

# Juvenile bottlenecks and salinity shape grey mullet assemblages in Mediterranean estuaries

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Received 6 August 2007; accepted 22 October 2007

Available online 30 October 2007

## Abstract

Previous research has suggested that competitive bottlenecks may exist for the Mediterranean grey mullets (Osteichthyes, Mugilidae) at the fry stage with the exotic *Cyprinus carpio* (Osteichthyes, Cyprinidae) playing a central role. As a consequence, the structure of grey mullet assemblages at later stages is thought to reflect previous competition as well as differences in osmoregulatory skills. This paper tests that hypothesis by examining four predictions about the relative abundance of five grey mullet species in 42 Western Mediterranean estuary sites from three areas (Aiguamolls de l'Empordà, Ebro Delta and Minorca) differing in the salinity level and occurrence of *C. carpio*. Field data confirmed the predictions as: (1) *Liza aurata* and *Mugil cephalus* were scarce everywhere and never dominated the assemblage; (2) *Liza saliens* dominated the assemblage where the salinity level was higher than 13; (3) *Liza ramado* always dominated the assemblage where the salinity level was lower than 13 and *C. carpio* was present; and (4) *Chelon labrosus* dominated the assemblage only where the salinity level was lower than 13 and *C. carpio* was absent. The catch per unit effort of *C. labrosus* of any size was smaller in the presence of *C. carpio* than where it had not been introduced, which is in agreement with the juvenile competitive bottleneck hypothesis. Discriminant analysis confirmed that the assemblage structure was linked to the salinity level and the occurrence of *C. carpio* for both early juveniles and late juveniles as well as adults. The data reported here reveal that the structure of grey mullet assemblages inhabiting Mediterranean estuaries is determined by salinity and competitive interactions at the fry stage.

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**Keywords:** assembly rules; *Chelon labrosus*; community structure; *Liza aurata*; *Liza ramado*; *Liza saliens*; *Mugil cephalus*; salinity

## 1. Introduction

Ontogenetic niche shifts are common in teleosts fish whereby they gain access to new resources with age (Wootton, 1992). Shifting niches mean shifting biotic interactions between species inhabiting the same ecosystem. As a consequence, the population size and the assemblage structure observed at older stages is often the result of bottlenecks at

younger stages, of biotic or abiotic origin (Persson and Greenberg, 1990; Osenberg et al., 1992; Hjermmann et al., 2004).

Grey mullets (Osteichthyes, Mugilidae) commonly inhabit tropical and warm–temperate estuaries (McDowall, 1988; Blaber, 1997) where they play a crucial ecological role (Lafaille et al., 1998; Torras et al., 2000; Cardona et al., 2001) and usually support artisanal fisheries (McDowall, 1988; Blaber, 1997). Although these species typically spawn at sea, most are highly euryhaline (McDowall, 1988). Laboratory experiments have revealed distinct osmoregulatory strategies among European grey mullet species (Vallet et al., 1970; Lasserre and Gallis, 1975; Nordlie and Leffler, 1975; Nordlie et al., 1982; Kulikova et al., 1989; Shusmin, 1990; Cardona, 2000), resulting in differential distribution patterns along salinity gradients in the wild (Cardona, 2000, 2006). However,

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juvenile bottlenecks might also play a role in structuring grey mullet assemblages in Mediterranean estuaries (Cardona, 2006).

Grey mullets have complex life cycles involving a zooplanktophagous fry stage and several detritivorous/herbivorous post-fry stages (Drake et al., 1984; Arias and Drake, 1990; Cardona, 2001; Blanco et al., 2003). On the basis of stomach content analysis, Gisbert et al. (1995, 1996) concluded that the fry of five native grey mullet species (*Chelon labrosus*, *Liza aurata*, *Liza ramado*, *Liza saliens* and *Mugil cephalus* and those of an exotic cyprinid (*Cyprinus carpio*) were the sole members in Western Mediterranean estuaries of a trophic guild that preyed mainly on copepods and cladocerans. The interrelationships observed among these six species at the fry stage indicate that the fry of *M. cephalus* and that of *L. aurata* have the lowest chances of survival due to their lower competitive skills (Gisbert et al., 1995, 1996). Hence, they are expected to be scarcer than any other grey mullet species at the detritivorous/herbivorous post-fry stage. The fry of *C. labrosus* is also expected to face a juvenile competitive bottleneck where the exotic *C. carpio* has been introduced, as the fry of both species occur simultaneously and the fry of *C. carpio* is more competitive (Gisbert et al., 1996). Current knowledge about the distribution of Mediterranean grey mullets along salinity gradients reveals that *M. cephalus*, *L. ramado* and *C. labrosus* exhibit a preference for low salinity sites throughout the warm season whereas *L. aurata* and *L. saliens* concentrate at high salinity ones (Cardona, 2000, 2006). When the predictions from the juvenile competitive bottleneck theory are combined with that information, four new predictions emerge: (1) *L. aurata* and *M. cephalus* will never dominate grey mullet assemblages in Mediterranean estuaries; (2) *L. saliens* will dominate grey mullet assemblages where the salinity level is higher than 13; (3) *C. labrosus* will dominate grey mullet assemblages where the salinity level is lower than 13 and *C. carpio* does not exist; and (4) *L. ramado* will dominate grey mullet assemblages where the salinity level is lower than 13 and *C. carpio* exists. This paper aims to test the juvenile bottleneck hypothesis by testing those predictions.

## 2. Material and methods

### 2.1. Study sites

The study was conducted at three distinct areas in the Western Mediterranean. Aiguamolls de l'Empordà (42°14' N/3°6' E) and Ebro Delta (40°43' N/0°44' E) are in mainland Spain and have supported large population of *Cyprinus carpio* for several centuries (Demestre et al., 1977; De Sostoa et al., 1994). The distance between Aiguamolls de l'Empordà and Ebro Delta is 336 km, with only a few small and highly polluted estuaries in between. As a consequence, they can be considered as two independent units. The third area was the island of Minorca (Balearic archipelago, 40°0' N/4°0' E), 341 km west to Ebro Delta, where *C. carpio* has never been established (Cardona, 1994).

### 2.2. Sampling

Samples were collected throughout August and September 1997 at 42 different sites: 12 in Aiguamolls de l'Empordà, 11 in the Ebro Delta and 19 in Minorca. Sampling was conducted only in the summer because the structure of grey mullet assemblages is highly modified in autumn and winter due to spawning migrations (Cardona, 2006). Sampling sites were selected in agreement with salinity, although some salinity levels were poorly represented in some areas. Salinity was measured, using the Practical Salinity Scale, with a hand-held Refractometer at 1-m intervals along the water column. The first sample was always collected at the surface and the final sample at the bottom. This methodology allowed us to study water stratification and to calculate the average salinity of the water column at each sampling site. All three areas are tide-free. The salinity does not therefore change during the day. Connectivity with the sea was also considered and sampling sites were also classified as blind (irregular and unpredictable connexions with the sea), seasonally open (connected with the sea throughout most of the rainy season, i.e., October–May) and open (connected with the sea year round).

A trammel net 135-m long and 1.5-m deep, with a stretched mesh size of 25-mm, was laid for 24 h at each site. Trammel nets were used because they are less selective than gill nets (Perrow et al., 1996). This mesh size catches grey mullets with total lengths between 70 and 550 mm (Cardona, 2006). Once in the laboratory, all fish were identified and measured to the nearest millimetre (total length). For further analysis, the specimens of each species were classified in two categories in agreement with total length: early juveniles (shorter than 17 cm for *Liza saliens* and shorter than 20 cm for the other four species) and late juveniles and adults (larger than 17 cm for *L. saliens* and larger than 20 cm for the other four species). This is because early juveniles are typically 1- or 2-years-old (Brusle, 1981; Cardona, 1999) and hence local abundance is expected to reflect possible bottlenecks at the fry stage. However, this might not be true for larger fish as adults are thought to reshuffle from different estuaries after the spawning season (Almeida et al., 1995; Cardona, 2000). Abundance data are reported as catch per unit effort (CPUE) or number of fish caught per m<sup>2</sup> of net and hour of fishing.

### 2.3. Statistics

At a first glance, the best statistical treatment for the 2 × 2 factorial designs here used (salinity level × *Cyprinus carpio* presence/absence) would be a two-way ANOVA. However, the “high salinity and *C. carpio* presence” treatment does not exist given the incapacity of *C. carpio* for inhabiting high salinity sites. Furthermore, most of the data here reported departed from normality, even after being log-transformed. As a consequence, the non-parametric Mann–Whitney *U* test (Zar, 1984) was used to compare: (1) the average CPUE and relative abundance of each grey mullet species in low (<13) and high salinity (≥13) sites independently of *C. carpio* occurrence; and (2) the average CPUE and relative abundance of

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