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Distribution of the White-headed Duck *Oxyura leucocephala* is Affected by Environmental Factors in a Mediterranean Wetland

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Francisco Atiénzar, Maria Antón-Pardo, Xavier Armengol, and Emilio Barba (2012) Distribution of the White-headed Duck *Oxyura leucocephala* is affected by environmental factors in a Mediterranean wetland. *Zoological Studies* **51**(6): 783-792. The White-headed Duck *Oxyura leucocephala* is a globally endangered diving duck that breeds in a few wetlands in Spain, Asia, and northern Africa. Little is known about how environmental variables affect the duck's distribution, so information is required to protect wintering and breeding areas. We attempted to assess which morphometric (open water surface and shoreline development index; [SDI]) and limnological variables (chironomid larvae biomass, macrophyte seed density, macrophyte cover, Secchi disk depth, conductivity, water depth, and chlorophyll *a*) were important in predicting suitable habitat conditions for this duck in an important wetland for the species in southeastern Spain. Our study included 2 periods with contrasting hydrological conditions: "wet" (winter 2003 to summer 2004) and "dry" (spring to summer 2005). Limnological variables were measured, and bird censuses were performed once a month in each water body, while morphometric variables were estimated from aerial photographs. In the wet year, the probability of the presence of wintering ducks increased with a greater open water surface area. In spring, the likelihood of the species occurring increased with the SDI, biomass of chironomid larvae, and level of eutrophication, and decreased with an increasing open water surface area. In summer, a high density of macrophyte seeds, high water transparency, and greater macrophyte cover were positively correlated with the presence of ducks. In the dry year, water depth and chironomid biomass were positively related to the bird's presence in spring and summer. White-headed Ducks were selective regarding the conditions of the water bodies, having different habitat requirements in different stages of their annual cycle. In stressful hydrological conditions (severe drought), ducks sought relatively deeper water bodies independent of their morphometry. We propose suggestions for the species' conservation in terms of local habitat management strategies.
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Key words: Diving duck, Endangered species, Hydrological conditions, Limnological variables, Shoreline development index.

Waterbirds are tied to wetlands for most or all of their life cycle. Their activities are strongly influenced by biological, physical, and chemical factors of the water bodies where they live. For these animals, choosing the right wetland could have important consequences for reproduction and survival (Badyaev et al. 1996). Hence, knowledge of their habitat use and selection has become a useful tool for monitoring and managing waterbird populations (Løfaldli et al. 1992, Quevedo et al. 2006, Smart et al. 2006, Liordos 2010). Most waterfowl are capable of long-distance displacements during migration and dispersal (Navarro and Robledano 1995, Dobrynina and Kharitonov 2006) allowing them to search for an adequate habitat over large areas. The decision of choosing a certain wetland or even a water body within a wetland complex, depends

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on birds' capabilities to evaluate aspects such as water quality and the availability of food and nesting places (Cody 1985). Such resources and conditions may; however, vary both throughout the year and between years (Armengol et al. 2008), so places which are adequate for breeding could become inhospitable for wintering, or suitable places 1 yr might be completely dry the next year.

Relationships between aquatic bird communities and limnological characteristics have long been studied (see Comín and Herrera (2000) for a review). For example, Palmgren (1936) discussed the relationship between aquatic birds and the trophic status in Finnish lakes. Later studies also examined morphometric characteristics of lakes, which also affect aquatic bird populations (Kerekes 1990 1998 2002, McNicol and Wayland 1992, Staicer et al. 1994, Suter 1994, Armengol et al. 2008). Indeed, the trophic status, morphological characteristics, and abundance of macrophytes are considered among the main factors affecting waterfowl distributions and densities (Nilsson and Nilsson 1978, Amat and Sánchez 1982, Johnson and Montalbano 1984, Green 2000, Torres 2003, Roy et al. 2011). Moreover, some studies undertaken in North America and certain European lakes found that the presence of Carp (*Cyprinus carpio*) in wetlands leads to a destabilization of the ecosystem and a change in the composition of the bird fauna, since Carp both feed on aquatic invertebrates and destroy the bottom of lakes which affects the growth of subaquatic vegetation (Torres 2003, Torralva and Oliva-Paterna 2010, Nummi et al. 2011).

The White-headed Duck *Oxyura leucocephala* is one of the rarest Palearctic waterbirds, currently listed as globally endangered (IUCN 2011). In Spain, it appears in few wetlands, which is a major conservation concern since populations might be highly sensitive to local water level fluctuations and pollution. Hence, knowledge of habitat features favoring its presence is especially urgent to formulate management strategies for the species (Green 1996, IUCN 2011). However, although the presence of this duck is probably related to water chemistry and sediment characteristics (where it gets most of its food, mainly macrophyte seeds and chironomid larvae (Torres 1985, Sánchez et al. 2000)), information on its habitat preferences is very scarce (Torres 2003, Armengol et al. 2008). Generally, this species occupies highly productive wetlands with macrophyte cover that are relatively deep (70-400 cm) and have well-developed littoral vegetation (Díaz et al. 1996, Torres 2005). However, most of this knowledge is based on casual field observations, and little is based on systematic data collection (Armengol et al. 2008, Moreno-Ostos et al. 2008).

Our main goal was to identify which limnological variables, including water-body morphometry, affect the distribution of White-headed Ducks in different seasons through the year in an important Mediterranean wetland. We used data gathered during a relatively wet period (2003-2004; Armengol et al. 2008), and collected new data during a relatively dry period (2005), to also determine habitat preferences in years with contrasting hydrological conditions.

MATERIALS AND METHODS

Study area

The study was conducted in El Hondo Natural Park (hereafter El Hondo), located in southeastern Spain (Fig. 1), one of the warmest and driest areas on the Iberian Peninsula (Pérez 1994). This wetland suffers from important environmental problems; the most prominent is the scarcity of water in summer along with low water quality (eutrophy, salinity, and pollution, e.g., Colmenarejo et al. 2007). In spite of environmental degradation, this wetland is considered an important wintering and breeding area for many waterbirds, including the White-headed Duck (Torres 2003). However, the need for water for agriculture has increased conservation challenges for this species in this wetland.

El Hondo is a complex wetland having 2 large shallow reservoirs, Levante (L) and Poniente (P), and 3 small ponds, Norte (N), Sur de Poniente (SP), and Reserva (R). All of them were < 1.5 m deep during the study period, connected by channels, and surrounded by emergent vegetation dominated by reedbeds of *Phragmites australis* (Fig. 1). The ponds are filled with groundwater and runoff from irrigated cultivation areas; reservoirs receive water through a channel from the Segura River.

The study was conducted during 2 periods: (1) from Dec. 2003 to Sept. 2004 (considered hereafter as the wet period), a period characterized by higher water levels and increased flooded surfaces in the water bodies, with the presence of water in 1 or both reservoirs during most of the period; and (2) from Apr. to Aug. 2005 (the dry period hereafter), a period characterized by lower water levels and a much reduced flooded surface of the lakes (i.e., much of the coastline was dry, and there was only water in the deepest parts of the lakes), which is known to negatively affect the presence of White-headed Ducks (Armengol et al. 2008). Ponds and reservoirs contain, in wet years, relatively large quantities of fish, mainly Carps and *Mujol* sp. During dry years, the reduced water surface and depth cause strong reductions in fish populations.

Bird location

The presence of White-headed Ducks in each water body was assessed through monthly censuses in Dec. 2003-Sept. 2004, and in Apr.-Aug. 2005. As suggested by Bibby et al. (2000), birds were mapped early in the morning, when their activity was low, and they remained in flocks. Windy or rainy days were avoided. We used a telescope (Leica 20 × 60, Solms, Germany) to systematically scan the water surface of all the studied water bodies. We used elevated platforms, bird-watching observatories, or elevated land to achieve good visibility. We noted the location of each bird on 1: 1000 maps of the water bodies where a grid (200 × 200 m) was superimposed and reference points marked. Bird sampling was done before (early the same day or the day before) limnological sampling.

Morphometric variables

The general outline of each water body was digitized from 1: 5000 aerial photographs, made by the Conselleria de Medi Ambient (Regional Environmental Board) in 2000, using the ArcView 8.1 program (Environmental Systems Research Institute [ESRI] of Redlands, California). From these images, 2 morphological variables, the area of open water and the shoreline development index (SDI), were estimated for each water body. The SDI reflects the degree of sinuosity or of irregularity of the shoreline, and it is estimated as SDI = perimeter/2x $(\pi \times \text{area})^{0.5}$. A value of 1 indicates a perfect circle and values increase as the shoreline becomes more irregular (Wetzel and Likens 2000).

Limnological sampling

Samples for limnological characterization were taken once a month. In water bodies where birds were present in the previous census, we selected at least 2 sampling points in specific

Fig. 1. Map of the study site in Spain and the location of El Hondo Natural Park and its 5 water bodies: Poniente Reservoir (P), Sur de Poniente Pond (SP), Norte Pond (N), Levante Reservoir (L), and Reserva Pond (R). The gray color shows the vegetated surfaces. Black stars are sampling points.

places where the birds were observed, and at least 2 more points in places where birds were not present (Fig. 1). In water bodies where no birds were detected during the previous census, we selected at least 2 sampling points. Sampling points where birds were absent were selected to represent environmental variability, with sites both in open water and close to the littoral zone. Sampling sites remained fixed (moving 1-3 m to avoid sediment disturbance in consecutive samplings) during the study, as long as the presence of birds did not force us to move them; we noted the coordinates of each sampling point with a Garmin GPS 12 (Garmin, Southampton, UK).

At each sampling point, we took water samples at 0.3 m in depth for chlorophyll (Chl) *a* analyses. Chl *a* was determined spectrophotometrically in a 90% acetone extract after filtration of the sample through a Whatman GF/F glass-fiber filter (Whatman, Kansas, USA). The pigment concentration was calculated according to Jeffrey and Humphrey (1975). Electric conductivity (VWR EC300, VWR, UK), water depth, Secchi disk depth, and the percentage of macrophyte cover were measured *in situ*. The percentage of macrophyte cover in a circle 3 m in diameter around the sampling site was estimated by visual inspection by one of the authors (JA). Due to the shallowness of the lakes, the bottom could often be seen from the surface, and thus the Secchi disk depth could not be measured. In such cases, we used an index of the transparency (labeled % Secchi depth: Secchi disk depth with respect to pond depth expressed as a percentage; when both depths were equal, this value was 100%). Both variables, transparency and Chl *a* concentration, were used as indicators of the degree of eutrophication.

Sediment samples were taken with a homemade metacrilate corer of 6.4 cm in diameter to a depth of 10-12 cm. Samples were kept in a refrigerator and in the dark after collection, and the next day were sieved through 1- and 0.25-mm meshes, in a column. Seeds of *Ruppia* and *Potamogeton*, the most abundant seeds found in the sediment, were counted in these samples. The sum of the abundance/dm^2 of both seed types was used for analyses as ducks consumed both species (Suárez-R and Urios 1999, Sánchez et al. 2000). We also counted each chironomid larva of longer than 4 mm. Chironomid biomass (wet weight) per unit area in each sample was estimated by multiplying the density by the average chironomid weight estimated from our samples (2.26 mg, SD = 2.23, n = 222 individuals of different sizes).

Statistical analyses

In order to normalize the data for analyses, Secchi disk and macrophyte cover percentages were square-root arcsine-transformed; the other environmental variables were log(x + 1)-transformed, while seed density and chironomid biomass were square-root-transformed (Zar 1999). For each water body and sampling session, we averaged the values of the limnological variables at points where birds were present or absent.

With values of the transformed limnological variables, we performed principal component analyses (PCAs) and multivariate analyses to reduce the dataset to a few number of variables (components) which explain as much of the variance in the data as possible.

To analyze the likelihood of White-headed Ducks occupying a certain water body during winter, spring, and summer, we used binary logistic regressions, taking into account the best model found by the forward stepwise selection of variables. As covariates, we used principal components (PC1, PC2, and PC3), area, and the SDI. The 1st 3 PCs were considered in these analyses, based on broken-stick analyses (Jackson 1993), but results for PC2 and PC3 were not significant and are not presented here. As we had small sample sizes in 2005, we analyzed spring and summer together. We compared mean values of parameters measured during spring and summer 2003-2004 (wet period) and 2005 (dry period) using analyses of variance (ANOVAs). The mean ± standard error (S.E.) are given where appropriate.

RESULTS

During the wet period, the duck population ranged 43-777 individuals, with 346 (S.D. = 250) individuals on average. In contrast, during the dry period, the population ranged 0-132 individuals, with 23 (S.D. = 41) individuals on average.

The 2 reservoirs, Poniente and Levante, showed the highest open water surface and SDI. The lowest SDI was estimated for Norte pond, which was also the smallest pond. The smallest water bodies (Sur de Poniente, Norte, and Reserva) had perimeter/area ratios much higher than those of the 2 reservoirs (Table 1).

Average values for the limnological variables measured each season presented high temporal and spatial heterogeneity, including depth, vegetation cover, Chl *a*, and the density of seeds and biomass of chironomids in sediments (Table 2). The greatest depths were found in winter in all ponds, while these values were lower in summer. However, the maximum mean depth did not exceed 1 m, so the bottom of the lake was easily seen in most samplings, resulting in high transparency (% Secchi), except in some periods with high phytoplankton growth (Chl *a*). Conductivity ranged from 6.1 mS/cm in Levante to 18.4 mS/cm in Reserva, showing a slight seasonal increase due to an increase in temperature and thus evaporation rates. Variables measured in sediments showed great heterogeneity, with minima of 6.2 seeds/dm^2 and 0 mg of chironomids/dm^2 to maxima of 267.8 seeds/dm^2 and 169 mg of chironomids/dm^2.

Results from the PCA of limnological variables are summarized in table 3. The 1st PC (PC1) was significantly correlated with all variables. Negative loading values of PC1 during 2003-2004

Table 1. Values of 2 morphometric variables at the 1: 5000 scale of area (ha) and the shoreline development index (SDI) for 5 water bodies in El Hondo Natural Park

Water body	Area (ha)	SDI	Perimeter/Area (× 10^{-4} m)
Poniente	488.5	7.6	121.79
Sur Poniente	11.2	4.3	458.84
Norte	5.6	1.9	282.50
Levante	236.0	7.1	163.61
Reserva	59.7	4.5	206.87

Table 2. Average values of the main limnological variables measured in each water body in the different seasons studied

		Depth (cm)	Transparency (% Secchi depth)	Conductivity (mS/cm)	Chlorophyll *a* (g/L)	Vegetation (%)	Seeds (seed/dm^2)	Chironomid biomass (mg/dm^2)
P	Winter 2003-2004	-	-	-	-	-	-	-
	Spring 2004	82	94.0	9.6	8.8	30.5	52.5	50.2
	Summer 2004	33.2	87.1	27.8	341.9	49.8	171.9	20.1
	Summer 2005	-	-	-	-	-	-	-
SP	Winter 2003-2004	86.9	98.8	13.9	13.5	0.0	172.2	169.0
	Spring 2004	95.1	89.5	15.2	75.0	36.7	173.0	42.5
	Summer 2004	57.7	99.2	17.7	46.5	42.5	112.7	20.9
	Summer 2005	45.6	96.5	14.5	20.0	42.6	267.8	0.0
N	Winter 2003-2004	74.1	100.0	15.9	6.6	2.8	129.3	97.9
	Spring 2004	72.4	100.0	16.4	7.1	30.0	85.2	76.3
	Summer 2004	42.9	73.3	16.2	10.5	28.0	129.5	10.7
	Summer 2005	42.4	100.0	16.1	6.3	21.1	130.3	0.0
L	Winter 2003-2004	94.9	87.4	6.1	38.7	0.0	43.8	6.4
	Spring 2004	72.2	95.2	7.3	5.5	35.0	22.8	62.4
	Summer 2004	33.0	75.0	13.9	62.2	12.5	6.2	0.0
	Summer 2005	53.4	78.9	10.8	4.3	0.3	25.7	0.3
R	Winter 2003-2004	62.7	96.7	15.1	25.4	0.3	44.5	80.8
	Spring 2004	74.5	93.9	16.6	59.1	10.8	73.3	79.3
	Summer 2004	41.6	98.9	16.5	60.9	46.7	264.7	54.0
	Summer 2005	43.8	91.5	18.4	21.1	9.1	148.6	0.0

P, Poniente Reservoir; SP, Sur de Poniente Pond; N, Norte Pond; L, Levante Reservoir; R, Reserva Pond.

and 2005 indicated eutrophic and deep waters with high chironomid biomass. Positive loading values corresponded to high macrophyte seeds and cover, and transparent waters.

During the wet period (2003-2004), wintering White-headed Ducks were more likely to be present on a water body as the area of open water increased (B = 0.024, Wald = 4.56, p = 0.033). During the breeding season (i.e., spring), birds preferred smaller ponds (B = -0.018, Wald = 7.37, p = 0.007) with highly irregular shorelines (B = 1.88, Wald = 8.64, p = 0.003). Moreover, the probability of the duck's presence increased at sites with more-negative values for PC1, i.e., birds preferred eutrophic waters with high chironomid biomass in the sediments (B = -5.362, Wald = 3.41, p = 0.065). In contrast, the probability of occurrence in summer increased with positive values of PC1. Hence, birds preferred ponds with high macrophyte cover, transparent water, high seed density, and high electric conductivity (B = 2.36, Wald = 4.68, p = 0.031). Mean values for those variables which were significantly correlated with the presence of ducks in this period are shown in figure 2.

During the dry year (spring-summer 2005), the presence of White-headed Ducks was positively correlated with negative values of PC1, i.e., birds seemed to search for deeper waters and high chironomid biomass (B = -2.95, Wald = 3.75, p = 0.053). Morphometric features were not statistically significant (p > 0.05).

Comparing mean values of limnological variables between water bodies where ducks were present for the period sampled in both years (spring-summer), birds were located where the mean water depth was greater during the dry year (67.8 ± 11.1 cm) compared to the wet year (41.4 ± 3.1 cm; F = 6.331, $d.f.$ = 20, p = 0.021, n = 34 samples). Ducks were also present where chironomid biomass was high during the dry year (0.096 ± 0.184 mg/dm^2 in the dry year vs. 0.010 ± 0.013 mg/dm^2 in the wet year; F = 5.055, $d.f.$ = 20, p = 0.036, n = 34 samples). No significant differences existed between years for the other limnological variables (all p > 0.05).

DISCUSSION

White-headed Duck distribution in eastern Spain, at a given stage of the annual cycle, markedly varies from year to year based on the temporal distribution of flooded areas with suitable characteristics (Armengol et al. 2008). Nevertheless, seasonal changes in duck-specific habitat requirements are poorly known (Armengol et al. 2008, Moreno-Ostos et al. 2008).

Green (2000) stated that species of the subfamily Anatinae appeared more often in wetlands with a high open water surface and shallow water during the winter. Such wetlands offer sufficient nutrients to support abundant primary production by phytoplankton and macrophytes, creating excellent foraging conditions for many aquatic birds (Paszkowski and Tonn 2000, Cole 1983 in Stevens et al. 2003). White-headed Ducks seem to have broader habitat requirements during the breeding season than during the winter (Amat and Sánchez 1982, Moreno-Ostos et al. 2008), and they even use lakes without shoreline

Table 3. Results of the principal component analyses based on limnological variables measured during the wet (2003-2004) and dry years (2005). Significant correlations (p < 0.05) among limnological variables and the 3 1st principal components (PCs) are shown in bold

	2003-2004			2005		
	PC1	PC2	PC3	PC1	PC2	PC3
Chironomid larval biomass (mg/dm^2)	**-0.253**	**0.539**	**0.575**	**-0.701**	-0.357	**0.450**
Macrophyte seeds (seeds/dm^2)	**0.397**	**0.594**	**0.263**	**0.761**	0.283	**0.509**
Electrical conductivity (mS/cm)	**0.799**	**0.279**	**0.208**	**0.633**	**0.581**	-0.247
Depth (cm)	**-0.836**	**0.249**	0.048	**-0.486**	**0.711**	0.361
Secchi depth (%)	**0.271**	**-0.464**	**0.751**	**0.756**	**-0.397**	0.153
Macrophyte cover (%)	**0.497**	**-0.567**	-0.041	**0.682**	-0.147	**0.568**
Chlorophyll *a* (mg/L)	**-0.610**	**0.480**	**-0.441**	**-0.670**	-0.131	-0.364
Eigenvalues	2.253	1.551	1.206	3.195	1.639	1.639
Explained variability (%)	32.19	22.16	17.24	45.65	17.83	16.16
(Accumulated)	32.19	54.35	71.58	45.65	63.48	79.64

vegetation (Green et al. 1999). Our study is consistent with that observation, as only areas of open waters predicted the presence of wintering ducks.

During the breeding season, the vegetation and irregularity of the shoreline immediately surrounding a lake may enhance use by White-headed Ducks, by positively affecting the availability of appropriate nesting sites (Green 2000, Paszkowski and Tonn 2000). Green (2000) noted that open environments, with a low ratio of shoreline length to water area, are suboptimal for breeding ducks, likely because a low ratio decreases the amount of suitable breeding places and increases the exposure of hatchlings to avian predators due to the scarcity of places to hide (Bouffard et al. 1987). Moreover, lakes with high SDI values receive more terrestrial inputs of nutrients and organic matter, which favors the development of littoral communities, providing resources to support high macroinvertebrate densities (Murkin and Kadlec 1986, Schindler and Scheuerell 2002). We found that during the breeding season, White-headed Ducks were more likely to occur in water bodies with high values

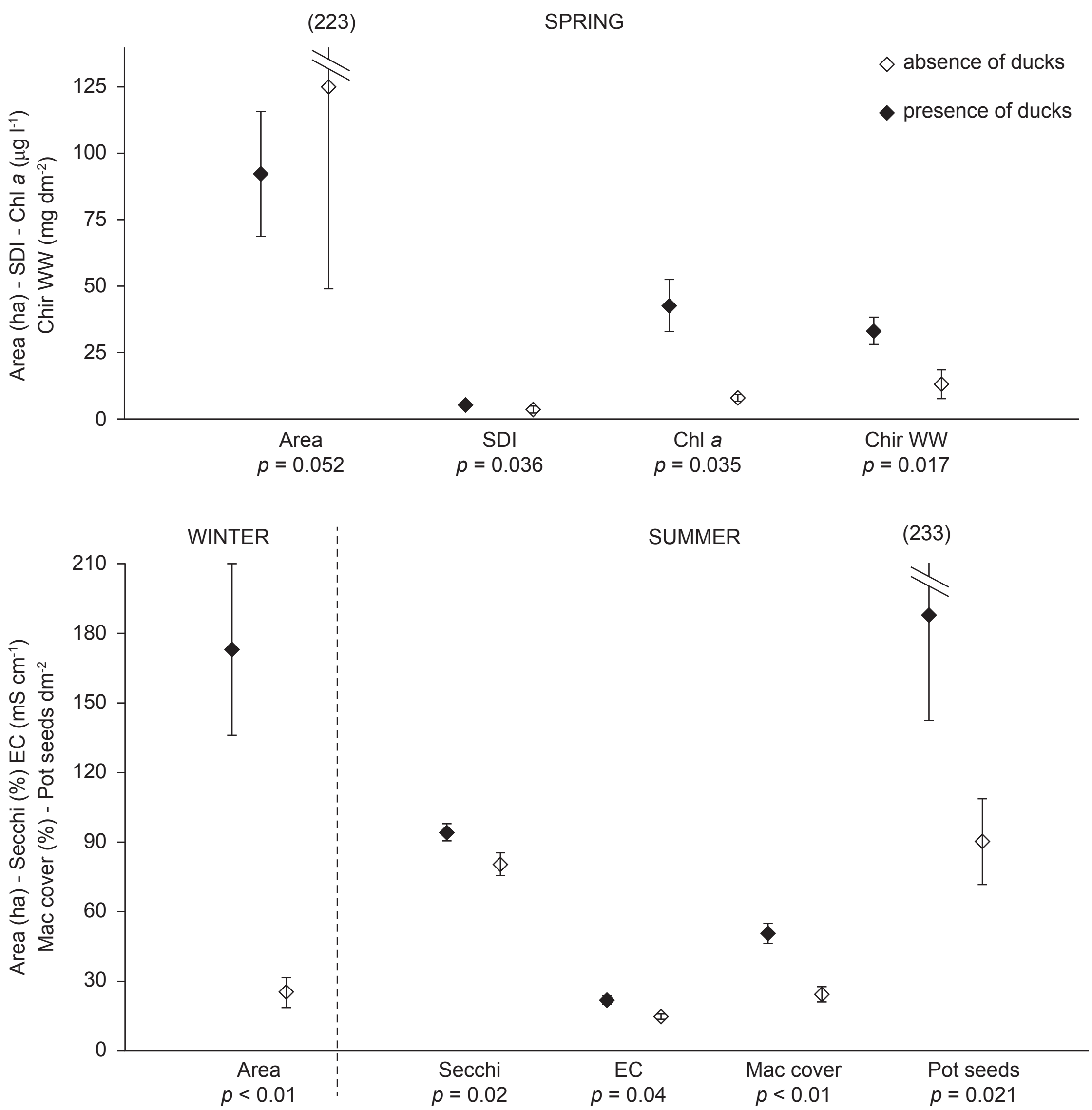

Fig. 2. Mean ± SE of limnological variables that significantly differed (*p* values are shown) between areas where White-headed Ducks were present (black dots) and absent (white dots) during winter, spring, and summer 2003-2004. EC, electrical conductivity; Chir WW, chironomid wet weight; SDI, shoreline development index; Mac cover, macrophyte cover; Pot seeds, Potamogeton seeds; Chl *a*: chlorophyll *a* concentration. Some upper limits of SE are shown in parenthesis above the bars.

of SDI (4-8) and low surface areas (5-60 ha). Considering those ponds that usually support White-headed Ducks (Poniente, Sur de Poniente, Levante, and Reserva), Sur de Poniente and Reserva had SDI values greater than those of the 2 largest reservoirs.

Feeding ecology and diet are also major factors shaping waterbird habitat requirements for reproduction and rearing young (Green 2000, Krapu and Reinecke 1992 in Green and Selva 2000, Gardarsson and Einarsson 2002). In particular, the availability of protein-rich food (chironomid larvae, Amat and Sánchez 1982, Green et al. 1999, Sánchez et al. 2000) seems crucial. Accordingly, we found that during the breeding season, White-headed Ducks were more likely to use more eutrophic (higher Chl *a*) water bodies with higher chironomid biomass values.

Little is known about White-headed Duck habitat requirements in summer. Moreno-Ostos et al. (2008) found a significant positive relationship between the number of White-headed Ducks and the transparency of the water. Armengol et al. (2008) reported that some limnological variables (electric conductivity, Secchi depth, macrophytes, and seeds) affected the presence of White-headed Ducks during this season. We found that food availability was related to the duck's presence, as it was more likely to occur in wetlands with high seed densities in sediments. During summer, energy-rich food is required for chick growth (Gardarsson and Einarsson 2002). A good example of changing food needs involves Marbled Teals *Marmaronetta angustirostris*, which show marked seasonal fluctuations in the importance of different dietary components. Chironomids are important before and during the breeding season, while seeds are particularly important after the breeding season (Green 2000, Green and Sánchez 2003). Additionally, we found that White-headed Ducks were more often present in areas with higher electric conductivity. Typically, high electric conductivity (i.e., salinity) negatively affects all breeding ducks, because it causes high duckling mortality directly via dehydration or by reductions in the food supply (Green 2000). However, salinity levels in our study area were lower (ca. 15 mS/cm) than those known to cause duckling mortality (ca. 30-40 mS/cm, Green 2000). Within the salinity values found in the studied wetlands, this factor should not have been relevant, and other variables might be actual drivers of bird distribution.

Ducks were present where water depths were significantly higher during the dry season compared to the wet season, when birds seemed to be more affected by limnological characteristics. The reason for this pattern was that during the wet year, both very shallow and "deep" water bodies held water and ducks, so the mean depth of water bodies containing ducks was relatively low. During the dry period, most shallow water bodies (e.g., Poniente reservoir) had dried out, and only deeper basins held water and ducks. Therefore, the overall mean depth of the water bodies where ducks were present during the dry season was higher. By analyzing different Mediterranean wetlands, Armengol et al. (2008) also showed that under conditions of severe drought, White-headed Ducks preferentially occurred in relatively deeper water bodies during the breeding season. Ducks probably abandon places where the water level is too low, below 50 cm (FA, pers. observ.), because the shoreline, where littoral vegetation is used by ducks for building nests, remains dry and ducks cannot breed there.

Management implications

Although globally threatened species are expected to benefit from general wetland conservation programs (e.g., Ramsar), measures focused on specific taxa are essential to minimize future extinctions. Hunting (the White-headed Duck is an incredibly easy bird to shoot given its lack of an escape response when facing hunters; Green et al. 1996) and introductions (North American Ruddy Ducks *Oxyura jamaicensis* which pose the greatest long-term threat, and fish such as Carps are important threats to White-headed Duck populations. The effective use of hunting regulations and habitat protection has undoubtedly played an effective role in promoting duck reproduction in the study area. For example, professional hunters were in charge of locating and eliminating Ruddy Ducks from Spanish wetlands to avoid reproduction with White-headed Duck individuals. However, to succeed with such a program, all countries with records of Ruddy Ducks should endorse and implement the International Ruddy Duck Eradication Strategy of the Bern Convention, and produce official statements of intent regarding Ruddy Duck control.

Overuse/unsustainable use of water resources for irrigation and man-made modifications to many wetlands are critical threats to the species which are contributing to changes in its distribution (Li and Mundkur 2003). That is what occurred in our study area. Our study revealed an urgent need for habitat management in El Hondo Natural Park. This wetland ecosystem has a very important problem of water supply (high water demand for agricultural use, low rainfall, etc.) that has negatively affected White-headed Duck reproduction. During some years, the species could not breed because both reservoirs in El Hondo were completely dried out. Results presented in this paper reveal that short-term conservation measures are urgently required to maintain suitable water levels throughout the year and especially to avoid massive water extraction during the breeding season, a critical period for the species. We recommend a measure that could be taken in case of water scarcity during the breeding season: initial withdrawal of water from the largest reservoir (Poniente) because it has the lowest perimeter/area ratio (less optimal habitat features for breeding).

Water depth might be not a problem for White-headed Ducks outside of the breeding season. We observed individuals feeding at depths < 50 cm. Taft et al. (2002) considered that water depths of > 20-25 cm were suitable for diving ducks. Nevertheless, the scarcity of water could also influence the selection of wintering places, particularly in El Hondo, where the largest water bodies are shallow reservoirs that are artificially filled and which remain empty or partially flooded in dry years.

In conclusion, environmental factors affected the White-headed Duck distribution to varying degrees depending on the season. Our findings have important implications for waterbird and wetland conservation programs. In winter, birds required large areas of open water to be present. During the breeding season, their distribution was more affected by morphometric and limnological variables, as they required ponds with eutrophic waters and a high perimeter/area ratio. Thus, White-headed Ducks appear highly selective of breeding habitat.

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