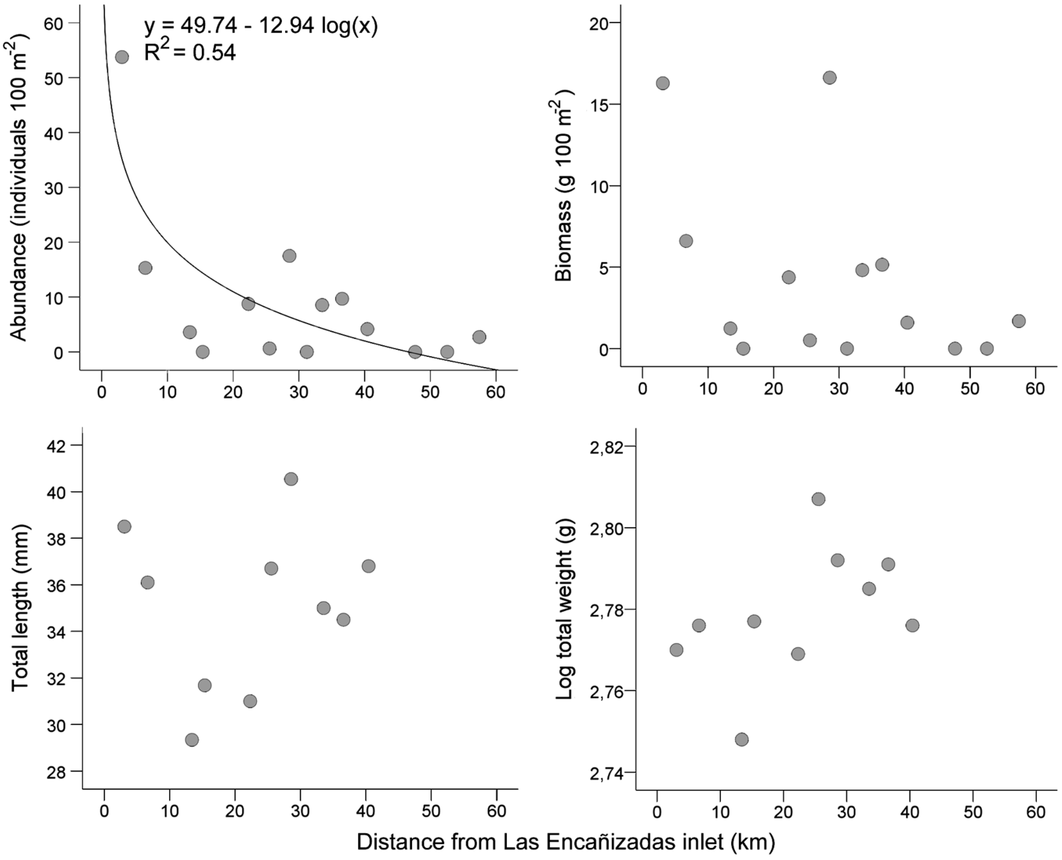

Figure 4. Relationships between the distance from Las Encañizadas inlet and the abundance (top left), biomass (top right), cohort mean TL (bottom left) and condition (bottom right) of *Sparus aurata* during April 2004.

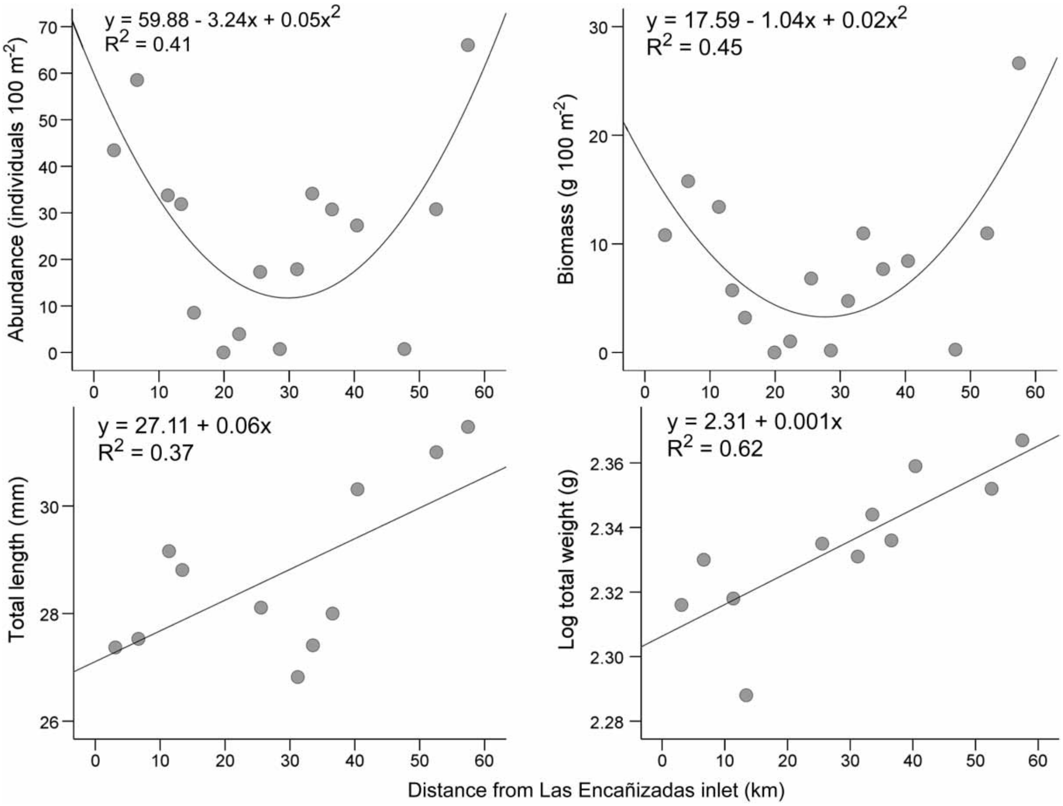

Figure 5. Relationships between the distance from Las Encañizadas inlet and the abundance (top left), biomass (top right), cohort mean TL (bottom left) and condition (bottom right) of *Liza aurata* during February 2003.

of *L. aurata* and *L. ramada* were lower at sites S1–S4, indicating that these individuals had been recently recruited into the lagoon. In the same way, the presence of a younger cohort (C2) for *Sparus aurata* at the S1 and S2 sites was most likely related to the proximity of the Las Encañizadas inlet. The presence of individuals from cohort C2 at S13 was probably related to the proximity of the Marchamalo inlet. Close to this inlet there was a shallow area with a high value as a nursery, called 'El Vivero' ('the nursery') by local fishermen, which has been lost due to urban land development (Pérez-Ruzafa et al. 2004), a situation that probably negatively affects the suitability of this area for settlement by *S. aurata* juveniles, as reflected by the lower abundance and biomass values at this site.

Pérez-Ruzafa et al. (2004) pointed out the scarce presence of Mugilidae and Sparidae larvae in the ichthyoplankton assemblage of the Mar Menor, suggesting that these species colonize the lagoon in juvenile stages. As suggested by results from regression analyses, the increased condition of *L. aurata* and *L. ramada* juveniles coincide with the dominant currents inside the lagoon, which run from north to south along the inner shoreline, with higher values at those sites farthest from the Las Encañizadas inlet. This situation could be related to the fact that the first individuals of the same cohort entering the lagoon could benefit by spending more time in the favourable lagoon environment, reaching higher condition values than later individuals. A recent study highlights the importance of the littoral areas adjacent to salt marsh habitats that line the internal coast of the lagoon (see Figure 1), for these species (Verdiell-Cubedo et al. 2013). These littoral areas present shallow bottoms (<0.5 m) and support well-developed meadows of *Cymodocea nodosa* and *Ruppia cirrhosa*, conditions that might increase the suitability of the Mar Menor for juveniles of *L. aurata* and *L. ramada* by providing abundant food supplies and protection against predators (Franco et al. 2006; França et al. 2009), thus resulting in their increased condition.

Previous studies in the Portuguese estuaries showed that younger *Solea solea* (Linnaeus, 1758) cohorts presented higher condition values than older cohorts (assessed through RNA : DNA ratios) (Fonseca et al. 2006; Vasconcelos et al. 2009), which contrasts with the results obtained in the present study. These differences are explained by the fact that nucleic-based condition indices reflect short-term changes in condition (a few days), whereas morphometric indices reflect long-term changes (weeks) and, consequently, they are more appropriate to compare

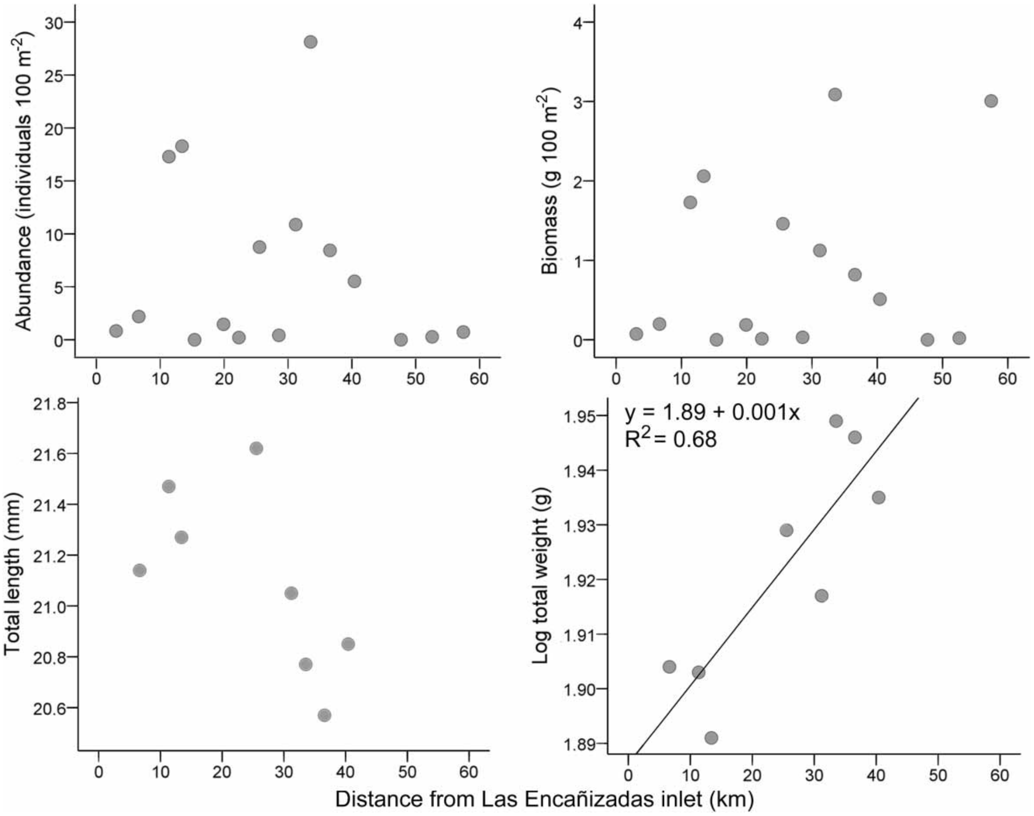

Figure 6. Relationships between the distance from Las Encañizadas inlet and the abundance (top left), biomass (top right), cohort mean TL (bottom left) and condition (bottom right) of *Liza ramada* during February 2003.

fish condition over a wide spatial and temporal range (De Raedemaecker et al. 2012).

There were no significant relationships of growth and condition of *S. aurata* with hydrographical circulation patterns within the lagoon. This situation could be due to seasonal or interannual differences in hydrographical conditions within the lagoon, as temperate coastal lagoons, such as the Mar Menor, exhibit high temporal variability in their environmental conditions (Pérez-Ruzafa et al. 2007). Nevertheless, the observed higher mean condition values of *S. aurata* at those sites farthest from the Las Encañizadas inlet (S8–S13) indicated the potential value as a nursery of the Mar Menor for this species.

Table IV. Mean abundance (ind. 100 m^{-2}) of the studied species in different studies on European estuarine systems and in the present study.

Estuarine system	*Sparus aurata*	*Liza aurata*	*Liza ramada*
Rihios estuary (Koutrakis 2004)	–	1.7–512.5	3.3–285.0
Strymon estuary (Koutrakis 2004)	–	0.3–138.8	0.5–481.6
Porto-Lagos lagoon (Koutrakis et al. 2005)	–	1.1–64.6	0.6–152.3
Venice lagoon (Franco et al. 2006)	<0.1	0.1–0.6	0.2–4.2
Portuguese estuaries (França et al. 2009)	<0.1	<0.1	<0.1
Mar Menor lagoon (present study)	7.7	26.1	5.9

In conclusion, this study indicates the valuable role of the Mar Menor as a nursery area for the studied species. Nevertheless, it is necessary to improve existing knowledge about the recruitment patterns of juveniles of such species in the lagoon, as well as many others of ecological and/or commercial interest (e.g. *Dicentrarchus labrax* (Linnaeus, 1758), *Diplodus puntazzo* (Walbaum, 1792), *Diplodus sargus* (Linnaeus, 1758), etc.), that colonize the lagoon during their juvenile stages (Verdiell-Cubedo et al. 2013). Moreover, further research will be necessary in order to identify critical habitats for their optimal growth and survival within the lagoon, which will be important for both management purposes and the enhancement of fisheries.

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