Limnetica, 40(2): 417-433 (2021). DOI: 10.23818/limn.40.28

Habitat and weather conditions effects on long-term breeding population dynamics of five species of herons (Ardeidae) and Glossy ibis (Threskiornithidae) in the Valencian Community, Spain

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Received: 10/07/20 Accepted: 15/10/20

ABSTRACT

Habitat and weather conditions effects on long-term breeding population dynamics of five species of herons (Ardeidae) and Glossy ibis (Threskiornithidae) in the Valencian Community, Spain

Valencian wetlands include 65 % of the region's priority habitats and most are protected areas. Waterfowl populations are used as indicators of the state of these environments. We calculated the linear population trend by species, per wetland, of five Ardeidae and *Plegadis falcinellus* (Threskiornitidae) species using data from the annual census between 1984-2015 for 11 selected wetlands. We constructed a matrix with 42 habitat and meteorological variables, and evaluated the relation between these variables and population trends by a Correspondence Analysis. We found an increasing trend for most species. The populations of the L'Albufera de València Natural Park (NP) differed significantly from the rest. *Ardea cinerea*, *E. garzetta*, *B. ibis* and *A. ralloides* would be associated with large areas, and also with swamps and rice fields, while *A. purpurea* and *P. falcinellus* would be related to environments characterised by rainfall and the level of protection in the area. Rice fields and water management have been important for establishing breeding colonies.

Key words: population trends, breeding populations, Ardeidae, Mediterranean wetlands, protected areas, water birds counts, rice fields, heron populations

RESUMEN

Efectos del hábitat y las condiciones meteorológicas en la dinámica poblacional a largo plazo de cinco especies de garzas (Ardeidae) y el morito común (Threskiornithidae) en la región de Valencia, España

Los humedales valencianos incluyen el 65 % de los hábitats prioritarios de la región y la mayoría son áreas protegidas. Las poblaciones de aves acuáticas se utilizan como indicadores del estado de estos ambientes. Calculamos la tendencia poblacional lineal por especie, por humedal, de cinco especies de Ardeidae y de Plegadis falcinellus *(Threskiornitidae), utilizando datos del censo anual entre 1984-2015, para 11 humedales seleccionados. Además, construimos una matriz con 42 variables de hábitat y meteorológicas y evaluamos la relación entre estas variables y las tendencias poblacionales mediante un Análisis de Correspondencia. Encontramos una tendencia creciente para la mayoría de las especies. Las poblaciones del PN L'Albufera de València difieren significativamente del resto.* Ardea cinerea*,* E. garzetta*,* B. ibis *y* A. ralloides *estarían asociadas con áreas grandes y con pantanos y arrozales, mientras que* A. purpurea *y* P. falcinellus *estarían relacionados con ambientes caracterizados por las precipitaciones y el nivel de protección del área. Los campos de arroz y la gestión del agua han sido importantes en el establecimiento de colonias de cría.*

Palabras clave: *tendencias poblacionales, poblaciones reproductivas, Ardeidae, humedales mediterráneos, áreas protegidas, conteos de aves acuáticas, arrozales, poblaciones de garzas*

INTRODUCTION

Wetland ecosystems, which provide the population with lots of economic and intangible services, are the most threatened on the planet (Millenium Ecosystem Assessment, 2005; MedWet, 2016). Therefore, initiatives for their conservation are of vital importance (Millenium Ecosystem Assessment, 2005). Water bird trends are considered good indicators of wetlands status (Green & Figuerola, 2003; Gómez-López *et al.*, 2006; Palomino & Molina, 2009). Nevertheless, their effective efficiency depends partly on their scale (Green & Figuerola, 2003). On lower scales, the physical characteristics of wetlands, such as size, form, presence and distribution of emergent vegetation or proximity to other wetlands, influence water bird diversity and abundance (Craig & Beal, 1992; Green & Figuerola, 2003). On a larger scale, landscape heterogeneity is closely related to species richness (Atauri & de Lucio, 2001).

On the Mediterranean coast of the Iberian Peninsula, many lagoons and marshes represent most of the total area of wetlands in this region. Wetlands in the Valencian Community, located east of the Iberian Peninsula, harbour 65 % of the existing priority habitats and provide shelter for 50 % of the rare, endemic and threatened species of their biota (Ferrer-Polo *et al.*, 2006). These figures place these wetlands among the most valuable in the peninsula (Gómez-López *et al.*, 2006), and most are included in the Natura2000 Network (Red Natura, 2000) or the RAMSAR Convention. The majority of these environments are important breeding and wintering sites for waterfowl. The most important for both species richness and abundance are the wetlands of Prat de Cabanes-Torreblanca, L'Albufera de València, Marjal de Pego-Oliva, Salinas de Santa Pola, Lagunas de La Mata-Torrevieja and El Hondo (Martínez-Abrain *et al.*, 2016). Considering only the group of herons, the wetlands in the Valencian Community harbour 9.3 % of the winter population and 11.1 % of the breeding population in Spain, and respectively occupy fourth and fifth place nationally (Garrido *et al.*, 2012). L'Albufera de València is specifically the third most important site for heron reproduction in Spain (Garrido *et al.*, 2012).

The heron species evaluated in this study are *Egretta garzetta* (Little Egret), *Bubulcus ibis* (Cattle Egret), *Ardeola ralloides* (Squacco Heron), *Ardea cinerea* (Grey Heron), *Ardea purpurea* (Purple Heron), and one Threskiornitidae, *Plegadis falcinellus* (Glossy Ibis). Most of these species appear in some national or international protection or conservation category. Internationally, these species are classified as Least Concern on the IUCN Red List (BirdLife International, 2016), and the Purple Heron and the Glossy Ibis are included in Appendix II of the Bonn Convention (Council Decision 82/461/EEC). Therefore, they are subject to regulations and international cooperation to keep their populations safe. Moreover, in the Birds Directive (Directive 2009/147/EC), five of the studied species, except the Cattle Egret and the Grey Heron, are listed as threatened, vulnerable, rare or require special attention (Appendix I). In the Red Book of the Birds of Spain (Madroño *et al.*, 2004), the Squacco Heron is listed as Near Threatened and the Glossy Ibis as Vulnerable according to IUCN criteria. However, 16 years have passed since the last edition of the Red Book of the Birds of Spain, during which time the populations of some species may present changes; e.g., the Glossy Ibis, whose breeding and wintering populations have remarkably increased (Santoro *et al.*, 2013, 2016) which will probably change its conservation status in the next edition. The Squacco Heron is listed as Endangered on the National List of Endangered Species (Real Decreto 139/2011) and in the Valencia Catalogue of Endangered Fauna Species (Decreto 32/2004). On the same list, the Purple Heron is catalogued as Vulnerable. However, the overall breeding population of herons has increased from just over 2500 pairs (in the 1980s) to about 7000 in 2013 (Generalitat Valenciana, 2013), although their numbers have recently diminished by 43 % (Generalitat Valenciana, 2016). Some of these species found in any protection category have significantly increased in the last few decades in Spain, such as Grey Heron, Purple Heron, Squacco Heron and Glossy Ibis (Pérez-Aranda *et al.*, 2003; Figuerola *et al.*, 2003; Garrido *et al.*, 2012; Ramo *et al.*, 2013), and even these last two have

reached historic highs in the Valencian Community in 2015 and 2016 (Generalitat Valenciana, 2015; 2016). This increase has been considered a direct consequence of the environmental protection policies carried out in the wetlands of this region in the same time period (Martínez-Abrain *et al.*, 2016).

Our objectives were to evaluate the trends of the breeding populations of the study species in Valencian Community wetlands, and to elucidate which characteristics of this habitat, along with some weather conditions (i.e. temperature and rainfall), contribute or determine the size of these species' reproductive colonies. This information will help to manage both the species and habitats they occupy, which are mostly protected areas.

Figure 1. Location of the study wetlands to the east of the Iberian Peninsula. *Ubicación de los humedales estudiados en el este de la península ibérica.* (Marjal de Almenara: MA, Marjal dels Moro: MM, Marjal Xeresa-Xeraco: MXX, Marjal Hondo de Amorós: MHA, L'Abufera de Valencia NP: LANP, Pego-Oliva NP: PONP, Salinas de Santa Pola NP: SPNP, El Hondo NP: EHNP, La Pedrera Dam: ELP, Beniarrés Dam: EB, Embarcaderos Dam: EE)

METHODS

Study area

The Valencian Community is located to the east of the Iberian Peninsula (Fig. 1). Thirteen of the 48 sites on the List of Wetlands in this region (Generalitat Valenciana, 2002a) are SPAs (Birds Directive, 2009/147 / CE) included in the Natura 2000 Network. Marshes, lagoons and deltas are the environments with the largest heron colonies, where they nest mostly in marsh vegetation like reeds (*Phragmites* sp.) and bulrushes (*Typha* sp.), and represent 43 % of total breeding populations of these species in this region (Garrido *et al.*, 2012). The habitat surrounding these sites consists of either meadows and grasslands or agricultural areas, and extensive rice fields that are key for the foraging of herons and the Glossy Ibis (Hafner *et al.*, 1987, Fasola & Ruiz, 1996, Garrido *et al.*, 2012).

Of the 48 wetlands defined by the List of Wetlands in the Valencian Community, we selected 11 with active breeding for at least 3 consecutive years (during the 1984-2015 period) and with a minimum of 10 pairs (Fig. 1). These wetlands are L'Albufera de Vàlencia Natural Park (LANP), Salinas de Santa Pola Natural Park (SPNP), El Hondo Natural Park (EHNP), Pego-Oliva Natural Park (PONP), Marjal de Almenara (MA), Marjal dels Moros (MM), Marjal de Xeresa-Xeraco (MXX), Marjal Hondo de Amorós (MHA), Beniarrés Dam (EB), La Pedrera Dam (ELP) and Embarcaderos Dam (EE). Currently, 97 % of the entire breeding population of the Valencian Community nests in these localities (Generalitat Valenciana, 2015; 2018).

Population trends

Since 1984, SEO/BirdLife and the Conselleria de Medio Ambiente of the regional government have periodically conducted annual censuses using the same sampling technique. They derive the number of pairs from the number of

nests or adults incubating, except in areas with difficult access, where they were estimated from the number of adult reproducers present (Goméz-Lopéz *et al.*, 2006). In this study, we used the number of nesting pairs in the Valencian Community for the 32 years of consecutive censuses (1984-2015) and six species in all: Grey Heron, Purple Heron, Squacco Heron, Cattle Egret, Little Egret (Ardeidae), Glossy Ibis (Threskiornithidae).

The linear trend was calculated per species in each wetland and in the whole of the Valencian Community to observe breeding population trends in the long (32 years of censuses), mid (last 16 years) and short (last 8 years) terms. An autocorrelation analysis was performed on the number of breeding pairs per species in each wetland to verify that there was no spurious relation between population size and time (Santoro *et al.*, 2010). If data were autocorrelated, we assumed that there was no population trend, unless the significance value of the linear trend was $p < 0.01$ (Hatfield *et al.*, 1996; Santoro *et al.*, 2010).

To evaluate whether there was a preference shown by some species for certain wetlands, and if it was significantly more abundant in some than in others, the non-parametric Kruskal-Wallis test was performed (only the data from two localities were normally-distributed). In this way it was possible to identify which wetlands would be the most important for the conservation of each particular species. The Mann-Whitney *post hoc* test was used and box plots were generated. To determine if the populations of a given species covaried between different wetlands, the population sizes of each species in each wetland were analysed by a Spearman correlation with Bonferonni correction. We ran the analyses with version 3.14 of the Past3 programme (Hammer *et al.*, 2001).

How species composition changed with time and the order of colonisation in the most important wetlands were also evaluated by taking the number of pairs per species in each one at three different times during the census period: at the beginning (1984 for the LANP, 1985 for EHNP and 1988 for the rest), halfway (2000) and for the last census (2015).

Habitat variables

We created a matrix with 42 habitat variables that could be related to the population trends in each wetland (Table 1). As freshwater wetlands and marshes are positively related to heron colonies (Hafner *et al.*, 1987), the area of the marsh or flooded area (with or without vegetation) was included as a variable. This variable and the total area of the protected wetlands were obtained using GoogleEarth® (images from 2016), as was the distance from the wetland to the most important protected areas (L'Albufera de València and El Hondo). These wetlands house the largest heron populations (Garrido *et al.*, 2012; Generalitat Valenciana 2015; 2018) and trends in these large populations can influence the population trends in the closest wetlands. Likewise, we considered the average monthly temperatures during reproduction (March-July), and also the total rainfall during the non-breeding season (September-April) because it may affect success in the following breeding season (Hafner *et al.*, 1994; Lekuona, 2002). We obtained these weather data from the AEMET (Meteorology Statal Agency) database, available either on the web (AEMET OpenData) or provided by the agency. The conservation category and protection time of each locality were also considered as environmental protection policies and the protection status of colonies have an effect on population trends (Fasola *et al.*, 2010; Martínez-Abrain *et al.*, 2016). We also took into account the proportions of land use within radii of 5, 10 and 15 km around nesting colonies, calculated with GVSig (version 2.2.0.2313) from data on the latest available CorineLandCover map (2012). They were chosen because the type habitat surrounding breeding colonies influences their size and population trend, as well as the reproductive and feeding success of herons (Hafner *et al.*, 1987, Fasola *et al.*, 2010, Manikowska-Slepwronska *et al.*, 2016). Distances were selected by bearing in mind that herons feed mostly within a radius of between 5 and 10 km, but some species can move away as far as 15 km from the colony (Hafner *et al.*, 1987; Manikowska-Slepwronska *et al.*, 2019). We were unable to determine the variation in the area occupied by each land use type for the

Table 1. Variables considered in the Correspondence Analysis between the population sizes of heron species and the habitat characteristics of the different wetlands. *Variables consideradas en el Análisis de Correspondencia entre los tamaños poblacionales de las especies de garzas y las características de hábitat de los diferentes humedales.*

Variable	Description	Abbreviation
Wetland/year	Location /year of census	Ejem: MA88
Total area	Total area of the protected area in hectares	TotalArea
Area of marsh	Surface area in hectares occupied by the water body, including lake vegetation	MarshesArea
Distance to L'Albufera NP	Distance in kilometres from the location in question to the L'Albufera de València Natural Park	Dist.PNLA
Distance to El Hondo NP	Distance in kilometres from the location in question to the El Hondo Natural Park	Dist. PNEH
Precipitation	Accumulated rainfall between September and April each year, prior to the reproductive period	PPm
Average temperature	Average temperature between March and July each year (reproductive period)	Temp
Category	The locality's protection category (SPA birds, SCI, Natural Park, none)	Category
Protection	Years of protection	Protection
Percentage of water in 5, 10 and 15 km	Percentage of surface area covered by water (rivers, lagoons, estuaries, sea) within the radii of 5, 10 and 15 km around the colony	Water5Km Water10Km Water15Km
Percentage of marshes in 5, 10 and 15 km	Percentage of surface area covered by marshes within the radii of 5, 10 and 15 km around the colony	Marshes5Km Marshes10Km Marshes15Km
Percentage of salt flats in 5, 10 and 15 km	Percentage of surface area covered by salt flats within the radii of 5, 10 and 15 km around the colony	Sal5Km Sal10Km Sal15Km
Percentage of rice fields in 5, 10 and 15 km	Percentage of surface area covered by rice fields within the radii of 5, 10 and 15 km around the colony	Rice5Km Rice10Km Rice15Km
Percentage of other crops in 5, 10 and 15 km	Percentage of surface area covered by different crop types (permanent irrigation, fruit trees, olive trees, mixed) within the radii of 5, 10 and 15 km around the colony	OtherCrops5Km OtherCrops10Km OtherCrops15Km
Percentage of forest in 5, 10 and 15 km	Percentage of surface area covered by forest type vegetation (coniferous, broadleaf, mixed) within the radii of 5, 10 and 15 km around the colony	Forest5Km Forest10Km Forest15Km
Percentage of other vegetation in 5, 10 and 15 km	Percentage of surface area covered by low vegetation (bushes, pastures) within the radii of 5, 10 and 15 km around the colony	OtherVeg5Km OtherVeg10Km OtherVeg15Km
Percentage of urbanism/industry in 5, 10 and 15 km	Percentage of surface area covered by buildings (urbanism, industrial and commercial areas) within the radii of 5, 10 and 15 km around the colony	Urb5Km Urb10Km Urb15Km
Percentage of beaches in 5, 10 and 15 km	Percentage of surface area covered by beaches and dunes within the radii of 5, 10 and 15 km around the colony	Beach5Km Beach10Km Beach15Km
Grey Heron population size	Number of breeding pairs of Grey Heron (*A. cinerea*) for each census year	TpAc
Purple Heron population size	Number of breeding pairs of Purple Heron (*A. purpurea*) for each census year	TpAp
Squacco Heron population size	Number of breeding pairs of Squacco Heron (*A. ralloides*) for each census year	TpAr
Cattle Egret population size	Number of breeding pairs of Cattle Egret (*B. ibis*) for each census year	TpBi
Little Egret population size	Number of breeding pairs of Little Egret (*E. garzetta*) for each census year	TpEg
Glossy Ibis population size	Number of breeding pairs of Glossy Ibis (*P. falcinellus*) for each census year	TpPf

30-year study period because only the 2012 update of maps was available. Nevertheless, as these environments are stable on the surface, we assumed that the difference in the total area occupied by each land use type over the years was not likely to significantly or substantially modify the results. We evaluated the relation between the habitat characteristic and the annual number of breeding pairs in each wetland with a Correspondence Analysis (CA) which, from a graphical point of view, allows the possible relations between a set of variables to be analysed. In this case, wetlands were compared in each census year (rows) with the selected variables and the population size of each species (columns). This analysis was run with version 3.14 of the Past3 programme (Hammer *et al.*, 2001).

RESULTS

Population trends

All the study species showed a growing trend between 1984 and 2015 (Table 2). For no species

Table 2. Trends of the breeding populations of all the species in the studied wetlands in the long (32 years), mid (16 years) and short (8 years) terms, including slope (b), coefficient of determination (r^2) and the *p* values. *Tendencias de las poblaciones reproductivas de todas las especies en los humedales estudiados, considerando largo (32 años), mediano (16 años) y corto plazo (8 años). Se incluye la pendiente (b), el coeficiente de determinación (r^2) y el valor de* p. (MM: Marjal dels Moro, MA: Marjal de Almenara, MXX: Marjal Xeresa-Xeraco, MHA: Marjal Hondo de Amorós, LANP: L'Albufera de Valencia Natural Park, PONP: Pego-Oliva Natural Park, SPNP: Salinas de Santa Pola Natural Park, EHNP: El Hondo Natural Park, EE: Embarcaderos Dam, EB: Beniarrés Dam, ELP: La Pedrera Dam)

		Heron Species																	
Wetland	Years	Grey Heron			Purple Heron			Squacco Heron			Cattle Egret			Little Egret			Glossy Ibis		
		b	r^2	*p*	b	r^2	*p*	b	r^2	*p*	b	r^2	*p*	b	r^2	*p*	b	r^2	*p*
MM	32	3.67	0.64	< 0.01	0.33	0.46	< 0.01				1.02	0.24	0.02	0.72	0.27	0.01	1.5	0.35	< 0.01
	16	12.29	0.89	< 0.01	0.14	0.04	0.43				7.25	0.50	0.03	4.15	0.51	< 0.01	9.08	0.58	0.01
	8	17.01	0.91	< 0.01	0,07	0.003	0.88				11.25	0.60	0.04	7.68	0.66	< 0.01	16.57	0.69	0.04
MA	32				0.44	0.45	< 0.01	0.56	0.53	< 0.01	0.88	0.35	< 0.01	1.77	0.53	< 0.01			
	16				0.54	0.17	0.14	1.22	0.29	0.08	3.11	0.41	0.03	6.22	0.55	0.01			
	8				-0.78	0.10	0.44	0.26	0.009	0.82	4.14	0.33	0.14	6.96	0.35	0.16			
MXX	32	0.31	0.40	< 0.01	0.76	0.58	< 0.01	0.68	0.51	< 0.01	0.72	0.59	< 0.01	0.99	0.50	< 0.01	0.22	0.27	0.02
	16	0.09	0.01	0.68	0.76	0.44	< 0.01	1.90	0.66	< 0.01	1.86	0.60	< 0.01	3.54	0.70	< 0.01	1.42	0.47	0.04
	8	-1.38	0.42	0.08	1.20	0.34	0.13	3.62	0.70	0.01	1.36	0.17	0.31	5.24	0.67	0.01	2.71	0.58	0.08
MHA	8										56.79	0.31	0.19				5.86	0.31	0.25
LANP	32	13.24	0.29	< 0.01	-0.85	0.14	0.03	11.63	0.61	< 0.01	15.32	0.03	0.38	20.55	0.14	0.04	4.00	0.55	< 0.01
	16	-22.76	0.26	0.04	-0.77	0.06	0.37	11.92	0.21	0.07	-137.59	0.54	< 0.01	-23.18	0.08	0.29	21.77	0.85	< 0.01
	8	-36.21	0.27	0.19	5.81	0.82	< 0.01	46.06	0.49	0.05	-310.58	0.70	0.01	-37.11	0.08	0.51	34.43	0.98	< 0.01
PONP	32	0.57	0.29	< 0.01	0.73	0.21	0.01	0.59	0.76	< 0.01	0.72	0.49	< 0.01	2.71	0.53	< 0.01			
	16	0.10	0.002	0.84	-0.67	0.06	0.35	0.89	0.61	< 0.01	1.63	0.20	0.20	8.42	0.49	0.02			
	8	-2.63	0.32	0.14	-3.12	0.27	0.18	0.13	0.007	0.85	0.46	0.01	0.80	7.40	0.22	0.24			
SPNP	32	1.11	0.32	< 0.01	-0.38	0.11	0.11	1.70	0.41	< 0.01	49.85	0.36	< 0.01	-0.76	0.01	0.71	1.33	0.46	< 0.01
	16	-0.66	0.02	0.69	-1.75	0.33	0.05	0.36	0.004	0.85	-52.00	0.09	0.33	-0.61	0.008	0.76	1.48	0.10	0.30
	8	-7.25	0.56	0.05	-0.07	0.007	0.84	-4.06	0.15	0.34	-193.87	0.32	0.14	-5.54	0.31	0.19	-3.23	0.15	0.34
EHNP	32	0.64	0.18	0.06	-0.43	0.12	0.07	3.48	0.54	< 0.01	37.98	0.24	0.02	2.74	0.05	0.33	1.78	0.30	0.01
	16	7.75	0.53	0.06	-0.99	0.10	0.28	19.5	0.63	0.02	328.81	0.48	0.06	55.94	0.70	0.01	14.38	0.60	0.02
	8	7.75	0.53	< 0.01	1.76	0.30	0.16	24.36	0.69	0.02	500	0.74	0.01	69.64	0.77	0.01	17.75	0.64	0.03
EE	8	1.39	0.70	0.01															
EB	32	0.91	0.96	< 0.01															
	16	1.5	0.75	0.33															
	8	1.5	0.75	0.67															
ELP	32							0.31	0.60	< 0.01	3.19	0.66	< 0.01						
	16							-0.14	0.005	0.87	17.79	0.48	0.08						
	8							-1.4	0.56	0.08	10.91	0.28	0.28						
Valencia Region	32	18.53	0.48	< 0.01	1.03	0.13	0.04	17.39	0.73	< 0.01	102.33	0.55	0.01	26.48	0.23	< 0.01	83.42	0.44	< 0.01
	16	-9.90	0.06	0.36	-0.68	0.02	0.62	26.94	0.54	< 0.01	39.10	0.04	0.46	9.8	0.02	0.63	22.35	0.66	< 0.01
	8	-16.62	0.07	0.51	5.39	0.44	0.07	69.46	0.70	0.01	-4.75	0.0004	0.96	48.21	0.16	0.33	53.68	0.87	< 0.01

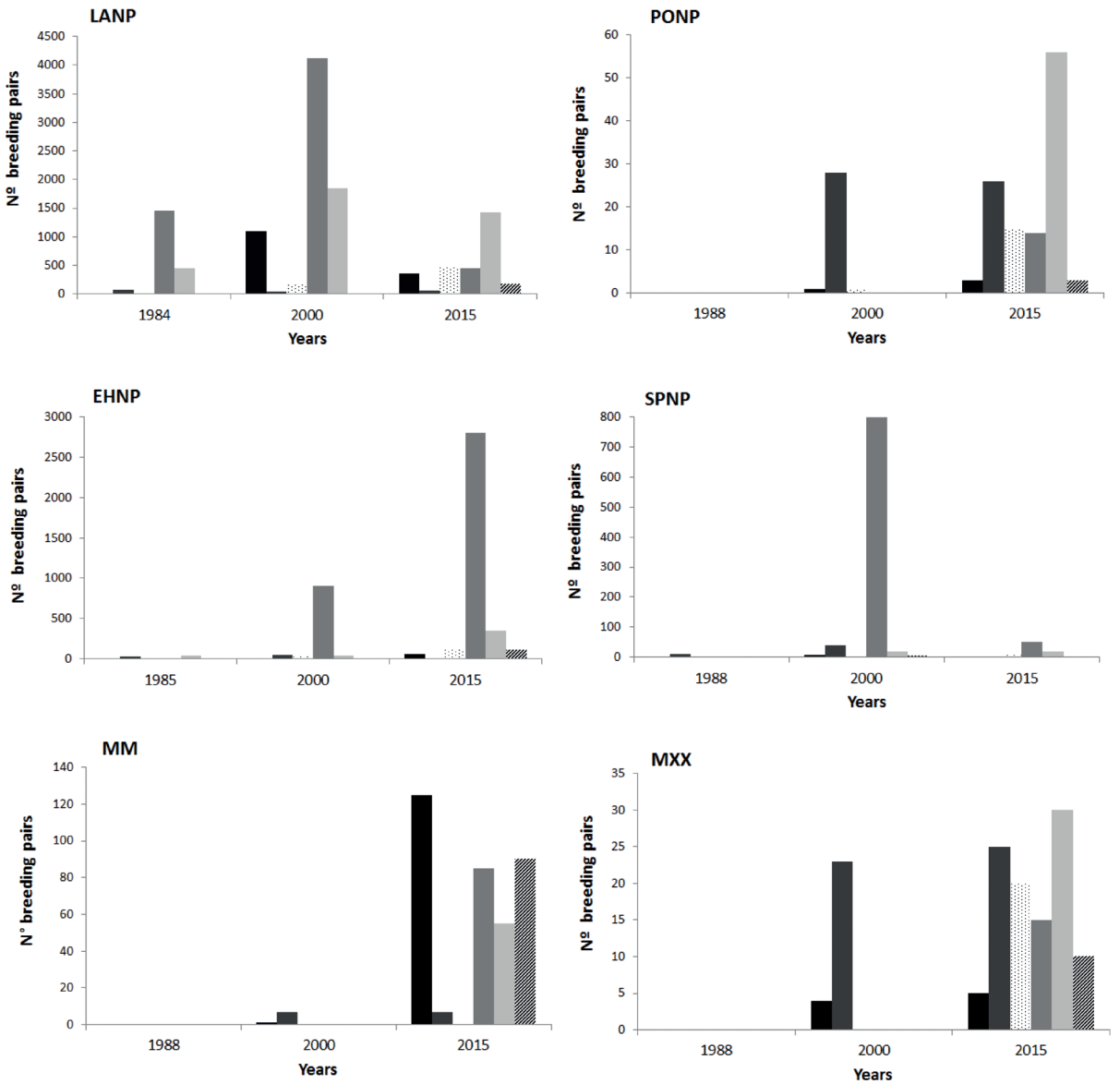

Figure 2. Number of breeding pairs per species at three different times during the 1984-2015 period for six wetlands in the study area. *Número de parejas reproductivas por especie en tres diferentes momentos entre el periodo 1984-2015 para seis humedales del área de estudio.* (■ Grey Heron-Garza Real ■ Cattle Egret-Garcilla bueyera ■ Purple Heron-Garza Imperial ■ Little Egret-Garceta común ▒ Squacco Heron-Garcilla cangrejera ▓ Glossy Ibis-Morito común)

was an autocorrelation found between the numbers of nesting pairs in two consecutive years. Indeed, the *p* of the linear trend was always ≤ 0.01 in those cases for which the coefficient of autocorrelation was > 0.80. Therefore, we considered that there was no autocorrelation.

Locally, the Purple Heron and Little Egret obtained the lowest r^2 values that were, however, significant in the long term (Table 2). For wetlands, all the species in all the localities showed significant positive trends, except for the Purple Heron, which showed a negative trend in SPNP, EHNP and LANP, which was significant only in LANP (Table 2). The Little Egret present-

ed no significant trend in EHNP or SPNP, nor did the Cattle Egret in LANP or MHA (Table 2). When considering the 16- and 8-year periods, throughout the Valencia Community only the Squacco Heron and Glossy Ibis continued to show a significant positive trend (Table 2). By analysing trends for wetlands, in the EHNP all species showed a significant trend in the mid and short terms, except for the Purple Heron (Table 2). The Grey Heron, Cattle Egret, Little Egret and Glossy Ibis showed a significant positive trend for both periods in MM, while the Squacco Heron and Little Egret did so in MXX (Table 2). In LANP, only the Glossy Ibis displayed positive trends in both the mid and short terms, whereas the Cattle Egret showed a significant negative trend during both periods, and the Grey Heron presented a negative trend during the 16-year period (Table 2).

Fluctuations in species composition

During the 30-year census, species richness and abundance has varied in each wetland. At the beginning of the census, breeding colonies were recorded only in LANP, EHNP and SPNP (Fig. 2). In 1984, LANP had colonies of Cattle Egret (most abundant), Little Egret, and Purple Heron (least abundant). Although the Grey heron has nested in the park since 1984, the few pairs (13) are not visible in the graph (Fig. 2). For this initial period, pairs of Purple Heron, Little Egret, Grey Heron, and one pair of Cattle Egret, were recorded in EHNP, and 10 pairs of Purple Heron were present in SPNP (Fig. 2).

Halfway through the period (2000), the Purple Heron had the most breeding pairs in MM, MXX and PONP, and a few Grey Heron pairs also settled in MM and PONP (Fig. 2). In EHNP, Cattle Egret was one of the most abundant species (as in SPNP and LANP), followed by the Purple Heron, Little Egret and Squacco Heron (Fig. 2).

In the last census (2015), all the species were present in all the monitored wetlands, except for the Squacco Heron, which was missing in MM, as was the Glossy Ibis in PONP (Fig. 2). The Little Egret was the dominant species in LANP, PONP an MXX, while it was the Grey heron in MM. The Cattle egret remained the most abundant breeding species in SPNP and EHNP (nearby localities; Fig. 2). The Cattle egret population diminished in LANP and became the third most abundant species after the Squacco Heron (Fig. 2). The Glossy Ibis has colonised the studied wetlands only recently and its biggest breeding population was found in LANP in 2015.

Relations among populations

The breeding populations of all the species present in LANP were significantly larger than the nesting populations of the same species in the other wetlands, except for the Glossy Ibis (Fig. 3), which indicates that it is the most important breeding colony of all those studied. For the Grey Heron, only the LANP population was significantly larger than in any other wetland. Otherwise, the EHNP and SPNP colonies were the second most important ones. The number of breeding pairs of Squacco Heron, Cattle Egret and Little Egret in these wetlands were significantly higher than for the other marshes, but their abundances did not differ from one another (Fig. 3). The Purple Heron showed significant differences among several populations (Fig. 3).

The breeding populations of the Squacco Heron and Grey Heron in the different localities correlated positively and significantly in most cases (Table 3). The breeding populations of the Cattle Egret and Little Egret in LANP showed no relation with any of these populations in other localities, while the other species correlated with the populations of MM, MXX, PONP and SPNP to a greater or lesser extent. The Purple Heron correlated negatively with the MM population (Table 3). All the nesting species in MXX correlated significantly with the species of PONP, except for the Purple Heron and Glossy ibis. Likewise, the population sizes of all the species present in MA significantly correlated with those of PONP and MXX (Table 3).

Habitat variables

In the CA, 82.14 % of total variance was explained on the first three axes (67.18 % on the first two). On the first axis (42.24 %), the variables with a greater weight in positive absolute values (> 1) were Distance to the L'Albufera NP (DistPNLA),

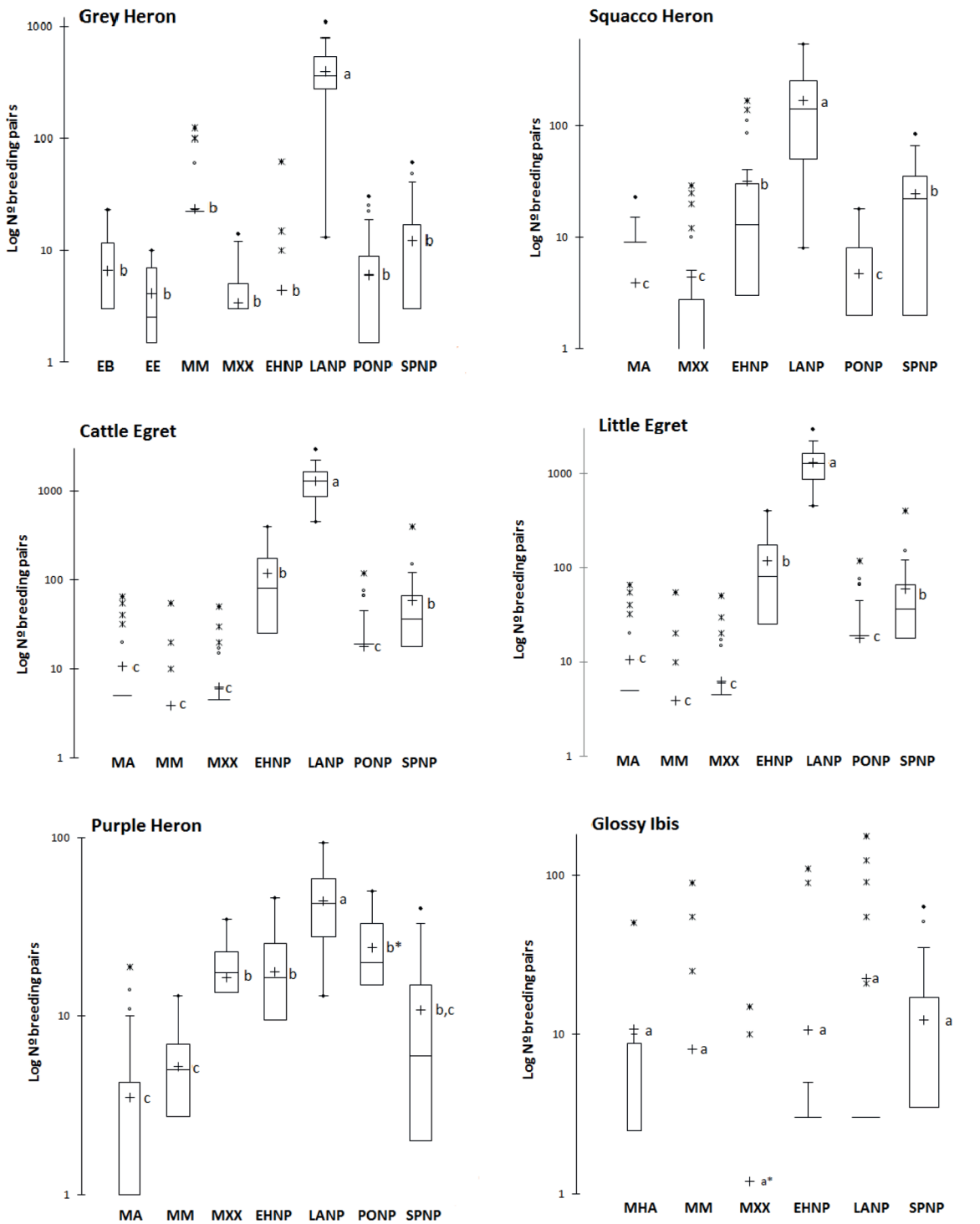

Figure 3. Nesting pairs per species between 1984 and 2015 in each studied wetland (+ mean, ◆ minimum/maximum, — median, ⊤ standard deviation, ○ atypical values ✳ extreme values. Same word: no significant differences, different word: significant differences. a* b* only significantly differs from SPNP). *Parejas nidificantes por especie entre 1984 y 2015 en cada humedal estudiado (+ media, ◆ mínimo/máximo, — mediana, ⊤ desviación estándar, ○ valores atípicos ✳ valores extremos. Letras iguales: no hay diferencias significativas, letras diferentes: hay diferencias significativas. a* b* solo difieren significativamente de SPNP).*

Precipitation (PP), Temperature (Temp), Protection category, Protection, Marshes, Other Vegetation, Other Crops, Beaches and Urbanism. Towards the negative side of the axis, the variables with the greatest weight were Water 10 km and Rice 15 km. However, Total area, Rice 5 km and Water 10 km (the other negative values on the axis) contributed to pull the population size variables of the Grey Heron, Little Egret, Squacco Heron and Cattle Egret towards this sector (Fig. 4). The LANP and EE wetlands were also located slightly towards the negative side of the axis, which were the two wetlands with the largest (total) area of those herein considered (Fig. 4). The population sizes of the Purple Heron and Glossy Ibis were associated with the variables located in the positive sector of axis 1, like marshes (MA, MM, MXX, MHA) and PONP (Fig. 4). The dispersion of points was basically due to the difference in rainfall in several years, and it was one of the variables with a greater weight (positive absolute value) on this axis. Marshes, mainly MM, MXX, MA and PONP, were apparently associated with the presence of Other Crops (not rice), Other Vegetation (non-forest), Urbanism, Marshes and Beaches (Fig. 4).

For axis 2, of the variables with a greater

Table 3. Statistic and *p* values of the Correlation Analysis between the populations of each heron species in the different studied wetlands. *Valor del estadístico y* p *del Análisis de Correlación entre las poblaciones de cada especie de garza en los diferentes humedales estudiados.*

Grey Heron

St\p	PONP	MXX	EB	SPNP	EHNP	LANP	MM	EE
PONP		< 0.0001	0	< 0.001	0.07	< 0.01	< 0.0001	1
MXX	0.86		0	< 0.001	0.19	< 0.001	< 0.01	1
EB	0	0		0	1	0.12	0	1
SPNP	0.83	0.78	0		1	0.28	< 0.01	1
EHNP	0.64	0.58	0.11	0.37		0.25	0.04	1
LANP	0.64	0.74	0.78	0.54	0.57		0.05	1
MM	0.88	0.73	0	0.73	0.66	0.60		1
EE	0	0	0.86	0	0.25	0.69	0	

Cattle Egret

St\p	MM	MXX	PONP	SPNP	MA	EHNP	LANP	ELP	MHA
MM		0.06	0.24	1	0.77	0.16	1	0	1
MXX	0.63		< 0.0001	1	< 0.0001	1	0.49	1	1
PONP	0.56	0.94		1	< 0.0001	1	0.16	1	1
SPNP	0.07	0.37	0.38		0.04	1	0.05	0.07	1
MA	0.50	0.85	0.86	0.66		1	0.16	0.87	1
EHNP	0.58	0.09	0.05	0.05	0.14		1	1	1
LANP	0.25	0.49	0.57	0.63	0.60	-0.03		0.87	1
ELP	0	0.50	0.50	0.70	0.54	0.19	0.54		1
MHA	0	0	0	0.67	0	0.67	-0.52	0	

Purple Heron

St\p	MM	MXX	PONP	SPNP	MA	EHNP	LANP
MM		0.27	1	1	0.05	1	0.04
MXX	0.46		0.18	1	0.03	1	0.78
PONP	0.19	0.49		1	< 0.0001	1	1
SPNP	-0.07	-0.27	-0.22		1	1	1
MA	0.59	0.62	0.86	-0.39		1	1
EHNP	-0.15	-0.30	-0.13	0.15	-0.18		1
LANP	-0.56	-0.40	-0.07	-0.20	-0.21	-0.28	

Little Egret

St\p	MM	MXX	PONP	SPNP	MA	EHNP	LANP
MM		< 0.01	0.03	1	1	1	1
MXX	0.72		< 0.0001	1	< 0.0001	1	0.54
PONP	0.64	0.91		1	< 0.0001	1	0.38
SPNP	0.11	-0.04	0.06		1	1	1
MA	0.29	0.97	0.86	0.13		0.35	1
EHNP	0.42	0.06	-0.01	0.09	-0.53		1
LANP	0.32	0.45	0.49	0.26	0.16	0.26	

Squacco Heron

St\p	PONP	MXX	MA	SPONP	EHNP	LANP	ELP
PONP		< 0.0001	< 0.0001	1	< 0.001	< 0.01	0.35
MXX	0.91		< 0.0001	1	< 0.001	0.02	1
MA	0.91	0.97		0.04	0.02	0.12	1
SPONP	0.38	0.33	0.64		1	< 0.01	0.3
EHNP	0.75	0.76	0.67	0.03		1	1
LANP	0.69	0.62	0.58	0.68	0.38		1
ELP	0.57	0.43	0.43	0.58	0.17	0.37	

Glossy Ibis

St\p	MM	MXX	MHA	SPNP	EHNP	LANP
MM		< 0.0001	1	0.03	0.04	< 0.01
MXX	0.79		1	0.21	0.57	0.09
MHA	0.00	0		1	1	1
SPNP	0.63	0.53	0		< 0.01	< 0.01
EHNP	0.64	0.47	0	0.77		0.06
LANP	0.69	0.58	0.42	0.69	0.62	

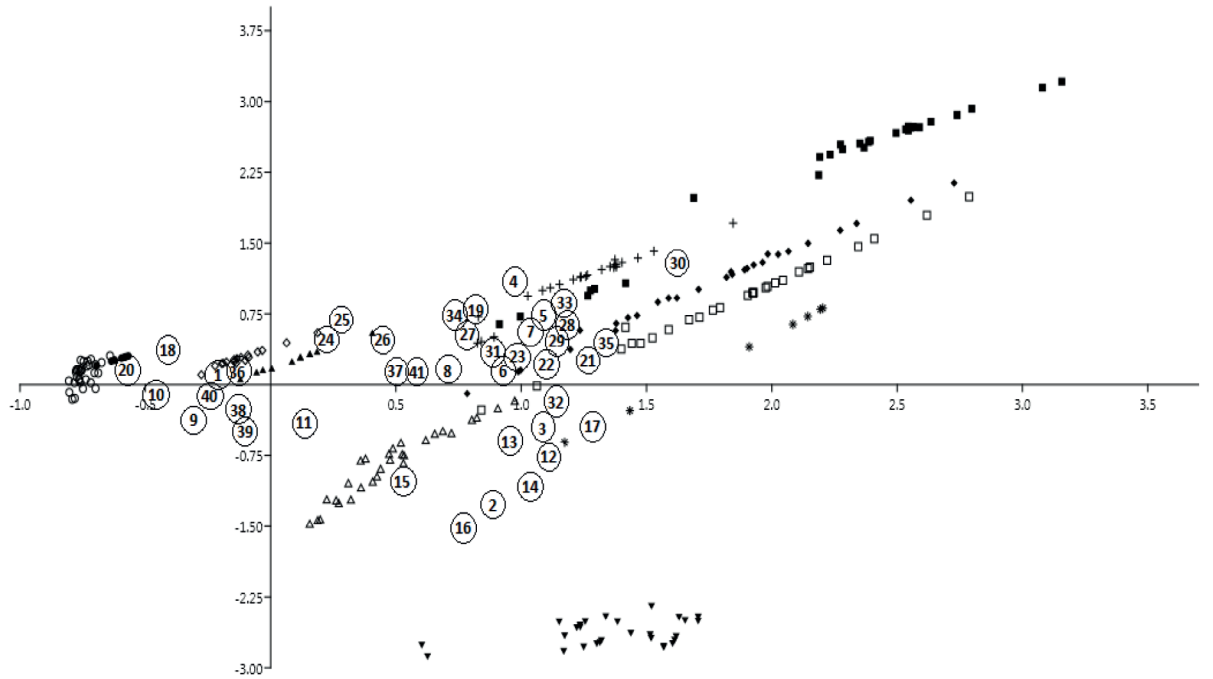

Figure 4. Correspondence analysis showing the relations between the studied wetlands and variables. *Análisis de correspondencia mostrando la relación entre los humedales y entre las variables estudiadas.* Wetlands- Humedales: ■ MM □ MXX + MA ✳ MHA ◆ PONP ○ LANP △ SPNP ▼ EHNP ● EE ▲ EB ◇ ELP / Variables: 1 TotalArea, 2 MarshesArea, 3 Dist.PNLA, 4 Dist. PNEH, 5 PPm, 6 Temp, 7 Category, 8 Protection, 9 Water5Km, 10 Water10Km, 11 Water15Km, 12 Marshes5Km, 13 Marshes10Km, 14 Marshes15Km, 15 Sal5Km, 16 Sal10Km, 17 Sal15Km, 18 Rice5Km, 19 Rice10Km, 20 Rice15Km, 21 OtherCrops5Km, 22 OtherCrops10Km, 23 OtherCrops15Km, 24 Forest5Km, 25 Forest10Km, 26 Forest15Km, 27 OtherVeg5Km, 28 OtherVeg10Km, 29 OtherVeg15Km, 30 Urb5Km, 31 Urb10Km, 32 Urb15Km, 33 Beach5Km, 34 Beach10Km, 35 Beach15Km, 36 TpAc, 37 TpAp, 38 TpAr, 39 TpBi, 40 TpEg, 41 TpPf.

negative weight, which seemed to characterise environments, we found Saltpans and Marshes, which led SPNP and EHNP to be located towards this sector of the axis (Fig. 4).

DISCUSSION

The results of this study confirm that the reproductive populations of the six considered species have increased in the last three decades. However, this increase appears to have stopped in the last half of the period, except for the Squacco Heron and Glossy Ibis. Moreover, the Grey Heron, Cattle Egret, Little Egret and Squacco Heron species seem to be associated with the environments characterised by having a bigger area, nearby freshwater bodies and the presence of rice fields. The Purple Heron and Glossy Ibis species would be associated with environments influenced mostly by rainfall and with some form of protection. Of all these variables, management of water bodies and rice fields, and administration of protected areas, would be those to consider when devising conservation plans for these species.

Between 1984 and 2014, 80 % of the reproductive water bird species in the Valencian Community, such as ducks, grebes and seagulls, have increased, of which 21 % are herons (Martinez-Abraín *et al.*, 2016; Garrido *et al.*, 2012). All our heron species have displayed an increasing breeding population trend in the last 30 years, which has also been observed in Doñana (SW Spain) over the 1984-2010 period (Ramo *et al.*, 2013) The populations of these species have increased in western Mediterranean wetlands since the 1970s (Galewski *et al.*, 2011). The breeding

populations of the Purple Heron, Grey Heron, Cattle Egret and Little Egret have displayed a significant positive trend, but not in the last 16 and 8 study years. Garrido *et al.* (2012) mentioned that in the Valencian Community, the Little Egret population seems to have stabilised in the last 10 years prior to their study (between 2000 and 2010) following a growth phase in the 1990s. A coherent trend has also been observed in the populations of the Grey Heron and Little Egret in NW Italy (Fasola *et al.*, 2010). Martinez-Abraín *et al.* (2016) found that the population trends of the Cattle Egret and Little Egret in the Valencian Community fit the logistic growth curve, which would be consistent with the fact that they have stopped showing a positive trend in the last 16 years. According to the same author, this would suggest that these species have recovered after the critical situation they were in at the beginning of the study, which was caused by the poor conditions of wetlands, and would have reached their carrying capacity. Their work also mentions that the Squacco Heron and Glossy Ibis are going through an exponential growth phase as they are the most recent colonisation (Martinez-Abraín *et al.*, 2016). This would coincide with the fact that these species displayed significant increasing trends in all the considered wetlands throughout our study period. In 2016, both species had more than 700 pairs distributed in eight different localities, which denotes their extended local distribution (Generalitat Valenciana, 2016).

Although the Cattle Egret has maintained a significant growing trend in the Valencian Community, when considering the whole period, it has displayed a decreasing trend in recent years in LANP. However, it has increased in other wetlands, especially in EHNP, which compensates local declines thanks to their increasing numbers in nearby areas (Garrido *et al.*, 2012).

The breeding populations of all the studied species in LANP were significantly more numerous than those in the other wetlands, and were the first colonies to be established in the region, which confirms the importance of this wetland for the reproduction of this species group. The Purple Heron was the first species to colonise the wetlands closest to LANP from the 1990s to a decade later, when other species began to arrive. The colony being established could be conditioned by the state of vegetation, which would offer adequate coverage and density (Santoro *et al.*, 2010), along with the presence of a small population to attract other individuals of the same species or of others (Pechuan, 1971; Prosper, 2000; Delord *et al.*, 2003; Santoro *et al.*, 2010). The last in this group of wetlands to be colonised was MM. In the wetlands of MXX and PONP, which are close to one another, the Purple Heron is the second most abundant species. Therefore, these protected areas play an important role in this species' conservation, considered to be Vulnerable in the Valencia Catalogue of Endangered Fauna Species.

Between 2006 and 2016, the most numerous nesting populations in LANP have dropped by 43 % due to the declining number of pairs of the Grey Heron, Little Egret and Cattle Egret (Generalitat Valenciana, 2016). However, populations have considerably increased in EHNP and, together with SPNP, could be concentrating part of the breeding population of the Cattle Egret and Little Egret of LANP. (Generalitat Valenciana, 2016). The number of both the Cattle Egret nests and Little Egret colonies is positively associated with the area occupied by rice fields (Tourenq *et al.*, 2000), and they depend on water conditions and variations in water quality (Hafner *et al.*, 1987; Bartolomé *et al.*, 1997; Garrido *et al.*, 2012). Therefore, the decline in the Cattle Egret and Little Egret populations in LANP could be indicative of a deterioration in rice field conditions as this variable characterises this wetland. In contrast, both species are present in larger numbers in EHNP, which may be a response to better water management (Generalitat Valenciana, 2016). The EHNP from 2011-2012 made improvements to the hydraulic infrastructure and changes in water management, which have favoured the increased quantity and quality of the water bodies in the park (Generalitat Valenciana, 2012). These species have benefited from this management as they find more water resources (marshes, ponds, irrigation canals), where they can further use as feeding areas. These water bodies have been shown an important association with size of colonies and these species' reproductive success (Hafner *et al.*, 1987; Bartolome *et al.*,

1997; Parejo *et al.*, 2001; Garrido *et al.*, 2012).

Most wetlands are characterised by the presence or proximity of other types of crops, shrub and grassland type vegetation (non-forests), urbanism and industry, marshes and beaches, especially coastal wetlands like MM, MXX, MA and PONP. Rainfall seems to considerably influence the environment of marshes as this variable causes different flood conditions, which would determine the availability of feeding areas in different years (Bancroft *et al.*, 1988; Hafner *et al.*, 1994). Colony size and reproductive success are positively related to the freshwater habitat area, which constitutes their feeding habitat and this, in turn, is affected by rainfall (Hafner *et al.*, 1987; Hafner *et al.*, 1994, Bennets *et al.*, 2000, Ramo *et al.*, 2013).

Spring rains would potentially have a stronger effect on these natural wetlands than on artificial ones (rice fields) like LANP (Sánchez-Guzmán *et al.*, 2007; Fasola *et al.*, 2010).

Four of the studied species (Grey Heron, Little Egret, Cattle Egret, Squacco Heron) were associated with the presence of rice fields and freshwater bodies, and with the total site area. This species may prefer similar environments to nests, where these three variables are the most important. Of these, the Grey Heron seems to be more associated with rice fields than the other three species, whereas the remaining three appear to be slightly more associated with permanent marshes (Hafner *et al.*, 1987). Rice fields are an important source of food for many waterfowl species, including herons and ibises (Fasola & Ruiz, 1996; Prosper & Hafner, 1996; Generalitat Valenciana, 2002b; Toral *et al.*, 2012), especially during the reproductive period when paddies relate positively to the size of breeding colonies (Hafner *et al.*, 1987; Lekuona, 2002). LANP, in addition to rice fields, is also characterised as the most extensive total area of the considered wetlands. This would explain why LANP is the site with the most breeding pairs (Pérez-Aranda *et al.*, 2003; Garrido *et al.*, 2012; Generalitat Valenciana, 2013). However, certain factors like reducing the flooding period or winter drainage intensification for soil preparation can negatively affect these species' populations (Prosper & Hafner, 1996; Ibañez *et al.*, 2010).

The Purple Heron and Glossy Ibis are more associated with marshes, which are, in turn, associated with rainfall (Toral *et al.*, 2012). These species seem to have a closer relation with protecting nesting areas. This relation is particularly important for the endangered Purple Heron, which has been able to recover only in recent years. In NW Italy, the protection status of breeding colonies was significantly related to population trends, as were feeding habitats (Fasola *et al.*, 2010). In our case, some species had permanently established in some wetlands 2-4 years after being declared protected areas.

The increase in heron populations, including threatened or vulnerable species, highlights the importance and effectiveness of conservation initiatives and protection policies, which are more critical locally during the reproductive season (Generalitat Valenciana, 2013; Martinez-Abraín *et al.*, 2016).

Reproductive success is typically higher in the colonies surrounded by rice fields and freshwater marshes (Hafner *et al.*, 1987; Delord *et al.*, 2003). Therefore, how paddies are managed will be a determining factor to maintain positive environmental externalities, such as the feeding, nesting and productivity of different bird species, including herons (Picazo-Tadeo *et al.*, 2009). This is especially true for LANP, whose production is adapting to more competitive markets and an increasingly strong pressure on water resources distribution (Picazo-Tadeo *et al.*, 2009). We also highlight the importance of conserving the wetland network (Red Natura, 2000) with management plans that incorporate measures for these nesting bird populations. Water management is a major aspect to consider in any management plan for these areas. Maintaining sufficiently flooded areas, which may be either artificial like rice fields or reservoirs, or natural like ponds and marshes, in breeding colonies' area of influence is vital for their conservation. The management plans of these protected areas should be reviewed to evaluate this aspect, and to invest, if necessary, in infrastructure and research to ensure good water resources management. These populations should always be considered a priority within the regional framework, and continuing with the typical metapopulations and source-sink dynam-

ics processes that might occur must be ensured.

ACKNOWLEDGMENTS

The authors thank the Department of Agriculture, Environment, Climate Change and Rural Development (Consellería de Agricultura, Medio Ambiente, Cambio Climático y Desarrollo Rural) for providing 32 years of nesting water bird census data about the wetlands in the Valencian Community. We also thank the State Meteorological Agency (AEMET) for climate data. We would also like to thank to Simone Santoro and another anonymous reviewer, who kindly provided suggestions that helped improve the manuscript. Finally, we are grateful to Mario Palacios for his advice with statistical analyses, Carla Olmo and Tàlia Alabadí for their help with using GIS and analysing maps, and Marjorie Machado and Natalia Ceballos for their help with the manuscript.

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