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Frogs as potential biological control agents in the rice fields of Chitwan, Nepal

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ABSTRACT

Anuran frogs are often considered generalist predators in rice fields and feed upon a variety of invertebrates. They may thus provide an invaluable ecosystem service, as many species belonging to the orders coleoptera, lepidoptera, orthoptera, homoptera and hemiptera are regarded as notorious rice pests, inflicting significant losses on rice production. In this study, we surveyed frogs in rice paddies of lowland Nepal during the dry and rainy seasons, approximately 3–4 weeks after rice had been planted. We used stomach flushing to study the dietary habits of anuran species encountered, and provide empirical evidence of the ecological service provided by frogs in this agricultural landscape. We found that frogs included a high proportion of crop pests in their diet, but consumption of pests varied between the rainy and dry seasons, frog species and even individual frogs. The ecosystem services provided by frogs are not limited to crop pest control, but, as our observations revealed, include consumption of a large number insects known to be important vectors of zoonotic diseases. We encourage both farmers and conservation planners to consider frogs as important biological pest controllers during the development of pest management and strategies in agricultural landscapes.

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1. Introduction

Rice field agro-ecosystems are important in terms of biodiversity conservation and provide habitat for several species of plants and animals, such as mammals, fish, birds and amphibians (Bambaradeniya et al., 2004; Machado and Maltchik, 2010). Rice (*Oryza sativa* L.) is the most important staple cereal crop in Asian countries and approximately 163 million hectares of land are cultivated with rice globally. Asia accounts for 89% of this total, with Nepal harboring about 1.5 million ha and cultivating more than 2000 varieties of rice (Rana et al., 2007). To increase food production in tandem with a growing human population, application of modern agricultural technologies and utilization of chemical fertilizers and pesticides is becoming widespread even across more remote regions of the world (Bhatnagar, 2001). However, due to extensive use of pesticides, many crop pest species have developed resistance to pesticides; e.g. the brown planthopper (*Nilaparvata lugens*) in Indonesia has become more resistant to insecticides over time (Settle et al., 1996). Fertilizers and pesticides also cause rapid land degradation, increased chemical pollution and negatively impact biodiversity (Matson et al., 1997). For example, recent studies have revealed that excessive use of chemical pesticides have significant negative effects on the growth and development of tadpoles and are a cause of behavioral impairment and genomic defects in anuran frogs (Cauble and Wagner, 2005; Govindarajulu, 2008). There is an urgent need for strategies to reduce pest populations while simultaneously minimizing ecological consequences within agricultural landscapes.

Management of insect pests remains a key problem for farmers worldwide (Matteson, 2000). Oerke and Dehne (2004) estimated

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that about 24% of rice yield losses are caused by insect pests. Several biological pest control techniques have been introduced in order to control crop pests in rice fields, while simultaneously reducing the need for chemical pesticide and fertilizer application (Hassanali et al., 2008). For example, fish-rice and duck-rice farming practices in China, where fish and ducks are cocultured with rice, substantially reduced pest levels in both farming systems (Lu and Li, 2006; Zhang et al., 2009; Xie et al., 2011). The introduction of parasitoids and insect pathogens have also been attempted (Savary et al., 2012).

Frogs are diverse and abundant inhabitants of rice fields (e.g. Bambaradeniya et al., 2004). Considered generalist predators, they feed upon a variety of invertebrates and small vertebrates. Despite the large number of studies describing dietary habits of anurans (e.g. Hirai and Matsui, 1999, 2002; Santos et al., 2004; Sabagh and Carvalho-e-Silva, 2008; Quiroga et al., 2009; Piatti and Souza, 2011), there is a paucity of studies about frog diets in rice fields (Hirai and Matsui, 2002; Piatti and Souza, 2011; Yousaf et al., 2010) and virtually no information is available from Nepal (but see Khatiwada et al. in review). Some of the most important anuran dietary groups include coleoptera, lepidoptera, orthoptera, homoptera, hemiptera (Hirai and Matsui, 1999; Mahan and Johnson, 2007). Many species in these groups are regarded as notorious rice pests, causing significant losses in rice production (Chen et al., 2005; Chitra et al., 2000; Kartohardjono and Heinrichs, 1984; Shu et al., 2000; Way and Heong, 1994). Although past studies have shown that tadpoles are an important biological controller of mosquitoe eggs and larvae (Bowatte et al., 2013; Mokany, 2007; Mokany and Shine, 2003), little is known about the feeding habits of adult anurans and their potential as biological pest controllers.

In this study, we quantify the consumption of crop pests by anurans in rice paddies of the Chitwan district in Nepal. We compare the season- and species-specific contribution of pests and non-pest prey species to anuran diets based on an extensive sample of stomach contents from 396 frogs of 10 different species. In addition, we estimate species richness and relative abundance of frogs found in this agro-ecosystem. Patterns of anuran diversity and crop pest consumption are discussed in the context of frogs as agents of biological pest control and the conservation value of rice paddies as anuran habitats.

2. Materials and methods

2.1. Study area

The study was carried out in the rice fields of the Bachhauli and Kumroj Village Development Committee (VDC) of Chitwan district, Nepal (Fig. 1). The study area lies in the buffer zone of Chitwan National Park, which is listed as a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and has high levels of biodiversity (Bhattarai and Kindlmann, 2011; Straede and Helles, 2000). The climate is subtropical. January is the coldest month (mean temperature 10 °C) and the warmest months are May to August (mean temperature 32 °C). Monsoonal rainfall occurs between June and September and the area receives the majority of annual rainfall during this period. However, short showers are common throughout the year. The average annual rainfall for 2003–2007 was 2429 mm/year for the nearby weather station of Bharatpur Airport (Anon, 2008).

In the region, rice is planted twice a year; once before the monsoon (March-May; hereafter referred to as the dry season) and once during the monsoon (June-October; hereafter referred to as the rainy season). Rice planted in March is harvested at the end of May or early June. Soon after, different varieties of rice that require more water are planted and then harvested in late September. The

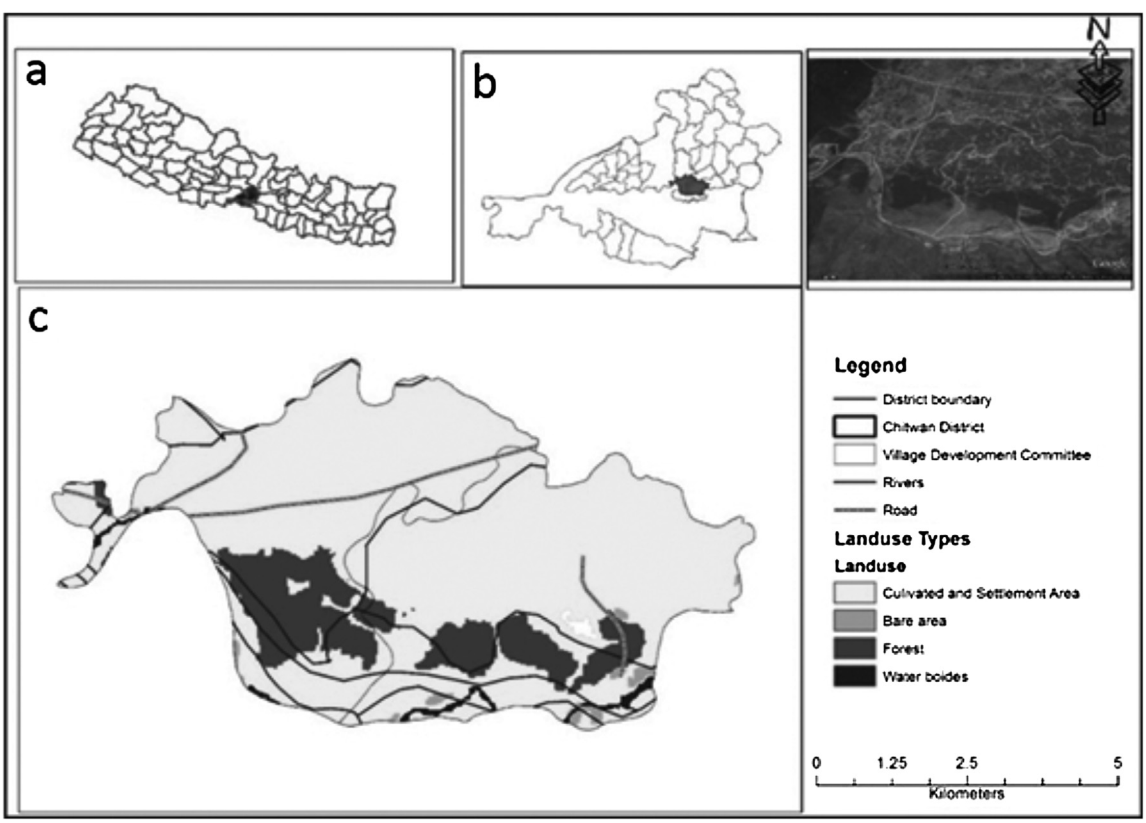

Fig. 1. (a) Map of Nepal indicating the Chitwan district. (b) The Chitwan district with the study area highlighted and (c) the land use pattern across the study area.

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