The role of ponds as feeding habitat for an umbrella species: best management practices for the black stork *Ciconia nigra* in Spain

Rubén Moreno-Opo, Mariana Fernández-Olalla, Francisco Guil
Ángel Arredondo, Rafael Higuero, Manuel Martín
Carlos Soria and José Guzmán

Abstract To establish recommendations for wetland management that promote wildlife diversity in Mediterranean habitats we examined the factors that determine feeding habitat selection by the black stork *Ciconia nigra* in ponds. The black stork is considered an umbrella species because it is threatened, requires large foraging ranges in priority areas, is selective in its choice of diet and nesting sites, and inhabits a characteristic biological community with endemic and threatened taxa. Eighty-five ponds were monitored in central and western Spain to detect the stork feeding. At the same time, pond variables that could affect black stork feeding preferences were periodically evaluated. Generalized linear mixed models were used to analyse principal components obtained from groups of factors related to structural, location and ecological conditions. The black stork selects ponds distant from roads, with a large surface area, high water level, shallow shores, low turbidity, few traces of wild ungulates on the shores, a high diversity of fish and amphibian species, and a vegetated perimeter, in flat and open areas. Potential factors affecting feeding behaviour are discussed. We suggest measures for pond construction and management that could favour this species in particular and biodiversity in general in the Mediterranean environment.

Keywords Best management practices, black stork, *Ciconia nigra*, feeding habitat, habitat selection, pond conservation, Spain, umbrella species

Introduction

Habitat destruction or alteration is considered the main cause of biodiversity loss (Laurence & Useche, 2009) and, because of the high rate of such destruction, it is necessary to evaluate management priorities for the conservation of ecological processes and biological complexity (Balmford et al., 2005). In the case of species associated with aquatic environments, isolation resulting from the loss of interconnected aquatic habitats is one of the most significant factors influencing their decline (Finn et al., 2009; Griffiths et al., 2010). It is therefore important to evaluate the ability of temporary or small ponds to meet the breeding, resting or feeding needs of species associated with aquatic environments (Brainwood & Burgin, 2009; Pinto-Cruz et al., 2009). Unlike large water bodies, the role of small water bodies as hotspots has not been evaluated until recently (Gómez-Rodríguez et al., 2009). In the Northern Hemisphere, although the number of natural ponds and lagoons is declining (Gallego-Fernández et al., 1999), the availability of man-made water bodies has increased but they are generally subject to a high degree of various types of disturbance (Oertli et al., 2009).

Man-made ponds are created in the Mediterranean basin mainly to supply the needs of wild ungulates and livestock and for irrigated agriculture. These ponds have different characteristics depending on their use, and their ecology varies depending on the intensity of use, the species present, human pressure, and the nature of the surrounding areas (Declerck et al., 2006). Man-made ponds are designed and managed mostly from an economic point of view and do not take into account environmental criteria. There is a lack of detailed information of the requirements of secondary consumer species at forest ponds but such information is more widely available for agricultural ponds (Paracuellos et al., 2002; Sebastián-González et al., 2010).

One way to assess habitats of high conservation priority is to determine the presence of threatened, key or umbrella species (Suter et al., 2002; Larsen et al., 2007; Delibes-Mateos et al., 2008). This is based on the principle that ecosystem protection can be optimized by conservation of the ecological requirements of these species (Lambeck, 1997). Among these requirements obtaining sufficient, suitable food is crucial and largely depends on the availability, abundance and quality of food resources (Newton, 1998; Begon et al., 1999). Adaptive mechanisms such as skill, experience and plasticity to resource variation are developed by some umbrella species to avoid negative affects on population parameters (Costillo et al., 2007).

The black stork *Ciconia nigra* is a long-distance migratory species whose breeding distribution includes the

Rubén Moreno-Opo (Corresponding author), Francisco Guil, Ángel Arredondo, Rafael Higuero, Manuel Martín, Carlos Soria and José Guzmán Fundación CBD-Habitat, Gustavo Fernández Balbuena, 2 E-28002, Madrid, Spain. E-mail ruben.moreno-opo@cbd-habitat.com

Mariana Fernández-Olalla Escuela Técnica Superior de Ingenieros de Montes, Universidad Politécnica de Madrid, Madrid, Spain

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Palaearctic and southern Africa (Del Hoyo et al., 1992). The western limit of its range is in the Iberian Peninsula, where the breeding population is estimated to be 405–483 pairs (Cano et al., 2006). Although the black stork is categorized as Least Concern globally (BirdLife International 2009) it is considered as Vulnerable in Portugal and Spain (Almeida et al., 2005; Ministry of the Environment, Rural and Marine Affairs, 2009). The species is considered an umbrella species (Lambeck, 1997; Fleishman et al., 2001; Roberge & Angelstam, 2004) because of its large foraging range (Jiguet & Villarrubias, 2004) and the specificity of its requirements for food and nesting sites (Lôhmus & Sellis, 2003; Seddon & Leech, 2008). The black stork's habitat is in areas with high conservation status that are also important for many other species (Simberloff, 1998; Vlachos et al., 2008), some of which are endemic to the Mediterranean region (Elvira, 1995; Rodríguez-Prieto & Fernández-Juricic, 2004; Bernardos et al., 2007). The black stork is a secondary consumer in the trophic chain, requiring invertebrate, amphibian, reptile and fish prey in various types of wetlands and grasslands (Ferrero & Pizarro, 2003; Hampl et al., 2005). The species is sensitive to habitat alteration and is particularly affected by human disturbances, such that its protection requires the promotion of best management practices for the environment on which it depends (Rosenvald & Lôhmus, 2003) and the maintenance of a broad network of land of favourable conservation status (BirdLife International, 2004).

Detailed knowledge of a species' selection of foraging habitat is essential for designing habitat management for conservation purposes (Manly et al., 1993; Zuberogoitia et al., 2006; Paiva et al., 2007). For the black stork several studies have indicated that calm stretches of streams and rivers, natural or man-made ponds, and reservoir tails near forested areas are the species' main feeding sites during the breeding season (Schneider-Jacoby, 1999; Ferrero & Pizarro, 2003). However, research has not addressed the variables contributing to this species' selection of feeding locations.

This study aimed to determine the characteristics of ponds and their surrounding areas that influence selection of feeding habitat by the black stork. Our goal is to recommend best management practices in pond construction or restoration to improve the conservation status of the communities inhabiting these aquatic hotspots.

Study area

We studied 85 ponds in central and western Spain (Fig. 1) on 21 privately owned estates in seven Special Protected Areas. We first inventoried and determined the location of wetlands on the estates and then selected five natural and 80 man-made ponds. The area includes forests with Mediterranean scrub and an agrosilvopastoral mosaic, dominated by tree species of the genus *Quercus* (*Q. rotundifolia* and *Q. suber*) and a shrub layer (principally *Cistus ladanifer*, *Genista* sp. and *Erica* sp.).

Methods

Black stork surveys

Data were collected during March–September from 2004 to 2007, coinciding with the presence of the black stork in the study area. The ponds were visited monthly to assess the presence of the stork, and only observations of actively feeding individuals were considered. The entire water surface was surveyed using telescopes and binoculars, mostly during 4 hours after sunrise and 2 hours prior to sunset, the most active feeding time of this species (Moreno-Opo et al., 2009). Black storks were aged according to plumage and the colouration of unfeathered parts (i.e. beak, legs and eye ring) and classified as juveniles (birds in their first year of life), subadults (birds 2–3 years old) or adults (4 years or older; Cramp, 1998; Ferrero & Pizarro, 2003).

Data collection

Previous studies have suggested that location, topography, habitat quality, human disturbances, pond productivity, vegetation and food availability may determine the feeding preferences of the black stork (Hancock et al., 1992; Cramp, 1998). A total of 17 variables that provide information on these topics were selected (Table 1). Eight of the variables were measured monthly (time-varying variables) and nine, related to the characteristics of each pond (time-invariant variables), were measured once only, where necessary using *ArcView v. 3.1* (ESRI, Redlands, USA). For the continuous time-varying variables the mean of all sampling occasions was calculated.

Statistical analyses

The dependent variable was the presence or absence of black storks; the species was considered present at a pond if it was recorded feeding during any visit. We calculated Spearman's rank coefficients to check for correlation among the 17 predictor variables. Then, because of potential collinearity, and to reduce the number of variables, we performed a principal components analyses (PCA) for each of three groups of variables (structural, location and ecological conditions; Table 1); this grouping facilitates ecological interpretation of the resulting principal components (Crawley, 2007; Williams et al., 2007). PCA computes variables that are linear combinations of the original variables and that are uncorrelated with each other. However, the components calculated in each of the three groups can be correlated with components in the other groups. We therefore created a set of competing models in which we checked that components from different groups

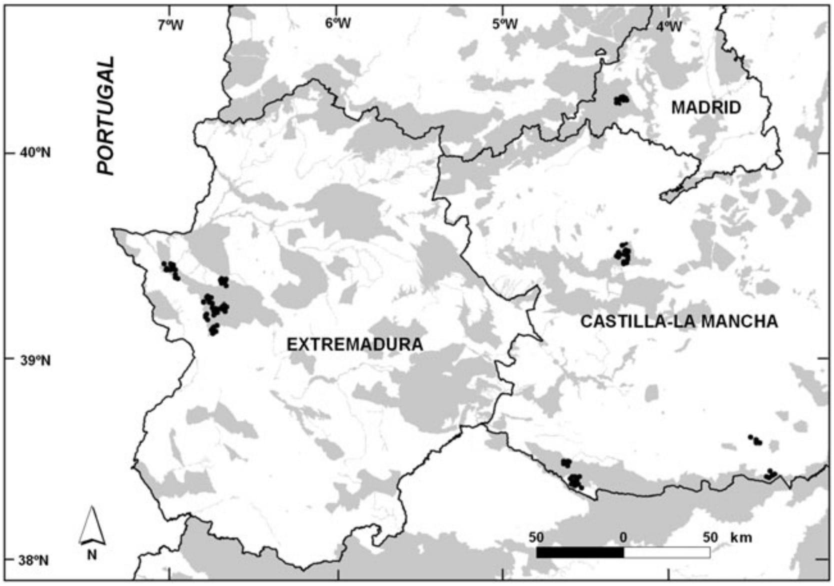

FIG. 1 The study area in Spain, with the location of the 85 studied ponds (black dots). The grey shading indicates Special Protected Areas for birds.

included in the same model were not correlated, using Spearman's rank correlation test.

Competing models were fitted using Generalized Linear Mixed Models (GLMM) with binomial errors and a log link function. All models included the random factor Special Protected Area, to correct for any unmeasured variation associated with the pond location. To examine whether the presence of livestock around the ponds can influence presence of black storks we repeated the analysis using only the 44 ponds in areas with livestock.

In all cases models were simplified by removing non-significant factors ($\alpha = 5\%$) after checking, using the likelihood criteria, that the simplification did not significantly change the model. Once we obtained a minimal adequate model for each competing model we chose the most parsimonious using the Akaike Information Criteria (Akaike, 1973). *R v. 2.8.0* (R Development Core Team, 2008) was used for all analyses.

Results

Black storks were detected at 20 ponds (23% of the total) in 34 sightings (1.42% of surveys). Sightings were during the post-breeding (41.2%), migration (35.3%) and breeding (23.5%) periods. The total number of storks observed was 49, with adults (70.7%) more abundant than subadults (19.5%) and juveniles (9.8%). From the PCA we chose the first three components, which explained 78.6, 75.7 and 69.2% of the variation, respectively, in the structural, location and ecological conditions variable groups. Table 2 shows the influence of each variable on the three components in each of the three groups of variables.

From these nine components (three in each of the three groups of variables), we discarded any that had significant between-group correlations (structural PC2 / location PC2: $\rho = -0.37$, $P < 0.001$; location PC2 / ecological PC3: $\rho = 0.26$, $P = 0.018$; structural PC3 / ecological PC2: $\rho = -0.29$, $P = 0.008$). We built four alternative GLIMM models and selected that with the lowest AIC as the most parsimonious. It included structural PC1 ($1.0482 \pm$ SE 0.3315; $z = 3.162$; $P = 0.001$), location PC3 ($-0.9973 \pm$ SE 0.3303; $z = -2.959$; $P = 0.003$) and ecological PC2 ($-0.8214 \pm$ SE 0.3498; $z = -2.348$; $P = 0.019$).

The results indicated that larger ponds with higher water levels and shallower shores, situated in flat open areas, are positively selected by the black stork. In terms of location, the distance to roads is the most important, with ponds farther from roads used more by the stork. A vegetated perimeter, none or few traces of wild ungulates on the shore, greater prey–species richness and lower turbidity also favour the presence of the species.

The black stork was seen at nine of the 44 ponds in estates with livestock exploitation. Following the same analysis procedure we found that the intensity of use of the ponds by livestock did not significantly influence the presence or absence of the black stork.

Discussion

As direct observation was used to determine the presence of the black stork at ponds it was not possible to determine whether black storks had fed routinely at a particular pond. Nevertheless, the high number (2,380) of our visits over 4 consecutive years increased the chances of detecting the species at any particular pond. The intensity of detection could, however, be improved by using camera trapping.

Feeding habitat selection

The positive relationship between the size of a pond and its selection by feeding black storks may be due to relatively

TABLE 1 The 17 measured variables, ordered by the three groups of variables used in the PCA (see text for details), to evaluate pond selection made by the black stork *Ciconia nigra* in central and western Spain.

Variable	Description
Structural	
Surface[1]	Area occupied by water level of pond at full capacity (m^2)
Slope[1]	Slope of area in which pond is located, within a radius of 500 m (%)
Max. depth[1]	Maximum depth of pond at full capacity (m)
Depth at 1 m[2]	Water depth 1 m from shore (m)
Capacity[2]	Water level as % of maximum capacity
Location	
Distance to trees[1]	Mean distance of six closest trees to shore (m)
Distance to nest[1]	Distance to nearest black stork nest (m)
Distance to track[1]	Distance of nearest paved or unpaved track to shore (m)
Distance to building[1]	Distance of nearest building to shore (m)
Distance to stream[1]	Distance to nearest permanent stream or river (m)
Distance to pond[1]	Distance to closest pond (m)
Ecological conditions	
Turbidity[2]	Bottom of pond can be clearly seen 1 m from shore (% of samples)
Wild ungulates[2]	No. footprints or faeces around <33% of perimeter of pond (% of samples)
Livestock[2]	No. footprints or faeces around <33% of perimeter of pond (% of samples)
Prey species richness[2]	No. of amphibian, reptile & fish species found by direct observation or through interviews with foresters, gamekeepers, fishermen or landowners
Plant richness[2]	No. of macrophytes & other water plant species observed in each survey
Vegetated perimeter[2]	Perimeter of pond occupied by vegetation taller than 50 cm (%)

[1] Time-invariant variables
[2] Time-varying variables

TABLE 2 The eigenvalues of the PCA, for the first three principal components only (see text for details), for each of the three groups of variables (structural, location and ecological conditions; Table 1) for the 85 ponds. The components that were retained in the GLMM analysis were PC1 in the structural group, PC3 in the location group and PC2 in the ecological group (see text for details).

Variable	PC1	PC2	PC3
Structural conditions			
Surface	0.5294	-0.3464	0.2081
Slope	-0.3978	-0.4871	-0.7252
Max. depth	0.3946	-0.6492	0.0463
Depth at 1 m	-0.4136	-0.4551	0.4210
Capacity	0.4844	0.1187	-0.5014
% variation explained	42.4	22.6	13.7
Location conditions			
Distance to trees	0.2258	-0.5910	-0.4424
Distance to nest	0.6247	-0.0272	-0.0061
Distance to track	-0.0476	0.0457	-0.8185
Distance to building	0.2936	0.6907	-0.1262
Distance to stream	0.4120	-0.3691	0.3371
Distance to pond	0.5482	0.1858	-0.0677
% variation explained	34.6	21.5	19.6
Ecological condition			
Turbidity	-0.3585	-0.1916	-0.5859
Wild ungulates	-0.2920	-0.6182	-0.3608
Prey species richness	0.6153	-0.3295	-0.2350
Plant richness	0.6340	0.0079	-0.3398
Vegetated perimeter	0.0748	-0.6873	0.5966
% variation explained	28.8	21.2	19.2

greater heterogeneity and diversity of resources in ponds with a larger water surface area (Oertli et al., 2002; Kadoya et al., 2004). Similarly, large ponds hold water for a longer period, even during the summer. This is a key factor in productivity and food availability in wetlands, particularly for secondary consumers (Maheswaran & Rahmani, 2002; Taft et al., 2002; Holm & Clausen, 2006). The negative relationship between deep water around shores and the presence of feeding black storks could be explained by the hunting behaviour of the species (Kahl, 1971). In general, the black stork walks through wetlands trying to locate and harpoon prey in the water, such that the depth of the water cannot exceed the approximate height of their legs (Cramp, 1998). The positive relationship between black stork presence and ponds in flat open areas could be related to the chances of detecting potential predators or other disturbances and the possibilities of successful alert flight (Fernández-Juricic et al., 2002).

Ponds selected by black stork for feeding are far away from roads frequented by humans. The species is sensitive to human presence and to the effects of certain anthropogenic activities during the summer (Rosenvald & Lôhmus, 2003; Cano et al., 2006). It therefore avoids areas where it is more likely that flight would be induced, because this disturbance would reduce its foraging efficiency with respect to time investment and associated stress (Blumstein et al., 2005; Young et al., 2005).

Black storks select well-developed coverage of aquatic vegetation along pond perimeters. This could be related to optimization and opportunities for capturing prey: ponds with an adequate abundance of plants and macrophytes and with good water quality have generally higher productivity values (Bilton et al., 2006; Akasaka et al., 2010), and hence may provide a greater relative abundance of macroinvertebrates, herpetofauna and fish. The type and frequency of prey capture varies depending on the area, time and age of the bird (Domínguez et al., 1985; Keller & Profus, 1992; Hampl et al., 2005). The highest energy efficiency is obtained from medium-sized fish (Ferrero & Pizarro, 2003; Chevallier et al., 2008). In both breeding and non-breeding birds, prey availability and feeding habitat quality determine the size of the foraging range and the selection of trophic sources (Keller & Profus, 1992; Jiguet & Villarrubias, 2004). Food shortages during the breeding season influence productivity in other stork species (Dallinga & Schoenmakers, 1987; Maheswaran & Rahmani, 2002) and therefore could also be a limiting factor in the population dynamics of the black stork.

The black stork also prefers wetland sites with a low occurrence of ungulates, which visit ponds to meet their water requirements. The presence of these wild animals can lower water quality, as well as adversely affect water visibility and food availability near the shore (Putman & Moore, 2002; Herrero et al., 2006), which is the typical feeding site for the black stork. Water turbidity has been shown to negatively affect the probability of detection and capture of prey by storks (Abrahams & Kattenfeld, 1997) and may explain why ponds with low turbidity levels seem to be visited more frequently by feeding individuals.

Conservation implications

In only a few studies on small water bodies has it been possible to assess the occurrence and activity of the species that are part of the biological community (Oertli et al., 2005). We have, however, been able to elucidate the factors that determine the presence of a predator, the black stork, in this type of wetland. The presence of black storks is evidence of the favourable ecological conditions of the wetland network close to their nesting sites (Jiguet & Villarrubias, 2004). Their foraging ranges are closely associated with the availability of suitable feeding sites and this is reflected, amongst other factors, in breeding success (Newton, 1998). Hence, the scarcity of suitable wetlands constitutes one of the main limiting factors for the species (BirdLife International, 2004; Jiguet & Villarrubias, 2004). The negative relationship between the distance of selected ponds to permanent fluvial waters illustrates the need for an adequate interconnected network of wetlands with suitable resources, such as rivers and streams, to meet the requirements of the black stork.

There are two main conservation implications arising from this study. Firstly, it is necessary to maintain a connected networks of ponds with high ecological quality. Secondly, it is important to ensure that ponds meet several ecological, topographic and location conditions (Simon et al., 2009; Ritcher et al., 2009). This is particularly important in environments where the fluvial network is limited and fluctuations in water availability are pronounced (González-Gajardo et al., 2009).

The management of Mediterranean wetlands has rarely taken into account the importance of ponds and their associated fauna and flora (Ministry of the Environment, 1999) but needs to do so because the number of temporary ponds with good water quality is declining (Gallego-Fernández et al., 1999; Zacharias et al., 2007). In addition, protection of natural or man-made ponds and the promotion of connections between them have been excluded from official conservation strategies, which have disregarded the value of these ponds (Oertli et al., 2009; Pinto-Cruz et al., 2009). It is therefore important to apply conservation actions to a habitat that is considered a priority by official legislation (Ruiz, 2008).

Management recommendations

To improve the conservation of a wide range of Mediterranean wetland-associated species, including the black stork, it is essential to implement conservation actions such as restoration (Rannap et al., 2009; Lesbarreres et al., 2010). The construction or adaptation of ponds could be carried out based on the following criteria: (1) water surface area to be as large as possible; (2) located in flat and open areas; (3) shallow water at the shores (< 30 cm); (4) located as far as possible from human roads or activity; (5) located as close as possible to other ponds; (6) absence of wild ungulates or an increase in the number of ponds in an area to reduce the concentration of ungulates; (7) promotion of the presence of amphibians and encouragement of best practices for increasing their relative abundance (Semlitsch, 2000); and (8) promotion of the presence of native fish species. To increase amphibian populations it is recommended that access to the shores by livestock is limited, good water quality maintained, the presence of water in the pond during summer prolonged, the water depth increased, aquatic vegetation encouraged and the concentration of nitrogenous compounds reduced (Galatowitsch et al., 2000; Jakob et al., 2003; Egan & Paton, 2004; Knutson et al., 2004; Rannap et al., 2009). To foster the settlement of native fish species in man-made ponds implementing introduction protocols is essential to avoid negative ecological effects (García-Jalón & Schmidt, 1995; Simões et al., 2009; Uchida & Nioue, 2009).

Our recommendations have been communicated to the appropriate authorities, both in Spain and Portugal, and to the managers of the private estates that are of importance for the black stork. Various official plans for the conservation of the species in Spain (Castilla-La Mancha and Castilla y León) and Portugal (the National Action Plan) already incorporate information from the results of this study. The development and implementation of a Natura 2000 network of protected areas in the Mediterranean now takes into account the importance of temporary ponds for the conservation of several priority biodiversity elements.

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References

ABRAHAMS, M.V. & KATTENFELD, M.G. (1997) The role of turbidity as a constraint on predator–prey interactions in aquatic environments. *Behavioural Ecology and Sociobiology*, 40, 169–174.

AKAIKE, H. (1973) Information theory as an extension of the maximum likelihood principle. In *Second International Symposium on Information Theory* (eds B.N. Petrov & F. Csaki), pp. 267–281. Akademiai Kiado, Budapest, Hungary.

AKASAKA, M., TAKAMURA, N., MITSUHASHI, H. & KADONO, Y. (2010) Effects of land use on aquatic macrophyte diversity and water quality of ponds. *Freshwater Biology*, 55, 909–922.

ALMEIDA, J., CATRY, P., ENCARNAÇAO, V., FRANCO, C., GRANADEIRO, J.P., LOPES, R. et al. (2005) Ciconia nigra. In *Livro Vermelho dos Vertebrados de Portugal* (eds M.J. Cabral, J. Almeida, P.R. Almeida, T. Dellinger, N. Ferrand de Almeida, M.E. Oliveira et al.), pp. 179–180. Instituto da Conservaçao da Natureza, Lisboa, Portugal.

BALMFORD, A., CRANE, P., DOBSON, P., GREEN, R.E. & MACE, G.M. (2005) The 2010 challenge: data availability, information needs and extraterrestrial insights. *Philosophical Transactions of the Royal Society of Biological Sciences*, 360, 221–228.

BEGON, M., HARPER, J.L. & TOWNSEND, C.R. (1999) *Ecologia*. Omega, Barcelona, Spain.

BERNARDOS, S., GARCÍA-BARRIUSO, M., SÁNCHEZ-ANTA, M.A. & AMICH, F. (2007) Composition, geographical affinities and endemism of the Iberian Peninsula orchid flora. *Nordic Journal of Botany*, 25, 227–237.

BILTON, D.T., MCABENDROTH, L., BEDFORD, A. & RAMSAY, P.M. (2006) How wide to cast the net? Cross-taxon congruence of species richness, community similarity and indicator taxa in ponds. *Freshwater Biology*, 51, 578–590.

BIRDLIFE INTERNATIONAL (2004) *Birds in Europe: Population Estimates, Trends and Conservation Status*. BirdLife Conservation Series No. 12. BirdLife International, Cambridge, UK.

BIRDLIFE INTERNATIONAL (2009) *Ciconia nigra. In IUCN Red List of Threatened Species v. 2010.4*. http://www.iucnredlist.org [accessed 16 February 2011].

BLUMSTEIN, D.T., FERNÁNDEZ-JURICIC, E., ZOLLNER, P.A. & GARITY, S.C. (2005) Inter-specific variation of avian responses to human disturbance. *Journal of Applied Ecology*, 42, 943–953.

BRAINWOOD, M. & BURGIN, L. (2009). Hotspots of biodiversity or homogeneous landscapes? Farm dams as biodiversity reserves in Australia. *Biodiversity and Conservation*, 18, 3043–3052.

CANO, L.S., FRANCO, C., PACHECO, C., REIS, S., ROSA, G. & FERNÁNDEZ, M. (2006) The breeding population of black stork *Ciconia nigra* in the Iberian peninsula. *Biota*, 7, 15–23.

CHEVALLIER, D., BAILLON, F., ROBIN, J.P., LE MAHO, Y. & MASSEMIN-CHALLET, S. (2008) Prey selection of the black stork in the African wintering area. *Journal of Zoology*, 276, 276–284.

COSTILLO, E., CORBACHO, C., MORÁN, R. & VILLEGAS, A. (2007) The diet of the black vulture *Aegypius monachus* in response to environmental changes in Extremadura (1970–2000). *Ardeola*, 54, 197–204.

CRAMP, S. (1998) *The Birds of the Western Palaearctic on CD-ROM*. Oxford University Press, Oxford, UK.

CRAWLEY, M.J. (2007) *The R Book*. John Wiley, New York, USA.

DALLINGA, J.H. & SCHOENMAKERS, S. (1987) Regional decrease in the number of white stork *Ciconia ciconia* in relation to food resources. *Colonial Waterbirds*, 10, 167–177.

DECLERCK, S., DE BIE, T., ERCKEN, D., HAMPEL, H., SCHRIJVERS, S. & VAN WICHELEN, J. (2006) Ecological characteristics of small farmland ponds: associations with land use practices at multiple spatial scales. *Biological Conservation*, 131, 523–532.

DEL HOYO, J., ELLIOT, A. & SARGATAL, J. (1992) *Handbook of the Birds of the World. Vol. 1*. Lynx Edicions, Barcelona, Spain.

DELIBES-MATEOS, M., DELIBES, M., FERRERAS, P. & VILLAFUERTE, R. (2008) Key role of European rabbits in the conservation of the Western Mediterranean basin hotspot. *Conservation Biology*, 22, 1106–1117.

DOMÍNGUEZ, L., GONZÁLEZ, J.L., GONZÁLEZ, L.M., GARZÓN, J. & LLANDRES, C. (1985) Datos sobre la alimentación de la cigüeña negra *Ciconia nigra* en España centro occidental. *Alytes*, 3, 51–56.

EGAN, R.S. & PATON, P.W.C. (2004) Within-pond parameters affecting oviposition by wood frogs and spotted salamanders. *Wetlands*, 24, 1–13.

ELVIRA, B. (1995) Conservation status of endemic freshwater fish in Spain. *Biological Conservation*, 72, 129–136.

FERNÁNDEZ-JURICIC, E., JIMÉNEZ, M.D. & LUCAS, E. (2002) Factors affecting intra- and inter-specific variations in the difference between alert and flight distances in forested habitats. *Canadian Journal of Zoology*, 80, 1212–1220.

FERRERO, J.J. & PIZARRO, V.M. (2003) *La cigüeña negra en Extremadura*. Junta de Extremadura, Mérida, Spain.

FINN, D.S., BOGAN, M.T. & LYTLE, D.A. (2009) Demographic stability metrics for conservation prioritization of isolated populations. *Conservation Biology*, 23, 1185–1194.

FLEISHMAN, E., BLAIR, R.B. & MURPHY, D.D. (2001) Empirical validation of a method for umbrella species selection. *Ecological Applications*, 11, 1489–1501.

GALATOWITSCH, S.M., WHITED, D.C., LEHTINEN, R., HUSVETH, J. & SCHIK, K. (2000) The vegetation of wet meadows in relation to their land-use. *Environmental Monitoring and Assessment*, 60, 121–144.

Gallego-Fernández, J.B., García-Mora, M.R. & García-Novo, F. (1999) Small wetlands lost: a biological conservation hazard in Mediterranean landscapes. *Environmental Conservation*, 26, 190–199.

García-Jalón, D. & Schmidt, G. (1995) *Manual práctico para la gestión sostenible de la pesca fluvial*. AEMS, Madrid, Spain.

Gómez-Rodríguez, C., Díaz-Paniagua, C., Serrano, L., Florencio, M. & Portheault, A. (2009) Mediterranean temporary ponds as amphibian breeding habitats: the importance of preserving pond networks. *Aquatic Ecology*, 43, 1179–1191.

González-Gajardo, A., Sepúlveda, P.V. & Schlatter, R. (2009) Waterbird assemblages and habitat characteristics in wetlands: influence of temporal variability on species–habitat relationships. *Waterbirds*, 32, 225–233.

Griffiths, R.A., Sewell, D. & McCrea, R.S. (2010) Dynamics of a declining amphibian metapopulation: survival, dispersal and the impact of climate. *Biological Conservation*, 143, 485–491.

Hampl, R., Bures, S., Baláz, P., Bobek, M. & Pojer, F. (2005) Food provisioning and nestling diet of the black stork in the Czech Republic. *Waterbirds*, 28, 35–40.

Hancock, J.A., Kushlan, J.A. & Kahl, M.P. (1992) *Storks, Ibises and Spoonbills of the World*. Academic Press, London, UK.

Herrero, J., García-Serrano, A., Couto, S., Ortuño, V.M. & García-González, R. (2006) Diet of wild boar *Sus scrofa* L. and crop damage in an intensive agroecosystem. *European Journal of Wildlife Research*, 52, 245–250.

Holm, T.E. & Clausen, P. (2006) Effects of water level management on autumn staging waterbird and macrophyte diversity in three Danish coastal lagoons. *Biodiversity and Conservation*, 15, 4399–4423.

Jakob, C., Poizat, G., Veith, M., Seitz, A. & Crivelli, A.J. (2003) Breeding phenology and larval distribution of amphibians in a Mediterranean pond network with unpredictable hydrology. *Hydrobiologia*, 499, 51–61.

Jiguet, F. & Villarrubias, S. (2004) Satellite tracking of breeding black storks *Ciconia nigra*: new incomes for spatial conservation issues. *Biological Conservation*, 120, 153–160.

Kadoya, T., Suda, S. & Washitani, I. (2004) Dragonfly species richness on man-made ponds: effects of pond size and pond age on newly established assemblages. *Ecological Research*, 19, 461–467.

Kahl, M.P. (1971) Spread-wing postures and their possible functions in the Ciconidae. *The Auk*, 88, 715–722.

Keller, M. & Profus, P. (1992) Present situation, reproduction and food of the Black Stork in Poland. In *The Storks of Europe. Proceeding of the International Conference, 1991* (eds J.L. Meriaux, C. Schierer, C. Tombal & J.C. Tombal), pp. 227–236. Institut Européen d'Ecologie, Metz, France.

Knutson, M.G., Richardson, W.B., Reineke, D.M., Gray, B.R., Parmelee, J.R. & Weick, S.E. (2004) Agricultural ponds support amphibian populations. *Ecological Applications*, 14, 669–684.

Lambeck, R.J. (1997) Focal species: a multi-species umbrella for nature conservation. *Conservation Biology*, 11, 849–856.

Larsen, F.W., Bladt, J. & Rahbek, C. (2007) Improving the performance of indicator groups for the identification of important areas for species conservation. *Conservation Biology*, 21, 731–740.

Laurence, W.F. & Useche, D.C. (2009) Environmental synergisms and extinctions of tropical species. *Conservation Biology*, 23, 1427–1437.

Lesbarreres, D., Fowler, M.S., Pagano, A. & Lode, T. (2010) Recovery of anuran community diversity following habitat replacement. *Journal of Applied Ecology*, 45, 148–156.

Lôhmus, A. & Sellis, U. (2003) Nest trees: a limiting factor for the black stork population in Estonia. *Aves*, 40, 84–91.

Maheswaran, G. & Rahmani, A.R. (2002) Foraging behaviour and breeding success of the black-necked stork *Ephippiorhynchus asiaticus* in Dudwa National Park, Uttar Pradesh, India. *Journal of Zoology*, 258, 189–195.

Manly, B.F.J., MacDonald, L.L. & Thomas, D.L. (1993) *Resource Selection by Animals. Statistical Design and Analysis for Field Studies*. Chapman & Hall, London, UK.

Ministry of the Environment (1999) *Strategic Plan for the Conservation and Sustainable Use of Wetlands in Spain*. Spanish Ministry of the Environment, Madrid, Spain.

Ministry of Environment, Rural and Marine Affairs (2011) Royal Decree 139/2011, of 4th February, for the development of the [. . .] Spanish Catalogue of Endangered Species. BOE46: 20912–20951.

Moreno-Opo, R., Arredondo, A., Soria, C., Guil, F., Higuero, R. & Guzmán, J. (2009) La cigüeña negra *Ciconia nigra* en concentraciones postnupciales y migratorias ibéricas: fenología, actividad y estructura de edades. *Ecología*, 22, 127–134.

Newton, I. (1998) *Population Limitation in Birds*. Academic Press, London, UK.

Oertli, B., Auderset, D., Castella, E., Juge, R., Cambin, D. & Lachavanne, J.B. (2002) Does size matter? The relationship between pond area and biodiversity. *Biological Conservation*, 104, 59–70.

Oertli, B., Biggs, J., Céréghino, R., Grillas, P., Joly, P. & Lachavanne, J.B. (2005) Conservation and monitoring of pond biodiversity: introduction. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 15, 535–540.

Oertli, B., Céréghino, R., Hull, A. & Miracle, R. (2009) Pond conservation: from science to practice. *Hydrobiologia*, 634, 1–9.

Paiva, V., Ramos, J., Martins, J., Almeida, A. & Carvalho, A. (2007) Foraging habitat selection by little terns *Sterna albifrons* in an estuarine lagoon system of southern Portugal. *Ibis*, 150, 18–31.

Paracuellos, M., Castro, H., Nevado, J.C., Oña, J.A., Matamala, J.J., García, L. & Salas, G. (2002) Repercussions of the abandonment of Mediterranean saltpans on waterbird communities. *Waterbirds*, 25, 492–498.

Pinto-Cruz, C., Molina, J.A., Barbour, M., Silva, V. & Espírito-Santo, M.D. (2009) Plant communities as a tool in temporary ponds conservation in SW Portugal. *Hydrobiologia*, 634, 11–24.

Putman, R.J. & Moore, N.P. (2002) Impact of deer in lowland Britain on agriculture, forestry and conservation habitats. *Mammal Review*, 28, 141–164.

R Development Core Team (2008) *R: A Language and Environment for Statistical Computing, Reference Index Version 2.8.0*. R Foundation for Statistical Computing, Vienna, Austria.

Rannap, A., Lôhmus, A. & Briggs, L. (2009) Restoring ponds for amphibians: a success story. *Hydrobiologia*, 634, 87–95.

Ritcher, S.C., Crother, B.I. & Broughton, R.E. (2009) Genetic consequences of population reduction and geographic isolation in the critically endangered frog *Rana servosa*. *Copeia*, 4, 799–806.

Roberge, J.M. & Angelstam, P. (2004) Usefulness of the umbrella species concept as a conservation tool. *Conservation Biology*, 18, 76–85.

Rodríguez-Prieto, I. & Fernández-Juricic, E. (2004) Effects of direct human disturbance on the endemic Iberian frog *Rana iberica* at individual and population levels. *Biological Conservation*, 123, 1–9.

Rosenvald, R. & Lôhmus, A. (2003) Nesting of the black stork *Ciconia nigra* and white-tailed eagle *Haliaeetus albicilla* in relation to forest management. *Forest Ecology and Management*, 185, 217–223.

Ruiz, E. (2008) *Management of Natura 2000 Habitats. 3170 Mediterranean Temporary Ponds*. Technical Report 2008 07/24. European Commission.

Schneider-Jacoby, M. (1999) Breeding distribution and ecology of the black stork *Ciconia nigra* in Sava alluvial wetlands, Croatia. *Acrocephalus*, 20, 167–176.

Sebastián-González, E., Sánchez-Zapata, J.A. & Botella, F. (2010) Agricultural ponds as alternative habitat for waterbirds: spatial and temporal patterns of abundance and management strategies. *European Journal of Wildlife Research*, 56, 11–20.

Seddon, P.H. & Leech, T. (2008) Conservation short cut, or long and winding road? A critique of umbrella species criteria. *Oryx*, 42, 240–245.

Semlitsch, R.D. (2000) Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management*, 64, 615–631.

Simberloff, D. (1998) Flagships, umbrellas and keystones: is single-species management passé in the landscape era? *Biological Conservation*, 83, 247–257.

Simôes, J.R., Arruda, C. & Simberloff, D. (2009) Introduction of non-native freshwater fish can certainly be bad. *Fish and Fisheries*, 10, 98–108.

Simon, J.A., Snodgrass, J.W., Cassey, R.E. & Sparling, D.W. (2009) Spatial correlates of amphibian use of constructed wetlands in an urban landscape. *Landscape Ecology*, 24, 361–373.

Suter, W., Graf, R.F. & Hess, R. (2002) Capercaillie *Tetrao urogallus* and avian biodiversity: testing the umbrella-species concept. *Conservation Biology*, 16, 778–788.

Taft, O.W., Colwell, M.A., Isola, C.R., & Safran, R.J. (2002) Waterbird responses to experimental drawdown: implications for the multispecies management of wetland mosaics. *Journal of Applied Ecology*, 39, 987–1001.

Uchida, Y. & Nioue, M. (2009) Fish species richness in spring-fed ponds: effects of habitat size versus isolation in temporally variable environments. *Freshwater Biology*, 55, 983–994.

Vlachos, C.G., Bakaloudis, D.E., Alexandrou, O.G., Bontzorlos, V.A. & Papakosta, M.A. (2008) Factors affecting the nest site selection of the black stork *Ciconia nigra* in the Dadia-Lefkimi-Soufli National Park, north-eastern Greece. *Folia Zoologica*, 57, 251–257.

Williams, D., Acevedo, P., Gortázar, C., Escudero, M.A., Labarta, J.L., Marco, J. & Villafuerte, R. (2007) Hunting for answers: rabbit *Oryctolagus cuniculus* population trends in north eastern Spain. *European Journal of Wildlife Research*, 53, 19–28.

Young, J., Watt, A., Nowicki, P., Alard, D., Clitherow, J. & Henle, K. (2005) Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. *Biodiversity and Conservation*, 14, 1641–1671.

Zacharias, I., Dimitriou, E., Dekker, A. & Dorsman, E. (2007) Overview of temporary ponds in the Mediterranean region: threats, management and conservation issues. *Journal of Environmental Biology*, 28, 1–9.

Zuberogoitia, I., Martínez, J.E., Martínez, J.A., Zabala, J., Calvo, J.F. & Castillo, I. (2006) Influence of management practices on nest site habitat selection, breeding and diet of the common buzzard *Buteo buteo* in two different areas of Spain. *Ardeola*, 53, 83–98.

Biographical sketches

Rubén Moreno-Opo works on the management of projects and conservation strategies for threatened species. He is interested in resolving conflicts between wildlife and socio-economic interests through scientific research and application of technology, social awareness and monitoring. Mariana Fernández-Olalla is investigating the ecological relationships between predator and prey species and the development of demographic models for threatened species. Francisco Guil develops conservation projects for the fauna of the Iberian Peninsula, especially for the limitation of non-natural mortality factors and to strengthen prey species populations and habitat management. Ángel Arredondo, Rafael Higuero, Manuel Martín, Carlos Soria and José Guzmán are field technicians with experience in monitoring and protecting threatened species of birds and mammals in Mediterranean environments.