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LIMNOLOGICAL VARIABLES RELEVANT TO THE PRESENCE OF THE ENDANGERED WHITE-HEADED DUCK IN SOUTHEASTERN SPANISH WETLANDS DURING A DRY PERIOD

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We have studied the distribution of the white-headed duck (*Oxyura leucocephala*), an endangered diving duck, living in wetlands in Alicante (southeast Spain). Coordinated with these observations, we made a limnological characterization of the water and sediment of several lakes within these wetlands, selecting those both with the presence and absence of the duck. Limnological variables analyzed included those related with the trophic status (water transparency, dissolved nutrients in the water, and chlorophyll *a* concentration), those related with the water mineralization, depth, macrophyte cover, and potential food items in the sediment (mostly chironomidae larvae and macrophyte seeds). The study was done during a dry period (spring and summer of 2005). In the examined period, a large reservoir (which was the preferred place by white-headed ducks in previous years) dried out in spring. Consequently, the population of white-headed ducks in the area was much lower and the birds distributed themselves among other water bodies in the surrounding wetlands. Using the limnological variables, we performed a Principal Component Analysis (PCA). The first, but especially the third factor, extracted from the analysis showed an ordination of the samples which separated the water bodies where the duck was present. Correlated with these factors, we have found variables regarding morphometry, trophic status, and food availability in the sediment of the lakes. Under these conditions of severe drought, white-headed ducks were distributed preferably in deeper lakes with more chironomid biomass, and also in lakes with a lower macrophyte cover and greater turbidity. Within the range of conditions available, the ducks did not show preferences for salinity and they were found from mesotrophic to hipertrophic waters.

Key words: White-headed duck, endangered species, habitat selection, dry period

INTRODUCTION

Waterbirds are animals which spend an important part of their life cycles in or depending on aquatic ecosystems. They can produce important effects on aquatic ecosystems (HURLBERT & CHANG 1983, RODRÍGUEZ-PÉREZ 2006, RODRÍGUEZ-PÉREZ & GREEN 2006) and can be very important components of the food web (MITCHELL & WASS 1996), particularly in shallow lakes or in the littoral area of deeper lakes. Nevertheless, birds have been frequently overlooked in limnological studies (STEINMETZ *et al.* 2003). Some effort has been done trying to connect the study of waterbirds with limnological processes in recent years (e.g. KEREKES & POLLARD 1994), but this field is still in its infancy.

The white-headed duck (*Oxyura leucocephala*) is a diving duck which gets most of its food, mainly macrophyte seeds and chironomid larvae (SÁNCHEZ *et al.* 2000), from sediment. Although the presence of this duck is probably related to the characteristics of the water and the sediment, information on the habitat preferences of this bird is very limited (TORRES 2003).

The white-headed duck shows a Palaearctic distribution whose population has suffered an important regression throughout its distribution area. Mid-winter counts indicate that the population has undergone a very rapid decline of over 50% in the last 10 years. Nowadays, this species is classified as globally endangered (BIRDLIFE INTERNATIONAL 2006, MADROÑO *et al*. 2005). Nevertheless, in south-eastern Spanish wetlands, particularly in El Hondo Natural Park, a population increase has been observed during the last years (TORRES & ALCALÁ 1997, GREEN 1999, TORRES 2003). In 2000, El Hondo held nearly 70% of the Spanish population. Within this wetland, white-headed ducks preferably occupied the two shallow reservoirs included in that natural park. Since these reservoirs are managed for the irrigation of adjacent fields, strong fluctuations of the water level have caused large fluctuations of the population of ducks in recent years (BARBA *et al*. 2005). Moreover, El Hondo is heavily polluted, with severe anthropic alterations (VIÑALS *et al*. 2001). In the last few years, general limnological studies (RODRIGO *et al*. 2001, RODRIGO *et al*. 2002), studies dealing with aquatic invertebrates (ARMENGOL-DÍAZ *et al.* 2002, FUENTES *et al.* 2005, GREEN *et al.* 2005), and studies focussing on endangered duck species (GREEN & SÁNCHEZ 2003, BARBA *et al*. 2004, 2005) have been conducted in this natural park.

During spring and summer 2005, one of the two large reservoirs used predominantly by the white-headed duck in previous years dried out, while the other had been dry since late 2004 (BARBA *et al*. 2004, 2005). As a consequence, part of the duck population moved to some other ponds within the park and the surrounding wetlands, while others disappeared from the area. Our aim in this paper was relating the presence or absence of white-headed ducks to the limnological features of several water bodies in the study area in order to find out which factors were more relevant for the habitat selection of this species during a period of extreme drought.

MATERIALS AND METHODS

Study site

The study was conducted in southeastern Spain, one of the warmest and driest areas on the Iberian Peninsula, with a mean annual temperature of 18–19 ºC and a mean annual rainfall of 200 mm (PÉREZ 1994). In this area, near the coast, there were several wetlands which are remains of old coastal lagoons in the floodplains of the rivers Segura and Vinalopó (Fig. 1). These wetlands suffer important environmental problems, of which the most prominent is the scarcity of water in summer along with a low quality of the water (eutrophy, salinity and pollution). In spite of that, these wetlands are considered as important areas for wintering and breeding of many waterbirds. Most of these waterbodies are included in international conventions (e.g. Ramsar), and have been legally protected during the last years as natural parks or local nature places. At the same time, these areas also showed an increasing anthropic pressure, since they are placed within important tourist areas. Land occupation for urbanization, industry, and also the need of water for human use and agriculture has enhanced the problems of conservation of these areas.

We have studied lakes located in three wetlands: "El Hondo" Natural Park (hereafter "El Hondo"), "Salinas de Santa Pola" Natural Park (hereafter "Santa Pola") and "Clot de Galvany" Local Natural Place (hereafter "Clot de Galvany"). El Hondo is a complex wetland having two large reservoirs and several smaller ponds connected by channels and surrounded by emergent vegetation dominated by sedges. Reservoirs are filled, when water is available, through a channel coming from Segura River mouth, about 8 km in a straight line. In 2005 only one reservoir had water at the beginning of the study, and this dried out in summer. Santa Pola is formed by several interconnected ponds and marshes which were antique saltpans; in part of the wetland there is still commercial exploitation of the saltpans. Although it is a protected area, the ponds are also used for aquaculture and regulated hunting. Clot de Galvany is a small wetland surrounded by tourist buildings; there are few temporary ponds and a permanent one which receives water from a sewage treatment plant that lacks tertiary

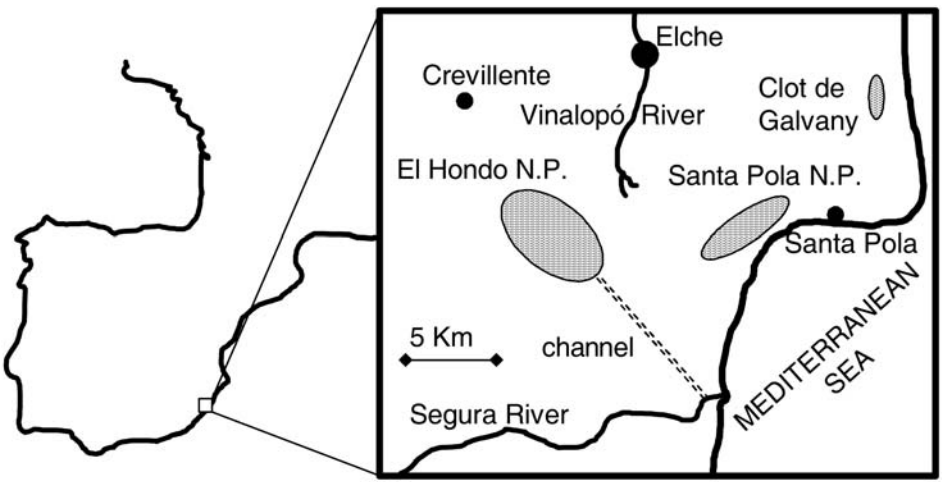

Fig. 1. Map showing the study site in Spain and the relative location of the three wetlands within the study area

treatment of water, so this water enters with a high nutrient concentration. When the reservoirs are full of water, white-headed ducks are usually concentrated there, although some groups of ducks can be observed in the other ponds of these three areas.

Within these three wetlands, we focused on nine waterbodies, many of them known to have held white-headed ducks in previous years (JLE, unpublished data): five from El Hondo: "Embalse de Levante" (EL), "Charca Sur de Poniente" (W), "Charca Norte" (N), "Reserva" (R) and "Saladar" (SA); two ponds from Santa Pola: "Santa Fe" (SF) and "Charcol" (CH); and other two from Clot de Galvany: "Galvany Norte" (GN) and "Galvany Contacto" (GC). All of them were very shallow and showed marked differences in several limnological variables such as salinity, macrophytes, chlorophyll *a* and dissolved nutrients.

Abundance and distribution of white-headed ducks

Censuses of white-headed ducks were carried out fortnightly between March and September 2005. Counts were done early in the morning, when the bird activity was low and birds remained in flocks (BARBA *et al.* 2005). Windy or rainy days were avoided. We used a telescope (Leica 20×60) to systematically scan the water surface of all the studied waterbodies. For that, we used elevated platforms, bird watching observatories, or land elevations to achieve good visibility. Apart from counting them, we noted the placement of each bird on 1:1000 maps of the waterbodies where a grid (200×200 m) was superimposed and reference points marked. These maps where the presence and abundance of the birds at each 200×200 m square were noted were elaborated previously (early the same day or the day before) to the limnological sampling.

Limnology (water and sediment)

Samples for limnological characterization were taken once a month. We selected at least two sampling sites at five waterbodies (EL, R, W, N, SF) and one sampling site for the rest of ponds (CH, GN, SA, GC). Sampling points were selected in open areas in the middle of the smaller lakes. When more than one point was selected in a pond, we tried to represent the environmental variability selecting sites both in the middle of the lakes and closer to the littoral. Sampling sites remained fixed (moving 1–3 meters around to avoid sediment disturbance in consecutive samplings) during the study; we noted the coordinates with a GPS. In waterbodies where more than one sampling site was selected, we tried to represent sites where birds were present in the previous census.

At each sampling point, we took water samples at 0.3 m depth for chemical and pigment analyses. Conductivity and water temperature (VWR EC300), pH (VWR pH 100), dissolved oxygen (WTW 330i), depth, Secchi disc depth, and percentage of macrophyte cover were measured *in situ*. We have estimated by eye the percentage of the macrophyte cover in a circle 3 m in diameter around the sampling site. Due to the shallowness of lakes, the bottom could be seen from the surface and usually Secchi disc depth could not be measured. To tackle this problem, we used an index of the transparency (Secchi depth%). This index was the percentage of Secchi disc depth with respect to pond depth.

$$\text{Secchi depth} = \frac{\text{Secchi depth}}{\text{Pond depth}} \times 100$$

Thus, if Secchi depth is equal to the depth (which means that the bottom could be observed from the surface), the value of the index is 100%, lower values of percentage mean lower transparency and difficulties for light to reach the bottom.

Among the chemical parameters, ammonia (Aquamerck Ref. 1.14567.0001) and alkalinity (Aquamerck Ref. 1.18764.0001) were measured by colorimetry and volumetry, respectively. Chlorophyll *a* was determined spectrophotometrically in a 90% acetone extract after filtration of the sample through a Whatman GF/F glass fibre filter. Pigment concentration was calculated according to JEFFREY and HUMPHREY (1975). Dissolved nitrate (Spectroquant Ref. 1.14942.0001), nitrite (Spectroquant Ref. 1.14776.0001) and phosphate (Spectroquant Ref. 1.14848.0001) were measured from GF/F glass fibre filtered samples by colorometry (APHA 1980). For these measures we used a Hitachi U2001 Spectrophotometer.

Sediment samples were taken with a metacrilate corer of 6.4 cm diameter to a depth of 10–12 cm. Samples were kept in a refrigerator and obscurity after collection, and the next day were sieved through 1 mm and 0.25 mm, in a column. From these samples, seeds of *Ruppia* and *Potamogeton*, the most abundant seeds found in the sediment, were counted. We have also counted each chironomid larvae longer than 4 mm, collected from both sieves. These samples were stored in 70% ethanol for later counting. Chironomid biomass in each sample was estimated from linear measurements of the individuals. The relationship between length and biomass was estimated for 309 individuals of different length (range 0.4 to 1.8 cm) where length and weight was measured.

Statistical analyses

All the limnological variables were log (x + 1) transformed except Secchi disk and macrophyte cover percentages which were square-root arcsine transformed (ZAR 1999); pH is a logarithmic value so it was not transformed. We performed a Principal Component Analysis (PCA) including all the limnological variables to explore which set of variables were more correlated with the presence of ducks. PCA is a statistical procedure widely used in ecological studies (PARINET *et al*. 2004, VAUGHAN & ORMEROD 2005). One of its main advantages is that it can reduce the information given by a set of variables to a smaller group of variables (factors) which explains most of the total variance. Therefore, the presence/absence of ducks could be related to high or low values of factors which include several limnological variables.

To prospect significant differences between variables with the presence and absence of ducks, we have compared series of data taken in places with and without white-headed ducks by using independent t-tests for samples of different size. For all these analyses we have used the statistical package SPSS 12.0.

RESULTS

Number and distribution of white-headed ducks among waterbodies

EL was flooded at the beginning of the study period and most of the white-headed ducks present in the studied wetlands were concentrated in this reservoir (e.g. 91% in early April; Fig. 2). However, this reservoir dried out very quickly during spring due to water extraction for irrigation; it was virtually dry by late April, and most of the ducks moved away. About half of the initial population remained in the study area, occupying different waterbodies (including part of EL where some water entered by the end of May) during the next few weeks, while the rest of the individuals were not detected within the study area. An increase of the population was detected by early July, more or less reaching the initial levels, but most of it was concentrated in Santa Fe. This increase was not related to relevant changes in the water levels of the studied waterbodies, and EL remained completely dry. It is remarkable that some waterbodies, both in El Hondo (N, SA) and in Santa Pola, (CH) remained unoccupied throughout the study period. Therefore, in absence of the preferred site (EL, where ducks concentrate if available), white-headed ducks distributed selectively among other available sites with different intensities, even avoiding some waterbodies closer to the preferred site. Many of them abandoned the general area altogether when the preferred site dried out.

Limnological characteristics of the waterbodies

Table 1 shows a summary of the limnological characteristics of the studied waterbodies. All of them were very shallow, but with differences between sites. The shallowest was CH, with an average depth of 20.6 cm, and the deepest was SF at 48.2 cm. Water transparency was relatively low. Despite the shallowness, light did not reach the sediment in some of the lakes. The lowest values for this variable were found in SF and GN, while the light always reached the bottom in N.

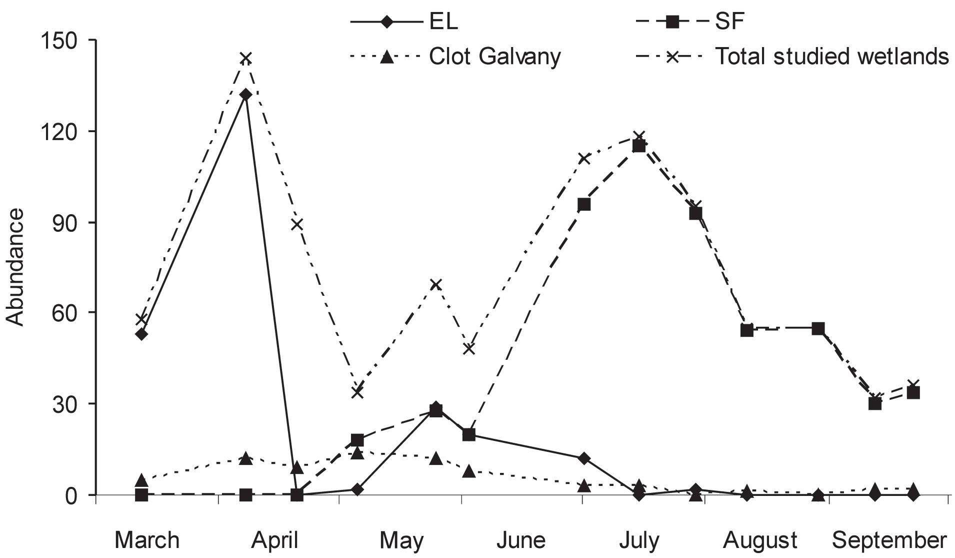

Fig. 2. Changes in the population of white-headed ducks during spring and summer 2005 at the most relevant sites from the three studied wetlands, as well as the total population of the study area

Table 1. Averaged values and variation coefficient (CV) of some selected limnological variables in each of the studied waterbodies. Abbreviations: Transp = transparency, Macroph = macrophyte, Chlor = Chlorophyll *a*

		Salinity g/l	Depth (cm)	Area (ha)	Transp (% Secchi)	Macroph % cover	Chlor mg/l	PO_4 mg/l	NO_3 mg/l
EL	Average	6.7	47.0	245.7	82.2	0.4	5.48	0.19	0.24
	CV	28.8	36.1		5.5	47.1	58.81	79.97	54.94
R	Average	9.6	49.7	66.2	87.4	6.5	28.50	0.05	0.36
	CV	29.9	24.3		18.5	89.2	59.64	7.92	49.98
W	Average	8.5	44.6	13.5	95.7	39.6	19.25	0.04	0.33
	CV	11.9	53.8		6.0	79.1	28.79	8.72	32.54
N	Average	9.5	42.4	6.7	100.0	21.1	6.26	0.05	0.68
	CV	22.6	29.6		0.0	88.3	36.08	8.73	84.48
SA	Average	7.1	45.9	6.0	82.4	27.9	7.79	0.04	0.27
	CV	13.0	13.0		30.6	84.1	131.56	22.62	88.11
SF	Average	14.7	48.2	24.4	48.7	4.5	182.58	0.05	0.25
	CV	31.1	6.2		24.5	108.1	40.37	26.69	19.82
CH	Average	14.4	20.6	20.3	91.8	60.0	199.27	0.06	0.26
	CV	31.2	35.0		20.3	79.6	70.06	22.06	21.88
GN	Average	19.2	46.2	0.6	77.6	0.0	52.62	0.08	0.21
	CV	39.7	34.7		26.6		93.60	17.39	9.94
GC	Average	1.2	31.3	1.0	100.0	6.0	296.77	2.42	0.25
	CV	19.5	33.7		0.0	250.2	132.59	47.46	22.50

Average values of salinity ranged from subsaline (GC presented 1.2 g/l) to hiposaline waters. As usual in these warm and dry conditions, all water bodies probably showed strong evaporation with an increase in salinity during summer. Some ponds (CH, SF, and GN), reached the highest values in the range of mesosaline waters (> 20 g/l; HAMMER *et al.* 1983) by the end of the summer.

We found notorious differences in macrophyte cover among the different ponds and also among stations in the same pond; CH, W, SA, and N presented the highest cover. Dominant macrophytes were *Ruppia maritima* and *Potamogeton pectinatus*, which appeared together in most of the systems. *Chara* sp. also reached dense populations in some areas of R and W. We have not quantified the proportion of both macrophytes (*Ruppia* and *Potamogeton*) independently in the field, but *Ruppia* seeds were usually much more abundant in the sediment of the lakes.

Mean chlorophyll *a* values indicated that three water bodies (EL, N, and SA) were mesotrophic, one (W) was eutrophic, and five (R, SF, CH, GC, and GN) were hypertrophic (following VOLLENWEIDER & KEREKES 1980). The high phosphate and chlorophyll *a* concentration found in GC is remarkable, but the water level of this pond was maintained by the effluent from a sewage treatment plant, with only physical and chemical treatments.

Multivariate analysis

A PCA was performed with all the samples (a total of 87 from 9 waterbodies) and with 17 limnological variables, including those from water and sediment. We selected the first three principal components extracted; the percentage of variance explained by them was respectively 26.2, 13.9, and 13.0. Correlation coefficients between these three factors and the different limnological variables analyzed are shown in Table 2. The first factor extracted (F1) showed greater positive correlation with total dissolved nitrogen, ammonia, dissolved phosphate, alkalinity, and nitrite concentration; and high negative correlations with conductivity, *Ruppia* seed density, pH, and dissolved oxygen. Among positive correlations with the second factor (F2), we would like to mention *Potamogeton* seed density, alkalinity, and nitrate, while stronger negative correlations were obtained with chlorophyll *a*,

Table 2. Pearson correlation coefficients between the limnological variables and the first three factors extracted from the PCA. In bold, correlation coefficients > 0.3

	CP1	CP2	CP3
Variance explained (%)	**26.23**	**13.91**	**13.04**
Ruppia seeds	**–0.514**	0.201	–0.278
Potamogeton seeds	–0.010	**0.568**	0.028
Chironomids larvae	0.206	–0.232	**–0.464**
Conductivity	**–0.833**	0.260	–0.202
Temperature	–0.182	0.018	0.264
pH	**–0.452**	**–0.588**	**0.395**
Dissolved oxygen	**–0.428**	0.040	**0.563**
Depth	0.028	0.289	**–0.549**
% Secchi	**0.348**	**0.304**	**0.568**
Macrophytes	–0.265	0.085	**0.672**
Chlorophyll-a	–0.217	**–0.684**	0.054
Alkalinity	**0.568**	**0.508**	–0.141
Dissolved nitrite	**0.430**	0.266	**0.373**
Dissolved nitrate	0.232	**0.486**	0.282
Dissolved ammonia	**0.885**	–0.299	–0.060
Total dissolved N	**0.923**	0.009	0.130
Dissolved phosphate	**0.776**	**–0.477**	0.059

pH, and dissolved phosphate. The third factor (F3) appeared positively correlated with macrophyte cover, water transparency, and dissolved oxygen; and negatively with depth and chironomid biomass.

As we were interested in the limnological characteristics of the sites where white-headed ducks were present or absent, we identified each sample as having or not having ducks at the time of sampling (i.e. the date of sampling or the day before). Figure 3 represents the distribution of the samples in the plane determined by F1 and F3, which produced the best segregation of samples with and without ducks. Factor 1 arranged the samples with higher conductivity in the negative part of this axis while samples with greater nutrient content were situated in the positive part; samples with white-headed duck were distributed all along this axis. A group of samples where white-headed ducks were present appeared grouped in the positive part of this axis; they corresponded to GC, which was the pond with less conductivity and highest concentrations of phosphate and ammonia. Factor 3 ordinated samples without ducks mostly in the positive part, in waters with more macrophytes and transparency, and samples with ducks in the negative part correlated with higher chironomid larvae biomass and depth. Thus, ducks were present in

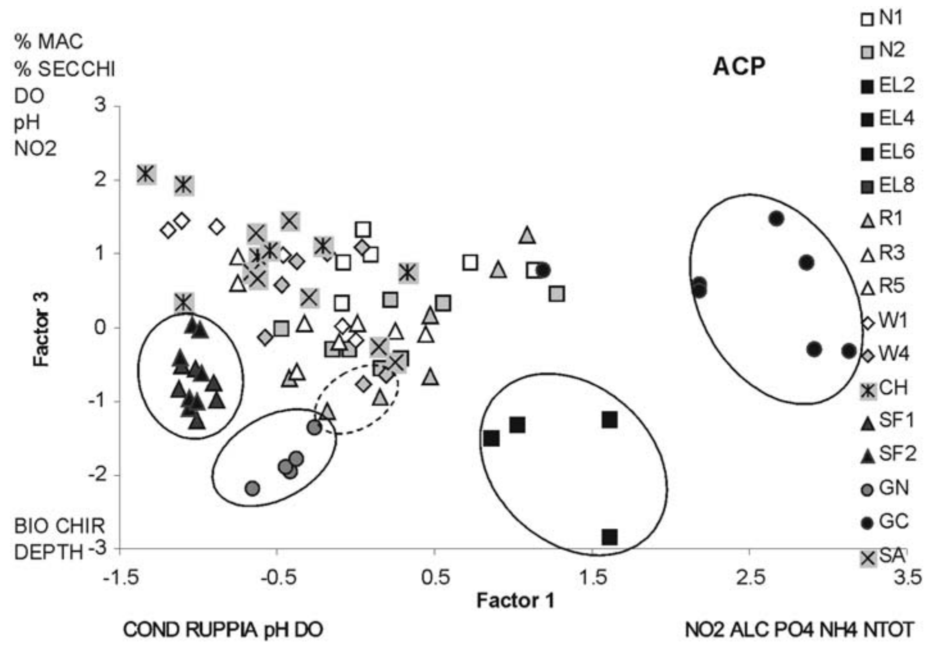

Fig. 3. Relative position of the samples in a plane determined by first and third factors extracted by PCA. Groups of samples where the white-headed ducks were present are indicated with circles. Dashed line circle indicates sampling sites where white-headed ducks were only present occasionally. Abbreviations as in Table 1

Table 3. Comparison of average values ± SE for some limnological variables measured in sampling sites with or without white-headed ducks. Probability values using independent t-tests are indicated, in bold those with P<0.05.

	NO ducks	ducks PRESENT	P(t-test)
pH	8.34 ± 0.07	8.25 ± 0.15	0.7
Nitrite (mg/l)	0.159 ± 0.029	0.122 ± 0.056	0.54
Nitrate (mg/l)	1.65 ± 0.17	1.2 ± 0.1	0.16
Ammonium (mg/l)	0.7 ± 0.2	2.4 ± 0.9	**0.007**
Total Dissolved N (mg/l)	2.94 ± 0.28	4.09 ± 0.92	0.11
Dissolved phosphate (mg/l)	0.106 ± 0.033	0.745 ± 0.293	**0.0003**
Alkalinity	1.48 ± 0.06	1.62 ± 0.13	0.33
Water Temperature (ºC)	26. 0 ± 0.5	23.4 ± 1.0	**0.017**
Conductivity (mS/cm)	17.4 ± 0.9	15.9 ± 2.3	0.48

deeper waters with higher chironomid biomass and they were absent in transparent waters with a greater macrophyte cover, and also in waters with a higher pH, nitrate and nitrite concentrations, and dissolved oxygen.

Characteristics of sites with and without white-headed ducks

As indicated in the methods, we located and counted the ducks on the same day or the day before the limnological sampling, therefore the obtained results ac-

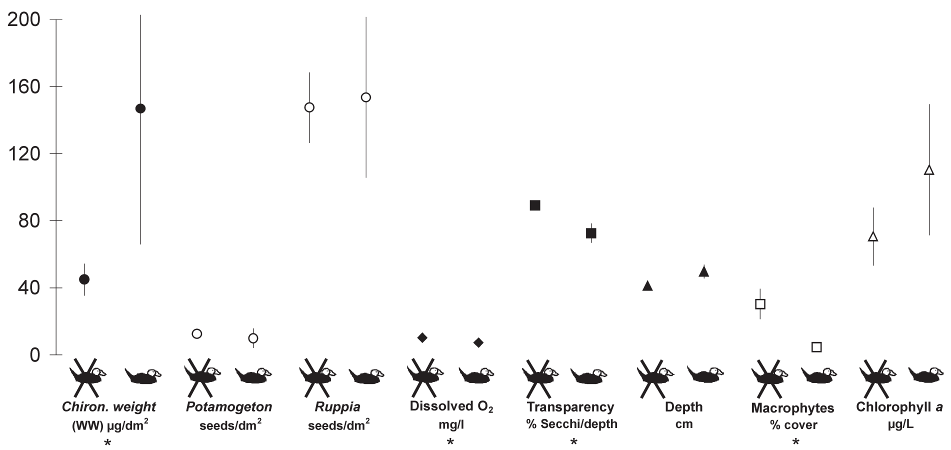

Fig. 4. Comparison of average values for some limnological variables measured in sampling sites with or without white-headed ducks. Vertical bars shows ± 1 SE. * indicates significant differences (p< 0.05) between both sets of values using independent t-tests for samples of different size

curately represent conditions experienced by the ducks. For a set of limnological variables that we considered relevant (in part as a result of the PCA above), we estimated the mean values for sampling sites where ducks were present and for those where ducks were absent (Fig. 4). We found significant differences ($p \leq 0.05$), as some variables strongly correlated with the above mentioned F3. Samples with lower values of macrophyte cover or chironomid biomass but lower transparency and dissolved oxygen were correlated with the presence of ducks. Birds also tended to select deeper sites ($p = 0.08$). Table 3 shows the same analyses for some other variables, but significant differences appeared only for temperature, phosphate, and ammonia.

DISCUSSION

Waterbodies in south-eastern Spain suffer different types of perturbations, most of them due to human pressure (VIÑALS *et al*. 2001). As a result of these, and because of their natural variability, we found a group of waterbodies with a wide array of environmental conditions. Moreover, during periods of drought, we found low water levels or even alternating periods with and without water. These conditions usually result in sediment compacting and produce an increase of nutrient release from the sediment (DE GROOT & GOLTERMAN 1994). The high evaporation in spring and summer along with the lack of water supplies caused a decrease of water level in the lakes, which was coupled with an increase of salinity. Thus, we have found great differences and notorious temporal changes in salinity in the studied waterbodies.

The lakes showed, in general terms, eutrophic conditions, in part due to the low quality of water inputs, which mainly came from agricultural runoffs, from waters used in aquaculture ponds, or even from a waste water treatment plant (BARBA *et al.* 2005). Water input to the reservoirs arrived sporadically through a channel from the Segura River after the spring rains, and used to have very high nutrient concentrations (BARBA *et al.* 2005) probably due to surface runoff in the lower river basin. Also, the high concentrations of waterfowl which are found in these waterbodies can contribute to an increment of eutrophication (e. g. GERE & ANDRIKOVICS 1994). It might sometimes prove to be difficult to classify a lake into a trophic category. There are some indicators for this purpose (VOLLENWEIDER & KEREKES 1980), but in very shallow lakes with a high nutrient concentration, the role of macrophytes has been undervalued. We have chosen mean chlorophyll *a* as an indicator of the trophic category (VOLLENWEIDER & KEREKES 1980), but some of the lakes that appear as mesotrophic or eutrophic following this criterion could be assigned to a higher trophic level, because this criterion (and other criteria commonly used to assign the trophic status) makes it difficult to consider the role of macrophytic vegetation. When it grows, this vegetation incorporates a large proportion of dissolved nutrients from the water and could out-compete phytoplankton (responsible for chlorophyll *a* concentration in the water), especially in waters so shallow that light can easily reach the bottom (SCHEFFER *et al*. 1993, SCHEFFER 2004) even under high turbidity. In fact, macrophytes have been used in the restoration of eutrophic waters (e. g. STRAND & WEISNER 2001, RUGGIERO *et al.* 2003). Some of the studied lakes (N, CH, SA, W, and CH) developed dense macrophyte populations that kept waters clear with low nutrient and chlorophyll *a* concentrations, because the nutrients had been incorporated into the macrophytes.

The main patterns of variation that the PCA indicated (shown by the variables correlated with F1) are related to the differences in salinity and nutrients. This factor separated a group of samples, correlated with high nutrient concentration and low conductivity, which was segregated with positive values of F1; these samples correspond with GC, which receives sewage treated waters with a high nutrient concentration and low salinity. Samples with white-headed duck were distributed all along this horizontal axis; which means that they were found in all trophic conditions available at our studied lakes (i.e. from mesotrophic to hypertrophic). These results are in concordance with those of other authors (MARTÍNEZ *et al.*1989, MARTÍNEZ & CASTRO 1990) who have found this duck in a wide array of trophic conditions. We can also add that, in our study, white-headed ducks did not show preference for conditions that showed particular salinity.

A second source of variation (F2) was also related to the trophic gradient; in this case F2 was strongly correlated with chlorophyll *a*, pH, and dissolved phosphate. Trophic status is a common source of variation in limnology. RODRIGO *et al.* (2003), in an intensive study of 32 shallow waterbodies sampled on the same day (excluding the impacts of seasonal variation), found a strong correlation of the main factors extracted through PCA with indicators of trophic status.

The third factor appeared to be correlated with some other variables which could be related to trophic status (as dissolved oxygen, % Secchi disc depth) and also with macrophytes (which, as mentioned above, could also indicate a higher trophic status). This factor was also correlated with depth and chironomid biomass. Thus, it separated samples from deeper sites and with more chironomids, aspects that we believe favour the foraging behaviour of the white-headed ducks.

It is remarkable that, in our analysis, the correlation coefficient of the three factors with temperature was very low. Although temperature is, of course, one of the main factors associated with seasonal variation in temperate lakes, and this is usually the main variation source in many studies (e. g. ARMENGOL *et al.* 1998, GROVER & CHRZANOWSKI 2006), two reasons explain our results. First, our study was done between April and September; thus, we missed a great part of the annual variation in temperature. Second, there was a large variation in temperature during the day (for instance, in lakes from El Hondo as N, W, or R, we have found daily variations to be around 6 ºC, BARBA *et al*. 2004); as the sampling time changed for the different lakes and sampling sessions, daily variations in temperature can hide the seasonal variation.

When we represented the first and third factors, the samples from water-bodies where the duck was present appeared in groups at the lower section of the graph, with the exception of those from GC, which had some specific characteristics and will be discussed separately below. Most samples with ducks were associated with negative F3 values, which were correlated with depth and benthic chironomid larvae biomass. This is the most important food source of the white-headed duck in Spain (SÁNCHEZ *et al.* 2000) and in other locations as well (e. g. GREEN *et al.* 1999). In the positive section of F3, we find the samples without white-headed ducks, which appeared correlated with transparent waters and with a greater macrophyte cover. However, some authors have found a positive relation between the presence of white-headed ducks and that of aquatic vegetation (TORRES 2003). Since white-headed ducks include macrophyte seeds in their diet (SÁNCHEZ *et al.* 2000), lakes with macrophytes are probably preferred. However, the plants themselves should be a problem for the diving birds to reach the sediment so, at a finer scale; ducks would be expected to avoid dense macrophyte beds. More studies are necessary to corroborate this. F3 did not segregate the samples from GC, a pond where some white-headed ducks were present along the study; the samples from this pond had intermediate values in F3 axis. This is explained by it being a very shallow pond with transparent waters and a high nitrite concentration (correlated with positive values of this axis), but it otherwise had no macrophytes and was the second in chironomid biomass (correlated with negative values).

Values obtained for the different variables comparing the places with and without white-headed ducks support the results obtained through PCA and allow us to infer the range of environmental conditions where this species can be found.

Habitat selection is one of the crucial steps in the life cycle of many animals. It is particularly important for species which have to migrate or change their habitat when environmental conditions deteriorate, since they have to make frequent decisions on where to stay. The white-headed duck is a species which inhabits shallow lakes in arid zones. In these areas, lakes are ephemeral ecosystems which often can dry out. Results obtained in this study show that this species is very plastic concerning the conditions of the water bodies which it can occupy, and this includes both the characteristics of the water column and of the sediment. This plasticity, along with the high mobility also observed, is something to be expected in a species living in more or less ephemeral habitats. However, even this species avoids some of the water bodies apparently available within the study area, indicating some degree of selectivity.

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