Science of the Total Environment 511 (2015) 288–297

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Unravelling trophic subsidies of agroecosystems for biodiversity conservation: Food consumption and nutrient recycling by waterbirds in Mediterranean rice fields

Juan G. Navedo [a,b,*], Steffen Hahn [c], Manuel Parejo [b], José M. Abad-Gómez [b], Jorge S. Gutiérrez [b,d], Auxiliadora Villegas [b], Juan M. Sánchez-Guzmán [b], José A. Masero [b]

[a] Instituto de Ciencias Marinas y Limnológicas, Universidad Austral de Chile, Facultad de Ciencias, Campus Isla Teja, 5090000 Valdivia, Chile
[b] Conservation Biology Research Group, Universidad de Extremadura, Avda. Elvas s/n, 06002 Badajoz, Spain
[c] Department Bird Migration, Swiss Ornithological Institute, Seerose 1, 6204 Sempach, Switzerland
[d] Department of Marine Ecology, Royal Netherlands Institute for Sea Research (NIOZ), PO Box 59, 1790 AB Den Burg, Texel, The Netherlands

HIGHLIGHTS

- Waterbirds foraging and roosting in Extremadura´s rice fields recycled more than 1.0 kg·ha^{-1} of N and 0.2 kg·ha^{-1} of P during winter.
- Additionally, 2.3 tons of N and 550 kilograms of P were removed from rice fields and transported to adjacent reservoirs.
- These should result in a direct benefit for rice farmers by improving nutrient recycling through defecation with respect to artificial fertilization, highlighting the important ecosystem services provided by waterbirds.
- Our findings may be especially helpful for environmental management decisions regarding rice agroecosystems, which can often serve as important areas for the conservation of migratory waterbirds.

ARTICLE INFO

Article history:
Received 5 October 2014
Received in revised form 19 December 2014
Accepted 21 December 2014
Available online xxxx

Editor: C.E.W. Steinberg

Keywords:
Cranes
Dabbling ducks
Ecosystem services
Extremadura
Isotopes
Management
Nitrogen
Phosphorous

ABSTRACT

Waterbirds can reallocate a considerable amount of nutrients within agricultural fields and between agriculture sites and wetlands. However their effects on biogeochemical cycles have rarely been quantified. We estimated bird numbers, diet (from stable isotope analysis), food supply, and the food consumption on rice fields by overwintering waterbirds in one of the most important areas for rice production in southwestern Europe and a key area for various migrating and resident waterbird species. Herein, we modelled the nutrient (N and P) recycling in rice fields, and their transport to reservoirs. The energy consumption by waterbirds (96,605 ± 18,311 individuals) on rice fields during winter averaged at 89.9 ± 39.0 kJ·m^{-2}, with its majority (89.9%) belonging to foraging on rice seeds. Thus, the birds removed about 26% of rice seeds leftover after harvest (estimated in 932.5 ± 504.7 seeds·m^{-2} in early winter) wherein common cranes and dabbling ducks (four species) were the most important consumers. Waterbirds foraging and roosting in the rice fields recycled more than 24.1 (1.0 kg·ha^{-1}) of N and an additional 5.0 tons (0.2 kg·ha^{-1}) of P in the Extremadura's rice fields during winter. Additionally, we estimated that 2.3 tons of N and 550 kg of P were removed from rice fields and transported to reservoirs. The seasonal foraging of wildlife should result in a direct benefit for rice farmers by improving nutrient recycling through defecation by waterbirds with respect to artificial fertilisation. Additionally, rice fields located in the cranes' core wintering areas can provide sufficient food supply to induce habitat shift from their traditional wintering habitat in 'dehesas' to rice fields, which causes indirect socioeconomic benefit through reduced acorn consumption by cranes. Our modelling approach may thus be especially helpful for management decisions regarding rice agroecosystems in areas which are also important for the conservation of migratory waterbirds.
© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Agriculture can have significant implications for wild animal and plant species, and is thus relevant for biodiversity conservation (Liang et al., 2001; Liu et al., 2013). The biodiversity differs between agroecosystems wherein two components are often recognised:

* Corresponding author at: Instituto de Ciencias Marinas y Limnológicas, Universidad Austral de Chile, Facultad de Ciencias, Campus Isla Teja, 5090000 Valdivia, Chile.
E-mail address: jgnavedo@uach.cl (J.G. Navedo).

http://dx.doi.org/10.1016/j.scitotenv.2014.12.068
0048-9697/© 2014 Elsevier B.V. All rights reserved.

'planned' biodiversity, which relates to the crops and livestock intentionally included; and 'associated' biodiversity, which encompasses all flora and fauna colonising the agroecosystem from surrounding environments (Vandermeer and Perfecto, 1995). The abilities of such associated diversity to thrive depend upon the management and structure of the agroecosystem (Altieri, 1999). Thus, agroecosystem management is crucial to improve economic and ecological sustainability, and the final result of agroecological 'design' should be to use the proposed management systems in ways that are specifically in tune with local biodiversity, as well as existing environmental and socioeconomic conditions (Altieri, 1995; Campbell, 2006). Despite the well-documented role of the remains of agriculture production after crop harvesting (e.g. Rand and Louda, 2006), and the associated detritus as energetic subsidies for invertebrate predators like arachnids and insects (e.g. Halaj and Wise, 2002; Birkhofer et al., 2008), the potential role of agroecosystems regarding vertebrate predators such as waterbirds has so far received little attention (Elphick et al., 2010).

Waterbirds play an important role in mass and energy fluxes within wetland food webs (e.g. Moreira, 1997; Post et al., 1998; Hahn et al., 2008), and often provide essential ecosystem services (reviewed by Green and Elmberg, 2014). Herein, waterbirds may remove a substantial proportion of the annual production of plants (e.g. Stafford et al., 2010) and macroinvertebrates (e.g. Moreira, 1997), and their excrements are in turn a natural source of nitrogen and phosphorus (e.g. Frost et al., 2009). During recent decades, many herbivorous waterbird species have increased in numbers in the western Palearctic (Wetlands International, 2012). An important driving force for these population growths might be the current agricultural practices, which provide high-quality food nearly year-round, thereby enlarging the carrying capacities of terrestrial habitats for herbivorous waterbirds (van Eerden et al., 1996; Toral and Figuerola, 2010; Navedo et al., 2012). At sites where non-breeding waterbirds are numerous, their excrements can represent a major but local nutrient input of N and P (Portnoy, 1990; Manny et al., 1994). On the other hand, some waterbirds show commuting behaviour, foraging in agricultural crops and resting in neighbouring wetlands (e.g. Mayes, 1991; Gill, 1996). They may therefore be responsible for a considerable reallocation of nutrients within agricultural fields (Green and Elmberg, 2014), and between agriculture sites and wetlands, including inland waterbodies (Hahn et al., 2008). To date, waterbirds' effects on nutrient and other biogeochemical cycles are yet poorly understood, so they are currently the subject of ongoing research (see review in Green and Elmberg, 2014).

Recently, rice (*Oryza sativa*) has become the world's most important crop in continental areas (Elphick, 2010), and rice fields occupy over 1% of the Earth's ice-free land surface (Maclean et al., 2002). Many migratory waterbirds use rice fields as foraging grounds outside the breeding season (e.g. Elphick, 2010; Masero et al., 2011; Santiago-Quesada et al., 2014). In temperate regions like the Mediterranean, most rice is grown under flood during the warm summer period, and fields are left fallow during winter (Maclean et al., 2002). Waterbird abundances peak during this winter season (Sánchez-Guzmán et al., 2007; Eadie et al., 2008; Rendón et al., 2008), and predation pressure on rice fields by non-breeding waterbirds is expected to be high (Remsen et al., 1991; Shuford et al., 1998; Eadie et al., 2008; Amano, 2009; Toral and Figuerola, 2010). Overall, waterbirds mainly rely on spilled grain (Stafford et al., 2010; Toral et al., 2012; Santiago-Quesada et al., 2014) and, to a minor extent, on macroinvertebrates (e.g. Brochet et al., 2012). The high abundance of waterbirds during the non-breeding periods often lasts several months, and thus their increasing number will presumably cause a parallel increase in nutrient flux to rice fields via defecation (Bird et al., 2002; Liu et al., 2014). Despite this obvious potential of waterbirds to mediate nutrient inputs (Post et al., 1998; Hahn et al., 2008; Frost et al., 2009), data on nutrient recycling by waterbirds in rice fields are still scarce (Stafford et al., 2006; Elphick, 2010).

Here, we studied diet, food consumption and nutrient recycling by overwintering waterbirds in Mediterranean rice fields located in the Extremadura (SW Spain), which is one of the most important areas for rice production in Western Europe. Extremadura's rice fields are of international importance for several migratory waterbirds, including common crane (*Grus grus*) (Sánchez-Guzmán et al., 2007), black-tailed godwit (*Limosa limosa*) (Masero et al., 2011) and several dabbling duck species (*Anas* spp.) (Navedo et al., 2012). Some species, especially dabbling ducks, use rice fields as foraging grounds during the night and commute to adjacent freshwater reservoirs to roost during the day (Navedo et al., 2012), whereas a proportion of overwintering cranes forage in the rice fields during daylight and fly to roost in adjacent reservoirs at dusk (Sánchez et al., 1999; Prieta and Del Moral, 2008), and thus may transport nutrients from the rice fields to the surrounding reservoirs. The aims of this study were (1) to estimate the trophic subsidy of the agroecosystem as the total amount of energy removed by waterbirds through consumption of rice seeds and macroinvertebrates; (2) to quantify the recycling of local nutrients by defecation of waterbirds in rice fields; (3) to estimate the allochthonous nutrient loading via excreta by waterbirds to adjacent reservoirs.

2. Methods

2.1. Study area

Extremadura's rice fields (24,207 ha on average during 2005–2010 period) are located in the Guadiana river basin (SW Spain; 38°N 6°W) (Fig. 1). The cycle of rice production starts with preparation of the fields in March, followed by flooding and sowing until the end of May. Rice growth is commenced in September and harvesting starts in October. At the end of November, many fields are rolled and flooded again, thus providing large areas of shallow water throughout the winter.

2.2. Waterbird abundance and local food supply

We carried out monthly counts of waterbirds overwintering in the Extremadura rice fields (November–February 2004–2005 and 2007–2008), using the methodology described by Sánchez-Guzmán et al. (2007). Briefly, the total study area was divided into four counting sectors where different teams performed simultaneous daylight counts on each sector, using binoculars and telescopes. The number of dabbling ducks counted monthly (November–February 2007–2010) in the adjacent reservoirs was assumed to forage at night in the rice fields of the study area (data from Navedo et al., 2012; unpublished data from northern pintails (*Anas acuta*) and common teals (*Anas crecca*) equipped with radio- and GPS/GSM-transmitters).

The majority of waterbirds overwintering in the study area are herbivorous species that rely on rice seeds left over on the ground after harvest (see results). We quantified the potential availability of rice seeds at the beginning of the wintering season (November 2009) by collecting soil samples (3–5 replicates each) in harvested fields, using a core of 6.6 cm in diameter and 12 cm in depth. The samples ($n = 37$) were taken randomly from five sectors of different sizes (range: 2075–8300 ha) which harboured the highest numbers of waterbirds. The areas included rolled as well as unrolled fields. Samples were stored in plastic bags and frozen until further processing. After thawing, the soil samples were sieved (mesh size: 1.0 mm) and all rice seeds counted to estimate the density of rice seeds per sample. We used a conversion factor of 0.02 g of dry mass per rice seed (average dry mass of a rice seed in the study area in November; $n = 30$) to estimate the biomass of rice seeds available for foraging waterbirds.

2.3. Diet composition

We used stable carbon isotopes ($\delta^{13}C$) and stable nitrogen isotopes ($\delta^{15}N$) of whole blood to determine the diet composition of waterbirds foraging in the rice fields. Whole blood typically archives the isotopic

Download English Version:

https://daneshyari.com/en/article/6327459

Download Persian Version:

https://daneshyari.com/article/6327459

Daneshyari.com