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ORIGINAL ARTICLE

A new species of extinct little owl from the Pleistocene of Mallorca (Balearic Islands)

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Abstract *Athene vallgornerensis* nov.sp. (Aves: Strigiformes: Strigidae) from the Early Pleistocene of the island of Mallorca (Balearic Islands, Western Mediterranean) is described. The material came from a fossil assemblage obtained in a collapsed gallery from Cova des Pas de Vallgornera (Llucmajor, south of Mallorca), the longest karstic system currently known in the Balearics. Associated remains include primitive representatives of the insular endemic fauna of Mallorca (*Myotragus*, *Hypnomys*, *Nesiotites*), as well as fossils of bats, birds (among them, *Tyto balearica*), lizards and toads. Although only two bones of *Athene* have been obtained, its highly distinctive tarsometatarsus—short, highly robust and significantly small—differentiates it from the remaining extant and extinct *Athene* species from the Palaearctic, justifying its description as a new species. At least four insular species of *Athene* are now known from the Mediterranean area, and two groups can be identified according to the shape of their tarsometatarsi.

Keywords *Athene vallgornerensis* nov.sp. · Balearic Islands · Early Pleistocene · Tarsometatarsus · Fossil Strigiformes

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Zusammenfassung

Eine neue kleine, ausgestorbene Eulen-Art aus dem Pleistozän von der Insel Mallorca (Balearen)

In dieser Arbeit wird *Athene vallgornerensis* nov.sp. (Aves: Strigiformes: Strigidae) aus dem frühen Pleistozän von der Insel Mallorca (Balearen, westliches Mittelmeer) beschrieben. Das Material stammt von einer Fossilvergesellschaftung in einem zusammengefallenen Gang des Höhlensystems Cova des Pas de Vallgornera (Llucmajor, im Süden von Mallorca), dem ausgedehntesten bislang bekannten karstartigen Systems auf den Balearen. Weitere Funde in dieser fossilen Ansammlung konnten anderen primitiven Vertretern der endemischen Insel-Fauna zugeordnet werden (Myotragus, Hypnomys, Nesiotites), wie auch Überresten von Fledermäusen und Vögeln (darunter *Tyto balearica*), Eidechsen und Kröten. Obwohl nur zwei Knochen von *Athene* gefunden wurden, ermöglichen deren höchst eindeutiger kurzer, außergewöhnlich robuster und besonders kleiner Tarsometatarsus eine klare Unterscheidung von den anderen existierenden und ausgestorbenen *Athene*-Arten aus der Paläarktis und rechtfertigen deshalb die Beschreibung als neue Art. Damit sind jetzt mindestens vier *Athene*-Arten aus dem Mittelmeerraum bekannt, von denen zwei Gruppen anhand der Form ihrer Tarsometatarsi identifiziert werden können.

Introduction

The present paper concerns the study of the fossil remains of a little owl coming from the Early Pleistocene site of Cova des Pas de Vallgornera (Llucmajor, Mallorca)

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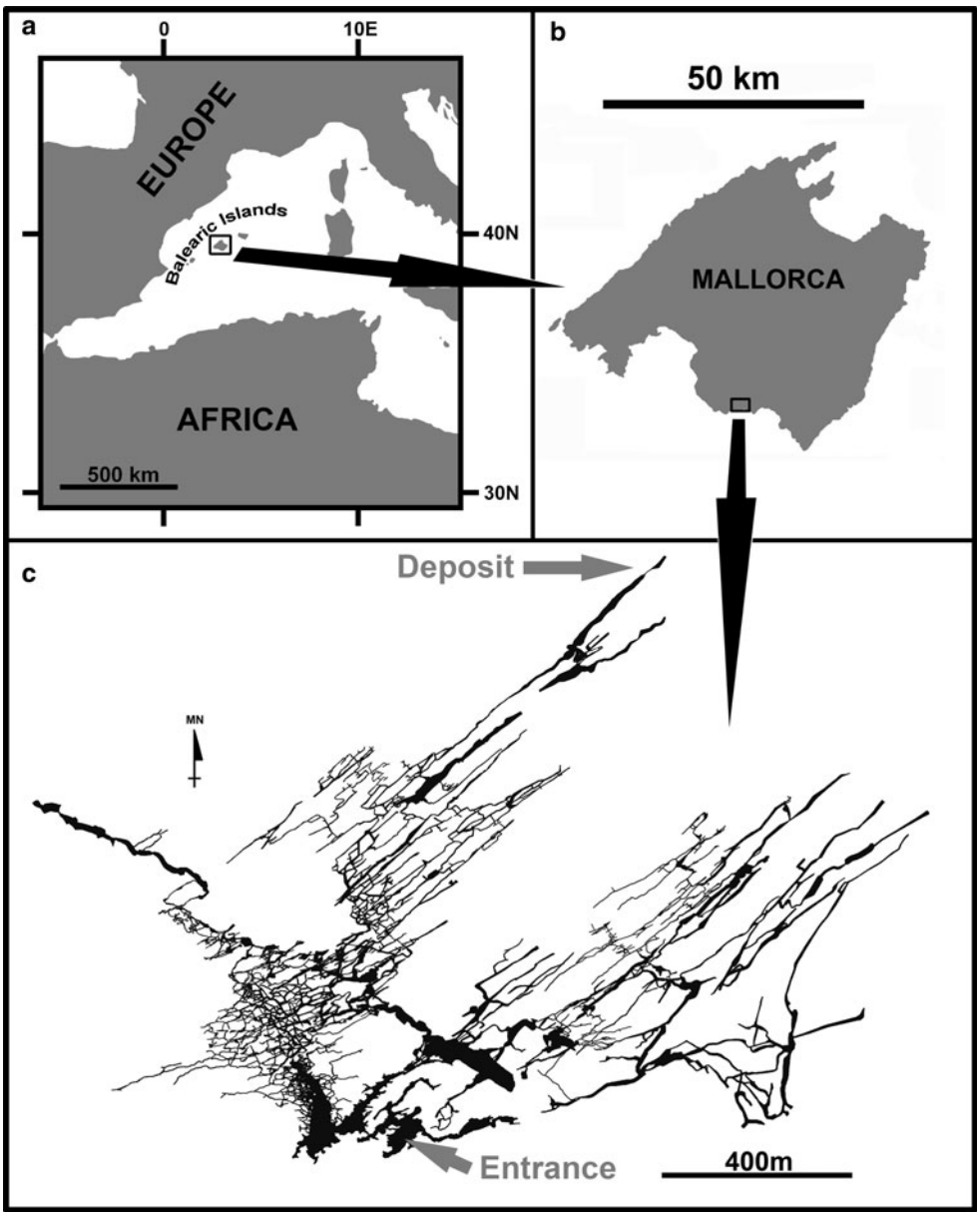

Fig. 1 Location of the Cova des Pas de Vallgornera (**a, b**). Topographic survey of the cave (**c**) redrawn from Gràcia et al. (2009). Topographic survey by the Balearic Federation of Speleology (FBE). *Grey arrows* indicate the location of the fossiliferous deposit and the sole current entrance (human-made) of the cave

(Fig. 1). This site is an extensive maze cave (65 km explored), partially drowned by brackish phreatic water, that lies in a tabular platform built up by an Upper Miocene reef limestone sequence (Fornós et al. 2010). Its exploration allowed the discovery of a rich early Lower Pleistocene deposit at the end of a gallery ("Galeria del Tragus"). The gallery runs in a southwest–northeast direction with a length of 300 m, average width of 18 m and height of 20 m in the so-called "Sector Descobriments 2004" (Merino et al. 2006). A smaller final chamber, the "Sala del Col·lapse" (Collapse Hall), accessed through a narrow passage, displays a huge collapse of blocks sealing the alleged former entrance through which the original specimen is presumed to have gained entry. Among the fossils obtained there, three bones belonging to Strigiformes have been identified. One of them is a complete ulna of *Tyto balearica.* The other two represent a new and so far undescribed species of genus *Athene* and were located at the Collapse Hall, in the surface level of reddish sandy silts.

The presence of endemic Strigiformes is a characteristic trait of the Pleistocene fauna from the Mediterranean islands. Fossil endemic species have been described on Crete (*Athene cretensis*, Late Pleistocene, Weesie 1982), Corsica and Sardinia (*Bubo insularis*, Late Pleistocene, Mourer-Chauviré and Weesie 1986; *Athene angelis*, Middle and Late Pleistocene, Mourer-Chauviré et al. 1997), and Sicily (*Athene trinacriae*, Middle Pleistocene,

Pavia and Mourer-Chauviré 2002; *Tyto mourerchauvireae*, Middle Pleistocene, Pavia 2004; *Aegolius martae*, early Middle Pleistocene, Pavia 2008). A high diversity of endemic insular species of Strigiformes is also a characteristic of other archipelagos (e.g. West Indies, Arredondo 1976) and periods (e.g. Gargano, Upper Pliocene, Ballmann 1973, 1976). On islands, in the absence of autochthonous Carnivora, birds frequently monopolise the predatory guilds (e.g. Alcover and McMinn 1994), and evolve to be adapted to the peculiar insular ecological conditions (e.g. Pavia and Mourer-Chauviré 2002; Louchart 2005), changing their body size and proportions.

Four species of Strigiformes have been recorded so far as fossils in Mallorcan Quaternary sites: (1) *Tyto balearica*, obtained in different Early and Middle Pleistocene sites (Mourer-Chauviré et al. 1980; Ballmann and Adrover 1970); (2) *Tyto alba*, recorded in Late Pleistocene and Holocene deposits (Mourer-Chauviré et al. 1977; McMinn and Alcover 1992); (3) *Otus scops*, recorded from the Middle and Late Pleistocene, and with doubt (as *Otus* cf. *scops*) from an Early Pleistocene site (Mourer-Chauviré in Alcover et al. 1981; Seguí et al. 1997); and (4) *Athene noctua*, recorded at the Late Pleistocene (Seguí et al. 1997). A fifth reported species, initially identified as *Strix aluco* (Ballmann and Adrover 1970), was later tentatively referred to *Tyto balearica* (see Mourer-Chauviré et al. 1980).

Little owls (genus *Athene*) seem to speciate particularly rapidly under genetic isolation on islands, as documented by the presence of at least three different fossil species of the genus on several Mediterranean islands. Currently, the European Little Owl *Athene noctua*, the sole western Palaearctic species of the genus, occurs over the whole of Europe except for northern areas, Corsica and the Balearic Islands.

Methods

A complete right tarsometatarsus and a pedal phalanx curated at the Vertebrate Collection of the Mediterranean Institute for Advanced Studies (Acronym: IMEDEA), under accession numbers IMEDEA-91958 and IMEDEA-91897, respectively, have been studied.

A direct comparison with all the small- and middle-sized living Strigidae from the western Palaearctic has been carried out. The material has also been compared with the Pleistocene species of *Athene*. Measurements follow the criteria of Campbell and Bocheński (2010). Corresponding bone measurements from Weesie (1982), Mourer-Chauviré et al. (1997) and Pavia and Mourer-Chauviré (2002) have been used in the comparisons. Anatomical nomenclature follows Livezey and Zusi (2006).

Systematic palaeontology

Class Aves Linnaeus, 1758
Order Strigiformes Wagler, 1830
Family Strigidae Leach, 1819
Genus *Athene* Boie, 1822
Athene vallgornerensis nov.sp.

Holotype IMEDEA-91958, complete right tarsometatarsus (Fig. 2a).

Referred material IMEDEA-91897, near complete terminal phalanx, broken at its distal apex (Fig. 3a).

Etymology The specific name *vallgornerensis* derives from the locality name, Cova des Pas de Vallgornera.

Type locality Cova des Pas de Vallgornera, Llucmajor, Mallorca, Balearic Islands.

Age The fossil assemblage is attributed to MN17 (i.e. Early Pleistocene according to the Gibbard et al. 2010 update of the Quaternary base).

Distribution Only known from its type locality.

Diagnosis Species of *Athene* of small size with a tarsometatarsus shape and general aspect similar to *Athene noctua*, but characteristically shorter and more robust. It presents a well-developed *cotyla lateralis* with a narrow lateral extension and a well-developed *crista medialis hypotarsi* that is caudally oriented. In proximal view, a deep *sulcus hypotarsi* slightly laterally oriented. Remarkably massive *trochlea metatarsi*.

Differential diagnosis Major differences between IMEDEA-91958 and the four species of the same genus compared (*A. noctua*, *A. cretensis*, *A. angelis* and *A. trinacriae*, representing all the living and extinct western Palaearctic species of *Athene*) are mainly in terms of size and proportions. Additionally, in lateral view, the lateral extension of the *cotyla lateralis* is wider in *A. angelis*, and *A. cretensis* while in *A. noctua* and in IMEDEA-91958 it is narrower. The *crista medialis hypotarsi* is more developed in *A. trinacriae* and *A. angelis* and it is more caudally oriented in *A. angelis* and *A. vallgornerensis*. The proximal end of the tarsometatarsus is more robust in *A. cretensis* than in the remaining species, *A. vallgornerensis* included. The *trochlea metatarsi* are, in relation to the length of the bone, larger in *A. vallgornerensis* than in *A. noctua* and *A. cretensis*.

Description and comparison

IMEDEA-91958 and *Athene* share the following combination of diagnostic traits. In proximal view, the *sulcus*

Fig. 2 Comparison of the tarsometatarsus of the different species studied in cranial (first or *upper row*), caudal (*second row*), distal (*third row*) and proximal (fourth or *lower row*) views. **a** *Athene vallgornerensis* nov. sp., IMEDEA 91958, right, holotype; **b** *Athene noctua*, IMEDEA 21889, left, inverted; **c** *Athene cretensis*, Li837, left, inverted; **d** *Athene angelis*, cast, right; **e** *Otus scops*, IMEDEA 21868, right; **f** *Asio otus*, IMEDEA 12520, left, inverted; **g** *Asio flammeus*, IMEDEA 20671, right; **h** *Strix aluco*, IMEDEA 11975, right; **i** *Surnia ulula*, IMEDEA 21824, left, inverted; **j** *Aegolius funereus*, IMEDEA 21822, right; **k** *Glaucidium passerinum*, IMEDEA 90008, left, inverted

hypotarsi is relatively deep and the *cotyla lateralis* is relatively long and craniocaudally oriented. Both have a second *foramen vasculare distale*, apparently exclusive to *Athene* and some specimens of *Otus scops*. *Athene* and IMEDEA-91958, present a wider and more prominent lateral part of the *trochlea metatarsi III* than its medial part. In lateral view, the *crista medialis hypotarsi* merges gradually into the shaft of the tarsometatarsus. Nevertheless, it differs considerably in size and proportions from all the extant and extinct western Palaearctic *Athene* species, indicating that it definitively belongs to a different taxonomic entity. The *phalanx ungualis* of IMEDEA-91897 displays features identical to *Athene noctua*, but it is larger and more robust.

The two bones obtained in Cova des Pas de Vallgornera differ markedly from the corresponding bones of all the living small- and medium-sized European Strigidae (see Figs. 2 and 3). IMEDEA-91958 is a short and robust tarsometatarsus. *Surnia*, *Aegolius* and *Glaucidium* have a characteristic extremely short and robust tarsometatarsus, but very different from that of IMEDEA-91958. They present a more open *sulcus hypotarsi* than in the fossil specimen, mainly due to a lateral extension of the *cotyla lateralis* that laterally limits the *sulcus*. These three genera have a single *foramen vasculare distale*, while the fossil specimen (like *Athene* and some *Otus*) has a second clearly separated foramen, distally aligned with the first. The fossil also differs from *Aegolius*, *Surnia* and

Fig. 3 Comparison of the terminal phalanx of the different species studied in lateral view. **a** *Athene vallgornerensis* nov. sp., IMEDEA 91987; **b** *Athene noctua*, IMEDEA 21717; **c** *Otus scops*, IMEDEA 21868; **d** *Asio otus*, IMEDEA 12520; **e** *Asio flammeus*, IMEDEA 3997; **f** *Strix aluco*, IMEDEA 11975; **g** *Surnia ulula*, IMEDEA 21833; **h** *Aegolius funereus*, IMEDEA 21822; **i** *Glaucidium passerinum*, IMEDEA 90008

Glaucidium in the shape of the lateral extension of the *cotyla lateralis*; in the first two genera, this extension ends wider than in *Athene*. In *Glaucidium*, this extension is very short.

A characteristic feature of the tarsometatarsus of *Otus* is the equally-sized rims of the *trochlea metatarsi III* (Olson 1982). IMEDEA-91958 presents the lateral rim of the *trochlea metatarsi III* wider and more prominent than its medial part. The *sulcus hypotarsi* is more closed in *Otus* than in the fossil specimen. In lateral view, the *crista medialis hypotarsi* merges into the shaft of the tarsometatarsus more abruptly than in the fossil. The tarsometatarsi of *Asio* and *Strix* differ from IMEDEA-91958 in their greater length and robustness, and their *sulci hypotarsorum* are more open. The tarsometatarsi of the species of these genera display a deeply excavated cranial surface, while in the fossil specimen it is flat, as in *Athene noctua*.

Despite the *phalanx ungualis* having few diagnostic traits, some differences between IMEDEA-91897 and the remaining western Palaearctic Strigidae can be observed (Fig. 3). In ventral view, in *Aegolius* and *Surnia*, the *tuberculum flexorium* is more prominent than in *Athene* and IMEDEA-91897. *Otus* has the *tuberculum flexorium* shallower than IMEDEA-91897 and the complete phalanx is very straight. The *phalanx ungualis* of *Asio* is remarkably straighter than in the fossil and in *Athene*. Additionally, in *Asio* and *Strix*, the distance between *tuberculum flexorium* and the body of the claw is proportionately much smaller than in the fossil and in *Athene*.

On the basis to their morphological characteristics, both Strigidae bones obtained from Cova des Pas de Vallgornera are attributed to *Athene*. The tarsometatarsus of Strigidae is a highly characteristic bone, and its richness in diagnostic features has made it a suitable bone to be used in taxonomical analysis. Within *Athene*, the tarsometatarsus IMEDEA-91958 differs from all living and extinct western Palaearctic species, representing a new species as described here.

The size and proportions of IMEDEA-91958 were compared with the tarsometatarsus of extant and extinct western Palaearctic species of *Athene* (Table 1). IMEDEA-91958 is c. 20% shorter than *A. noctua* (i.e. comparing total length, TL, of both species; TL *A. vallgornerensis*/TL *A. noctua* × 100–100), but 37% more robust (i.e. comparing robustness indexes, RI, of both species; RI *A. vallgornerensis*/RI *A. noctua* × 100–100). The tarsometatarsus of *Athene*

Table 1 Mesurements (in mm) of the tarsometatarsi of *A. vallgornerensis* nov.sp. and middle- and small-sized western Palaearctic strigids for comparison

Measurement	*Athene vallgornerensis*	*Athene noctua*			*Athene cretensis*			*Athene angelis*		
	nov.sp.	Range	Mean	*n*	Range	Mean	*n*	Range	Mean	*n*
TL	28.6	34.8–37.4	35.66	5	39.2–46.7[a]	42.18[a]	46	38.3–40.7[a]	39.39[a]	8
PW	6.5	6.4–6.8	6.62	5	7.7–7.9	7.8		8.2		
HL	3	2.9–3.6	3.18	5	3.4–3.8	3.6		4.2		
HW	1.5	1.6–2	1.72	5	1.9–2	1.95		2.1		
mWS	3.5	3–3.6	3.18	5	3.2–4.0[a]	3.58[a]	46	4.1–4.6[a]	4.29[a]	12
DW	7	6.9–7.3	7.14	5	8–8.3	8.15		9.1		
RI	12.24	8.45–10.34	8.93	5	7.71–9.51	8.50	46	10.25–11.8	10.95	8

Measurement	*Athene trinacriae*			*Otus scops*			*Asio otus*			*Asio flammeus*		
	Range	Mean	*n*	Range	Mean	*n*	Range	Mean	*n*	Range	Mean	*n*
TL	39.6–42.7[b]	40.9[b]	7	24–26.9	25.50	5	36.6–40	38.32	5	42.3–44.6	43,45	2
PW	6.7–7[b]	6.85[b]	4	4.6–5.1	4.86	5	7.7–8.5	8.12	5	8–9	8,50	2
HL				2.4–3.1	2.58	5	4.4–4.8	4.62	5	4.5–4.7	4,60	2
HW				1.3–1.6	1.46	5	1.7–2	1.80	5	2–2.1	2,05	2
mWS	2.9–3.7[b]	3.16[b]	7	2.4–2.6	2.46	5	4.1–4.4	4.30	5	4.6–4.8	4,70	2
DW	7.2–8[b]	7.52[b]	5	5–5.8	5.36	5	9.1–10	9.48	5	9.6–10.4	10,00	2
RI	6.57–9.07	7.71	7	9.34–9.88	9.65	5	10.99–11.83	11.23	5	10.76–10.87	10,82	2

Measurement	*Strix aluco*			*Surnia ulula*			*Aegolius funereus*			*Glaucidium passerinum*
	Range	Mean	*n*	Range	Mean	*n*	Range	Mean	*n*	
TL	47.2–49	48.03	3	25.4–25.9	25.70	3	22.2–23.4	22.67	3	16.7
PW	9.4–9.6	9.53	3	8.5–9	8.80	3	5.7–6.4	6.00	3	5.2
HL	5.2–5.8	5.53	3	4.3–4.5	4.37	3	2.9–3.5	3.23	3	2.8
HW	2.3–2.6	2.43	3	2.2–3.2	2.73	3	1.3–1.6	1.40	3	1.2
mWS	5–5.3	5.13	3	5.7–5.9	5.77	3	3.4–4.1	3.70	3	3.2
DW	10.8–11.4	11.03	3	10.2–10.5	10.33	3	6.3–7.4	6.80	3	5.4
RI	10.20–11.23	10.69	3	22.09–22.78	22.44	3	15.32–17.52	16.30	3	19.16

TL total length, *PW* proximal width, *HL* hypotarsus length, *HW* hypotarsus width, *mWS* minimum shaft width, *DW* distal width, *RI* robustness index (mWS/TL × 100)

[a] Data obtained from Mourer-Chauviré et al. (1997)

[b] Data obtained from Pavia and Mourer-Chauviré (2002)

angelis from Corsica is large (36% longer than *A. vallgornerensis* nov.sp., 9% longer than *Athene noctua*) and robust (32% more than *A. noctua*). Remarkably, the degree of robustness is very similar in *A. vallgornerensis* and *A. angelis*, giving them a similar appearance. The two other insular species, *A. trinacriae* and *A. cretensis*, have a much longer and more slender tarsometatarsus (Fig. 2).

Two subspecies of *A. noctua* have been described from the European Plio-Pleistocene: *A. n. lunellensis* (Middle Pleistocene, Mourer-Chauviré 1975) and *A. n. veta* (Late Pliocene–Early Pleistocene, Jánossy 1974). The measurements of the sole tarsometatarsus attributed to *A. noctua lunellensis* by Mourer-Chauviré (1975) are remarkably greater than *A. vallgornerensis*. *A. noctua veta* was described based on a fragment of coracoid (Jánossy 1974) from Rebielice Krolewskie in Poland, but it was later synonymized to *Aegolius funereus* (Mlìkovský 1992).

Weesie (1999) obtained an *Athene* sp. left tarsometarsus of small size in Su Corbeddu Cave (Late Pleistocene, Sardinia), and suggested that it could represent a new undescribed insular form. Nevertheless, Pavia and Mourer-Chauviré (2002) considered that it could be assigned to *A. noctua*. Consequently, this material has been discarded for comparison. Alcover (1989) reported *Athene* cf. *veta* from the Late Pliocene–Early Pleistocene of Cova de Ca Na Reia, Eivissa, but it was not figured and the fossil has not been located.

The phalanx IMEDEA-91897 has a similar shape to *Athene noctua*, although it is larger (Fig. 3). No phalanges of the three insular species of *Athene* described are available for comparative purposes.

Discussion

Although IMEDEA-91958 is the sole large bone recovered of *Athene vallgornerensis*, it differs considerably, in size or shape, from the remaining extant and extinct *Athene* species. Although the size differences between IMEDEA-91958 and *A. angelis* are remarkable, the great similarity of their shape suggests that they could have shared a common ancestor (Fig. 2). The Pleistocene fauna from Corsica–Sardinia and Mallorca–Menorca share some mammalian taxa (e.g. shrews derived from mainland *Asoriculus*, related glirids and the closely related bovids *Nesogoral* and *Myotragus*) and both islands are situated in the western Mediterranean Sea, suggesting that they were settled by closely related fauna. In contrast, the Pleistocene mammalian fauna from Sicily and Crete does not share taxa closely related to the Mallorcan one. The emerging insular *Athene* species distribution pattern, with *A. vallgornerensis–A. angelis* displaying the highest similarities, fits well with these data. The presence of *Athene vallgornerensis* in Mallorca improves the knowledge of the evolution of little owls on the Mediterranean islands, where two main types of insular little owls seem to have evolved, one displaying a short and robust tarsometatarsus (*A. angelis* and *A. vallgornerensis* nov.sp.) and the other with a slender and longer tarsometatarsus (*A. cretensis* and *A. trinacriae*). The relatively long legs of *A. cretensis* and *A. trinacriae*, associated with relatively shorter wings, have been interpreted elsewhere as indicative of a more terrestrial life-style than *Athene noctua* (Weesie 1982; Pavia and Mourer-Chauviré 2002; Louchart 2005). Long legs are also characteristic of *A. cunicularia*, the Burrowing Owl, a species displaying terrestrial habits, while *A. angelis* should have had a less terrestrial life-style, according to its body shape and proportions (Louchart 2005). The life-style of *A. vallgornerensis* remains unknown.

A. vallgornerensis nov.sp. represents the fifth species of Strigiformes reported as fossil material in Mallorca. This Early Pleistocene Mallorcan representative of the genus *Athene* is unknown from the late Pleistocene and Holocene sites, as also happens with *Tyto balearica*.

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