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Use of seasonally flooded rice fields by fish and crayfish in a Mediterranean wetland

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ABSTRACT

Rice fields constitute a significant proportion of the existing wetlands in the Mediterranean basin and are important areas for the conservation of different vertebrate species, especially birds. However, little is known on how fish and crayfish use rice fields in Mediterranean areas. In this work we analyze fish communities and crayfish populations occupying rice fields and their associated irrigation network (inflow and outflow channels) in the Ebro Delta (NE Spain). We set fyke nets in 104 sites and captured almost 23,000 fish belonging to 19 species, 9 of which were found to occupy rice fields, as well as over 3000 red swamp crayfish (*Procambarus clarkii*). Stone moroko (*Pseudorasbora parva*), common carp (*Cyprinus carpio*), dojo loach (*Misgurnus anguillicaudatus*) and Eastern mosquitofish (*Gambusia holbrooki*) were the most common fish found in rice fields. More than 95% of the fish individuals captured belonged to non-native species. Dojo loach, a recently introduced species well adapted to rice cultivation cycles in its native range, used rice fields as reproduction ground. Outflow channels seemed to be a more important source of fish colonizing rice fields than inflow channels. Colonization was the main limitation for the establishment of fish populations in rice fields and fish tended to be more abundant in rice fields than in channels for any given frequency of occurrence. The importance of fish as trophic resource for natural predators and the possible interactions between fish occupying rice fields and rice yield, largely unexplored in the Mediterranean areas, could be managed by modulating connectivity between rice fields and irrigation channels. Rice fields, however, are not important areas for the conservation of native fish biodiversity, being largely occupied by non-native fishes. Moreover, the influence of low-conductivity water diverted for rice cultivation on natural wetlands favors the establishment and expansion of different non-native fish species.

1. Introduction

Rice is one of the most important crops worldwide, being the staple food for almost half the whole human population (Tsuruta et al., 2011). In 2009 rice fields occupied over 158 million hectares around the world, almost 90% of them in Asia (FAOSTAT, 2011). The majority of rice fields are placed in former natural wetlands and approximately 15% of the world's wetland area corresponds to rice paddies (Lawler, 2001). Thus, apart from their socio-economic importance, rice fields are a prominent component of the planet's wetlands. It is therefore important to understand how wetland biota uses rice fields and the role of these human-created wetlands in the conservation or decline of biodiversity. This is especially relevant in the current context of degradation and loss of natural wetlands, which have resulted in the disappearance of over 50% of the original wetland areas in regions such as Europe or the USA (e.g., Keddy et al., 2009; Strum et al., 2013).

From a global perspective, the area devoted to rice cultivation in south western European countries is relatively small (less than 0.3% of global area), but these figures grow in importance when put in the context of the available wetland area. For example, the total area designated by Portugal, Spain and Italy as Wetlands of International Importance in the framework of the Ramsar convention is around 432,000 hectares (data from www.ramsar.org; accessed September 2011), while 386,000 hectares were devoted to rice fields in 2009 in those three countries. Moreover, the crop has expanded in Western Europe in the last decades, increasing by 53% between 1961–65 and 2005–09 (5-year averages) (Fig. 1). These increases have been especially important in Italy (+90%) and Spain (+75%), while the extension of rice fields

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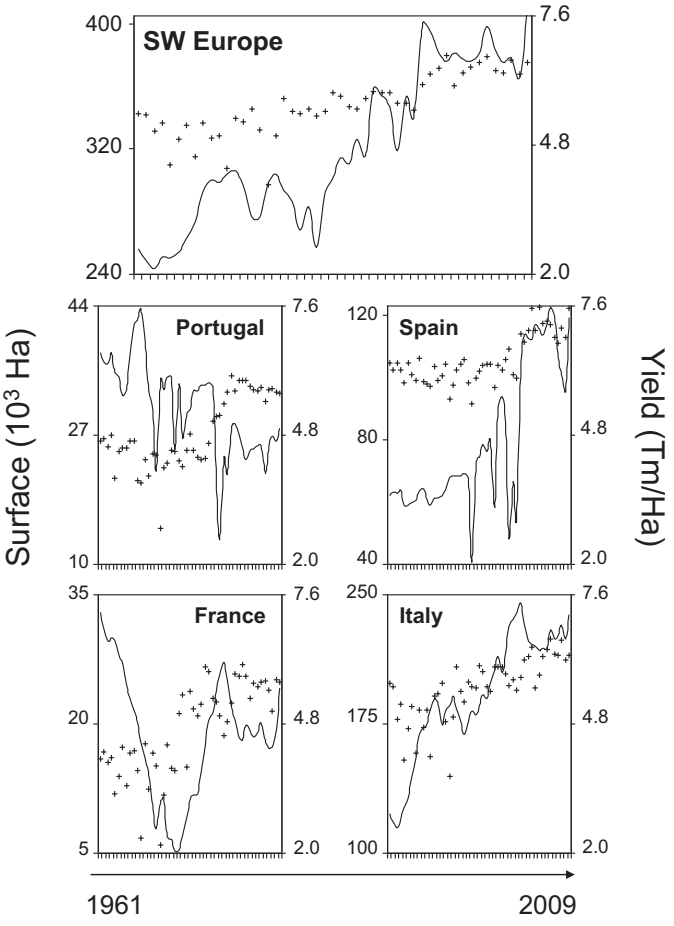

Fig. 1. Evolution along a 49-year period (1961–2009) of: (i) the area devoted to rice cultivation (lines); and (ii) rice yield (crosses) in south-western Europe, presented also separately for Portugal, Spain, France and Italy. Data obtained from FAOSTAT (2011).

decreased in the same period in France and Portugal. Rice yields have also increased in these four countries (Fig. 1), arguably due to the use of agrochemicals (e.g., Suárez-Serrano et al., 2010a).

European rice fields are placed mainly in lowland river plains or deltas under Mediterranean-type climatic conditions. Fields are inundated between spring and summer, thus having an inverted hydroperiod to that of surrounding natural temporal wetlands, which tend to be dry during summer (Pearce and Crivelli, 1994). In fact, rice fields provide the only available surface freshwater during summer droughts in many Mediterranean wetlands. Rice fields are drained and kept dry during autumn and winter to allow the oxidation of organic matter in soils, although some fields may be maintained flooded during autumn to enhance water bird populations, whether for hunting or with a focus on conservation (Forés and Comín, 1992; Elphick, 2004).

Rice fields can be occupied by a rich biota, including algae, aquatic plants, many invertebrate taxa and a variety of aquatic and semi-aquatic vertebrates (Lawler, 2001). Fish are often absent from natural temporary wetlands (Batzer and Wissinger, 1996), but they can occupy seasonally flooded rice fields due to their high connectivity to larger aquatic systems through irrigation infrastructures. As happens in natural wetlands, fish can be key elements in the dynamics of rice field biota, since they can structure communities through top–down mechanisms (Batzer and Wissinger, 1996) and be important prey for other organisms that use rice fields, such as reptiles (Santos et al., 2000) or birds (Lane and Fujioka, 1998).

Most of the research focused on the use of rice fields and their associated aquatic habitats by fish has been developed in Asian countries (e.g., Bambaradeniya and Amerasinghe, 2003; Katano et al., 2003). Many Asian rice landscapes are managed as different types of rice-fish systems, in which farmers favor the populations of aquatic animals in rice fields (mainly, but not only, fish) to increase their harvest (Amilhat et al., 2009b; Koseki, 2014). There is only sparse information on the occurrence of fish on south western European rice fields, where fish populations are not enhanced by farmers for fish production. In fact, to our knowledge, no study has specifically analyzed fish communities in European rice fields.

Here we provide information about the composition of fish communities that use rice fields in the Ebro Delta, a large coastal wetland area in north eastern Iberian Peninsula. We also characterized fish communities in associated irrigation channels, both inflow and outflow ones, attempting to identify the origin and features of fish that colonize rice fields. Specifically, our aims are: (i) to characterize the identity and relative abundance of fish occupying rice fields and their associated irrigation network; (ii) to assess the importance of the different possible pathways of occupation of rice fields by fish; and (iii) to analyze the population structure of the most common fish species in the different aquatic environments linked to rice cultivation. The results are used to discuss the possible interactions between fish communities and rice cultivation as well as the importance of rice fields for the conservation of fish and other biodiversity components.

2. Study area

The Ebro Delta is a large alluvial plain formed in a West–East direction by the deposition of sediments as the Ebro River enters the Mediterranean Sea. Around 20,000 hectares (more than 60% of the delta surface) are nowadays used for rice cultivation. Rice fields are irrigated with water from the river. Some 40 m^3/s are diverted at the Xerta dam (some 60 km upstream from the delta) through two main channels, one at each side of the river, built in 1860 (right side) and 1912 (left side) (March and Cabrera, 1997). Once entering the Delta, these two main channels are subdivided to form a complex network of smaller channels, taking low-conductivity water from the river to rice fields. Inundated rice fields have relatively shallow waters (in general less than 15 cm) and, due to the saline nature of soils, a high water renovation rate (3 to 5 days) during rice growing season, between April and September. After harvest, inundation is maintained until January following agro-environmental measures, mainly to benefit water birds. Water outflows from fields are conducted either back to the river or the sea through an equally complex network of drainage channels. Inflow and outflow webs of channels are connected exclusively through rice fields. The total channel network sums more than 1000 km in length (March and Cabrera, 1997). Inflow channels are made of concrete and have strong water current, while most outflow channels have a ground (silty) bottom and carry much more calmed waters. Inflow channels are dried once every year (between January and February) for maintenance operations.

3. Methods

3.1. Sampling

Fish communities were sampled between June and October in 2007, 2008, and 2009. We sampled fish communities in 104 sites: 40 inflow channels, 29 rice fields, and 35 outflow channels. We chose outflow channels that were more dependent on water leaving rice fields, avoiding those that were near the sea, the natural lagoons or the Ebro River. Fish were captured with unbaited fyke nets, which had a single wing (of approx. 1m), two