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Review

A review of post-war changes in rice farming and biodiversity in Japan

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ABSTRACT

Flooded rice fields can provide habitats for wetland species and ecosystem services similar to those of natural wetlands. During the last three decades, however, farming practices and management systems have been intensified in many rice-producing countries. In addition, more recent socioeconomic changes have caused agricultural abandonment in some parts of East and Southeast Asian countries such as Japan. This study reviewed long-term statistics on rice farming, as well as the impact of agricultural intensification and abandonment on farmland biodiversity at multiple spatial scales in Japan. The impact of pesticide use was greatest in the 1950s–1970s, when the use of highly toxic agents had not yet been prohibited. More recently, different components of agricultural intensification have been the largest threat for various taxa, for example, chemical pesticides for aquatic plants and invertebrates and modern efficient irrigation/drainage systems for amphibians, fishes, and waterbirds. The negative impacts of agricultural abandonment on farmland species have been rapidly increasing with the expansion of abandoned fields and the subsequent vegetation succession and loss of habitat heterogeneity. We also discuss the effectiveness of environmentally friendly farming practices, including the reduced use of pesticides, winter paddy flooding, and installation of fishways, to reduce the negative impacts of agricultural intensification on farmland species in rice-paddy landscapes.

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1. Introduction

Rice (*Oryza sativa*) is one of the world's most important crops. It is grown in at least 114 countries around the world (Maclean et al., 2002) and is a staple food for nearly half of the world's population (Juliano, 1993). Rice production continues to be greatest in Asia, where 90% of the crop is grown, but it has also been stable or increasing in the Americas, Africa, and Europe (see fig. 1 in Elphick, 2010). Most rice is grown under flooded conditions (Maclean et al., 2002), so if they are managed appropriately, rice fields can provide habitats for wetland species (Elphick, 2000; Fasola and Ruíz, 1996; Toral et al., 2012) and ecosystem services similar to those of natural wetlands (Natuhara, 2013). Given that many wetland species continue to be threatened by the loss and degradation of habitat (Gibbs, 2000; Zedler and Kercher, 2005), the value of rice fields as artificial wetlands will become vastly more important in the future.

During the last three decades, however, farming practices and management systems have been intensified to varying degrees in many rice-producing countries (Kiritani, 2000; Lane and Fujioka, 1998; Parsons et al., 2010). In addition, recent socio-economic changes have caused agricultural field abandonment in some parts of East and Southeast Asian countries such as Vietnam, Korea, and Japan (Kubo, 2013; Lee et al., 2002; Osawa et al., 2013). Both agricultural intensification and abandonment may threaten biodiversity in rice-paddy landscapes (Katoh et al., 2009), as has also been suggested in other similar agricultural landscapes in Europe (Benton et al., 2003; Sirami et al., 2007). Thus, there is an urgent need for a better understanding of the impact of relatively recent changes in rice-farming practices on biodiversity to develop effective conservation strategies, including agri-environmental schemes (Amano, 2009; Ibáñez et al., 2010).

Japan has a wide topographic gradient (the landscape ranges from high mountains to coastal plains; Yamaura et al., 2011), and its land is mainly covered by forests (68.5% of the land area) and agricultural areas (12.6%; FAO, 2013). The major crop is rice, accounting for 48.4% of the total cultivated area (Statistics Bureau, 2013a). Agricultural landscapes have historically been heterogeneous and consisted of rice fields, agricultural ditches, semi-natural grasslands, forests, and rivers that have supported the life cycles of many terrestrial and aquatic species (Kadoya and Washitani, 2011; Katoh et al., 2009). At the end of World War II in 1945, agricultural intensification, including increased use of agricultural chemicals and habitat consolidation, began to expand rapidly across the country (MAFF, 2012a). Since the 1980s, agricultural abandonment has also rapidly increased, and abandoned fields currently constitute > 10% of the total farmland area (MAFF, 2012b). Therefore, Japan is an ideal place to study the impacts of agricultural intensification and abandonment on farmland biodiversity. However, existing studies have not been summarized across major taxa in relation to long-term statistics on rice farming in Japan. This knowledge should also be useful when considering future conservation management in other rice-producing countries.

In this review, our goals are threefold. First, by using long-term statistics on rice farming, we show post-war changes in farming practices and management systems in Japan. Second, we summarize empirical studies in which temporal or spatial variations in farmland species were quantified at multiple spatial scales (from local to national) in relation to agricultural intensification or abandonment. Finally, we discuss future conservation studies in rice-paddy landscapes, focusing on the effectiveness of environmentally friendly farming practices. Mammals are excluded from this review because most mammalian species do not depend directly on rice fields during their life cycles.

2. Farmland species and their population trends

In Japan, flooded rice fields harbor many taxonomic groups of aquatic organisms, including more than 30 groups of small organisms ranging in size from 30 μm to 2 cm (e.g., phytoplankton, zooplankton, and benthic organisms; Yamazaki et al., 2001). At least 184 species of weeds, causing different degrees of crop damage, have been observed in rice fields or surrounding levees (Kasahara, 1951). More than 27 species of aquatic invertebrates (not including rice pests), 15 species and 2 subspecies of amphibians, 11 species of fishes, and 49 species of birds are known to be moderately to heavily dependent on rice fields for breeding or foraging (a list of the animal species is shown in Table S1). The number of species is clearly underestimated for invertebrates and fishes for which relatively scarce data are available.

Despite the acknowledged importance of long-term monitoring (Magurran et al., 2010), there are few such studies of agricultural landscapes in Asian countries. In Japan, a national survey has monitored major taxa such as vegetation, insects, amphibians, reptiles, fishes, and birds once every 5 years since 1978 (MOE, 2013). However, this survey has three potential problems in terms of quantifying population trends in some species: (1) the entire area is not covered for some taxa (Yamamoto and Kusumoto, 2008), (2) the quality and accuracy of survey data vary among years (Amano and Yamaura, 2007), and (3) the nationwide monitoring was ended in 1998 for all species except birds (MOE, 2013). Other national surveys have targeted only bird species (Table 1).

Owing to these difficulties, population trends at a nationwide scale have only been quantified for bird species, and the trends are highly variable among species (Table 1). Most Anatidae, except for the Baikal teal (*Anas formosa*), and Gruidae populations have been stable or increasing in the last two to three decades, probably because of enforced protection from overhunting, food provisioning by local people, and increased residual grain in rice fields due to mechanization (for more details, see Amano, 2009; Fujioka et al., 2010). Ardeidae populations also have been stable and have expanded their breeding ranges in some areas, probably because of an increased amount of fish in inland water bodies after the use of highly toxic pesticides and pollutants such as DDT was banned in the 1970s (Fujioka et al., 2010). In contrast, most Charadriiformes populations have been decreasing during the last two decades (Amano, 2006). Using these data, Amano et al. (2010a) showed that wader species dependent on rice fields have been decreasing at a greater rate than species not dependent on rice fields. In addition, the size of the breeding range has contracted for farmland specialists but not for generalists (Amano, 2009; Amano and Yamaura, 2007). These trends suggest a negative impact resulting from changes in rice farming at a national scale.

For other farmland taxa, several published studies have quantified population trends at the regional or local scale. A rapid decline in species richness and abundance has been observed in the course of field consolidation and abandonment as well as urbanization (Table 2). Although we could not find similar data for plants and invertebrates, many scientists and field workers have noted the rapid decrease of low-trophic-level species after agricultural intensification (Kiritani, 2000). Currently, many species are listed as threatened in the national and regional Red Lists (Table S1). These trends also suggest the current crisis in farmland biodiversity in Japan, but more studies at a larger spatial scale are needed to quantify and predict population trends of these taxa.

In 2003, Japan launched a new nationwide monitoring survey (Monitoring Sites 1000 Project: Biodiversity Center of Japan, 2012) targeting multiple taxa and their main habitats, such as forests, grasslands, farmlands, and agriculture-forest mosaics. The data can be useful in revealing spatial or temporal relationships between agricultural environments and farmland biodiversity at a national scale.

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