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POPULATION INCREASE OF THE GREAT BUSTARD *OTIS TARDA* IN ITS MAIN DISTRIBUTION AREA IN RELATION TO CHANGES IN FARMING PRACTICES

INCREMENTO DE LA POBLACIÓN DE AVUTARDA COMÚN EN SU PRINCIPAL ZONA DE DISTRIBUCIÓN EN RELACIÓN A CAMBIOS EN LAS PRÁCTICAS AGRÍCOLAS

Carlos A. MARTÍN[1] *, Carmen MARTÍNEZ[2], Luis Miguel BAUTISTA[2] and Beatriz MARTÍN[3]

SUMMARY.—We update and present relevant information regarding the abundance and distribution of the great bustard *Otis tarda* in Castilla y León (Spain) in 2008, compare it with previous census results, and analyse the effects of agricultural changes on the provincial abundance and distribution of the species. The study area was surveyed from four-wheel drive vehicles driven at low speed (20-30 km/h) along predetermined transects, stopping frequently at prominent spots. The intention was to detect all the great bustards present in the study area. The great bustard population in Castilla y León during the breeding season of 2008 was 14,025 birds: 5,637 males, 7,760 females and 628 individuals whose sex could not be determined. The population was 34% greater in 2008 than in 1998 when the area surveyed in both censuses is compared. Population increases were recorded in all provinces except for Soria, where no birds were observed. Not all local populations within provinces increased: we detected population declines of over 10% in 43 (27%) of the 160 polygons surveyed both in 1998 and 2008, population increases of over 10% in 93 (58%) polygons, and largely stable populations (changes less than 10%) in 24 (15%) polygons. Provincial increases in bustard numbers were positively correlated with increases in the extent of unirrigated legume crops. The great bustard population in Castilla y León in 2008 was the largest in the world, accounting for 27-32% of the global population and about 47% of the estimated Spanish population. The spread of unirrigated legumes, crops that are promoted by agri-environment schemes, may have fostered the observed population increase between 1998 and 2008. A survey of the region every ten years is proposed to monitor future population trends.

Key words: agri-environment, census, conservation, farmland birds, legume crops, *Otis tarda*, population increase.

[1] Departamento de Zoología y Antropología Física, Facultad de Biología, Universidad Complutense, C/ José Antonio Novais 2, 28040 Madrid, Spain.

[2] Departamento de Ecología Evolutiva, Museo Nacional de Ciencias Naturales, CSIC, José Gutiérrez Abascal 2, E-28006 Madrid, Spain.

[3] Fundación Migres, Ctra. N-340, Km.96.7, Huerta Grande, Pelayo, Algeciras, E-11390 Cádiz, Spain.

* Corresponding author: ca.martin@bio.ucm.es

RESUMEN.—Actualizamos y aportamos nueva información sobre la abundancia y distribución de la avutarda común *Otis tarda* en Castilla y León (España) en 2008, comparamos dicha información con la de censos anteriores, y analizamos los efectos de la transformación agrícola sobre la abundancia provincial de la especie. El área de estudio fue censada en recorridos predefinidos con vehículos todo terreno a baja velocidad (20-30 km/h) y realizando paradas frecuentes en lugares con amplio campo visual. El objetivo fue detectar y contabilizar todos los individuos presentes en el área de estudio. La población reproductora de avutarda censada en 2008 fue de 14.025 aves: 5.637 machos, 7.760 hembras y 628 aves cuyo sexo no pudo determinarse. El número de avutardas contabilizadas en 2008 fue un 34% superior al de 1998 teniendo en cuenta el área muestreada en ambos censos. Se registraron incrementos poblacionales en todas las provincias excepto en Soria donde, al igual que en la primavera de 1998, no se detectó la especie. Las poblaciones locales no se incrementaron en todos los lugares ni en la misma proporción: en 43 (27%) de los 160 polígonos visitados en 1998 y 2008 se produjeron descensos poblacionales superiores al 10%, 93 (58%) polígonos experimentaron un aumento poblacional superior al 10%, y en 24 (15%) no se observaron cambios superiores al 10%. El incremento en el número de avutardas censadas en cada provincia se correlacionó positivamente con el incremento en la superficie de leguminosas de secano. Concluimos que la población de avutardas de Castilla y León censada en 2008 fue la mayor del mundo, representando alrededor del 47% de la estima poblacional de España y el 27-32% de la mundial. La expansión de cultivos adecuados para la especie como las leguminosas de secano, que son subvencionadas por programas agroambientales, han debido favorecer el aumento poblacional observado entre 1998 y 2008. Sin embargo, para confirmar la tendencia al alza en la población de Castilla y León y sus causas, es necesario mantener un programa de censos de la especie con una periodicidad al menos decenal.

*Palabras clav*e: agroambiental, aves de medios agrícolas, censo, conservación, incremento poblacional, leguminosas, *Otis tarda*.

INTRODUCTION

The great bustard *Otis tarda* is described as globally threatened following considerable declines in its population and distribution throughout its range during the past two centuries (Collar, 1996). In most cases these reductions have been associated with habitat loss, habitat fragmentation and human persecution (Morales and Martín, 2002). Consequently the species is classed as *Vulnerable* in the Red List of the International Union for Conservation of Nature (IUCN, 2010). Spain holds about 60% of the global population according to recent estimates (27,500-30,000 birds, Palacín and Alonso, 2008). Despite its apparently large Spanish population, the great bustard is also threatened in Spain and is classed as *Vulnerable* in the Spanish Red Book (Palacín *et al.*, 2004). It is included in the Spanish List of Wildlife Species under Special Protection (BOE 46, 2011).

The largest population of great bustards within the Iberian Peninsula is located in the region of Castilla y León, where it is fairly evenly distributed. This region accommodates 45% of the Spanish population (Alonso *et al.*, 2005b). Therefore the demographic dynamics of this population may have a considerable influence on both national and global population trends. The first reliable census in Castilla y León was carried out in 1998 and established a breeding population size of slightly over 10,000 birds (E.T.I., 1998; Martínez, 1999, 2008), between a fifth and a quarter of the world population. Here we present the main results of the second great bustard census in Castilla y León, which was carried out in 2008.

An increasing general trend towards agricultural intensification occurred in Spain and other western European countries during the final quarter of the 20th century, reducing the extent of fallow land and pastures and even introducing some irrigation into traditional farming areas. Such changes in the farming landscape may threaten great bustard populations in the Iberian Peninsula (Moreira *et al.*, 2005; Pinto *et al.*, 2005; but see Morales *et al.*, 2006). The size of the great bustard sub-populations in each province of Castilla y León might thus be expected to have changed according to the provincial farming trends. The total area cultivated with unirrigated legumes crops that are largely promoted under agri-environment schemes, increased in Castilla y León during the 1998-2008, although not uniformly throughout the region. Thus the regional effects of agricultural transformations on great bustards between 1998 and 2008 were hitherto unknown.

To assess the regional conservation status of the great bustard in Castilla y León in the first decade of 21st century and to analyse the population trend post-1998, we update and present relevant information regarding its abundance and overall distribution in 2008, compare it with the results of the 1998 census and analyse the effects of agricultural changes on the provincial abundances of the species.

Study area and methods

Castilla y León is the largest of the Spanish regions, over 94,000 km^2. It is comprises most of the northern meseta, the Northern Spanish Plateau, and consists of nine provinces: Ávila, Burgos, León, Palencia, Salamanca, Segovia, Soria, Valladolid and Zamora. Here great bustards live on the agricultural plains cultivated with cereals (wheat *Triticum* sp. and barley *Hordeum* sp.), sunflowers *Helianthus annuus* and various legumes (lucerne *Medicago* sp. and vetch *Vicia* sp.). The traditional crop rotation system has usually been maintained in the region, favouring land mosaics comprising sown fields intermixed with fallows and stubbles of different ages. Data on the provincial areas cultivated with unirrigated legumes were obtained from the regional farming statistics of Castilla y León (source: www.marm.es/es/estadistica/temas/) for both 1998 and 2008.

We conducted an absolute count of great bustards by monitoring the favourable area for the species in the region. The surveys consisted of systematic and predetermined transects on tracks and roads in sampling units or polygons of 56 ± 14 km^2 (mean ± SD; N = 184 polygons). The great bustard population in 2008 was surveyed within the same 160 polygons visited in the 1998 survey (E.T.I., 1998) plus 24 new polygons, covering a total census area of 10,299 km^2. New polygons accounted for about 12% of the study area and were selected according to previous data on the species' distribution and observations from wildlife wardens.

The census itinerary was covered at low speed (< 30 km/h) making frequent stops at vantage points to look for birds carefully. The same routes were followed in both surveys wherever possible. Polygon boundaries were determined by logistic requirements. Such constraints were necessary due to the considerable size of the area surveyed for this study. To avoid counting the same birds repeatedly if they moved, between three and six four-wheel drive vehicles were used simultaneously within adjacent polygons. The intention was to detect each and every one of the great bustards present in each polygon (an absolute measure of abundance; see details about the census rationale in Alonso *et al.*, 2005b).

The census was conducted between the 2nd and 27th of March 2008, since the maximum aggregations of great bustards at their display grounds or leks occur at this time.

Polygons that were not surveyed in 1998 were also visited, between the 4th and 16th of April. Twelve persons were distributed between six vehicles, ensuring that at least one person in each car had previous experience of great bustard surveys. Observers used binoculars, 20-60× telescopes, GPS and 1:50,000 maps. A census work-day began at dawn and ended at dusk with a break between 11:00 and 16:00 hours GMT, a time of day when great bustards remain inactive or hidden and are difficult to detect (Martínez, 2000). Surveys were always conducted in favourable conditions, in the absence of precipitation, fog or strong wind. The area surveyed daily did not exceed 80-100 km^2 for each team. In areas without significant discontinuities, such as Tierra de Campos and Tierra de Campiñas, six teams simultaneously surveyed them in the shortest possible time to avoid duplicating records.

Results

Population abundance and distribution

The number of great bustards surveyed in Castilla y León during the breeding season of 2008 was 14,025 birds: 5,637 males, 7,760 females and 628 individuals whose sex could not be determined (not sexed = 4.5%, table 1). A sex ratio of 1.38 females per male was calculated. Provincial sex ratios were about 1.1:1 in León, Salamanca, Burgos, about 1.4:1 in Zamora and Palencia, and 1.6:1 in Valladolid, Ávila, and Segovia.

Two-thirds of the breeding great bustards of Castilla y León were located in Zamora and Valladolid provinces (table 1). Palencia had the third highest provincial population, hosting over 15% of the regional population, followed by León. Smaller populations were located in Burgos: which accounted

Table 1

Numbers and sexes of great bustards surveyed in the nine provinces of Castilla y León region in spring 2008.
[Números y sexos de avutardas comunes censadas en las nueve provincias de Castilla y León en la primavera de 2008.]

				Total	
Province	**Males**	**Females**	**Not sexed**	**N**	**%**
León	561	627	37	1225	8.7
Palencia	877	1179	123	2179	15.5
Burgos	136	161	0	297	2.1
Zamora	1978	2691	181	4850	34.6
Valladolid	1415	2251	218	3884	27.7
Salamanca	408	436	20	864	6.2
Ávila	238	377	49	664	4.7
Segovia	24	38	0	62	0.4
Soria	0	0	0	0	0.0
Castilla y León	**5637**	**7760**	**628**	**14025**	**100.0**

for 2.1% of the regional population, and Segovia: where only 62 individuals were observed, 0.4% of the regional population. No birds were detected in the six polygons located in Soria province, the same result as in spring 1998.

The regional distribution was fairly uniform, comprising two areas separated by the Duero River (figure 1). More than two-thirds of the population (10,133 birds) was concentrated within the cereal plains of Tierra de Campos, north of the Duero. This extensive area includes sectors of five provinces: southeastern León, northeastern Zamora, northwestern Valladolid, southern and central Palencia, and an area in western Burgos. The remaining population (3,892 birds) was on the plains south of the Duero, from southeastern Zamora, north-western Salamanca, southern Valladolid and northern Avila, to the centre and west of Segovia province.

Most great bustards (70% of the regional population, see table 2) were located in areas included within the European Natura 2000 network. The Special Protection Area (SPA) with the largest subpopulation of great bustards was the Lagunas de Villafáfila (18% of the regional population), where both the greatest number of birds (*c*. 2,500) and the highest density (> 7 birds/km^2)

TABLE 2

Numbers of great bustards found within areas included in the European Natura 2000 network of Castilla y León in spring 2008. More than 70% of the great bustards counted in Castilla y León were within Special Protection Areas (SPAs) (see details in the main text).
[Números de avutardas comunes censadas en áreas de la red europea Natura 2000 de Castilla y León en la primavera de 2008. Más del 70% de las avutardas censadas en Castilla y León estaban en Zonas de Especial Protección para las Aves (ZEPA; SPA en inglés). Véanse detalles en el texto principal.

SPA	Provinces	Number of birds
Camino de Santiago	Palencia	650
Campos de Alba	Salamanca	48
La Nava-Campos Norte	Palencia, Valladolid, León	1416
La Nava-Campos Sur	Palencia, Valladolid	485
La Nava-Rueda	Valladolid	86
Lagunas de Villafáfila	Zamora	2509
Llanuras del Guareña	Zamora	412
Oteros-Campos	León, Valladolid	707
Oteros-Cea	León, Valladolid	70
Penillanuras-Campos Norte	Valladolid, Zamora, León	390
Penillanuras-Campos Sur	Valladolid, Zamora	724
Tierra de Campiñas	Valladolid, Ávila, Salamanca	2204
Tierra del Pan	Zamora, Valladolid	210
TOTAL		**9911**

were recorded. The Tierra de Campiñas (16%, *c*. 2,200 birds, 1.6 birds/km^2) and La Nava-Campos Norte (10%, c. 1,400 birds, 2.6 birds/km^2) were the next two highest-ranked sites.

Population trend

All provinces experienced population growth between 1998 and 2008, with the exception of Soria where no birds were observed in either census. The number of great bustards in the 160 polygons surveyed in 1998 and 2008 was 34.4% greater in 2008 (table 3). These 160 polygons included 96.3% of the great bustards recorded in 2008 and therefore reflect the regional trend reliably. Population growth was higher in the subpopulation north of the Duero River (42.7%) than in the southern one (14.4%). Similarly, northern provinces (mainly Burgos and Palencia) showed higher population growth than southern provinces (Ávila and Salamanca; see table 3). The cumulative annual growth rate for the regional population between 1998 and 2008 was 3.0%.

We found five polygons (3.1%) with no bustards in 1998 that were occupied in 2008 and six (3.7%) that were occupied in 1998 but not in 2008. Great bustard regional density increased by 34.5%, from 1.10 birds/km^2 in 1998 to 1.48 birds/km^2 in 2008. We detected population increases of over 10% in 93 (58%) of the 160 polygons surveyed both in 1998 and 2008; population declines of over 10% in 43 (27%) polygons and stability in 24 (15%) polygons in which population changes were below 10%. These proportions differed between the subpopulations north and south of the Duero, with greater increases in the northern subpopulation (north: 66%, 26% and 8% of the polygons showing population increase, decrease and stability respectively, N = 96; south: 47%, 28% and 25% of the polygons showing increase, decrease and stability respectively, N = 64; $\chi^2 = 43.02$, df = 2, $P < 0.01$).

TABLE 3

Regional and provincial increases in great bustards in Castilla y León between spring 1998 and spring 2008, considering only the 160 polygons surveyed in both censuses.
[Incrementos regional y provinciales de avutardas comunes en Castilla y León entre las primaveras de 1998 y 2008, considerando sólo los 160 polígonos muestreados en ambos censos.]

Province	1998	2008	Increase (%)
León	995	1224	23.0
Palencia	1237	2158	74.4
Burgos	148	277	87.2
Zamora	3827	4628	20.9
Valladolid	2463	3660	48.6
Salamanca	845	864	2.1
Ávila	518	664	28.4
Segovia	9	26	188.9
Soria	0	0	0.0
Castilla y León	**10042**	**13501**	**34.4**

Agricultural effects on population abundance and distribution

The total area cultivated with unirrigated legumes in Castilla y León increased by 39.9% between 1998 and 2008, although not uniformly throughout the region (figure 2). A sharp increase in legume cultivation occurred in the provinces of Burgos, Segovia and Palencia, where the area sown doubled between 1998 and 2008. Valladolid, Ávila

FIG. 1.—The study area of Castilla y León, Spain. Provincial borders, sampling units (184 polygons) and the Duero River are also shown. Grey-shaded areas within polygons indicate the distribution of the great bustard within the sampling units in spring 2008.
[El área de estudio en Castilla y León, España. Se muestran los límites provinciales, las unidades de muestreo (184 polígonos) y el río Duero. Las áreas grises dentro de los polígonos indican la distribución de la avutarda común en las unidades de muestreo en la primavera de 2008.]

and Zamora have shown a moderate growth in the area cultivated with legumes. In contrast, in Leon and Salamanca there has been a reduction in the area sown with legumes, resulting in the loss of 49% and 44% of these crops respectively.

The ten-year increase in the provincial number of great bustards was positively correlated with the increase in the extent of unirrigated legumes (figure 2, Pearson correlation: r = 0.916, P <0.01, N = 8 provinces). In addition, the surface area cultivated with lucerne in 2008 was positively correlated with the number of great bustards in 2008 (Pearson correlation: r = 0.818, P = 0.013, N = 8 provinces).

Discussion

The population of great bustards in Castilla y León is the largest in the world and has increased greatly within just a decade (1998-2008). There are least two explanations for this increase: the continuing hunting ban and the increase in some agri-environmental farming practices.

Population abundance and distribution

There were about 14,000 great bustards in Castilla y León region in spring 2008. This population represents some 47% of the esti-

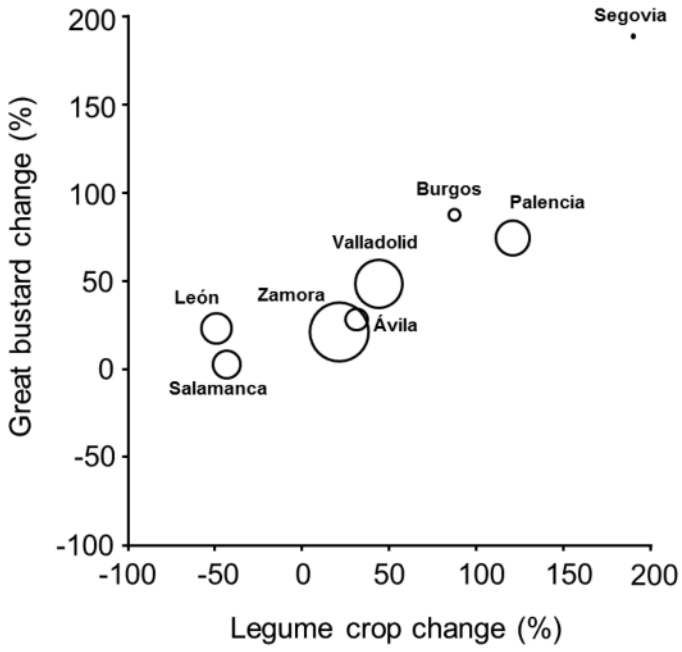

Fig. 2.—Great bustard population increases between 1998 and 2008 in the provinces of Castilla y León relative to the changes in the area cultivated with non-irrigated legumes. Point size is proportional to the number of birds in 1998. Soria province is omitted since no birds were detected there.
[Incremento poblacional de la avutarda común entre 1998 y 2008 en las provincias de Castilla y León en relación a los cambios en el área cultivada de leguminosas de secano. El tamaño de los puntos es proporcional al número de aves en 1998. La provincia de Soria no se incluyó al no detectarse aves allí.]

mated Spanish population, 45% of that of the Iberian Peninsula and 27-32% of the world population. These numbers highlight the importance of the Castilla y León population on both the national and global scales.

As expected in this species, more females than males were recorded in 2008 (7,700 females and 5,600 males). However the overall sex ratio (1.38 females per male) showed a slight bias towards females when compared with other nearby populations (Alonso *et al.*, 2003a; Alonso *et al.*, 2005a; Alonso *et al.*, 2005c), which may reflect quite similar mortality in both sexes, and an apparently good state of the population within the whole of Castilla y León. The regional sex ratio is stable when compared with that in 1998 (1.37 females per male) suggesting that the populations of both sexes have grown proportionately and that inter-sexual differences in mortality have remained rather stable.

The great bustard maintains a fairly continuous distribution on the cereal plains north and south of the Duero River (see details in E.T.I., 2009). Since nearly three-quarters (70%) of the regional population was located within areas included in the European Natura 2000 network (table 2), the great bustard distribution is largely, if not totally, well protected in this region. Just three of the 13 SPAs supporting great bustards, namely the Lagunas de Villafáfila, Tierra de Campiñas and La Nava-Campos Norte, account for 44% of the regional population, which emphasises the importance of these sites for the conservation of the species.

Population trend

The great bustard population in Castilla y León showed a 34.4% increase between 1998 and 2008 in the areas monitored in both surveys. In both regional censuses the survey methods were the same, the sampling effort was of equivalent intensity and most of the potential bustard habitat was prospected. The results of the two surveys are therefore entirely comparable and the detected population increase is considered real and not attributable to any methodological differences. This population rise has not been achieved through a regional range expansion but rather by an increase in population density, from 1.10 birds/km^2 in 1998 to 1.48 birds/km^2 in 2008.

The increase seems to be due to a positive balance between recruitment and mortality rates within the region and not to immigration from neighbouring populations. Movements of some individuals to Castilla y León from other regions cannot be totally discarded, but radio-telemetry has shown that these are unusual (> 400 birds radio-tracked throughout Spain; Martín, 1997; Alonso *et al.*, 2000; Morales *et al.*, 2000; Alonso *et al.*, 2001; Martín, 2001; Alonso *et al.*, 2005a; Magaña, 2007; Palacín, 2007; Martín *et al.*, 2008), and only one case of immigration to Castilla y León from another region was detected: a male great bustard from Navarra (northeast of Castilla y León) that settled as an adult in Burgos after travelling more than 170 km from its natal area. Even if such behaviour was common in the Navarra population, its small size (30 birds, Alonso *et al.*, 2005b) means that it could not produce enough birds to account for the population increase in Castilla y León. Other movements between Castilla y León and neighbouring regions have also been observed, but these were seasonal movements that do not affect the size of the breeding population of Castilla y León (Alonso *et al.*, 2001; Martín, 2001; Palacín, 2007; Alonso *et al.*, 2009). Therefore the observed increase represents a cumulative annual growth rate of 3.0%.

The first and perhaps the main factor determining the population increase is the reduction of mortality rates and subsequent population recovery derived from the national hunting ban that was instituted in 1980

(Alonso and Alonso, 1990). This protection scheme may have contributed to the recovery of the great bustards not only in Castilla y León but also in some other neighbouring populations (Alonso *et al.*, 2003b; Alonso *et al.*, 2005b).

In addition, the sharp increase during 1998-2008 in the regional area cultivated with unirrigated legumes, a highly nutritious and major component of the diet of great bustards (Alonso and Alonso, 1990; Peris *et al.*, 1992; Lane *et al.*, 1999), will have had a positive effect by reducing mortality and increasing productivity. Populations of all provinces showed an increase that correlates with the change that has occurred in the area under unirrigated legumes. Such cultivations are largely subsidised by agri-environment schemes of the European Common Agricultural Policy, which aim to reduce biodiversity loss by promoting extensive agricultural practices. The importance of dry legume crops for farmland birds has also been reflected in the recovery of another bustard species, the little bustard *Tetrax tetrax* (Bretagnolle *et al.*, 2011).

Although the population trend of the whole region and of each of its provinces is positive, decreases have been detected in some areas. Most of these decreases may simply be due to differences in the distribution of the birds during both censuses, probably involving short-term movements between neighbouring polygons. Nevertheless some other declines could be related to habitat loss or deterioration in local areas although this possibility needs to be tested carefully. In this respect, the proportion of polygons showing population increases and decreases differed between the subpopulations north and south of the Duero River, with a higher proportion of increases in the former. This is in line with the higher population growth detected in northern subpopulation (42.7%) relative to the southern one (14.4%), and may be associated with different habitat changes affecting the two subpopulations. However this hypothesis remains untested since no detailed fine-scale data on land-use is currently available.

In conclusion, the present study shows that Castilla y León held more great bustards in 2008 than anywhere else in the world, with over 14,000 birds, about 30% of the global population. We detected a regional population growth of 34% between 1998 and 2008. The population increase is likely to have been the outcome of an enduring hunting ban and an increase agri-environmental farming practices that favour the species. Regular monitoring of the species across the region is needed in order to detect future population trends and their possible causes, since changes in the size and distribution of this population would considerably affect the global viability of the great bustard. We suggest that regional surveys of the species in Castilla y León should be conducted at least every ten years.

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