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INTERSPECIFIC ASSOCIATIONS IN HABITAT USE BETWEEN MARBLED TEAL AND OTHER WATERBIRDS WINTERING AT SIDI BOU GHABA, MOROCCO

Andy J. GREEN* [1] and Mustapha EL HAMZAOUI**

SUMMARY.—*Interspecific associations in habitat use between marbled teal and other waterbirds wintering at Sidi Bou Ghaba, Morocco.*
Aims: To study the spatial associations of non-breeding marbled teal *Marmaronetta angustirostris* with other wintering waterbirds. To assess the information such interspecific associations can provide about habitat requirements of globally threatened species.
Location: Sidi Bou Ghaba (34º 10' N, 06º 39' W), a closed-basin lagoon on the Atlantic coast of northwest Morocco.
Methods: Flock-scan sampling during eight days in February 1995, five in March 1995 and two in October 1997.
Results: In February and March, marbled teal showed a positive spatial association with gadwall *Anas strepera*, green-winged teal *A. crecca* and crested coot *Fulica cristata* and a negative association with mallard *A. platyrhynchos* and gulls. There was a very different pattern in October, when marbled teal had a positive association with mallard and a negative one with crested coot. In March, individual marbled teal positioned at different distances to the shoreline were significantly associated with different waterbird species along a continuum from crested coot (closest to shoreline) to greater flamingo *Phoenicopterus ruber* (farthest). Similarly, individuals in different behaviours were associated with different waterbird species, those swimming being most associated with flamingos and northern pintail *A. acuta*. This is because swimming teal tended to be in the most open areas frequented by these species.
Conclusions: The interspecific associations of marbled teal covary with the behaviour and microhabitat use of individual birds. Studying the spatial association between a threatened species and other birds can provide misleading information on the habitat requirements of the former if results are inconsistent over space and time. This illustrates the complexities of studying the habitat selection of waterbirds.
Key words: habitat selection, marbled teal, Morocco, spatial distribution, wintering waterfowl.

RESUMEN.—*Asociaciones ínter especificas en el uso de hábitat entre la cerceta pardilla y otras aves acuáticas invernando en Sidi Bou Ghaba, Marruecos.*
Objetivos: Estudiar las relaciones espaciales entre la cerceta pardilla *Marmaronetta angustirostris* y otras aves acuáticas fuera de la época de cría. Evaluar la información que las asociaciones ínter específicas pueden aportar sobre los requerimientos de hábitat de las especies mundialmente amenazadas.
Localidad: Sidi Bou Ghaba (34º 10 'N, 06º 39' W), una laguna endorreica en la costa atlántica del noroeste de Marruecos.

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Métodos: Escaneo de individuos en bandos durante ocho días en febrero 1995, cinco en marzo 1995 y dos en octubre 1997.
Resultados: En febrero y marzo, las cercetas pardillas demostraron una asociación espacial positiva con el ánade friso *Anas strepera*, la cerceta común *A. crecca* y la focha moruna *Fulica cristata* y una asociación negativa con el ánade azulón *A. platyrhynchos* y con gaviotas. En octubre había un patrón muy diferente, cuando la pardilla tuvo una asociación positiva con el ánade azulón y negativa con la focha moruna. En marzo, individuos de cerceta pardilla situadas a distintas distancias de la orilla estaban asociadas con distintas especies vecinos, las más próximas asociándose con la focha moruna y las más alejadas asociadas con el flamenco común *Phoenicopterus ruber*. Igualmente, individuos comportándose de maneras diferentes estaban asociadas con distintas especies de aves acuáticas, las nadando asociándose con flamencos y con el ánade rabudo *A. acuta*. Esto se debe a que las pardillas nadando solían estar en las zonas más abiertas utilizadas por estas especies.
Conclusiones: Las asociaciones ínter especificas de la cerceta pardilla covarían con el comportamiento y microhábitat de un individuo concreto. El estudio de las asociaciones espaciales entre una especie amenazada y otras aves puede proporcionar información engañosa sobre los requisitos de hábitat de la primera si los resultados son contradictorios a lo largo del espacio y tiempo. Esto ejemplifica las complejidades del estudio de la selección de hábitat por las aves acuáticas.

Palabras clave: aves acuáticas invernantes, cerceta pardilla, distribución espacial, Marruecos, selección de hábitat.

Introduction

In order to design effective conservation measures for globally threatened bird species, it is essential to understand their habitat requirements and other aspects of their ecology. Yet threatened species tend to be particularly rare, making it hard to collect good data on their ecology. For that reason, it is potentially useful to study how the habitat use of the threatened species overlaps in space with that of more widespread and/or abundant species whose ecology is better known. Such spatial associations may shed light on the ecological niche and habitat requirements of the threatened species.

Several recent studies (*e.g.* Green, 1998; Fuentes *et al.*, 2004) have addressed the ecology of the globally threatened marbled teal *Marmaronetta angustirostris* (IUCN Vulnerable, Birdlife International, 2001) during the breeding season. However, there is a lack of information on its habitat use outside the breeding period. The current study aims to determine what spatial relationships non-breeding marbled teal show with other waterbird species, and how these relationships vary with the habitat use and behaviour of an individual teal. We consider how this information helps us to understand the habitat requirements of marbled teal.

Material and methods

Data were collected at Sidi Bou Ghaba (34º 10' N, 06º 39 'W), a brackish, hypertrophic, endorreic lagoon 6 km long with an area of 100 ha amongst dunes on the Atlantic coast of northwest Morocco protected as a Ramsar Site and Biological Reserve of 702 ha dominated by juniper *Juniperus phoenicea* forest (Thévenot, 1976; Morgan, 1982; Hughes and Hughes, 1992; Green and El Hamzaoui, 2000). This site is extremely important for marbled teal in the nonbreeding season, when up to 1,680 birds have been recorded, but less than 10 pairs breed there (Green, 1993).

Water levels undergo major seasonal and annual variations and the lagoon is divided into two major sections (see Green and El Hamzaoui, 2000 for details): a deeper (maximum 2.5

m), permanent, brackish, central section subjected to considerable human disturbance (local visitors using the area as a picnic site) along the eastern shoreline and a shallow, temporary, brackish to saline southern section (maximum depth 0.7 m) protected as a strict reserve, with anthropogenic use limited to illegal cattle grazing. Emergent vegetation is restricted to a dense fringe along the shoreline. Spot conductivity measures were 14 mS cm^{-1} (19 February 1995, pH 8.67) and 13 mS cm^{-1} (19 October 1997, pH 9.04) in the central section and 46 mS cm^{-1} (13 March 1995) and 29 mS cm^{-1} (19 October 1997, pH 8.97) in the southern section.

Data were collected for the whole daylight period by instantaneous flock-scan sampling with a telescope (Altmann, 1974). Scans were conducted at half-hourly intervals, using up to two observers and changing position during the scan to cover all those areas in use by marbled teal at a given time. Data were collected from 12 - 21 February 1995 (on eight separate days), 12 - 21 March 1995 (on five days) and 17 - 18 October 1997, scheduling scans so as to give equal coverage to each hour of the day for each period.

For each individual marbled teal scanned, the following details were recorded: behavioural category (see below); distance to shoreline (considered to be the inner edge of the fringe of emergent vegetation, or the bank itself where there was no such fringe) estimated visually in metres; type of shoreline habitat; species to which the nearest waterbird (from hereon known as the nearest neighbour) belonged. There were a total of 2453 duck sampling events in October, 1851 in February and 1401 in March. The major behavioural categories were: Sleep (resting behaviour with head-on-back); Loaf (resting behaviour without head on back); Comfort (preen, bathe, etc.) and Swim. Feeding was rarely observed and mainly occurred at night (see Green and El Hamzaoui, 2000 for details).

The observed associations of marbled teal with other waterbird species were compared with those expected based on the composition of the waterbird community in each study period, as determined from censuses carried out on 12.2.95, 12-13.3.95 and 16.10.97. The percentage of nearest neighbours constituted by each species (excluding observations with conspecific neighbours) was compared with expected values calculated from the proportion of all other waterbirds represented by that species. For February and March, we compared observed and expected nearest neighbour frequencies for each species for each study day, with a two-tailed matched pairs Wilcoxon signed-ranks test. In order to avoid the risk of artefactual negative associations for rare species resulting from a small but non-zero expected value (*e.g.* if the expected value is 0.01, the observed value is always likely to be zero), only those species for which expected observations averaged more than one per day in both months were considered. We made an exception for gadwall *Anas strepera*, which had an expected value lower than one for February, but a much higher observed value. Similar statistical analyses were not carried out for October owing to the small number of study days.

The distribution of nearest neighbour species for teal in different behaviours were compared using χ^2 tests, based on the proportion of scans for which each neighbour species was associated with each teal behaviour. We compared the distance to shoreline D for teal with different species as nearest neighbours with analysis of variance, using mean values for each day and neighbour species. Data were ln (D+1) transformed to avoid correlations between group means and variances.

Flock-scan data such as ours have considerable problems of non-independence which are often underestimated. The behaviour and position of different individual teal at a given moment is partly dependent on that of conspecifics in the same flock. The position of birds at half hourly intervals is also inter-related. Thus we used conservative methods to analyse interspecific associations in relation to behaviour and habitat use, summing our observations into few data points. An additional problem in studies such as ours is that the proportion of time spent associated with different neighbour species or in different behaviours are interdependent (since they must sum to unity). Whilst recognising that compositional analysis provides a solution to this latter problem (Aebischer *et al.*, 1993), we were unable to use this method owing to the high proportion of zero values in our data.

Results

Associations with different waterbird species

In February and March 1995, marbled teal showed a positive spatial association with green-winged teal, gadwall and crested coot and a negative association with mallard and *Larus* gulls (Table 1). A different pattern was observed in October 1997, when marbled teal were positively associated with mallard and shoveller as well as green-winged teal, and negatively associated with coots (Table 1), although not enough days were studied to allow statistical analysis.

Nearest neighbours and habitat use

In March 1995, marbled teal associated with different neighbour species were positioned at significantly different distances to the shoreline (Fig. 1). Teal with crested coot as neighbours were closest to the shoreline, and those

Table 1

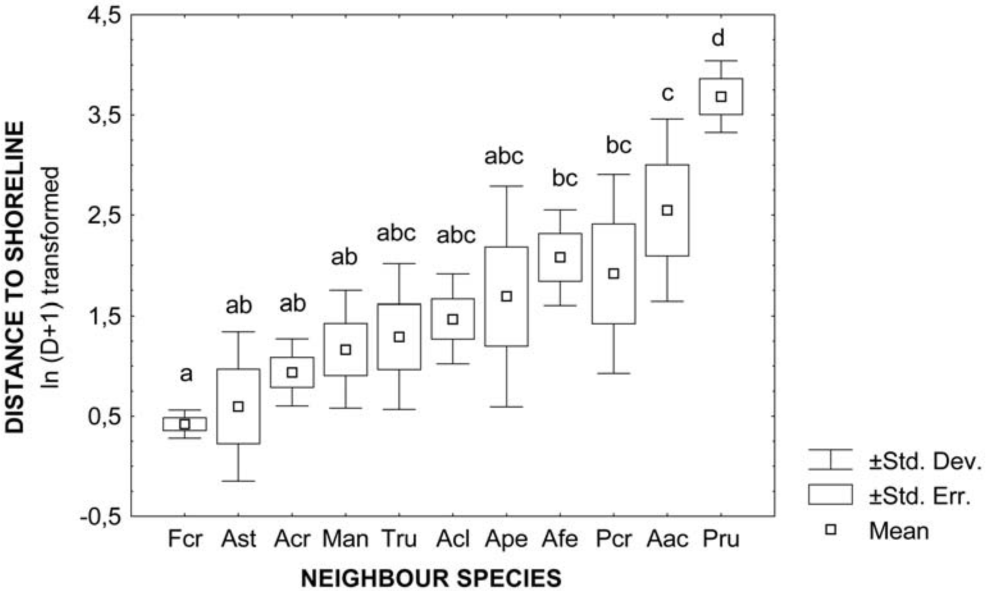
Comparison between observed (obs%) and expected (exp%) proportions of other waterbird species recorded as nearest neighbours to marbled teal at Sidi Bou Ghaba.
[Comparación entre proporciones observadas (obs%) y esperadas (exp%) de otras especies de aves acuáticas registradas como las más cercanas a las cercetas pardillas en Sidi Bou Ghaba.]

	February 1995		March 1995			October 1997	
Species	Obs%	Exp%	Obs%	Exp%	W	Obs%	Exp%
wigeon	1.3	2.2	5.1	3.9	+31	0	0
gadwall	2.6	0.5	1.7	1.0	+7*	1.5	0.1
gw teal	28.4	5.9	11.1	3.1	+0**	35.1	5.3
mallard	0.2	2.4	1.7	6.1	-0**	8.8	2.8
shoveller	43.3	67.9	45.9	37.1	-25	40.7	6.0
eu pochard	17.9	5.0	5.9	4.5	+10	0	1.6
cr coot	3.9	2.5	9.6	5.7	+10*	3.1	16.1
gulls	0.4	1.6	0.1	6.3	-0**	0	0

Species considered are, in descending order, *Anas penelope*, *A. strepera*, *A. crecca*, *A. platyrhynchos*, *A. clypeata*, *Aythya ferina*, *Fulica cristata* and large gulls (*Larus fuscus* and *L. cachinnans* combined). Exp% was calculated from the composition of the waterbird community. Associations for February and March combined were tested with two-tailed matched pairs Wilcoxon signed-ranks test, using paired obs and exp values for each study-day (n for test = 11). W is Wilcoxon statistic, + indicating positive association with marbled teal and - indicating negative association. * $P < 0.05$; ** $P = 0.004$. The total number of waterbirds recorded (in a wetland of 100 ha) were 3312 in February, 818 in March and 3736 in October.

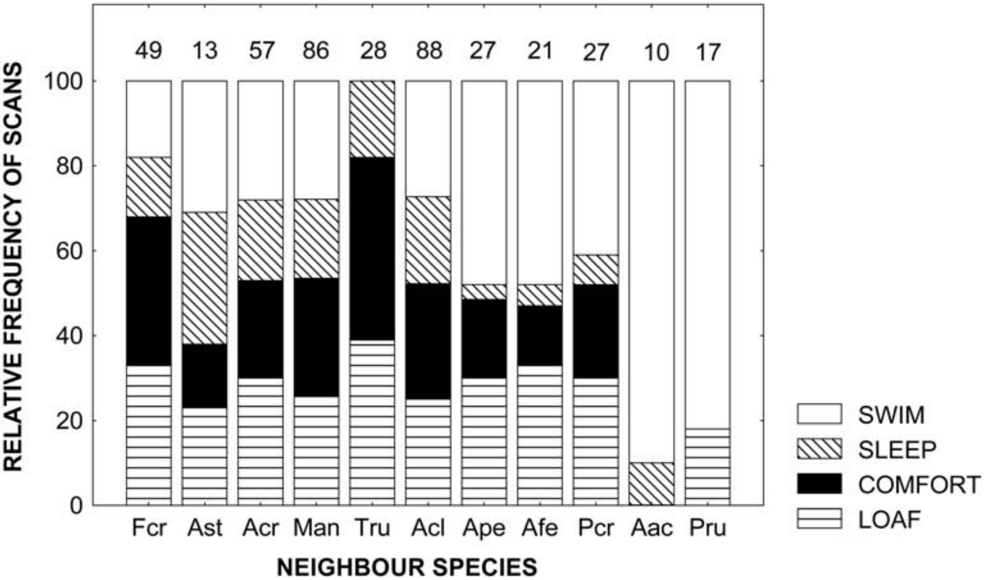
FIG. 1.—Distribution of distances to shoreline (D) recorded in March 1995 at Sidi Bou Ghaba in relation to the identity of the nearest neighbour. Data used are average distances for each study day (*n* = 4 or 5 for each neighbour species) transformed as $\log_e$ [D+1]. Species, in order of increasing means, are: crested coot (Fcr), gadwall (Ast), green-winged teal (Acr), marbled teal (Man), little grebe (Tru), shoveller (Acl), wigeon (Ape), great-crested grebe (Pcr), eurasian pochard (Afe), pintail (Aac), greater flamingo (Pru). Differences between neighbour species were highly significant (One way ANOVA $F_{10,39} = 8.1$, $P < 0.001$). Species not sharing letters above the bars were statistically significant from each other, based on Newman-Keuls post hoc tests.

*[Distribución de distancias a la orilla (D) registradas en marzo 1995 en Sidi Bou Ghaba, en relación con la identidad del vecino más próximo. Los datos presentados son las medias de las distancias para cada día del estudio (*n *= 4 o 5 para cada especie de vecino) transformadas como* $\log_e$ *[D+1]. Las especies, en orden creciente de medias, son: focha moruna (Fcr), ánade friso (Ast), cerceta común (Acr), cerceta pardilla (Man), zampullín chico (Tru), pato cuchara (Acl), ánade silbón (Ape), somormujo lavanco (Pcr), porrón común (Afe), ánade rabudo (Aac), flamenco rosa (Pru). Las diferencias entre especies de vecinos son altamente significativas (ANOVA de una vía,* $F_{10,39} = 8.1$, $P < 0.001$*). Especies que no comparten letras encima de las barras son significativamente diferentes, según las pruebas Newman-Keuls de post hoc.]*



with greater flamingo as neighbours were farthest. Similar patterns were observed in February (mean distance to shoreline for different neighbour species followed the order: crested coot < green-winged teal < marbled teal < gadwall < shoveller < eurasian pochard *Aythya ferina* < wigeon *Anas penelope*) but differences between species were not significant (one-way ANOVA, $F_{6,30} = 0.62$, $P > 0.05$). Data were not collected on enough days to enable a similar analysis for October, but the pattern observed was very different (mean distance to shoreline for different neighbour species followed the order: green-winged teal < mallard < gadwall < pintail < marbled teal < shoveller < little grebe < great-crested grebe < crested coot).

FIG. 2.—Associations of different marbled teal behaviours with different nearest neighbour species in March 1995. Shown are the relative proportions (percentages) of scans for each species in which each behaviour-neighbour combination was recorded. See Fig. 1 for key to species codes. A χ^2 test was carried out on the number of scans in which each behaviour-neighbour combination was recorded (total number of scans for each species shown above the bars). Differences between neighbour species were highly significant ($\chi^2_{21} = 55.74$, $P < 0.001$).
[Asociaciones de distintos comportamientos de la cerceta pardilla con las distintas especies de vecino más próximo en marzo 1995. Para cada especie, se presenta la proporción relativa (porcentaje) de escaneos en la que se registró cada comportamiento. Véase Fig. 1 para los códigos utilizados para cada especie. Se realizó una prueba χ^2 sobre el número de escaneos en el que se registró cada combinación de comportamiento y vecino (se cita el número total de escaneos para cada especie encima de las barras). Las diferencias entre especies de vecino fueron altamente significativas (χ^2_{21} = 55,74, P < 0,001).]



Nearest neighbours and behaviour

Associations with different neighbour species covaried with marbled teal behaviour. In March, neighbour associations varied significantly between the major behaviours (Fig. 2). Individuals swimming were more likely to be associated with those waterbird species found farther away from the shoreline (particularly the pintail and flamingo) than individuals sleeping or in comfort behaviour (compare Figs. 1 and 2). The pattern for individuals loafing was intermediate. Similar analyses of behaviour and neighbour associations for other months were not significant (October $\chi^2_8 = 8.75$, $P > 0.05$; February $\chi^2_{15} = 8.19$, $P > 0.05$).

Discussion

Although we recorded strong patterns in the spatial associations of marbled teal with other waterbird species in a given month, major differences were observed between February-March 1995 and October 1997. These differences were connected with the redistribution of birds and changes in the waterbird community at Sidi Bou Ghaba in different years. In 1995, water levels were lower and ducks and crested coots were concentrated together in the permanent, central lake area, but mallards were concentrated in *Juncus* shorelines used little by marbled teal, which used mainly cattail *Typha angustifolia* shorelines (Green and El Hamzaoui, 2000). In 1997, crested coot numbers were much higher and remained concentrated in the central lake feeding on unusually dense beds of sago pondweed *Potamogeton pectinatus*, whereas the ducks were concentrated together in the southern lake where different species (including marbled teal and mallards) roosted together on the open shores (especially sandy beaches). Hence marbled teal were positively associated with crested coot and negatively associated with mallard in 1995, and *vice versa* in 1997. Despite these differences over time, marbled teal consistently selected areas of habitat close to the shoreline and made much less use of open water than expected at random (Green and El Hamzaoui, 2000).

The positive and negative spatial associations recorded between marbled teal and other waterbird species reflected different degrees of horizontal niche overlap in habitat selection between species. Our observations provided no evidence to suggest that more direct interactions (e.g. kleptoparasitism or competitive exclusion) were responsible for these relationships. Similarly, our finding that marbled teal in different behaviours were associated with different waterbird species reflects the different spatial distribution of teal in different behaviours (*e.g.* swimming teal were farthest from the shore, Green and El Hamzaoui, 2000), combined with the different habitat use of other species. Independent data collected during our study suggested that the ranking of distance to shoreline for individual teal with distinct neighbour species (Fig. 1) closely reflects the real differences between waterbird species in their position on the shoreline-open water continuum (Green, 2000).

There is debate about the extent to which the position of different duck species along this shoreline - open water continuum is influenced by differences in bill morphology (and its relation to changes in the sizes of food items along this continuum) and whether it is consistent between different spatial scales (Nudds *et al.*, 1994; Pöysä *et al.*, 1996; Nudds *et al.*, 2000). In our diurnal study, the positions of different species along this spectrum did not closely reflect their foraging niches, since marbled teal and many other nonbreeding ducks are largely nocturnal foragers (McNeil *et al.*, 1992; Tamisier and Dehorter, 1999; Green and El Hamzaoui, 2000). We suggest that the spatial relationships between different species are influenced by too many parameters (*e.g.* wetland depth profiles, distribution of emergent and submerged vegetation and of predators) to be consistent between wetlands, or even within wetlands on a temporal scale. Wetlands such as Sidi Bou Ghaba occupied by marbled teal in the Mediterranean region tend to be subjected to major fluctuations in habitat conditions over time (Green, 2000).

We suggest that the changes over time recorded in waterbird spatial associations in this study illustrate the complexities in these patterns and their relationship with habitat use. Data on the associations between a threatened species and other birds may easily lead one to make erroneous conclusions about the habitat requirements of the former. This is illustrated by the significant positive association between marbled teal and the regionally threatened crested coot in 1995. This might lead one to assume that these species share similar habitat requirements. However, as indicated by a switch to a negative association in 1997 and by data collected over a broader scale from different Moroccan wetlands (Green, 2000; Green *et al.*, 2002), these two species have very different habitat needs.

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