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Fish composition and assemblage in the anthropogenic-modified tidally-restricted Doñana (Spain) marshlands

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ABSTRACT

The Guadalquivir estuary is the largest estuarine area on the southern Atlantic coast of Europe; its anthropogenic tidally-restricted marshes are partly within the boundary of the Doñana National Park, southern Spain. Our two-year study describes the spatial and temporal patterns of the fish assemblages in the Doñana marshlands in terms of species richness, abundance and biomass. The main families were Mugilidae and Cyprinidae, which accounted for 40.9% of the total species richness. Unlike the fish assemblages found in other European estuaries, Doñana was dominated in both biomass and abundance by freshwater species, mainly invasive exotic species. The spatial analysis of the assemblage showed four significant fish groups corresponding to different habitats established *a priori* and related to the salinity gradient. Assemblages did not show a seasonal pattern and the temporal fish groups observed were mainly related to the hydrological cycle and the extreme drought that occurred during the study period.

1. Introduction

Shallow estuarine marshes and waters play an important role in productivity and provide an essential habitat for juvenile and threatened fish species (Thiel et al., 2003; McLusky and Elliott, 2004). Parameters such as salinity, temperature, water turbidity and water level, which vary greatly in estuaries, strongly influence the spatial and temporal composition of fish communities (Marshall and Elliott, 1998; Selleslagh and Amara, 2008).

Mediterranean areas are characterized by recurrent droughts related to most of the parameters described above, together with other physical, functional and evolutionary factors. Several studies have shown the effects of the variation in freshwater input on fish communities in other geographical areas (Whitfield, 2005) as well as in the Iberian Peninsula (Costa et al., 2007; Dolbeth et al., 2010; Baptista et al., 2010). The ecological functioning of many estuaries has been largely altered by human activities. The most significant anthropogenic stressors in these ecosystems are related to resource exploitation and land-claim (i.e. rice crops), species introductions, pollution, climate change and hydrological infrastructures (McLusky and Elliott, 2004; Vasconcelos et al., 2007; Bromberg-Gedan et al., 2009; Courrat et al., 2009). Barriers, dikes and levees have been built in many marshlands worldwide and have restricted tidal amplitude, altering the physicochemical cycles and affecting the habitat and biota (Harrington and Harrington, 1982; Roman et al., 1984; McGovern and Wenner, 1990; McLusky and Elliott, 2004; Chícharo et al., 2006; Valentine-Rose et al., 2007).

The Guadalquivir estuary originally had about 250,000 ha of shallow water area, but during the first half of the 20th century much of the land was transformed for agriculture and the original natural area was reduced by about 80%. The remaining 20% of the natural marshlands are included within the boundary of the Doñana National Park, a critically important area for different sectors of biodiversity (Fernández-Delgado, 2005a). In the 1960s, natural channels connecting these residual natural marshlands with the main river were blocked with sluices, and a wall about 1.5 m high stopped natural tidal flooding, isolating the marshlands from the low area of the estuary (Montes et al., 1998). Consequently, freshwater coming from the streams surrounding this marshland, which are strongly influenced by agricultural activities, cannot completely mix with the saline waters coming from the Guadalquivir estuary. The result is a tidally-restricted marshland dominated by shallow, stagnant freshwater (Fernández-Delgado, 2005a,b; Bayán, 2006). Natural estuarine processes are currently limited to the main channel of the Guadalquivir River, which is an important nursery area for many fish and invertebrate species (Drake et al., 2002; Sobrino et al., 2005).

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There are few studies on the ichthyofauna of the Doñana National Park and most focus primarily on fish communities living in the main channel of the Guadalquivir River (Hernando, 1978; Fernández-Delgado, 1987; Drake et al., 1999, 2002; Sobrino et al., 2005; Fernández-Delgado et al., 2007). The aim of our two-year study was to interrogate the first data on the fish assemblages in these isolated and disturbed marshlands, focussing on the spatial and temporal variation in species richness, abundance, biomass and ecological guilds. We hypothesized that the fish assemblage from the *Doñana marshland* was not uniform across the spatial zonation of the system and, because the historical transformation of the landscape has resulted in a marshland that is not connected with the main flow of the Guadalquivir River, this assemblage is strongly affected by its unnatural tidally-restricted conditions.

2. Methodology

2.1. Study area

The study was carried out in the remaining marshlands of the Guadalquivir estuary. Most of the sample locations were within the boundary of the Doñana National Park (*Doñana marshlands*) (Fig. 1). In natural conditions, the annual hydrological cycle of these marshlands begins in autumn with a phase of progressive freshwater flooding by rainfall and the water coming from the surrounding temporary streams (i.e. La Cigüeña, El Partido). The highest water levels are reached in winter and spring. After this season, the drying up phase begins, and the marsh is completely dry by the middle of summer until the next wet period. Despite this, this hydrological cycle is strongly affected by the isolation of the marshlands and human management of the sluices (Fernández-Delgado, 2005a).

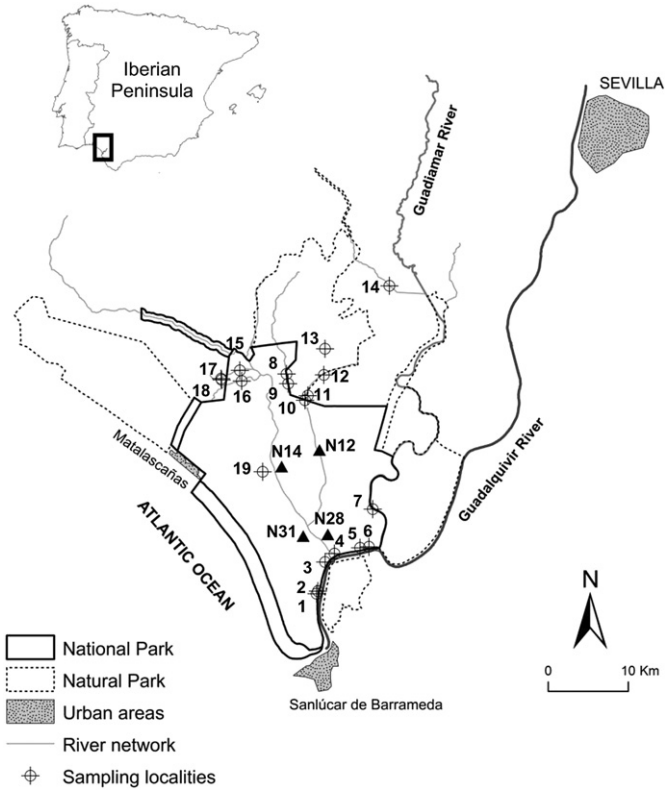

Fig. 1. Map of the Doñana marshland showing the sampling locations and the hydrological reference points.

Halophytic vegetation, mainly *Salicornia* spp., is still present due to the residual salinity remaining in the land. The climate in Doñana is temperate with warm dry summers. During the study period, the average monthly temperature ranged from 7.1 °C to 25.5 °C.

2.2. Sampling and environmental data

Fish were collected six times, twice in *autumn* (September 2003 and September 2004), twice in *winter* (February 2004 and February 2005) and twice in *summer* (July 2004 and August 2005). Four habitat types in the marshland were sampled: 1) intertidal creeks and remaining intertidal ponds within the marshland (*external marsh*; locations 1–7); 2) remaining ponds without an intertidal influence (*internal marsh*; locations 8–13); 3) small streams flowing into the marshland (*streams*; locations 14–16), and 4) small ponds (*ponds*; locations 17–19). All of these habitats were shallow areas (less than 80 cm deep) with dispersed patches of seagrass meadows and soft substrata (muddy-sandy sediments).

Sampling was performed using sets of three fyke nets with different mesh sizes (one of each mesh size: 0.1, 0.5 and 1.0 cm), and each set was placed covering an area of about 100 m^2. The fyke nets remained in the water for approximately 24 h. The three mesh sizes were used to reduce the bias on small-sized fishes (Malavasi et al., 2004). The sampling effort was homogeneous throughout the sampling locations depending on the total area of available habitat at each sampling event. Taxon biomass and abundance were standardized to BPUE (biomass per set hour) and CPUE (catch per set hour).

Fish were anaesthetized using clove oil, counted and weighed (TW ± 0.1 g) *in situ*, and then released. Juvenile individuals were transported to the laboratory to be identified. All fish were identified at species level, except *Carassius* spp., since it is not yet certain which species is established in the Guadalquivir basin and further genetic studies are needed (Kalous et al., 2012; Kalous, pers. comm.). All of the taxa were classified according to the estuarine use functional group defined by Franco et al. (2008) and using backgrounds from previous works (Mathieson et al., 2000; Elliott et al., 2007; Drake, pers. comm). *Gambusia holbrooki* was assigned to the freshwater ecological guild in *ponds* and *streams* and to the estuarine guild in marsh areas because the species has a highly variable phenotypic plasticity that allows it to inhabit and breed in both habitats (Pyke, 2005). The conductivity was recorded (HANNA® HI 8733) before the fyke nets were set. Water level and precipitation data were obtained from four reference points (N12, N14, N28 and N31) from the limnological monitoring programme carried out by the Doñana Biological Station (http://icts-rbd.ebd.csic.es). These reference points were selected because they showed the best hydrological cycle of the area.

2.3. Data analysis

The spatial and temporal variation in the community biomass and abundance was analysed with a multivariate approach using the computer software package PRIMER 6.0 (Plymouth Routines In Multivariate Ecological Research). Mean abundance and biomass values were calculated for each species across sampling events for the temporal analysis and locations for the spatial analysis. Sampling events and locations were ordered using non-metric multidimensional scaling (NMDS) based on ordination with the Bray–Curtis dissimilarity measure calculated with root–root transformed abundance and biomass data (Clarke, 1993). The stress (S) value of each NMDS plot was calculated and classified as an 1) excellent representation ($S < 0.05$), 2) good representation ($0.05 < S < 0.10$), or 3) useful representation ($0.10 < S < 0.20$) (Clarke and Warwick, 2001). A cluster analysis was applied to