Body Size and Sexual Dimorphism in the Southernmost Subspecies of the Burrowing Owl (*Athene cunicularia cunicularia*)

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BODY SIZE AND SEXUAL DIMORPHISM IN THE SOUTHERNMOST SUBSPECIES OF THE BURROWING OWL (*ATHENE CUNICULARIA CUNICULARIA*)

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ABSTRACT.—We studied body size and sexual dimorphism in the southernmost subspecies of the Burrowing Owl (*Athene cunicularia cunicularia*) at the Pampas of Argentina, and we compared our data with those from other subspecies in the Americas. A total of 58 individuals were captured and their coloration pattern (plumage and bare parts), body linear measurements (wing chord, standard tail length, tarsus length and width, forearm length, exposed culmen length, and hallux claw length), and body mass were recorded. In addition, we banded each individual and took a blood sample from 44 individuals for molecular sex determination. In general, the body size measurements reported for *A. c. cunicularia* in this study agreed with previous reports based on museum specimens for the same subspecies, and were near the upper range for the species. In addition, tarsi of *A. c. cunicularia* were large in comparison to those of other subspecies. Sexes differed little in size, with tarsus length, tail length, and wing chord being slightly greater in males, and culmen length and mass slightly greater in females. However, mean values of these measurements did not differ statistically between sexes. The southernmost subspecies of Burrowing Owls, *A. c. cunicularia*, has a larger body size than the North American and Caribbean subspecies, which suggests geographical variation in body size of this species throughout its distributional range.

KEY WORDS: *Burrowing Owl*; Athene cunicularia; *body size*; *coloration pattern*; *dimorphism index*; *Pampas region*.

TAMAÑO CORPORAL Y DIMORFISMO SEXUAL EN LA SUBESPECIE MÁS AUSTRAL DE *ATHENE CUNICULARIA CUNICULARIA*

RESUMEN.—Se estudió el tamaño corporal y el dimorfismo sexual de la subespecie más austral de *Athene cunicularia cunicularia* en las Pampas de Argentina, y se compararon nuestros datos con aquellos de otras subespecies de América. Se capturó un total de 58 individuos y se registró el patrón de coloración (plumaje y partes expuestas), las medidas corporales lineales (cuerda del ala, longitud estándar de cola, longitud y ancho del tarso, longitud del antebrazo, longitud del culmen expuesto y longitud de la garra del hallux) y el peso. Además, cada individuo fue anillado y se tomó una muestra de sangre de 44 individuos para realizar la determinación molecular del sexo. En general, las medidas corporales descritas para *A. c. cunicularia* en este trabajo concordaron con estudios previos basados en especímenes de museo para la misma subespecie y se ubicaron cerca del límite superior para la especie. Además, *A. c. cunicularia* presentó tarsos largos en comparación con otras subespecies. Se encontraron pocas diferencias de tamaño entre sexos, con el largo de tarso, largo de cola y cuerda del ala siendo levemente mayores en los machos, y el largo de culmen y el peso levemente mayores en las hembras. Sin embargo, no se observaron diferencias en los valores medios de estas medidas entre sexos. La subespecie más austral de *A. c. cunicularia* mostró un tamaño corporal mayor que las subespecies de América del Norte y el Caribe, lo cual sugiere una variación en el tamaño corporal para esta especie a lo largo de su área de distribución.

[Traducción de los autores editada]

The Burrowing Owl (*Athene cunicularia*) is a raptor that inhabits open habitats of the Nearctic and Neotropical regions (del Hoyo et al. 1999). This species nests in distinctive subterranean burrows (König et al. 1999, Marks et al. 1999). Nevertheless, its habitat requirements seem to be quite broad, as this owl nests in natural habitats such as shortgrass prairies

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and treeless plains, but also in modified habitats, such as pasturelands, croplands, golf courses, cemeteries, airports, vacant lots in urban areas, and wherever there are stretches of open land (Haug et al. 1993). In part, due to this ability to live in a variety of habitats, this species is one of the most common and recognized raptors across the Americas.

Currently, twenty subspecies are recognized for this owl (del Hoyo and Collar 2014), although most of the information about its ecology and biology is restricted to the North American subspecies (Marks et al. 1999). For example, the bulk of data on body measurements of Burrowing Owls are available only for the subspecies *floridana* from Florida and the subspecies *hypugaea* from Colorado (Earhart and Johnson 1970, Haug et al. 1993, Plumpton and Lutz 1994), although partial information is also available for other subspecies (Clark 1997). It has been reported that races vary mainly in size, in depth of coloration, and in the strength and extent of markings (Marks et al. 1999), although detailed studies to support this assumption are lacking. In addition, the sexes differ little in body size (Haug et al. 1993), which represents an exception to the typical reversed sexual dimorphism (RSD) of raptors (Newton 1979).

We here report on the body measurements and sexual dimorphism of the southernmost population of the Burrowing Owl (*A. c. cunicularia*) from the Pampas of Argentina. We also compare our measurements with those of other subspecies inhabiting different geographic areas of this owl's distribution.

METHODS

The subspecies *A. c. cunicularia* inhabits the southernmost area of the species' distribution, ranging from South Bolivia, Paraguay, Uruguay, and Brazil to Tierra del Fuego in southern Argentina (König et al. 1999, del Hoyo and Collar 2014). Our study was carried out along the southeastern coast of Buenos Aires Province, Argentina (37°44′–37°51′S, 57°24′–57°30′W). This area is dominated by the typical environments of the Pampas region (Soriano et al. 1991), such as pampean grasslands, psammophytic grasslands, and wetlands, as well as human-modified environments, such as agroecosystems (grazing fields, pasturelands, and croplands), and periurban areas (villages; Vervoorst 1967). Preliminary surveys allowed us to locate more than 50 Burrowing Owl mating pairs and identify their territories in the study area.

During 2009–2014, we captured adult owls in the three main habitats of the Burrowing Owl in the study area: agroecosystems, periurban areas, and native grasslands. We captured individuals using balchatri traps, bow nets, and noose carpets placed at burrow entrances (Bub 1991, Bloom et al. 2007). We adhered to guidelines for the use of animals in research and to the legal requirements of Argentina (permit numbers: 2145-14331 and 22500-24871). We took the following measurements of each individual: wing chord and standard tail lengths, which were measured using a metal ruler and are expressed in mm; forearm, exposed culmen, hallux talon length, and tarsus length and width, which were measured using a digital calliper and are expressed in mm; and mass, which was measured using a spring scale and is expressed in g (Hull and Bloom 2001). In addition, we marked each individual using numbered colored bands (Varland et al. 2007). We calculated the dimorphism index (DI; Storer 1966) to allow comparison with previous reports that used this index to compare measurements between sexes (Earhart and Johnson 1970, Plumpton and Lutz 1994). This index reports positive values if the female is larger and negative values if the male is larger. In addition, we evaluated differences in body measurements between males and females using Student's *t*-tests (Zar 2010). We also recorded the coloration pattern of each individual (color of legs, cere, iris, and plumage). A color chart based on Narosky and Yzurieta (2010) field identification guide (Vertebrates lab, University of Mar del Plata) was used to describe the coloration pattern of individuals captured. Furthermore, we took a blood sample to perform molecular sex determination (primers 2550F/2718R; Dubiec and Zagalska-Neubauer 2006). Values are expressed as mean ± SE.

RESULTS

We captured 58 Burrowing Owls in the study area. The mean values of wing chord, tail length, tarsus length, and mass recorded were near the upper range for the species (Tables 1, 2). To our knowledge, our measurements of hallux talon length, tarsus width, and forearm length were novel for the species (Table 1). In general, the values of body measurements we report here for the *cunicularia* subspecies agree with reports based on museum specimens for the same subspecies, except for tarsus length, which was larger in our study (Table 2); however, as a caveat, it is possible that this result may be due to differences in how the measurements were made and/or the biases inherent in comparing live and preserved specimens. In addition, wing

Table 1. Body measurements of the Burrowing Owl (*Athene c. cunicularia*) individuals captured between 2009–2014 at the Pampas Region (Buenos Aires, Argentina), and comparison with data from North American subspecies (data taken from Haug et al. [1993]). Body linear measurements are expressed in mm; mass is expressed in g. Values are mean ± SE, with *n* in parentheses.

	A. c. cunicularia (Buenos Aires, Argentina)			*A. c. hypugaea* (Colorado, U.S.A.)		*A. c. floridana* (Florida, U.S.A.)	
Measurement	All (58)	Male (11)	Female (33)	Male	Female	Male	Female
Mass	202.4 ± 3.0	200.6 ± 4.7	201.4 ± 3.1	146.3 ± 1.9 (38)	156.1 ± 3.6 (39)	148.8 ± 1.5 (113)	149.7 ± 1.7 (167)
Wing chord length	179.0 ± 1.4	180.3 ± 3.3	178.6 ± 1.9	163.5 ± 1.1 (38)	159.4 ± 1.1 (39)	166.3 ± 0.5 (45)	163.6 ± 1.1 (75)
Standard tail length	83.3 ± 0.9	84.4 ± 1.7	82.8 ± 1.1	80.1 ± 0.7 (38)	77.4 ± 0.7 (31)	72.2 ± 1.0 (111)	67.9 ± 0.9 (162)
Exposed culmen length	15.4 ± 0.1	15.3 ± 0.3	15.5 ± 0.2				
Hallux claw length	11.0 ± 0.1	10.7 ± 0.2	11.1 ± 0.2				
Tarsus length	56.9 ± 0.7	57.1 ± 1.4	55.8 ± 1.0				
Tarsus width	4.9 ± 0.1	5.0 ± 0.2	4.8 ± 0.1				
Forearm length	80.1 ± 0.8	79.6 ± 1.1	79.3 ± 1.2				

chord measurements for the *cunicularia* subspecies agreed with values reported for other subspecies from South America, which range from a minimum of 168 mm in *grallaria* to a maximum of 213 mm in *juninensis* (Table 2). These values are larger than those reported for North American subspecies (ranging from a minimum of 154.5 mm in *floridana* to a maximum of 181 mm in *hypugaea*), which in turn are larger than those of Caribbean subspecies (ranging from a minimum of 142 mm in *brachyptera* to a maximum of 169 mm in *rostrata*; Table 2). The individuals of the *cunicularia* race had long tails in comparison with other subspecies. The majority of owls measured in our study (87.5%) had tails longer than 80 mm (Table 1), whereas Caribbean subspecies had the shortest tail lengths (all <80 mm, except for the extinct race *guadeloupensis*), and North American subspecies showed intermediate values (Table 2). Bill size varied little among Burrowing Owl subspecies, ranging from 13 mm for the North American subspecies *hypugaea* to 17 mm for the Caribbean race *rostrata* (Table 2), with the *cunicularia* subspecies also within this range (Table 1). The most striking difference we recorded was tarsus length: >93% of individuals of the *cunicularia* subspecies had tarsi >50 mm (Table 1), but there are no reports of such large legs in other subspecies (Table 2).

We sexed 44 individuals using molecular techniques, from which we identified 33 females and 11 males. The values of the DI indicated that tarsus length, tail length, and wing chord were slightly greater in males, whereas culmen length was slightly greater in females (Table 3). In contrast, previous studies based on museum specimens of *cunicularia* indicate that wing chord was the only measurement larger in females (Table 3). Similarly, data from North American and Caribbean subspecies showed that males were larger than females for most linear measurements (Table 3). In addition, we found that females were slightly heavier than males (DI = 0.37). However, we did not find any significant differences between sexes for the measurements taken in our study (*t*-test, $P > 0.13$ for all measurements).

The captured owls varied little in the coloration pattern of bare parts. Eyes of most individuals were bright yellow, with the only exception being a one-eyed owl with a green iris. Most owls had greenish-olive ceres (82.2%, $n = 45$), and the remaining few had grayish-brown ceres (17.8%). Although most owls had olive-grey legs (63%), we

Table 2. Range of values of body measurements for Burrowing Owl subspecies, based on museum specimens (data taken from Clark [1997] and König et al. [1999]). Values are expressed in mm. NA: North America, C: Caribbean, SA: South America.

RACE	RANGE	*n*	WING	TAIL	CULMEN	TARSUS
hypugaea	NA	69	162.5–181	71.5–86	13–15	40–48.5
floridana	NA	20	154.5–170	70–80.5	14–15.5	41–46.5
rostrata	C	12	160–169	70–79.5	15.5–17	44.5–49
troglodytes	C	12	145–165.5	64.5–76.5	14–15.5	38–45.5
amaura†	C	6	145.5–154	70–75.5	14–15.5	39.5–41.5
brachyptera	C	2	142–152	63.5	13.5–14.5	40–41.5
guadeloupensis†	C	3	158–162.5	75.5–86.4	15–15.5	42.5–46.2
cunicularia	SA	10	179.5–181	83.7–86.6	15.5–16	46.8–47.3
carrikeri	SA	1	173	78	14	46
grallaria	SA	–	168–198	–	–	–
juninensis	SA	–	193–213	–	–	–

† extinct.

also found individuals with pale buff (30.4%) or brown legs (6.5%, $n = 45$).

The sexes differed in plumage coloration, with males being markedly lighter overall than females. Females had more extensive barring of breast and belly compared to males, and males had more marked white throat patches and eyebrows than females, especially during the breeding period.

DISCUSSION

The Burrowing Owl is one of the few strigiform species that inhabits sites all across the Americas. Perhaps due its abundance and conspicuousness, this owl has been described in almost every area of its geographical range and, as a consequence, a myriad of races has been postulated. However, the species shows a rather wide individual variability in size and weight (König et al. 1999). Thus, it is probable that some of the proposed races reflect merely individual variation or intergrading populations (Marks et al. 1999), but others are geographically distinct and are presumably isolated (Haug et al. 1993).

Table 3. Dimorphism Index (DI) for body measurements of the Burrowing Owl (*Athene c. cunicularia*) individuals captured between 2009–2014 in the Pampas region (Buenos Aires, Argentina), and comparison with other subspecies, calculated from data of Haug et al. (1993) and Clark (1997). The DI reports positive values if the female is larger and negative values if the male is larger.

	DIMORPHISM INDEX			
RACE	WING	TAIL	CULMEN	TARSUS
hypugaea	−2.54	−3.43	−2.14	−5.21
floridana	−1.64	−6.14	−0.67	−2.53
rostrata	−0.49	−8.33	−0.62	−4.12
troglodytes	−0.13	−4.99	−2.67	−1.92
amaura†	−0.47	−1.79	4.14	−2.48
cunicularia (museum)	0.83	−3.41	−3.17	−1.06
cunicularia (this study)	−0.94	−1.94	1.44	−2.35

In this study, we analyzed available data on body measurements across different races of the Burrowing Owl, in a comparative framework with novel data on the southernmost subspecies, *A. c. cunicularia*. Most linear body measurements agreed with previous reports for the same subspecies, and were similar to those for other subspecies in South America (Clark 1997). In addition, several of the measurements (i.e., wing chord, tail length) suggested a relationship between body size and geographical range, with South American races being larger than North American races, and these in turn larger than Caribbean races. In general, the body sizes of birds are associated with geographical gradients in temperature and humidity (James 1970). Climatic rules, such as Bergman's Rule—the increase in body size with cooler temperatures and latitude—reflect these correlations (Blackburn et al. 1999), and many owl species with distributions covering a broad range of latitudes follow this rule (Marks et al. 1999). This relationship has been postulated previously for Burrowing Owls (e.g., Marks et al. 1999, König et al. 1999), but more information on little known subspecies is needed, especially for those from South America and the Caribbean. We also

found that individuals of the *cunicularia* race showed the largest tarsus of all the subspecies compared, which would constitute the most distinctive feature of this subspecies and would support the geographical gradient pattern.

The DI indicated low to moderate sexual size dimorphism in most of the body measurements for the Burrowing Owl. Females of the *hypugaea* race were heavier than males in one study (DI = 6.62; Plumpton and Lutz 1994), but not in others (DI = −1.62; Earhart and Johnson 1970). Except for the exposed culmen length, which was larger in females, all other measurements did not suggest RSD in Burrowing Owls.

Several hypotheses have been postulated to explain the occurrence of RSD in raptors. One of the most accepted states that RSD is related to predatory habits and that it increases with prey mobility (Newton 1979). In addition, the maintenance of RSD in raptors has been related to three main factors: trophic competition between sexes, sexual selection, and role differentiation during breeding (Pande and Dahanukar 2012). The Burrowing Owl feeds mainly on temporally abundant food resources (i.e., arthropods and rodents; Bellocq 1987, Torres-Contreras et al. 1994, York et al. 2002, Cavalli et al. 2013) and is a largely monogamous species (Coulombe 1971, Haug et al. 1993); hence, trophic competition and sexual selection would not favor size differences between the sexes. Although the Burrowing Owl shows role differentiation, with females doing most of the parental care and males delivering food to the nest (Martin 1973), this factor may not be strong enough to drive sexual size dimorphism in this owl.

Coloration patterns of bare parts varied little in our study, which in part agrees with general descriptions for the species (König et al. 1999, Marks et al. 1999). Nevertheless, some coloration features of this race apparently differ from previous reports. For example, the dominant color of ceres is described as grayish-brown (König et al. 1999), but we described ceres of most *cunicularia* owls as greenish-olive; however, this could potentially be a matter of color interpretation. In addition, we found variability in the coloration of the tarsus and toes. Although most individuals had the typical olive-grey legs (König et al. 1999), we also found individuals with pale buff or brown legs. Differences in age and food consumption among individuals have been postulated as the primary factors influencing color variation in the bare parts of raptors (McDonald 2003, Sarasola et al. 2011). We believe that the coloration pattern of tarsi and toes observed in Burrowing Owls in our study may be attributable to age rather than to dietary differences among individuals, because the diet of this owl varies little among the different habitat types in our study area (Cavalli et al. 2013). Moreover, the Burrowing Owl is a relatively long-lived bird species (ca. 11 yr; de Magalhaes and Costa 2009) and, although we only captured adult individuals, these were likely different ages.

Because the coloration pattern of eyes, ceres, tarsus, and toes was similar between males and females, none of these characteristics would be useful for sex differentiation. However, we found that the sexes differed in overall plumage coloration, as males were markedly lighter than females, as previously described (Thomsen 1971). The more extensive barring of females' plumage has been described as a useful field criterion to differentiate sexes for this owl (Thomsen 1971). However, we also found that the white throat patches and eyebrows of males may also be valuable to differentiate them. Both features were more evident during the breeding period and have been associated with copulation behavior (Thomsen 1971), and may be influenced by differential sun-bleaching between sexes (Haug et al. 1993). However, we observed this difference between males and females throughout the year in our study area; hence, this feature may be useful to differentiate sexes, at least for *cunicularia*.

Burrowing Owls at the southernmost end of their distribution in the Pampas of Argentina had larger values of most body size measurements than their North American counterparts. In addition, the scarce reports for subspecies from Central America indicate that these races are even smaller than North American ones. This suggests that there is a geographical variation in body size of the species throughout its range, which would support Bergmann's Rule. However, an evaluation of subspecific taxa with modern systematic methods (Marks et al. 1999), as well as morphological data from other regions of the Burrowing Owl's distribution (König et al. 1999), would be useful to assess the validity of the subspecies and the geographical pattern of size variation in this raptor.

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