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Grass management intensity affects butterfly and orthopteran diversity on rice field banks

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ABSTRACT

Agricultural intensification through landscape homogenization has been identified as one of the main drivers of the recent biodiversity decline in European farmlands. In particular, the loss of non-cropped habitats has often deprived farmland species of feeding and nesting sites, refuge areas, and dispersal corridors. In this framework, well-managed field margins may play a key role for wildlife conservation in agroecosystems, providing additional suitable habitat patches for many species, which also include several natural agents of pests' biological control. In rice crops, paddy banks are usually heavily managed by farmers, which remove vegetation through chemical or mechanical procedures, with a consequent limitation of the potential role of levees in maintaining a functional agroecosystem. The aim of this study was to investigate the response of butterfly and orthopteran diversity to different grass management practices on rice field banks, namely herbicide spraying, mowing, and no management. Between April and September 2016, we sampled butterflies and orthopterans on 30 and 22 paddy levees respectively, located in three sites within the intensive rice crop district of northern Italy. Herbicides spraying proved to be the most detrimental practice for these insects, producing a considerable reduction in species richness and abundance in comparison with unmanaged and mown banks. The impacts of mowing were less pronounced than those of chemical treatments; however, frequent cutting caused a significant reduction in butterfly and orthopteran diversity on levees. Our results highlight the importance of unmanaged banks in preserving insect diversity in rice crops, while herbicide spraying should be avoided. Low frequency and rotational mowing could represent sustainable management solutions to meet biodiversity and husbandry requirements in this agroecosystem.

1. Introduction

During the last decades, agricultural intensification in Europe led to a widespread decline in farmland biodiversity (Donald et al., 2001; Kleijn et al., 2009; Robinson and Sutherland, 2002), especially through a reduction of landscape heterogeneity (Benton et al., 2003; Tscharntke et al., 2005). Field enlargement to increase agricultural production caused a progressive loss of marginal habitats (Marshall and Moonen, 2002; Stoate et al., 2001), while mechanical and chemical control of weeds and pests has drastically reduced the suitability of boundaries for farmland wildlife (Vickery et al., 2009). The key role of field margins for biodiversity conservation has been widely recognized in literature (Marshall and Moonen, 2002), as they provide foraging and breeding sites, overwintering habitats and refuge from detrimental agronomic practices for many species (Ekroos et al., 2008; Kells and Goulson, 2003; Pywell et al., 2004, 2005; Vickery et al., 2009). In addition, many arthropods found in these habitats may play a valuable role in biological control and integrated pest management (Bianchi et al., 2006; Symondson et al., 2002; Thies and Tscharntke, 1999), with consistent benefits to agriculture.

Rice fields are recognized worldwide as surrogate habitats for wetland species, representing an important agroecosystem for biodiversity conservation in lowlands (Bambaradeniya et al., 2004; Czech and Parsons, 2002; Duré et al., 2008; Fasola and Ruiz, 1996; Lawler, 2001; Lupi et al., 2013; Giuliano and Bogliani, 2018). Although far from the main world producers, Italy is the most important European country in terms of rice production. Paddy fields extended over 234,133 ha in 2016, representing about 50% of European rice dedicated fields (FAOSTAT, 2018). However, recently rice cultivation in Italy underwent a dramatic intensification (Bogliani, 2008), likewise to what described by Katayama et al. (2015) in Japan. This process occurred similarly to other cultivation types, producing a general landscape homogenization with a progressive reduction of semi-natural habitats (Katayama et al., 2015). Therefore, rice systems are today mainly

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composed by few dominant habitat structures (Bambaradeniya et al., 2004): (1) flooded paddies; (2) irrigation canals and ditches; and (3) paddy banks (also called bunds or levees), normally composed by earthen-made mounds (about 1 m wide), that enclose water and separate adjacent fields.

Rice field margins are usually heavily managed by farmers (Cardarelli and Bogliani, 2014), which remove vegetation with chemical or mechanical procedures, mainly to allow an easy control of the inlet and outlet of paddy floodwaters and to contain weeds. The result is often a strip dominated by resistant grasses (e.g. Poaceae, Cyperaceae) or a belt of bare soil. Nevertheless, when natural vegetation is present along rice field banks, this habitat potentially becomes suitable for some nesting birds (e.g. Northern Lapwing *Vanellus vanellus*, Mallard *Anas platyrhynchos*; Longoni, 2010), also favoring species typically related to rice paddies for reproduction (e.g. Eurasian Bittern *Botaurus stellaris*; Longoni et al., 2011). In addition, levees managed at low intensity can produce positive effects on arthropods, by supporting high spider abundances (Tahir and Butt, 2009) and by ensuring the establishment of functionally complex ground beetle assemblages (Cardarelli and Bogliani, 2014). Even if evidences exist on the essential role that vegetated banks could have in the maintenance of a functioning rice ecosystem, few studies were so far specifically focused on the effects of different levee management strategies on arthropods diversity. In this context, our research analyses the response to banks management of two insect groups rarely investigated in rice crops, but representing important components of farmland biodiversity.

Butterflies (Lepidoptera: Papilionoidea, Hesperoidea) are among the most studied arthropods throughout the European agroecosystems. These insects are largely used as environmental indicators of habitat quality and human impact, since many species are characterized by a high ecological sensitivity (Erhardt, 1985; New, 1997; Oostermeijer and van Swaay, 1998; Stefanescu et al., 2005). Butterflies are also considered good pollinators (Willmer, 2011; Winfree et al., 2011), especially because they are able to carry pollen farther than other insects, providing important benefits in maintaining a long-distance gene flow between plant populations (Courtney et al., 1982; Herrera, 1987). Unfortunately, these insects recently underwent a widespread decline, in particular where an intensive agriculture is present (Bubová et al., 2015; van Dyck et al., 2009; van Swaay et al., 2010). Indeed, an extensive literature is available on the impacts of agricultural practices on butterfly diversity and abundance (Bubová et al., 2015), also highlighting the detrimental effects of insecticides (Gilburn et al., 2015). Furthermore, agricultural intensification is one of the main drivers of the recent Large Copper's (*Lycaena dispar*) decline in northwestern Europe (Pullin et al., 1998; van Swaay et al., 2010), where this butterfly is considered one of the most endangered species. The conservation value of *L. dispar* has been widely recognized in this area, leading to its inclusion in the Annexes II and IV of the EC "Habitat" Directive (92/43/CEE). In northern Italy, Large Copper initially coped with the progressive farmland expansion by finding a suitable secondary habitat in rice fields (Balletto et al., 2005), where its life history plants (belonging to the genus *Rumex*) were able to satisfy their hygrophilous requirements, growing on rice field banks or along irrigation canals. Nevertheless, the recent introduction of more intensive management practices, such as the massive use of herbicides during the growing season, resulted in a decline of *L. dispar* populations also in these habitats (Balletto et al., 2005).

Orthopterans (Orthoptera: Ensifera, Caelifera) represent another important component of farmland invertebrate assemblages. These insects are good indicators for grassland ecosystems health as they strongly respond to management intensification, both by decreasing species richness and population density (Báldi and Kisbenedek, 1997; Fischer et al., 1997; Marini et al., 2008; van Wingerden et al., 1992). Moreover, orthopterans play a key role in food webs, representing a substantial food resource for birds (Barker, 2004; Bretagnolle et al., 2011; Fasola and Cardarelli, 2015; Rodríguez and Bustamante, 2008), and in ecosystem services, helping farmers in weed control through an effective seed predation (Ichihara et al., 2015). Similarly to butterflies, agricultural intensification is considered one of the main causes for orthopterans' decline in European farmlands, producing in particular a widespread habitat loss for many species (Hochkirch et al., 2016).

In this paper, we evaluate the effects of different grass control procedures in rice field banks on butterfly and orthopteran diversity. Since both *taxa* proved to be efficient environmental indicators, we suppose that they may respond with a decrease in species richness and abundance with increasing management intensity. With the choice of butterflies and orthopterans as target *taxa*, we aim to investigate the impacts of levee management techniques on two different functional groups in rice agroecosystem, i.e. pollinators (adult butterflies) and phytophagous (orthopterans) insects, providing a comprehensive assessment of the ecological effects of different grass control systems on paddy banks. This paper also proposes some management recommendations for rice growers, in order to improve the suitability of rice agroecosystems for biodiversity.

2. Materials and methods

2.1. Study area

The study was carried out in three sites (overall surface: 4.23 km^2), within the properties of two rice farms, both located in the rice crop district of northwestern Italy (Pavia province). In particular, our samplings were performed in two sites belonging to the Buffa's farm, in the municipalities of Robbio (45°18′45.02″N; 8°35′18.53″E) and Rosasco (45°16′10.59″N; 8°34′51.07″E); while a third site, belonging to the Braggio's farm, was selected within the municipality of Zeme (45°11′42.55″N; 8°38′25.01″E) (see maps in Appendix A). The three sites were separated by each other by a minimum distance of 5.26 km (Robbio-Rosasco), while 13.70 km and 9.18 km spaced apart Zeme from Robbio and Rosasco respectively. The overall study area was included in a landscape heavily dominated by rice fields, where the occurrence of other cultivation types and semi-natural habitats (e.g. grasslands, woodlands, etc.) was limited and scattered (see Appendix A).

Both the rice farms which hosted our research followed the principles of the integrated production, thus applying similar rice farming procedures in the three investigated sites, also including a comparable water management within paddies. Pesticide treatments within fields were limited to selective herbicides and fungicides, while no insecticides were applied by farmers in our study area.

Rice was sown at the end of April/beginning of May in dry paddies. Then, in the first months after sowing (May and June), rice fields were periodically flooded and dried, in order to allow a correct roots development in rice sprouts and to facilitate the access into paddies with machineries for periodical treatments. Between July and late August a permanent water layer was maintained within fields and no supplementary treatments were performed, finally drying paddies few weeks before harvesting (September–October).

During 2016, butterflies and orthopterans were sampled on a selection of rice field banks in the three sites described above. Levees were characterized by a width of 1–2 m, with a grass cover dominated by plants belonging to the families Poaceae and Cyperaceae. However, at the beginning of the sampling period (just after herbicide treatments), some banks were covered by bare ground, although vegetation was able to re-grow in the following months. All the selected banks had rice paddies as adjacent habitat, at least on one side; while, in some cases, one of the bank sides ran along canals or farm roads. Overall, no significant differences in landscape composition were observed around the investigated levees (see details in Appendix A).

According with the aim of this research, levees were chosen in order to take into account the most common grass management techniques employed in the region, all represented in the three investigated sites: