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Small creeks in a big lagoon: The importance of marginal habitats for fish populations

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ABSTRACT

Temperate transitional water systems, as in the case of the Venice Lagoon, are characterised by many different shallow-water habitats. The availability of trophic resources and the low predator pressure make salt marshes one of the most important habitats for many fish species, both resident and marine migrant, but several anthropogenic pressures, erosion and relative sea level rise in particular, are causing a significant loss of this habitat. A part from natural habitats, in many small islands of the Venice lagoon, artificial creeks of different size and morphology are present, once used in traditional aquaculture activities or built up as defence lines. Aims of this study is to analyse and compare the structure and composition of fish communities inhabiting small-sized creeks, considering both the natural and artificial ones, in order to evaluate the ecological importance of these marginal habitats for fish populations. A particular attention was given to artificial sites, assessing their ecological value as alternative refuge habitats to natural salt marsh creeks. One year samplings conducted in four sites (two natural salt marshes and two artificial creeks) allowed to describe the local fish communities, which comprised 20 species overall. The analysis of how water parameters and habitat structure influenced the fish communities showed the importance of the connection between small creeks and the open lagoon, but also the refuge function offered by confined systems. High abundances of resident fish species listed in the Annex II of the Habitat Directive were observed and juveniles of eight species of marine migrant fish were found, some of which are of economic importance. This study underlined the presence of significant densities of juvenile marine migrant and lagoon resident fish species in the two artificial habitats. Actually, species richness and density resulted to be, in some cases, higher than in natural salt marsh systems. Results of this study emphasize the ecological importance of these marginal habitats for many fish species, of both conservation and economic importance Thus a proper management and restoration strategy of these sites is needed to maintain their functionality and to buffer the disappearance of natural salt marshes.

1. Introduction

Salt marshes constitute one of the most important habitats in temperate transitional water ecosystems (Kennish, 2002; Airoldi and Beck, 2007; Lowe and Peterson, 2014). They play several ecological roles for animal populations, and in particular for fish species (Mathieson et al., 2000; Kneib, 2000). Indeed, these habitats host abundant populations of both estuarine resident and migrant species, with higher fish densities relative to adjacent unvegetated open-water habitats (Franco et al., 2006a,b). The ecological importance of these habitats is mainly due to the high level of trophic resources available and to the refuge function from predation deriving from a complex morphological structure (Rountree and Able, 2007). Furthermore, many fish species living in these areas are of conservation or commercial relevance (Franco et al., 2010, 2012). The importance of these habitats for aquatic fauna derives from their high spatial heterogeneity; salt marshes consist of a complex mosaic of microhabitats such as vegetated edges, subtidal and intertidal creeks, pools and ponds (Minello et al., 2003). Among them, salt marsh creeks in particular host high fish density (Desmond et al., 2000; Franco et al., 2006a,b).

In the last decades, many anthropic pressures determined a substantial loss of salt marsh habitats worldwide (Airoldi and Beck, 2007; Fagherazzi, 2013). Land claim, erosion, pollution, aquaculture and relative sea level rise determined the alteration or the complete destruction of these habitats. A major loss of salt marsh habitats occurred also within the Venice lagoon, the largest Mediterranean coastal lagoon, with salt marsh surface reduction from about

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149 km^2 in 1912 to 37 km^2 in 2003 (Cucchini, 1928; Silvestri et al., 2003), mostly due to the effects of anthropogenic-induced erosion (Sarretta et al., 2010). Furthermore, a strong reduction of the extent of salt marshes (Carniello et al., 2009) or even their complete disappearance (Cola et al., 2008) are predicted over the next 50 years. Even if in the last decades many salt marsh restoration activities have been carried out to counterbalance this negative trend (Carniello et al., 2009), some of the causes of marsh loss has not been, or cannot be, easily prevented. Subsidence and relative sea level rise have been addressed as among the major causes of salt marsh loss (Bock et al., 2012; Kirwan and Megonigal, 2013), particularly in situation with a lower income of sediments such as in the case of the Venice lagoon. For the Adriatic Sea, during the XX century, sea level rose at a rate of 1.3 mm y^{-1}, and by the year 2100 it could rise 14–49 cm (Scarascia and Lionello, 2013).

In the Venice lagoon, small inter/subtidal creeks a few meters wide only, with a mean depth of 0.5–1.5 m, may be also found within lagoon islands. They are mainly man-made artificial creeks, once used for traditional fish farming, as small marinas or as defence line during the two world wars.

While navigation channels are subjected to periodic maintenance and a certain degree of pollution and disturbance due to boat traffic, the other two types of artificial creeks are now mainly abandoned and partly renaturalised. These artificial habitats were built mostly during the XIX–XX centuries and can be divided into two main categories. The first one is composed of closed systems, once regulated by water gates but now mostly abandoned; in some cases, water infiltration by nearby channels allows for a partial water renewal. These habitats, as part of an integrated form of land use, are composed of a network of shallow water creeks used for fish farming, crossing through fields and orchards. In most of the cases, these traditional activities are now strongly diminished or completely abandoned, resulting in a renaturalisation of both terrestrial and aquatic habitats. A second group of artificial creeks comprises more open systems, mainly used as marinas or to defend military buildings. These creeks often present step stone banks and a greater depth, up to two meters, allowing navigation to small boats. Thus, for their morphology these are tide influenced habitats, but even during low tide a complete drainage of the water does not occur, allowing the permanence of fish within the creek. On the whole, Venice lagoon hosts about 100 km of these artificial creeks. Waltham and Connolly (2013) proposed the maintenance and restoration of artificial tidal lakes along the Gold Coasts in Queensland (Australia) as a process in some way inverse to land claim. Similarly, within the Venice lagoon, despite a simpler morphology, the network of artificial creeks could in part buffer the biodiversity loss due to salt marsh disappearance by providing suitable habitats for many fish species, even of conservation and commercial interest. Most of these artificial creeks are located in marginal and scarcely populated areas, thus avoiding impacts from the many anthropogenic pressures that affect other lagoon habitats, perhaps with the exception for those deriving from small-scale agricultural practices. Conversely, the lack of a regular control and maintaining of many sites determined, in some cases, a progressive burial due to sediment and detritus accumulation.

Considering the increasing loss rate of salt marshes, in a context of local and global pressures, this study focused on small artificial creeks within the Venice lagoon, to assess if these canals can be a habitat for fish fauna, even though the comparison with the most similar natural habitats, such as salt marsh creeks. Over a one-year period, the two main typologies of small-sized artificial creeks were investigated: one is a closed system, isolated from lagoon circulation, while the other one is an open creek, strongly influenced by sea water. Moreover, two natural salt marsh creeks were chosen as reference points and sampled at the same time, in order to: (1) investigate the ecological role of artificial creeks as habitat for fish fauna, (2) assess how the degree of connection with the open lagoon influence the fish community and (3) compare the fish fauna and the environmental conditions between artificial and natural habitats.

We expected that the differences in habitat structures between artificial and natural sites, especially as a result of the weak/absent tide regime in the former, would influence the composition of fish communities. In particular, the partial to complete isolation from lagoon open waters would increase the refuge function from aquatic predators typical of shallow water creeks, thus resulting in higher fish density in artificial sites. The assessment of environmental and fish community characteristics of artificial creeks, in comparison to natural salt marshes, is here provided as a baseline for the development of future management and restoration plans of these sites in the largest Mediterranean coastal lagoon, in order to buffer the biodiversity loss expected to occur as a consequence of natural salt marsh loss.

2. Materials and methods

The Venice lagoon is one of the largest lagoons along the coasts of the Mediterranean Sea, with a surface of about 540 km^2. It is a microtidal transitional water ecosystem, where tides can reach 1 m of excursion, characterised by wide extensions of shallow brackish water interrupted by a network of deeper channels and salt marsh habitats. Four sampling sites were chosen within the Venice lagoon (Fig. 1): two creeks within natural salt marsh habitats (N1 in the northern basin and N2 in the southern basin) were used as reference sites and were compared to two artificial creeks (A1 and A2) within two islands of the lagoon. The natural sites comprised small-sized intertidal creeks (200–250 m long, 2–4 m width), with a maximum depth of 0.7 m, which completely drain during the low tide phase. Among the artificial aquatic habitats present within the Venice lagoons, two sites were chosen in order to represent two "extreme" situations.

A1 was a ring-shaped ditch (about 700 m long, 8 m width) situated next to one of the lagoon sea-inlet and thus strongly influenced by seawater. A small connection allowed partial water exchanges with the lagoon, but a maximum depth of 2 m, together with the height of the connecting opening (about 1 m below the mean sea level), prevent from the complete drainage during low tide phase. A2 was a closed system of inland small-sized creeks (about 500 m long, 5 m width) isolated from lagoon waters, with a mean depth of 0.5 m and no tide excursion. In each sampling site, 11 sampling campaigns were performed from March 2010 to March 2011 with a beach seine net (8 m long, knot-to-knot distance of 2 mm). Three net tows were conducted during each campaign, in order to determine the explored area, length and width of each tow were measured. Sampled fish were photographed on millimeter paper and then released. Only when necessary, a representative subsample of fish was sacrificed with an excess of 2-phenoxyethanol and preserved in 8% buffered formaldeid. During each sampling event, the main chemico-physical water parameters were recorded: temperature (digital thermometer, ±0.1 °C), salinity (optical refractometer, ±1), dissolved oxygen (Winkler method, ±0.1 mg L^{-1} subsequently converted in percentage of saturation) and turbidity (portable nephelometer, ±0.1 ftu). In June three cores of sediment (Ø 3 cm) were collected in each site to determine the content of organic matter in the upper sediment layer (10 cm), estimated as loss on ignition (Loi 550).

Each specimen was identified to species level and density of each species was estimated by dividing the total abundance for the sampled surface. Each species was then assigned to a functional guild according to Franzoi et al. (2010). For data analysis,