Biological Conservation 165 (2013) 179–186

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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

Mediterranean amphibians and the loss of temporary ponds: Are there alternative breeding habitats?

Mário Ferreira, Pedro Beja *

EDP Biodiversity Chair, CIBIO-Centro de Investigação em Biodiversidade e Recursos Genéticos, Universidade do Porto, Campus Agrário de Vairão, 4485-661 Vairão, Portugal

ARTICLE INFO

Article history:
Received 14 February 2013
Received in revised form 22 May 2013
Accepted 28 May 2013
Available online 29 June 2013

Keywords:
Agricultural landscapes
Artificial habitats
Dynamic occupation models
Farm ponds
Habitat loss
Irrigation
Mediterranean temporary ponds

ABSTRACT

In farmland landscapes, amphibians often breed in artificial water bodies, which may offset at least partly the loss of natural wetlands associated with agricultural intensification. It is possible, however, that artificial habitats provide conditions for a minor proportion of the regional species pool, benefiting just a few widespread generalists. We assessed these alternative views by documenting the decline of temporary ponds in a Mediterranean farmland landscape between 1991 and 2009, and by estimating the occupancy of natural (temporary ponds and streams) and artificial water bodies (farm ponds, irrigation channels and drainage ditches) by amphibians across the breeding season (February–June 2010). We used hierarchical Bayesian dynamic multi-species occupancy modelling to control for differences in detectability across species, sampling occasions and habitat types. Over two decades the farmland landscape lost 56% of its temporary ponds, of which 89.3% were destroyed through agricultural activities such as cultivation, conversion to permanent farm ponds, and drainage. The survival rate of ponds was lowest within an irrigated perimeter, and there was no positive effect of protection by a natural park. Estimated species richness per site was at least twice as high in temporary ponds as in the other habitat types. From the 10 amphibian species recorded, seven had the highest occupancy in temporary ponds, and were absent or occurred rarely in artificial habitats. Only a single generalist species was widespread in farm ponds and irrigation channels. The results suggest that artificial water bodies are unlikely to sustain populations of most amphibian species in Mediterranean intensive farmland. Conservation efforts should be directed at protecting the temporary ponds still remaining within the farmed landscape, and at restoring or creating new temporary ponds where these have been lost during the last decades.

1. Introduction

Conservation on farmland is increasingly recognized to have a role in the global efforts for halting and reversing global biodiversity loss (Clough et al., 2011; Kleijn et al., 2011). If properly managed, agricultural landscapes may provide connectivity among protected areas (Donald and Evans, 2006), complementary resources for species using both natural and modified habitats (Mandelik et al., 2012), and additional or even the main habitats for a range of species of conservation concern in humanized regions (Moreira and Russo, 2007). The ability of agricultural landscapes to sustain high biodiversity levels, however, is often conditional on the presence of particular on-farm features such as woodland patches, scattered trees, hedgerows, or ponds, which have a disproportionate importance in relation to their size for promoting species persistence (Benton et al., 2003; Billeter et al., 2007). In recent decades, such habitats have been declining or suffering degradation due to ever more intensive agricultural land uses, requiring conservation researchers to explore ways for reducing these impacts (Benton et al., 2003; Curado et al., 2011; Fischer et al., 2010).

Amphibians are among the species of highest conservation concern due to their widespread decline worldwide, which seems to result directly or indirectly from human activities (Blaustein et al., 2011; Wake and Vredenburg, 2008). Despite their vulnerability to human pressures, many amphibian species are able to thrive in human-dominated landscapes, particularly in low intensity farmland (Crochet et al., 2004; Hartel et al., 2010; Knutson et al., 2004). This ability is favoured by the capacity of many amphibians to reproduce in artificial habitats, including for instance garden ponds, farm ponds, drainage ditches, and storm water retention pools (Brand and Snodgrass, 2010; Ficetola et al., 2004; Hazell et al., 2001; Herzon and Helenius, 2008; Maes et al., 2008). As a consequence, the proliferation of artificial water bodies in human-dominated landscapes could enhance amphibian reproduction opportunities and thus favour its conservation, eventually offsetting to at least some extent the loss of natural wetlands (Brand and Snodgrass, 2010; Casas et al., 2012; Knutson et al., 2004). There is the possibility, however, that artificial water bodies

* Corresponding author. Tel.: +351 252 660 416; fax: +351 252 661 780.
E-mail address: pbeja@cibio.up.pt (P. Beja).

0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.05.029

provide conditions for just a minor proportion of the species represented in a region, with the conversion from natural to artificial breeding habitats benefiting just a few widespread generalists and thus promoting functional homogenization in human-dominated landscapes (Clavel et al., 2011).

In the Mediterranean region, intensification of agricultural land uses is causing major changes in the availability of breeding habitats for amphibians, mainly where it involves the conversion from rain-fed to irrigated agriculture (Stoate et al., 2009). In particular, intensification causes widespread losses of temporary water bodies (Dimitriou et al., 2006; Zacharias and Zamparas, 2010), which are of utmost importance for amphibian reproduction in the Mediterranean region (Beja and Alcazar, 2003; García-Muñoz et al., 2009; Gómez-Rodríguez et al., 2009). At the same time, irrigation is associated with the creation of numerous artificial water bodies that might be favourable for breeding amphibians, including farm ponds, irrigation channels and drainage ditches (Casas et al., 2012; Fuentes-Rodríguez et al., 2013). A preliminary study in intensive Mediterranean farmland suggested that farm ponds were inhabited by just a few common species adapted to permanent water bodies, whereas species of conservation concern associated with temporary ponds were very scarce or absent in artificial habitats (Beja and Alcazar, 2003). However, that study was limited because it analysed only some of the breeding habitats represented in Mediterranean farmland, it used relatively small sample sizes of artificial habitats, and it did not control for eventual seasonal effects influencing habitat use by breeding amphibians (Diaz-Paniagua, 1992). Furthermore, the study did not account for variations in detectability, which affects occupancy estimates for a wide range of species (MacKenzie et al., 2003), including amphibians (Gómez-Rodríguez et al., 2012; Mazerolle et al., 2007).

We assessed whether artificial water bodies can provide alternative breeding habitats for amphibians in intensive Mediterranean farmland, thereby compensating to some extent the destruction of natural temporary ponds associated with the ongoing conversion from extensive, traditional rain-fed agriculture, to modern irrigated agriculture. To control for differences in detectability across species, habitat types, and seasons, we used models designed for dynamic metacommunity systems, based on hierarchical Bayesian multi-species occupancy modelling (Dorazio et al., 2010). Our primary objectives were to: (i) document the loss of temporary ponds in an intensive Mediterranean farmland landscape over nearly two decades (1991–2009) and identify its main causes; (ii) relate temporary pond survival to irrigation and protection status using Cox regression; (iii) estimate species richness and the occupancy of each amphibian species in the main natural and artificial water bodies; and (iv) assess variations in the occupancy of natural and artificial water bodies across the breeding season. We used the information collected to identify what amphibian species will likely be favoured and what will likely be lost under agricultural intensification in Mediterranean landscapes.

2. Methods

2.1. Study area

The study was conducted in the coastal plateau of southwest Portugal (Fig. 1). Climate is Mediterranean, with mean temperatures of approximately 16 °C and mean annual rainfall of approximately 650 mm, most of which falls from October to March. The landscape is predominantly flat and devoted to agriculture, largely dominated by irrigated arable crops and livestock production. Forest cover is restricted to some woodlots, and windbreaks of planted eucalyptus and pine trees delimiting agricultural fields. Agricultural management has become progressively more intensive since the early 1990s, including increases in livestock densities, pasture improvement, and building of road networks and irrigation infrastructures. Part of the area is included in the Mira Irrigated Perimeter (MIP), where public irrigation infrastructures (including dams and irrigation channels network) are available to private farmers. Part of the area is also included in a Natural Park (Parque Natural do Sudoeste Alentejano e Costa Vicentina), and is within a Site of Community Importance designated under the European Directive 92/43/CEE. The main water bodies that potentially can be used by breeding amphibians are temporary ponds, streams, farm ponds, irrigation channels and drainage ditches, which vary widely from each other in physical and ecological characteristics (Table 1). Exotic predators such as the Louisiana crayfish (*Procambarus clarkii*) and the pumpkinseed (*Lepomis gibbosus*) may occur in all water bodies, though they tend to be much less prevalent in temporary waters. See Beja and Alcazar (2003) and Pita et al. (2009) for additional information on the study area.

2.2. Pond survey

We conducted a temporary pond survey during the winter of 2008–2009. We used aerial photography, 1:25,000 topographic maps, field surveys, and the results of previous surveys made in 1991, 1993, 1996 and 2000 to identify all temporary ponds (Faria et al., 1993; Silva, 1998; Gordo and Galera, 2000). We visited every site that was identified in the previous surveys and recorded its state: present, destroyed or converted to a permanent farm pond. Whenever possible, the cause of pond destruction was recorded on the basis of field observations and interviews of local people. We defined temporary ponds as bodies of water occupying depressions, which are flooded during the rainy season for a sufficiently long period to allow the development of aquatic vegetation and hydromorphic soils, but which are not connected by surface waters to permanently flooded habitats such as rivers.

2.3. Amphibian sampling

We sampled amphibians in 2010, focusing on the main potential breeding habitats present in the study area (Table 1). We included all temporary ponds sampled by Beja and Alcazar (2003) that had not been destroyed. Those ponds had been selected following a stratified random procedure, by dividing the coastal plateau in seven geographic sectors and then selecting randomly nine ponds in each sector (Beja and Alcazar, 2003). The selection of sampling sites of the remaining habitat types also followed a stratified random procedure based on the same seven geographical sectors. In each sector we randomly selected four sites of each type of habitat from at least eight possible alternative sites that we recognized in the spring of 2009, and that were at least 500 m from each other. Overall, we sampled 38 temporary ponds, 31 farm ponds, 21 streams, 17 ditches and 15 irrigation channels. Sample size was constrained by the shortage of temporary ponds and streams in some sectors, and by the lack of irrigation channels and drainage ditches outside irrigated agricultural areas.

We sampled amphibians in four discrete periods during the wet season of 2010: (1) 6–16 February and 4–6 March; (2) 13–26 March; (3) 24 April–5 May; (4) 8–13 July. These periods match the main reproductive activity of amphibians in south-western Iberian Peninsula (Diaz-Paniagua 1992). Depending on the water available in the site, each sampling session consisted of three to six 30-s blind sweeps (mean = 3.1 sweeps, SD = 0.6, n = 362) with a 30 $\times$ 20 cm aperture dip-net, conducted by one person wading across the site and systematically covering all habitats available (Beja and Alcazar, 2003). Amphibian larvae were identified to species and returned to water at the end of each sampling session. Tadpoles of the European tree frog (*Hyla arborea*) and