Ardeola 57(1), 2010, 191-198

SEASONAL VARIATIONS IN HABITAT PREFERENCES OF THE PIN-TAILED SANDGROUSE IN AGRARIAN PSEUDO-STEPPES

VARIACIONES ESTACIONALES EN LAS PREFERENCIAS DE HÁBITAT DE LA GANGA IBÉRICA EN ESTEPAS AGRÍCOLAS

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SUMMARY.—We investigated habitat use and preferences of pin-tailed sandgrouse *Pterocles alchata* in agrarian pseudo-steppes of central Spain. We used radio-tracking to characterise habitat selection throughout the year and look for seasonal variations. Pin-tailed sandgrouses selected ploughed fields all year round, except in winter when they preferred stubble fields. Pasturelands were used more often than expected in the breeding and post-breeding seasons and fallows in winter and pre-breeding seasons. Cereal crops, olive groves and vineyards were avoided. Our results indicate that appropriate habitat management for the pin-tailed sandgrouse should take into consideration its habitat preferences during the full annual cycle.

RESUMEN.—Estudiamos el uso y las preferencias de hábitat de la ganga ibérica *Pterocles alchata* en el centro de España. Mediante radio-seguimiento caracterizamos el uso y selección de hábitat a lo largo de un ciclo anual, e investigamos las variaciones estacionales. Las gangas seleccionaron campos labrados durante todo el año, excepto en invierno, cuando prefirieren los rastrojos. Los pastos fueron seleccionados positivamente en la estación de cría y en la post-reproductiva, y los barbechos en la invernal y pre-reproductiva. Las siembras de cereal, olivares y viñedos fueron evitados. Un correcto manejo del hábitat de la ganga ibérica debería tener en cuenta sus preferencias de hábitat durante el ciclo anual completo.

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The pin-tailed sandgrouse *Pterocles alchata* is a medium-size steppe bird whose European population is concentrated mainly in the agricultural pseudo-steppes and pasturelands of the Iberian Peninsula (De Juana, 1997; BirdLife-International, 2004; Suárez *et al.*, 2006). This threatened species usually occurs in open, low intensity, non-irrigated agro-ecosystems where it feeds principally on the seeds it finds on the ground, and also, to a lesser extent, on green vegetation (De Juana, 1997; Suárez *et al.*, 1999b).

The habitat requirements of the pin-tailed sandgrouse have been studied using data from censuses (Martínez and De Juana, 1996; Suárez *et al.*, 1997a; Suárez *et al.*, 1999a and references therein; Campos, 2004; Martínez, 2005; Suárez *et al.*, 2006). Its abundance is linked to the agricultural mosaic formed by pseudo-steppes, where they use mostly ploughed fields, fallows and pasturelands during breeding, and first year fallows (stubbles) and recently sown cereal fields during the winter (Suárez *et al.*, 1999a and references therein). No study so far has evaluated habitat preferences throughout the year using radio-tracking, which ensure that observations are not biased due to changes in the detectability of the species in different substrates. In this study, we investigated habitat use and preferences of pin-tailed sandgrouse during an annual cycle and look for seasonal variations. We used radio-tracking to characterise habitat selection, and worked at a local scale, in an agricultural area typical of central Spain.

The study was conducted in the agricultural pseudo-steppes of Campo de Calatrava, within a Special Protection Area (SPA 157, ca. 38º 54' N, 3º 55' W, Ciudad Real province, 8,978 ha). The terrain is flat to slightly undulated, whit an elevation of 590 - 685 m a.s.l, and is primarily dedicated to dry cereal cultivation (mainly barley *Hordeum vulgare*, but also oats *Avena spp* and wheat *Triticum* spp.), whit minor fields of legumes (*Vicia* spp. and *Pisum sativum*), olive groves (*Olea europaea*) and vineyards (*Vitis vinifera*). Field size averages 3.26 ha (SD = 11.16 ha; N = 1,849). Most cereal are grown in a traditional rotation system that creates a landscape mosaic of sown, ploughed, stubble and fallow fields of different ages. Cereals are harvested between June and early July. Stubbles, fallows and small areas of short scrubland and pastureland are also used for extensive sheep grazing. The study area holds a population of ca. 200 breeding and ca. 1,000 wintering pin-tailed sandgrouse (author's unpublished data).

The pin-tailed sandgrouse is a *Pteroclidae* typical of steppes and extensive agricultural habitats that occurs in SE Europe, north of Africa, and the Middle East (De Juana, 1997). It is a highly gregarious species, in which flocking behaviour reaches a maximum during winter when groups of several hundred birds have been reported, while flocks are much smaller during the breeding season (De Borbón *et al.*, 1999; Martín *et al.*, 2010). The species is currently classified as a "Least Concern Species" at the world level (BirdLife-International, 2008) but holds an "Unfavourable Conservation Status" in Europe (BirdLife-International, 2004), and a "Vulnerable Status" in Spain (Suárez and Herranz, 2004).

Between 2007 and 2008 we caught 15 pin-tailed sandgrouses at night using large hand-held nets, spotlights and a thermal camera (Panatec, Spain). Sandgrouses were tagged with 11 g TW3 backpack-mounted radio transmitters (Biotrack, UK) and released at the capture site within 20 minutes after capture. The total weight of transmitter plus harness did not exceed the recommended limit of 3 - 5 % of the bird's weight (Kenward, 2001). Marked birds were subsequently located by radio-tracking, using Biotrack Sika telemetry receivers and a directional YAGI antenna. Birds were located weekly using visual observation or triangulation, until the transmitter battery was exhausted or until the bird died. For each tagged bird observation, we recorded (i) the geographical position (with a Garmin eTrex

Vista Cx GPS, nearest 3 - 4 m), (ii) the type of agrarian substrate (see table 1), and (iii) the number of individuals in the flock. We carried out radio-tracking surveys from dawn until dusk in order to include the whole day-time activity period of the species.

Since sandgrouses are highly gregarious and individual home ranges of radio tagged birds overlapped to a great extent, we pooled all fixes from the tagged birds and used those involving flocks observed on the ground to create a minimum convex polygon of 61.3 km^2. Habitats within this polygon and their proportions represented the habitat available to birds. The agrarian substrate types within this area (see table 1) were mapped using ArcMap 9.1 (ESRI 1999 - 2005) at different times during the life cycle of sandgrouse: (i) post-breeding (September-November 2007), (ii) winter (December 2007-February 2008), (iii) pre-breeding (March-May 2008) and (iv) breeding (June-August 2008). The area of each substrate was calculated using the ArcMap extension V-LATE.

For each season, we compared the distribution by habitats of the total number of birds observed in flocks containing radio-tagged individuals with the availability of the diffe-

TABLE 1

Main substrates in the study area and their relative surface.
[Cultivos principales en el área de estudio y su superficie relativa.]

Substrate	Code	Description	Proportion (%)
Crops			84.0
cereal	CE	crops of barley, oats or wheat	0 - 60
stubble	ST	recently harvested cereal or legume fields	0 - 60
fallow	FA	unploughed cereal fallows with one or more years and dense herbaceous coverage	5.2 - 10.6
plough	PL	ploughed fields, mostly without vegetation (< 20 % weed vegetation cover). When they had developed a significant herbaceous vegetation cover (> 20 %) they were classified as fallow land	9.7 – 29.2
legume	LE	crops of *Vicia* spp. or *Pisum sativum*	0 - 1.4
Pastureland	PA	fields of short scrubland and pastureland	7.2
Olive groves	OL	olive tree plantation	3.5
Vineyard	VI	vine plantation	3.1
Buildings	BL	urban areas, villages, country houses, wells, ruins	1.0
Others	OT	vegetation of rivers and streams, piles of stones, maize, fruit trees plantation	1.3

rent substrates using the chi-squared statistic. When the difference was significant ($P < 0.05$) we inferred that habitat use was selective (i.e. non-random) and constructed Bonferroni 95 % confidence intervals around the used sample proportion for each substrate (Neu *et al.*, 1974; Byers *et al.*, 1984). If the proportion of a given habitat fell either above or below the confidence intervals, then we inferred that the substrate was used in a lower or higher proportion than expected, respectively. In all tests it was necessary to combine some of the rare habitat categories because many low 'expected' values would have otherwise biased the resulting chi-square value: olive groves and vineyards were regrouped in the same land use category and legume crops (< 2 % in the study area) were included in the "other" land use category (see table 1).

We collected 419 sightings of radio-tagged sandgrouses (ca. 28 fixes per bird) that corresponded to 227 diurnal observations of sandgrouse flocks in which flock size was determined accurately in 194 of the cases. Average flock size was seasonally dependent, with mean flock sizes of 74, 98, 31 and 7 for the post-breeding, winter, pre-breeding and breeding seasons, respectively (ANOVA: $F_{3, 190} = 11.8$, $P < 0.0001$; table 2). Smaller flocks were observed in June and July when pairs were nesting and brood-rearing, compared with other seasons when birds aggregated in larger flocks, reaching maximum numbers in winter (maximum flock size of ca. 600 birds in December).

Habitat use of pin-tailed sandgrouse differed significantly from random in all seasons (post-breeding: $\chi^2_5 = 4{,}328.6$, $N = 4{,}960$, $P < 0.0001$; winter: $\chi^2_6 = 38{,}299.6$, $N = 5{,}567$, $P < 0.0001$; pre-breeding: $\chi^2_5 = 2{,}870.4$, $N = 1{,}069$, $P < 0.0001$; breeding: $\chi^2_5 = 757.4$, $N = 247$, $P < 0.0001$). Ploughed fields were consistently used and positively selected in all seasons except in winter (figure 1). They are likely to be an important source of seeds and green shoots, which form part of the diet of

TABLE 2

Number of radio-tracked pin-tailed sandgrouses and mean (± SE) number of locations per bird in each season. Associated number of flocks and accumulated number of sandgrouses are also shown.
[Número de gangas ibéricas marcadas con radio-tracking y número medio (± ES) de localizaciones por ave en cada estación. Se muestra el número de gangas ibéricas en bandos y acumulados.]

Season	N of radio-tracked birds	N of locations	N of flocks	N of birds
post-breeding (September-November)	10	14.3 ± 8.3	67	4960
winter (December-February)	14	11.4 ± 6.0	57	5567
pre-breeding (March-May)	10	5.3 ± 3.1	34	1069
breeding (June-August)	10	6.3 ± 4.6	36	247

sandgrouse throughout the year (De Juana, 1997; Suárez *et al.*, 1999b) and probably provide better camouflage and visibility for anti-predator vigilance. In contrast, cereal fields were used less often than expected, most probably because their tall and dense vegetation hinders adequate visibility around the birds (Barros *et al.*, 1996). Indeed, sandgrouse were observed in cereal fields when the height of crops was less than 25 cm, or when the cereal was recently sown or not even germinated (Guadalfajara and Tutor, 1987).

Stubble fields were intensively used in winter (figure 1) when sandgrouse form large flocks and usually associate with little bustards to feed on fallen grain and green shoots (Martín *et al.*, 2010). Other authors have also indicated that stubble fields are important

Habitat preferences of pin-tailed sandgrouse.
[Preferencias de hábitat de la ganga ibérica].

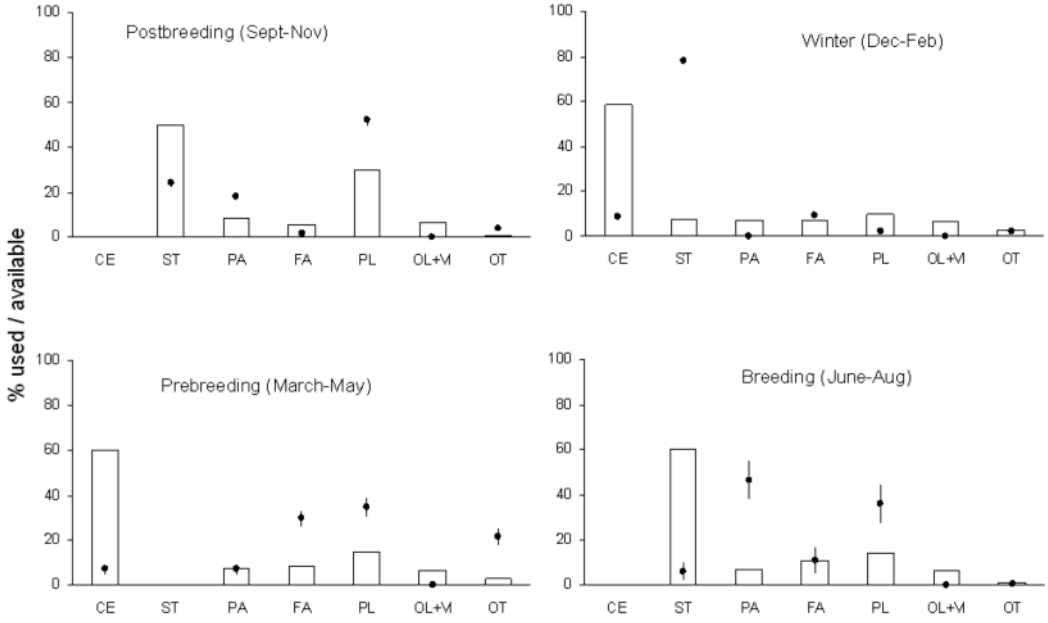

FIG. 1.—Proportion (± 95 % confidence limit) of habitat used by pin-tailed sandgrouse (black dots) and available on the study area (white bars) according to substrate types (seven categories; see table 1 for substrate definition and codes) and season (post-breeding N = 4,960 birds; winter N = 5,567; pre-breeding N = 1,069; breeding N = 247). For each season the null hypothesis that pin-tailed sandgrouse flocks occurred in substrates in proportion similar to their availability was rejected ($P < 0.001$).
[Proporción (± 95 % de límite de confianza) del hábitat usado por la ganga ibérica (puntos negros) y disponibles (barras blancas) en el área de estudio, de acuerdo con los tipos de vegetación (siete categorías; ver tabla 1 para la definición de vegetación y códigos) y estación (post-reproducción N = 4.960 aves; invierno N = 5.567; pre-reproducción N = 1.069; reproducción N = 247). Para cada estación, la hipótesis nula de que los bandos de gangas ibéricas aparecen en la vegetación en proporción similar a su disponibilidad fue desechada ($P < 0.001$).]

feeding grounds for other steppe birds, indicating that their maintenance could be of key importance for the conservation of steppe birds in general (Suárez *et al.*, 1997b; Tella and Forero, 2000; Lane *et al.*, 2001; Moorcroft *et al.*, 2002; Silva *et al.*, 2004).

Pasturelands and fallows were uniformly available across seasons. Nevertheless, whereas pasturelands were used more often than expected in the breeding and post-breeding seasons, fallow land was positively selected in the winter and pre-breeding seasons (figure 1). Both substrates offer a higher floristic diversity than crops and probably good opportunities to feed on different type of seeds. They might also be an important nesting habitat (authors' unpublished data). The use of these habitats might be conditioned by the height and density of vegetation (Barros *et al.*, 1996).

The "other" land use category was positively selected in the pre- and post-breeding seasons probably reflecting the importance of legume crops (figure 1). Other studies have reported a strong selection as feeding habitats of fields sown with legume crops, which, when available, can dominate the diet (De Juana, 1997; Suárez *et al.*, 1999a; Suárez *et al.*, 1999b). Lastly vineyards and olive groves were apparently avoided by sandgrouses, suggesting that increasing the relative area of such substrates would be detrimental for this species (Suárez *et al.*, 1999a; Suárez *et al.*, 2006).

Our results are overall consistent with those of previous studies, in which ploughed fields with weeds were found to be preferred and cereal fields avoided (Martínez and De Juana, 1996; Suárez *et al.*, 1997a; Suárez *et al.*, 1999a and references therein; Campos, 2004; Martínez, 2005). The differences between the results of this study and others (e.g. use of scrubland) might be in part explained by differences in the methods used (bias resulting from unequal detection probabilities in the different agrarian substrates in studies that not involved radio-tracking), or differences in habitat or classification of agrarian substrates between studied regions.

In conclusion, habitat preferences of pin-tailed sandgrouse varied throughout the year, the species favouring diverse stages of the rotational cereal cultivation system at different seasons. Proper habitat management for the pin-tailed sandgrouse should take into consideration its habitat preferences during the full annual cycle and should tend to maintain the habitat mosaics provided by extensive rotation cereal systems in Spain. Four aspects seem to be particularly important at least in our study area: (i) the planning of rotations should always incorporate substantial amounts of ploughed fields and fallows of different ages; (ii) agrarian works and herbicide input should be minimized in order to allow the growth in weed vegetation in ploughed and fallow fields; (iii) stubble fields should remain unploughed and unburned throughout the winter; and (iv) the relative area of vineyards and olive groves should not be increased.

ACKNOWLEDGEMENTS.—We thank farmers, hunting managers and gamekeepers of Campo de Calatrava for allowing us to work on their properties. N. Sumozas, M. Calero and I. Hervás collaborated during some stages of the field work. The study was financed by the Dirección General de Investigación (projects CGL2007-66322/BOS and CGL2008-04282/BOS), and the Consejería de Educación y Ciencia of Castilla-La Mancha (projects PAI08-0171-9582 and PAC06-137). The Consejería de Medio Ambiente y Desarrollo Rural of the Junta of Castilla-La Mancha allowed us to capture and radio-tag the birds. C. A. Martín holds a postdoctoral contract (I3P Programme, CSIC), and F. Casas was supported by a postdoctoral grant of the Junta de Comunidades de Castilla-La Mancha (JCCM). Two anonymous referees provided helpful comments on the paper.

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[Recibido: 03-07-2009]
[Aceptado: 10-02-2010]