Rivista Italiana di Paleontologia e Stratigrafia	volume 116	no. 1	1 pl.	pp. 119-138	March 2010

LATEGLACIAL BATS FROM THE "M" LAYERS OF THE ARENE CANDIDE CAVE (LIGURIA, ITALY)

LEONARDO SALARI

Received: December 17, 2009; accepted: March 9, 2010

Key words: Arene Candide Cave, North Italy, bats, Late Pleistocene, micro-climate, environment, human activities.

Abstract. The Arene Candide Cave (Finale Ligure, Northern Italy) is considered one of the most important prehistoric site in Italy. The archaeological excavations conducted by the "Istituto Italiano di Paleontologia Umana" of Rome revealed 3 different horizons: an upper horizon with Holocene human presence dated from the Neolithic to the Byzantine period, and two underlying Pleistocene horizons with Gravettian and Epigravettian lithic artefacts. The stratigraphical sequence of the upper Palaeolithic is divided in two groups of strata separated by a depositional gap: the "P" complex, divided in 13 layers, dated from 25,620 to 18,560 years BP, and the 5 "M" layers dated between 11,750 and 9,980 years BP (^{14}C non-calibrated dating).

In this paper the fossil bone remains of bats from "M" layers are described. Fifteen taxa, divided into 3 families and 6 genera have been identified: *Rhinolophus ferrumequinum*, *R. mehelyi*, *R. euryale*, *R. hipposideros*, *Myotis myotis*, *M. blythii*, *M. capaccinii*, *M. emarginatus*, *M. mystacinus* s.l., *Myotis* sp. (small sized), *Plecotus auritus* s.l., *Nyctalus lasiopterus*, *N. noctula*, *Barbastella barbastellus* and *Miniopterus schreibersii*. Comments for each of these taxa on current ecological and geographical distributions are presented, together with some osteometric measures and recent data referred to Late Pleistocene fossils bats in Italy. Finally, the value of this bat tanathocoenoses as a microclimatic, environmental, and human activity indicators is discussed.

Riassunto. La Caverna delle Arene Candide (Finale Ligure, Italia settentrionale) è considerata uno dei più importanti giacimenti preistorici italiani. Gli scavi archeologici, condotti dall'Istituto Italiano di Paleontologia Umana di Roma, hanno evidenziato 3 diversi orizzonti: un orizzonte superiore, olocenico, con frequentazioni umane dal Neolitico al periodo Bizantino, e due orizzonti pleistocenici con industria litica gravettiana ed epigravettiana. La sequenza stratigrafica del Paleolitico superiore è divisa in due gruppi di strati separati da una discontinuità stratigrafica: il complesso "P", suddiviso in 13 livelli e datato tra 25.620 e 18.560 anni fa, e i 5 livelli "M", datati tra 11.750 e 9.980 anni fa (^{14}C non calibrato).

In questo articolo sono esposti i dati relativi ai resti ossei di chirotteri provenienti dai livelli "M", riferiti alle fasi finali del Pleistocene superiore, momento chiave nei cambiamenti verso l'attuale distribuzione delle chirotterofaune. Sono stati individuati 15 taxa, ripartiti in 3 famiglie e 6 generi: *Rhinolophus ferrumequinum*, *R. mehelyi*, *R. euryale*, *R. hipposideros*, *Myotis myotis*, *M. blythii*, *M. capaccinii*, *M. emarginatus*, *M. mystacinus* s.l., *Myotis* sp. (piccola taglia), *Plecotus auritus* s.l., *Nyctalus lasiopterus*, *N. noctula*, *Barbastella barbastellus* e *Miniopterus schreibersii*. Tra questi, due specie non sono più presenti in Italia settentrionale e tre nella Liguria occidentale. Di ogni specie riconosciuta sono presentate alcune note relative alla distribuzione ecologica attuale, alcune misure osteometriche ed una ricognizione delle recenti segnalazioni di resti di chirotteri fossili riferiti al Pleistocene superiore in Italia. Viene, infine, discussa la valenza di questa tanatocenosi a chirotteri quale indicatrice microclimatica, ambientale e delle attività umane.

Introduction

In this paper are described the remains of bats collected in the "M" layers of the Arene Candide Cave in the archaeological excavations carried out by the "Istituto Italiano di Paleontologia Umana" of Rome in the years 1940-50, directed by L. Cardini.

The Arene Candide Cave is situated at about 90 m a.s.l. on the slope of Caprazoppa Mount, facing the Ligurian Sea, near to the city of Finale Ligure (Savona, Northern Italy). Early research and the first excavations undertaken by various researchers (A. Issel, D.G. Perrando, A.G. Barrili, M. Wall, N. Morelli, E.A. D'Albertis, A. Rossi) date from the second half of the XIX century. New and more careful excavations, conducted with stratigraphic methodologies in the years 1940-50 by L. Cardini and L. Bernabò Brea, revealed a stratigraphy comprising 3 different horizons: an uppermost horizon dated Holocene, with pottery levels ranging from the Neolithic to the Byzantine period, and two underlying Late Pleistocene horizons with Upper Palaeolithic lithic industry (Cardini 1941, 1946, 1955, 1980, 1994;

Formerly at the Department of Earth Science, "Sapienza" University of Rome. E-mail: leonardosalari@virgilio.it

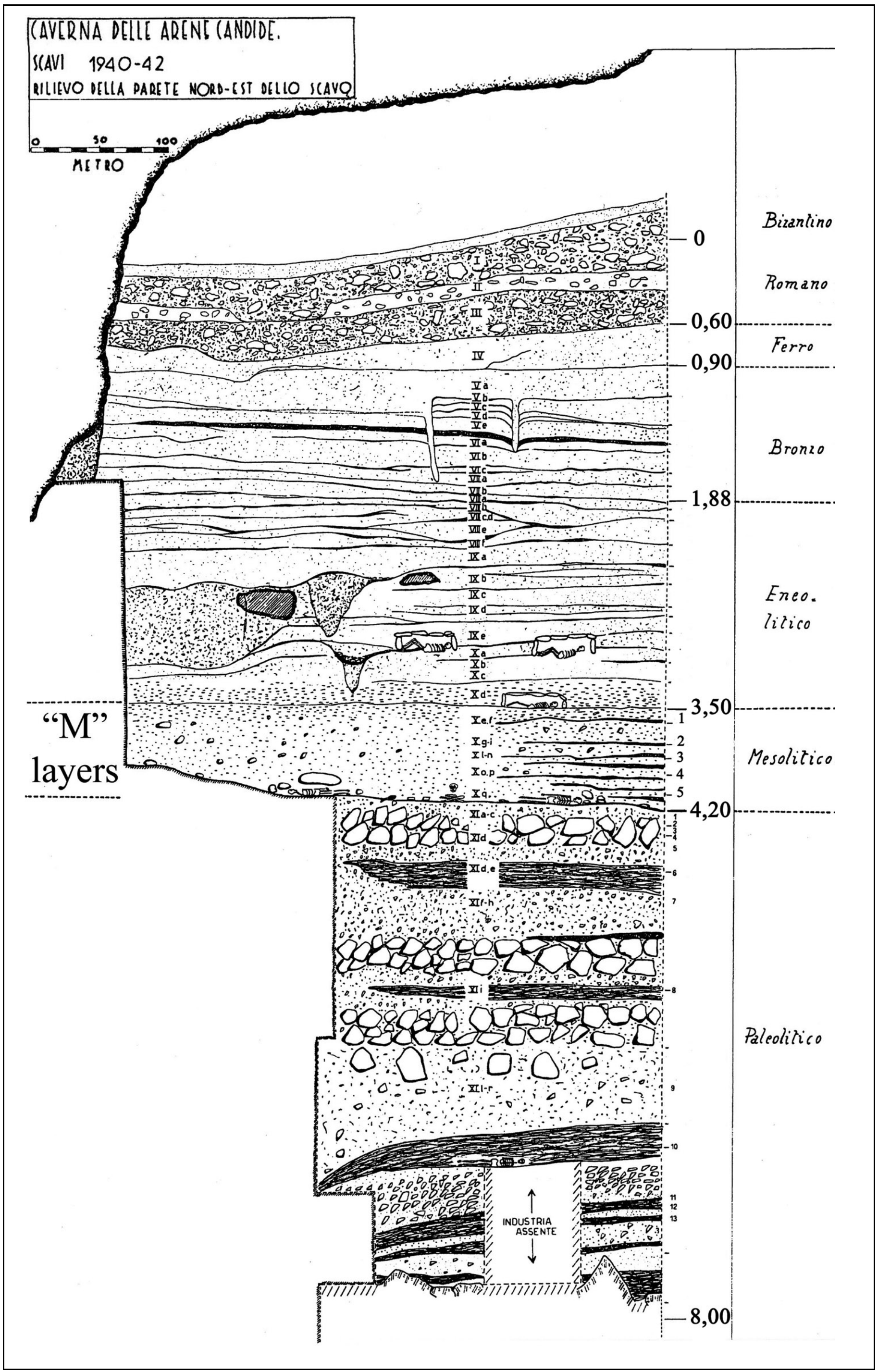


Fig. 1 - Arene Candide Cave: general stratigraphy on the 1940-42 excavations; the depth from the cave's floor are indicated on the right, were are also indicated the layers defined ad the end of the 1942 field season, and later reviewed ("Mesolitico" = "M" layers) (from Bietti & Molari 1994, emended).

Cardini & Biddittu 1967; Bietti 1987, 1994; Bietti & Molari 1994). The site was explored by a trench about 20 m^2 to the NE of the current main entrance, near a big rock pillar. The Late Pleistocene sequence interested a gradually reduced area and has been investigated to a depth of about 8.50 m under the surface. Later excavations conducted by S. Tinè in the years 1972-77 only affected the Neolithic layers; since 2008 new archaeological investigations started in the Palaeolithic layers, coordinated by R. Maggi.

The late Pleistocene sequence is divided into two groups of strata separated by a depositional gap: the lower "P" complex, divided into 13 layers dated between 25,620 ± 320 and 18,560 ± 210 years BP (^{14}C non-calibrated dating), with faunal remains and lithic industry referred to late Gravettian - early Epigravettian at the top of the succession, and the 5 layers of the "M" horizon, with lithic industry referred to late Epigravettian, with abundant faunal remains and with radiometric dating between 11,750 ± 95 and 9,980 ± 140 years BP (^{14}C non-calibrated dating) (Fig. 1). These values indicate the end of the Dryas II cold phase followed by the more temperate Allerød interstadial and the Dryas III cold stage (Bietti & Molari 1994). At the base of the "M" horizon a vast necropolis with at least 15 burials was discovered (Cardini 1980). With regard to the Late Pleistocene fauna, the results of studies concerning several groups are available, such as birds (Cassoli 1980), large mammals (Cassoli & Tagliacozzo 1994) and the taphonomy (Alhaique 1994).

A preliminary report on the bats from Arene Candide Cave was presented at the 6th National Conference of the Italian Archaeozoologists. In the "P" complex were identified *Myotis capaccinii*, *M. mystacinus* s.l., *Myotis* sp. (small sized), *Barbastella barbastellus* and undetermined Vespertilionidae (Salari 2009). This paper presents a more detailed study of the bat remains preserved in the "M" layers.

Materials and Methods

The fossils have been compared with osteological material, both fossil and recent, stored in the Department of Earth Sciences of the University of Rome "Sapienza", in the Department of Geological Sciences of the "Roma Tre" University and in the Laboratory of Quaternary Palaeontology and Archaeozoology of the National Museum of Prehistory and Ethnography "Pigorini" of Rome. The morphological and morphometrical observations and the measures given by Miller (1912), Lanza (1959), Topál & Tusnadi (1963), Menu & Sigé (1971), Felten et al. (1973), Sevilla García (1988), Sevilla & Lopez-Martinez (1988), Ruedi et al. (1990), Popov & Ivanova (2002), and Salari (2004) were also considered.

The morphological and morphometrical observations were performed with a stereoscopic microscope. The analyzed material was chosen on the basis of its systematic importance and consists of some skulls and fragments of skull, several maxillaries, numerous mandibles and mandible fragments, rare isolated teeth, numerous humeri and a high number of distal portions of humeri. Other skeletal parts (eg. radii, scapulae, metacarpals, coxal) while identify at family or genus level or even at a species level, were not considered because it would altered the statistical processing at the expense of the small sized species, probably under-represented for taphonomic reasons. Their small and fragile skeletal elements, in fact, are more frequently subject to the processes of differential destruction than those of larger species.

Each taxon was quantified both in numbers of remains (NR) (Tab. 1) and in the minimum number of individuals (MNI) (Tab. 2) and, when ever possible, osteometrical data and the size of the populations are given. Since most of the maxillas and mandibles only preserved the molar teeth, alveolar measurements are also given. In the tables (Tabs. 3-8), the following abbreviations were used for skull, mandible and humerus dimensions of the examined specimens: L = maximum length; C-C = rostral width between upper canines (incl.); M3-M3 = rostral width between third upper molars (incl.); C-M3 = length of upper tooth-row between CM3 (incl.); M1-M3 = length of upper molars (incl.); c-m3 = length of lower tooth-row between cm3 (incl.); m1-m3 = length of lower molars (incl.); Bd = distal breadth. Other abbreviations: min = minimum; max = maximum; mea = mean; s.d. = standard deviation.

Figure 2 shows the main Italian sites where late Pleistocene bat fossils have been recovered. The data concerning levels, about contemporary to the "M" horizon of the Arene Candide, are shown for osteometric comparisons, particularly from Grotta della Madonna (layer "L"), Grotta delle Mura (layer 3) and Grotta Continenza (cuts 43-30) (Tabs. 3-8).

Systematic Palaeontology

Order **Chiroptera** Blumenbach, 1779

Suborder **Microchiroptera** Dobson, 1875

Family Rhinolophidae Gray, 1825

Genus *Rhinolophus* Lacépède, 1799

Rhinolophus ferrumequinum (Schreber, 1774)

Pl. 1, figs 1, 4

Material: three fragmentary maxillaries, 20 mandibles of which 13 are fragmentary, 6 humeri and 23 distal portions of humeri.

Tab. 1 - Arene Candide Cave, "M" layers, Late Pleistocene, Chiroptera: numbers of bone remains determined (NR).

	M1	M1	M2	M2	M3	M3	M4	M4	M5	M5	Total	Total
Taxon	NR	%	NR	%	NR	%	NR	%	NR	%	NR	%
Rhinolophus ferrumequinum	22	3.5	8	5.9	14	5.0	6	3.2	2	3.8	52	4.0
Rhinolophus euryale	7	1.1	5	3.7	5	1.8	2	1.1			19	1.5
Rhinolophus mehelyi	50	7.9	8	5.9	25	9.0	21	11.3			104	8.1
Rhinolophus euryale/mehelyi	6	0.9			2	0.7					8	0.6
Rhinolophus hipposideros	2	0.3			1	0.4	1	0.5	3	5.8	7	0.5
Myotis myotis			2	1.5							2	0.2
Myotis blythii	372	58.9	79	58.5	173	62.0	127	68.3	38	73.1	789	61.4
Myotis capaccinii	3	0.5	1	0.7	3	1.1			1	1.9	8	0.6
Myotis emarginatus									2	3.8	2	0.2
Myotis mystacinus s.l.	1	0.2									1	0.1
Myotis sp.	1	0.2	2	1.5			2	1.1			5	0.4
Nyctalus lasiopterus			1	0.7							1	0.1
Nyctalus noctula									1	1.9	1	0.1
Plecotus auritus s.l.					1	0.4					1	0.1
Barbastella barbastellus	3	0.5	1	0.7	1	0.4	2	1.1	2	3.8	9	0.7
Miniopterus schreibersii	165	26.1	28	20.7	54	19.4	25	13.4	3	5.8	275	21.4
Total	632	100	135	100	279	100	186	100	52	100	1284	100

Tab. 2 - Arene Candide Cave, "M" layers, Late Pleistocene, Chiroptera: minimum number of individuals (MNI).

	M1	M1	M2	M2	M3	M3	M4	M4	M5	M5	Total	Total
Taxon	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%
Rhinolophus ferrumequinum	6	2.1	4	6.6	6	4.8	2	2.4	1	4.8	19	3.3
Rhinolophus euryale	3	1.0	3	4.9	3	2.4	1	1.2			10	1.7
Rhinolophus mehelyi	28	9.8	5	8.2	12	9.5	11	13.1			56	9.7
Rhinolophus euryale/mehelyi	3	1.0			2	1.6					5	0.9
Rhinolophus hipposideros	1	0.3			1	0.8	1	1.2	2	9.5	5	0.9
Myotis myotis			1	1.6							1	0.2
Myotis blythii	154	53.7	26	42.6	71	56.3	53	63.1	12	57.1	316	54.6
Myotis capaccinii	3	1.0	1	1.6	2	1.6			1	4.8	7	1.2
Myotis emarginatus									1	4.8	1	0.2
Myotis mystacinus s.l.	1	0.3									1	0.2
Myotis sp.	1	0.3	2	3.3			2	2.4			5	0.9
Nyctalus lasiopterus			1	1.6							1	0.2
Nyctalus noctula									1	4.8	1	0.2
Plecotus auritus s.l.					1	0.8					1	0.2
Barbastella barbastellus	3	1.0	1	1.6	1	0.8	2	2.4	1	4.8	8	1.4
Miniopterus schreibersii	84	29.3	17	27.9	27	21.4	12	14.3	2	9.5	142	24.5
Total	287	100	61	100	126	100	84	100	21	100	579	100

Tab. 3 - Arene Candide Cave, "M" layers, Late Pleistocene, Chiroptera: osteometric measurements (in mm) and comparison with living (measurements from a- Agnelli et al. 2004, b- Benda et al. 2003, and c- Felten et al. 1973) and lateglacial *R. ferrumequinum* (measurements from Salari & Di Canzio 2009 and Salari in press).

	Caverna delle Arene Candide					Grotta della Madonna		Grotta delle Mura		Grotta Continenza		Today	
	N	min	max	mea	s.d.	N	min-max	N	min-max	N	min-max	min-max	
Rhinolophus ferrumequinum													
C-M3	2	8.4	8.6	8.5	0.14							8.0-9.5 8.3-9.1	a b
M1-M3	3	5.0	5.5	5.3	0.29								
L. mandible	7	15.0	15.2	15.1	0.10					2	15.0-15.2	14.9-16.5	b
c-m3	16	8.8	9.3	9.1	0.16					3	8.8-9.2	8.7-9.7	b
m1-m3	18	5.8	6.5	6.1	0.16			1	6.2	4	6.0-6.2		
L. humerus	6	32.8	34.0	33.7	0.43					3	32.8-34.4		
Bd humerus	29	4.9	5.4	5.1	0.10	3	5.0-5.2	3	5.1-5.2	4	5.0-5.2	~ 5.1	c

Description and remarks. The morphology is typical of the genus *Rhinolophus*, the large size (Tab. 3) enables a definite attribution to the Big Horseshoe Bat. The measurements of the material fall within the range of variability of the living species and, in some cases, increase the variability of the lateglacial *R. ferrumequinum*.

The earliest records of fossils referred to *R. ferrumequinum* come from Pirro Nord (Apricena, Apulia), early Pleistocene (Tata & Kotsakis in press; Salari et al. in press). During the late Pleistocene this species is quite common in Portugal, Spain, France, England, Switzerland, Austria, Hungary, former Yugoslavia, Bulgaria, Greece, Russia, Armenia, Azerbaijan, Israel and other Eurasian localities (Capasso Barbato & Kotsakis 1986 with references; Sevilla & Chaline 2004; Sevilla et al. 2008; Salari & Di Canzio 2009 with references); in Italy the species is present in the localities of Isola di Palmaria, Covolo di Trene, Grotta di Paina, Grotta del Broion, Grotta della Ferrovia, Grotta di Monte Cucco, Grotta Continenza, Grotta di Cittareale, Grotta Polesini, Grotta Breuil, Riparo Salvini, Grotta S. Agostino, Grotta Cola, Grotta delle Mura, S. Maria di Agnano, Grotta della Madonna, Grotta Corbeddu and around of Alghero (Fig. 2 with references).

Today's range of distribution includes Central Europe, extending from Southern England and the Mediterranean basin through Asia to Japan. In Italy this species occurs in all regions (Horáček et al. 2000; Csorba et al. 2003; Agnelli et al. 2004).

R. ferrumequinum is a species of Mediterranean affinities, with preference for warm and open areas with trees and shrubs (vegetation mosaics), in limestone areas close to wetlands. The summer retreats of the species are found in buildings, rock crevices, hollow trees, caves and mine galleries, hibernation takes place in natural and artificial cavities with temperatures of about 7-12 °C (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002; Csorba et al. 2003).

	Caverna delle Arene Candide					Today	
	N	min	max	mea	s.d.	min-max	
Rhinolophus euryale							
C-M3	1			6.4		6.2-6.4 5.7-6.6	a b
M1-M3	2	3.7	4.0	3.9	0.21	3.7-4.1	d
L. mandible	2	11.4	11.6	11.5	0.14	10.8-12.2	b
c-m3	2	6.2	6.4	6.3	0.14	5.9-6.9	b
m1-m3	2	4.2	4.6	4.4	0.28	4.3-4.7	d
L. humerus	2			27.4			
Bd humerus	15	4.2	4.4	4.3	0.08	~ 4.3	c

Tab. 4 - Arene Candide Cave, "M" layers, late Pleistocene, Chiroptera: osteometric measurements (in mm) and comparison with extant *R. euryale* (measurements from a- Agnelli et al. 2004, b- Benda et al. 2003, c- Felten et al. 1973, and d- Popov & Ivanova 2002).

Rhinolophus euryale Blasius, 1853

Pl. 1, figs 2, 5

Material: two fragmentary maxillaries, 2 mandibles, 2 humeri and 13 distal portions of humeri.

Description and remarks. The morphology of maxillaries, mandibles and humeri is typical for the genus *Rhinolophus*. Some morphological features permit a secure attribution to *R. euryale* and not to other intermediate size species of the genus: the upper canine is robust, with trapezoidal occlusal outline and with a clear longitudinal groove in labial view, the upper molars have a distal concave edge and the labial cingulum is very prominent, and the mental foramen of the mandible is placed under p2 (see Sevilla García 1988; Sevilla & Lopez-Martinez 1988); the styloid process of the humerus is relatively long and thin, and in lateral view slightly dorsally inclined (Felten et al. 1973). The dimensions fall within the variability of living species (Tab. 4).

Fossil bats referred to *Rhinolophus* gr. *R. euryale* are known from the Early Pliocene in Bulgaria (Salari et al. in press). In the late Pleistocene the Mediterranean Horseshoe Bat is present in various sites in Spain, France, Poland, Hungary, former Yugoslavia, Bulgaria, Malta, Israel (Salari & Di Canzio 2009 with references) and in Italy at Grotta di Gabrovizza, Riparo Mezzena, Covolo di Trene, Grotta Polesini, Grotta Breuil and S. Maria di Agnano (Fig. 2 with references).

Today's range of distribution includes Southern Europe, South-Western Asia and North-Western Africa. In Italy this species occurs throughout the territory with the probable exception of some northern regions (Horáček et al. 2000; Csorba et al. 2003; Agnelli et al. 2004).

R. euryale is a species of strict Mediterranean affinities and prefers warm areas with abundant shrub or forest (deciduous), in areas rich in limestone caves and close to water environments. During the summer the roosts are located in caves mainly in warmer parts of the cavities; in winter it finds refuge in caves and mine galleries, preferably at temperatures around 10-12 °C (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002; Csorba et al. 2003).

Rhinolophus mehelyi Matschie, 1901

Pl. 1, figs. 3, 6

Material: one fragmentary maxillary, 4 mandible fragments, one humerus and 98 distal portions of humeri.

Description and remarks. This material has the typical form of the genus *Rhinolophus*. Some morphological features permit a secure attribution to *R. mehelyi* and not to other intermediate size species of the genus: the upper canine without longitudinal grooves in labial view, the upper molars with distal edge slightly concave and labial cingula accentuated, mental foramen of the mandible placed under the anterior part of p2; the p4 is robust and subrectangular with a pyramidal cusp, the cingulum shows two convexities separated by a shallow concavity in labial view (see Sevilla García 1988; Sevilla & Lopez-Martinez 1988); the styloid process is parallel to the axis of the humerus (see Felten et al. 1973). The dimensions of the material assigned to *R. mehelyi* agree with the variability of the living species (Tab. 5).

	Caverna delle Arene Candide					Grotta Continenza		Today	
	N	min	max	mea	s.d.	N	min-max	min-max	
Rhinolophus mehelyi									
C-M3	1			7.0				6.7-7.4 6.6-7.0	a b
M1-M3	1			4.2				4.1-4.4	d
L. mandible								12.2-13.1	b
c-m3	3	7.2	7.4	7.3	0.12			6.8-7.4	b
m1-m3	3			5.0				4.8-5.1	d
L. humerus	1			30.0					
Bd humerus	98	4.5	4.7	4.6	0.07	1	4.6	~ 4.5	c
Rhinolophus hipposideros									
L. humerus	4	22.8	23.1	23.0	0.17				
Bd humerus	7	3.1	3.3	3.2	0.07	1	3.1	~ 3.1	c

Tab. 5 - Arene Candide Cave, "M" layers, late Pleistocene, Chiroptera: osteometric measurements (in mm) and comparison with extant (measurements from a- Agnelli et al. 2004, b- Benda et al. 2003, c- Felten et al. 1973, and d- Popov & Ivanova 2002) and lateglacial *R. mehelyi* and *R. hipposideros* (measurements from Salari & Di Canzio 2009).

This species is known for sure from the middle Pleistocene in Spain and Italy, since the subspecies *R. m. birzebuggensis* Storch, 1974 is recognized as a valid species - *R. birzebuggensis* -, while other remains of the Pliocene and early Pleistocene attributed to *Rhinolophus* cf. *mehelyi* and *Rhinolophus* aff. *mehelyi* should be subjected to a systematic review (Tata & Kotsakis in press; Salari et al. in press). During the late Pleistocene *R. mehelyi* is reported in Malta, Spain, France, former Yugoslavia, Bulgaria, Armenia, Azerbaijan (Sevilla & Chaline 2004; Sevilla et al. 2008; Salari & Di Canzio 2009 with references) and in Italy at Borgio, Isola di Palmaria, Grotta del Broion and Grotta Continenza (Fig. 2 with references).

Today's range of distribution is discontinuous and extends through Southern Europe, Northern Africa and South-Western Asia (Horáček et al. 2000; Csorba et al. 2003). In Italy it occurs in Sardinia, Sicily and perhaps in Campania, but previous to 1980 it was also reported in Calabria and Apulia (Lanza & Agnelli 2002; Feola et al. 2003; Agnelli et al. 2004).

A species of strict Mediterranean affinities, with apparently similar habits to those of *R. euryale*, it prefers groves and land covered by tree-shrub vegetation. Both summer and winter roosts are found in caverns, caves and galleries located in limestone areas next to water, with temperatures of 15-24 °C in reproductive colonies and about 11-13 °C in winter (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002; Csorba et al. 2003).

Rhinolophus euryale Blasius, 1853 *vel* **Rhinolophus mehelyi** Matschie, 1901

Material: eight distal portions of humeri without styloid process.

Description and remarks. Being unable to appreciate the inclination of the styloid process and since the overlap in the range of size variability between *R. euryale* and *R. mehelyi*, this material could not be attributed with certainty to either of the two species.

During the late Pleistocene, fossil remains related to *R. euryale vel mehelyi* are reported in France, Spain and a few other sites in the Western Palaearctic (Salari & Di Canzio 2009 with references).

Rhinolophus hipposideros (Bechstein, 1800)

Pl. 1, fig. 7

Material: three humeri and 4 distal portions of humeri.

Description and remarks. The morphology is typical of the genus *Rhinolophus*; the small size (Tab. 5) allows a safe assignment to the Lesser Horseshoe Bat.

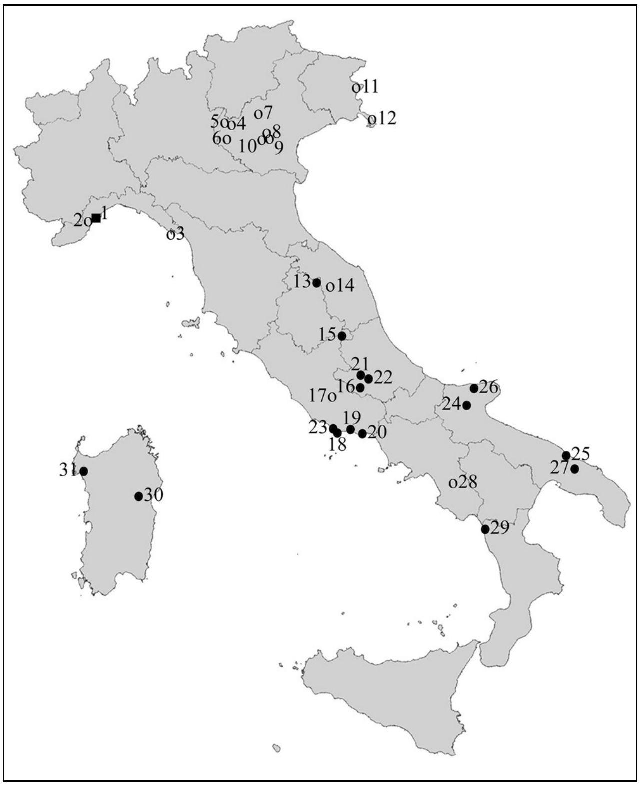


Fig. 2 - Main Italian sites where Late Pleistocene bats fossils have been found: 1) Arene Candide Cave; 2) Borgio (Tozzi 1969); 3) Isola di Palmaria (Cigna et al. 1967); 4) Covoli di Velo (Bona et al. 2006); 5) Grotta A di Veja, 6) Rpari Mezzena e Zampieri, 7) S.Vito di Leguzzano e Grotta Averla, 8) Grotta del Broion, 9) Covolo di Trene, 10) Grotta di Paina, 11) Velika Jama, 12) Grotta di Gabrovizza (Bon et al. 1991); 13) Grotta di Monte Cucco (Capasso Barbato & Kotsakis 1986); 14) Grotta della Ferrovia (Bartolomei 1966); 15) Grotta di Cittareale (Argenti et al. 2008); 16) Grotta Cola (Di Canzio & Petronio 2001); 17) Grotta Polesini (Radmilli 1974); 18) Grotta Breuil (Kotsakis 1991; Salari & Di Canzio 2009); 19) Riparo Salvini (Zhuowei & Kotsakis 2008); 20) Grotta S. Agostino (Tozzi 1970); 21) Grotta Continenza, 22) Grotta di Pozzo, 23) Grotta Barbara, 24) Grotta Paglicci, 25) Grotta delle Mura (Salari & Di Canzio 2009); 26) Ingarano (Petronio & Sardella 1998); 27) S. Maria di Agnano (Angelone et al. 2004; Salari & Di Canzio 2009); 28) Grotta di Castelcivita (Masini & Abbazzi 1997); 29) Grotta del Santuario della Madonna (Salari & Di Canzio 2009; Salari in press); 30) Grotta Corbeddu (Sondaar et al. 1984); 31) near Alghero (Kotsakis 1987). Solid square: Arene Candide; solid circles: fossil remains personally examined or data from publications with descriptions and/or images and/or measures; open circles: data from faunal lists.

R. hipposideros is known from the early Pleistocene from Malta; during the late Pleistocene it is reported in Malta, Spain, France, Poland, Hungary, former Yugoslavia, Bulgaria, Greece, Armenia, Israel (Sevilla et al. 2008; Salari & Di Canzio 2009 with references) and in Italy at Borgio, Covolo di Trene, S. Vito di Leguzzano, Grotta del Broion, Grotta Averla, Grotta

Continenza, Cittareale, Grotta Breuil and in the surroundings of Alghero (Fig. 2 with references).

This species is now distributed through Central and Southern Europe, England and Ireland, South-Central Asia to Kashmir and in North Africa. In Italy *R. hipposideros* occurs in all regions (Horáček et al. 2000; Csorba et al. 2003; Agnelli et al. 2004).

A species of Mediterranean affinities, it prefers warm areas, in environments characterized by alternating groves and open spaces, and wetlands in areas of limestone. Summer roosts and reproductive colonies are located in buildings and attics in colder regions, and in caves and mine galleries in warmer regions. In winter it shelters in caverns, caves, galleries and cellars, preferably at temperatures of 4-12 ° C and high humidity (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002; Csorba et al. 2003).

Family Vespertilionidae Gray, 1821

Genus *Myotis* Kaup, 1829

Myotis sp.

Pl. 1, fig. 11

Material: two fragmentary mandibles without teeth and 3 distal portions of humeri.

Description and remarks. The shape and size of mandibles agree with the smaller species of the genus; both the morphology and dimensions of the humeri can be referred to *M. daubentonii* or *M. emarginatus* or *M. nattereri* (see Felten et al. 1973).

Subgenus *Myotis* Kaup, 1829

Myotis (Myotis) blythii (Tomes, 1857)

Pl. 1, figs 8, 13

Material: one intact skull, 4 sub-intact and other cranial fragments, 20 maxillaries mostly fragmentary, 2 teeth M2, 177 mandibles of which 91 are fragmentary, one tooth m3, 35 humeri and 544 distal portions of humeri.

Description and remarks. The general features of the skull and jaw, dental and distal humerus morphologies relate these anatomical portions to a large sized species of the genus *Myotis*. The only morphological difference between the teeth of *M. myotis* and *M. blythii* is observed on the talonid of m3, that is more reduced in *M. myotis* (Topál & Tusnadi 1963; Sevilla García 1988). The talonid of m3 in the our fossil sample is similar to that of recent *M. blythii* and less reduced than in recent and fossil *M. myotis*. The relatively small size of this material (Tab. 6), including the isolated teeth (M2 length 2.3 mm, width 2.7 mm; m3 length 1.8 mm, width trigonid 1.4 mm, width talonid 1.0 mm), support the attribution to Lesser Mouse-Eared Bat. Average cranial and dental dimensions are even slightly smaller than those found in the late Pleistocene of the Central-Southern Italy (Tab. 6 - see Salari & Di Canzio 2009). In contrast, the length of the humeri in some cases exceeds the sizes measured in the late Pleistocene of Central and Southern Italy (Tab. 6 - Salari & Di Canzio 2009) and overlaps the range of variability of *M. myotis*. However, analyzing the size of the forearms of the two species, Ruedi et al. (1990) showed that these present a strong sexual dimorphism in the two species, with a wide range of overlap in their respective fields of variability, and not correlated with similar overlaps in the cranial and dental measurements. Therefore discrimination between the two species mainly relied on the distal epiphysis of the humeri, ascribing to *M. myotis* only the larger ones and of more robust aspect and all the remaining material was assigned to *M. blythii*.

M. blythii is known as a fossil since the Early and Late Pliocene; during the late Pleistocene it is reported in France, Austria, Hungary, former Yugoslavia, Bulgaria, Greece, Russia, Armenia, Azerbaijan, Israel (Sevilla et al. 2008; Salari & Di Canzio 2009 with references) and in Italy at Riparo Mezzena, Covolo di Trene, Velika Jama, Covoli di Velo, Grotta di Monte Cucco, Grotta Continenza, Grotta Barbara, Grotta Breuil, Riparo Salvini, Grotta S. Agostino, Ingarano, Grotta Paglicci, Grotta delle Mura, and Grotta della Madonna (Fig. 2 with references). Bone remains attributed to *M. myotis vel blythii* are also from Grotta Breuil, Grotta Continenza, Grotta della Madonna, Grotta dei Cocci and in other sites related to the Late Pleistocene and Early Holocene in Germany, Spain and other Western Palaearctic localities (Salari & Di Canzio 2009 with references; Salari in press). Finally, it seems reasonable to ascribe to *M. punicus* the remains from the late Pleistocene and Holocene strata of Malta and Northern Africa assigned to a rather large *M. blythii* (Tata & Kotsakis in press; Salari et al. in press).

The recent range of the species includes Southern Europe, the southern part of the Central Europe, east to China and Mongolia. In Italy this species occurs in all regions with the possible exception of Sardinia (Horáček et al. 2000; Agnelli et al. 2004).

It is a species of Mediterranean affinities, thermophilous; it appears that the biology of the Lesser Mouse-Eared Bat is on the whole very similar to that of Greater Mouse-Eared Bat. However, it differs significantly with regard to diet and, consequently, the areas of foraging: *M. blythii* prefers to hunt in areas more or less rich in grasslands, both primary (steppes, grasslands) and anthropogenic (meadows, pastures), avoiding the arid and denuded areas, or with degraded or freshly cut

Tab. 6 - Arene Candide Cave, "M" layers, late Pleistocene, Chiroptera: osteometric measurements (in mm) and comparison with living (measurements from a- Agnelli et al. 2004, b- Benda et al. 2003, c- Felten et al. 1973, d- Ruedi et al. 1990, and e- Storch 1974, Sicily only) and lateglacial *M. blythii*, *M. myotis* and *M. capaccinii* (measurements from Salari & Di Canzio 2009 and Salari in press).

	Caverna delle Arene Candide					Grotta della Madonna		Grotta delle Mura		Grotta Continenza		Today	
	N	min	max	mea	s.d.	N	min-max	N	min-max	N	min-max	min-max	
Myotis blythii													
L. skull	1			21.1						1	20.0	20.0-22.0 20.6-22.1 20.5-22.1	a b d
C-C	3	5.5	5.8	5.7	0.15					2	5.7-6.1	5.2-6.2 5.3-6.1	b d
M3-M3	4	8.6	9.0	8.8	0.23	1	8.7	1	8.7	3	8.6-9.0	8.0-9.3 8.6-9.8	b d
C-M3	16	8.3	9.1	8.7	0.26			3	8.8-9.0	4	8.8-9.0	8.0-9.7 8.1-9.1 8.3-9.1	a b d
M1-M3	31	4.8	5.2	4.9	0.19	1	5.0	4	5.0-5.2	4	5.0-5.2	4.6-4.8	e
L. mandible	74	14.3	16.4	15.5	0.47	2	16.0	5	16.0-16.8	19	15.8-17.0	15.3-17.2 14.2-16.1	b d
c-m3	96	8.8	10.1	9.4	0.33	2	10.0	12	9.4-9.8	33	9.2-9.8	8.8-9.8 9.0-10.1	b d
m1-m3	123	5.3	6.1	5.7	0.36	3	5.8	21	5.6-6.1	35	5.6-6.4	5.4-5.8	e
L. humerus	32	31.4	34.2	32.4	0.97	7	32.2-32.8			4	31.6-32.3	32.1	e
Bd humerus	536	3.8	4.3	4.1	0.17	15	4.0-4.2	18	4.0-4.2	10	4.0-4.3	4.0-4.6 4.0	c e
Myotis myotis													
L. humerus	1			35.2		4	33.6-34.6						
Bd humerus	2			4.4		7	4.4-4.6					4.0-4.6	c
Myotis capaccinii													
L. humerus	3	22.8	23.2	23.0	0.21	2	22.2-24.8			3	22.0-23.8	21.6	e
Bd humerus	8	2.6	2.9	2.8	0.11	3	2.7-2.9			5	2.8-2.9	2.7 2.7	c e

grass, and any type of woodland and forest. Hibernacula are found in hypogean cavities usually with a temperature of 4-14 °C (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

Myotis (Myotis) myotis (Borkhausen, 1797)

Pl. 1, fig. 9

Material: one humerus and one distal portion of the humerus.

Description and remarks. The morphology and the great dimensions (Tab. 6) argue for the attribution to *M. myotis*.

The Greater Mouse-Eared Bat is known since the early Pleistocene, the earliest record is from Cueva Victoria (Spain); in the late Pleistocene is recorded at several sites in Portugal, Spain, France, Belgium, Germany, Switzerland, Austria, Poland, former Yugoslavia, Romania, Ukraine (Terzea 1986; Sevilla & Chaline 2004; Salari & Di Canzio 2009 with references) and in Italy at Riparo Mezzena, Grotta A di Veia, Covolo di Trene, Grotta del Broion, Grotta di Monte Cucco, Grotta di Cittareale, Grotta Breuil, Grotta Cola, Grotta di Castelcivita, S. Maria di Agnano, Grotta della Madonna and around of Alghero (Fig. 2 with references).

The recent range of the species includes Eastern, Southern and Central Europe, reaching Southern England, and from the Mediterranean basin through Western Asia to the West Turkestan (Horáček et al. 2000). In Italy this species occurs in all regions, but most likely the specimens of Sardinia should be ascribed to *M. punicus* (Agnelli et al. 2004).

A species of Mediterranean affinities, thermophilous, it prefers temperate and warm places in plains and in hills, frequent in forest environments with sparse undergrowth and also in open and semi-desert environments, provided these are not far from woody areas. In fair weather it takes refuge in buildings, in underground natural or artificial environments and, more rarely, in the tree hollows; it normally winters in caves and galleries both natural and artificial, with temperatures of 2-12 °C and high humidity (85-100%) (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

Subgenus *Leuconoë* Boie, 1830

Myotis (Leuconoë) capaccinii (Bonaparte, 1837)

Pl. 1, fig. 10

Material: three humeri and 5 distal portions of humeri.

Description and remarks. Both the morphology and the dimensions (Tab. 6) of the distal epiphysis of these humeri agree very well with those of living species.

The oldest fossils of *M. capaccinii* are known from the early Pleistocene, the oldest recorded in Pirro Nord (Apricena, Puglia) and Ghar Dalam (Malta) (Salari et al. in press), but it is a quite rare species in Quaternary thanatocoenoses from the Western Palaearctic. In the late Pleistocene the species is reported in France, Hungary and probably Israel (Salari & Di Canzio 2009 with references) and in Italy at Grotta Continenza, Grotta Paglicci, Grotta Breuil, Riparo Salvini, Grotta della Madonna, surroundings of Alghero and probably at Covolo di Trene (Fig. 2 with references).

The current distribution includes the Mediterranean basin, South-Western Asia to Iran and Uzbekistan. In Italy this species occurs in all regions (Horáček et al. 2000; Agnelli et al. 2004).

A species of strict Mediterranean affinities, it frequents wooded or bushy karst areas associated with rivers or ponds. It is typically throglophilous, it refuges throughout the year in caves, caverns and cavities both natural and artificial, the winter shelters with temperatures between 4 and 15 ° C and relative humidity of 90-100% (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

Subgenus *Selysius* Bonaparte, 1841

Myotis (Selysius) emarginatus (Geoffroy, 1806)

Pl. 1, figs 11, 14

Material: a mandible with m1m2m3 and a distal portion of humerus.

Description and remarks. Both shape and size of the mandible are very similar to the extant species (Tab. 7); due to the presence of a mandible of this species in the same M5 layer, a distal fragment of humerus can be reasonably attributed to *M. emarginatus*, though the morphology and size might also refer to other species of the genus *Myotis* (see Felten et al. 1973).

The oldest records of *M. emarginatus* are from various sites referred to the early Pleistocene in Central and Eastern Europe; in the late Pleistocene the species is reported in France, Germany, Austria, Hungary, Ukraine, Russia (Salari & Di Canzio 2009 with references) and in Italy at Grotta di Monte Cucco, Grotta Polesini, Grotta Barbara and probably at Covolo di Trene (Fig. 2 with references).

	Caverna delle Arene Candide					Today	
	N	min	max	mea	s.d.	min-max	
Myotis emarginatus							
L. mandible				11.4		10.8-12.2	b
c-m3				6.9		5.9-7.1	b
m1-m3				4.0			
Bd humerus				2.7		2.6-2.7	c
***Myotis mystacinus* s.l.**							
Bd humerus	1			2.4		2.2-2.4	c
Nyctalus lasiopterus							
Bd humerus				3.7		~ 3.6	c
Nyctalus noctula							
Bd humerus				3.3		~ 3.2	c
***Plecotus auritus* s.l.**							
L. mandible	1			10.6		9.7-10.8 9.9-10.6	a b
c-m3	1			6.2		5.4-6.1 5.6-6.2	a b
m1-m3	1			3.9		3.4-3.9	a
Barbatella barbastellus							
L. humerus	3	24.4	24.8	24.7	0.19		
Bd humerus	9	2.6	2.8	2.7	0.07	2.7-2.8	c

Tab. 7 - Arene Candide Cave, “M” layers, late Pleistocene, Chiroptera: osteometric measurements (in mm) and comparison with living *M. emarginatus, M. mystacinus s.l., N. lasiopterus, N. noctula, P. auritus s.l.* and *B. barbastellus* (measurements from a- Benda & Ivanova 2003, Central Europe only, b- Benda et al. 2003, and c- Felten et al. 1973).

The current range of distribution includes Southern and Central Europe, South-Western Asia and North-Western Africa; in Italy this species occurs in all regions (Horáček et al. 2000; Agnelli et al. 2004).

As a thermophylous species of Mediterranean affinities, it prefers warm-temperate areas of plains and hills, limestone and wild environments; it frequents deciduous forest formations alternating with wetlands, but also more open environments. Summer roosts are found predominantly in buildings and tree hollows, but also in natural or artificial cavities; in winters the roosts change to caves or galleries with temperatures of 5-9 °C (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

Myotis (Selysius) mystacinus (Kuhl, 1817) *vel* **Myotis (Selysius) aurascens** Kusjakin, 1935

Pl. 1, fig. 12

Material: one distal fragment of humerus.

Description and remarks. Both the morphology and the dimensions (Tab. 7) agree very well with those of *M. mystacinus* (Felten et al. 1973). Recently, however, thanks to modern techniques of molecular biology and bioacoustics, flanked by the classical techniques based on morphological and morphometric criteria, several previously populations considered as subspecies and/or geographical races of *M. mystacinus* were ranked as valid species (Benda & Tsytsulina 2000). Among these, the occurrence in Northern Italy of *M. aurascens* was recognised. The biology of this species is still poorly known, but it is considered "Mediterranean (?)" (Agnelli et al. 2004). Therefore we consider advisable to refer our material to *M. mystacinus s.l.* (= *M. mystacinus vel M. aurascens*).

Fossils attributed to *Myotis* cf. *mystacinus* are known in Hungary from the early Pleistocene; in the late Pleistocene *M. mystacinus* is reported at various sites in Portugal, France, Belgium, Germany, Austria, Poland, former Czechoslovakia, Hungary, Bulgaria, Ukraine (Salari & Di Canzio 2009 with references) and in Italy at Grotta Breuil and probably at Covolo di Trene (Fig. 2 with references). However, considering the recently recognition in these regions of this cryptic species to *M. mystacinus*, we can not exclude that some of these fossils might be attributed to *M. aurascens*.

Today's range of distribution of *M. mystacinus* includes Europe, North-Western Africa and a great part of Asia to Japan. In Italy this species is probably present in all regions (Horáček et al. 2000; Agnelli et al. 2004). *M. mystacinus* is a nemoral species, prefering forests or open areas close to wetlands, and frequently is also observed in parks and gardens in towns, preferably near rivers or lakes. Hibernation takes place in natural and artificial cavities, with temperatures of 2-8 °C and high relative humidity, from 80 to 100% (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

The ecology and distribution of *M. aurascens* is less known. This species is distributed in the Balkans, Anatolia, Caucasus, Ukraine and Russia (Benda & Tsytsulina 2000; Hanák et al. 2001); in Italy so far it has only been reported in the provinces of Trento and Varese (Agnelli et al. 2004; Trizio et al. 2005).

Genus *Nyctalus* Bowdich, 1825

Nyctalus lasiopterus (Schreber, 1780)

Pl. 1, fig. 15

Material: one distal fragment of humerus.

Description and remarks. Both the morphology and the dimensions (Tab. 7) is in agreement with those of the living species.

Fossils of *N. lasiopterus* are rare, with a few records in the middle and late Pleistocene in Spain (Sevilla García 1988, 1989; López-García 2008; López-García et al. 2009), France (Jullien & Pillard 1969; Desclaux & Defleur 1997), Germany (Brunner 1958), Bulgaria (Popov 2000) and in Italy, near Alghero (Kotsakis 1987).

Today's range of distribution of the species is discontinuous extending from Southern Europe, Northern Africa and Western Asia to Uzbekistan (Horáček et al. 2000). Possibly all Italian regions could be included in the species range, but the records established after 1980 are restricted to the Tuscany and Sicily (Agnelli et al. 2004).

N. lasiopterus is a typical forest species and though occasionally reported in coniferous forests, it clearly prefers hardwood forests. Recently it has been observed predating on small birds. Roosts are mainly found in hollow trees, during the whole year, though occasionally it has been observed to use rock crevices as hibernacula and, more rarely, buildings (Mitchell-Jones et al. 1999; Agnelli et al. 2004).

Nyctalus noctula (Schreber, 1774)

Pl. 1, fig. 16

Material: one distal fragment of humerus.

Description and remarks. Both the morphology and the dimensions (Tab. 7) agree with those of the extant species.

The Noctule bat is known from localities as old as the middle Pleistocene in Central and Southeastern Europe, with remains ascribed to either *Nyctalus noctula?* or *Nyctalus* cf. *noctula*. In the late Pleistocene the species is reported in France, Germany, Romania, Bulgaria, Russia (Terzea 1986; Salari & Di Canzio 2009 with references) and in Italy at Riparo Zampieri, Grotta del Broion, Grotta della Ferrovia, Grotta Breuil, and Riparo Salvini (Fig. 2 with references).

Its present range of distribution includes Europe, North-Western Africa and much of Asia to Japan. In Italy this species is probably present in all regions except, perhaps, Sicily and Sardinia (Horáček et al. 2000; Agnelli et al. 2004).

As a nemoral species, it is typically found in woodland, preferring moist broadleaf or mixed forests, preferably close to water courses, but also frequents relatively dry forests. For wintering it takes refuge in hollow trees, in deep rock crevices and cracks of walls and other hiding places in buildings, mostly cold, with temperatures even below freezing (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

Genus *Plecotus* Geoffroy, 1818

Plecotus auritus (Linnaeus, 1758) *vel* **Plecotus macrobullaris** (Kuzjakin, 1965)

Pl. 1, fig. 17

Material: a mandible with p4-m3.

Description and remarks. The morphology of the mandible, the dental formula and the morphological characteristics of teeth agree with the classical descriptions of *P. auritus* (Miller 1912; Lanza 1959; Sevilla & Lopez Martinez 1988). The size of the material ascribed to this species (Tab. 7) falls within the range of variability of the extant species, excluding the presence of *P. austriacus* Fischer, 1829. Recent research including modern techniques of molecular biology and bioacoustics, flanked also by the classical techniques based on morphological and morphometric criteria, modified the status of certain subspecies and/or geographical races to specific level (Spitzenberger et al. 2003; 2006); this concerns *P. macrobullaris*, a species distributed in northern Italy, still poorly known, and possibly with similar ecological needs as *P. auritus*, but considered of a more Boreal nature (Agnelli et al. 2004). Considering these reasons, we have preferred to ascribe this mandible to *P. auritus* s.l. (= *P. auritus vel P. macrobullaris*).

P. auritus is recorded at several localities from Central and Eastern Europe. Earlier material described as *Plecotus* aff. *auritus* are reported in the early Pleistocene in Germany; during late Pleistocene the species is reported in France, Belgium, Germany, Austria, Poland, former Czechoslovakia, Hungary, Bulgaria, Ukraine, Russia (Salari & Di Canzio 2009 with references) and in Italy at Isola di Palmaria and Grotta di Pozzo (Fig. 2 with references). *P. auritus vel austriacus* is recorded in middle and late Pleistocene localities in Spain (Sevilla García 1988, 1989).

P. auritus currently occurs in Europe and most of Asia to Japan and the Himalayan region (Horáček et al. 2000). In Italy this species has only been reported in the northern and central regions, and in Sardinia, where it is in sympatry with its congeneric *P. sardus* (Agnelli et al. 2004).

P. auritus is a boreal species, found typically in woodland, mainly in deciduous forests and more rarely in coniferous forests, often observed as well in the parks and gardens of villages and towns. During the milder seasons the roosts are located in hollow trees and occasionally in rock fissures or in the roofs of buildings; during the winter it takes refuge in cellars and in hollow trees, as well as in caves and mines. As a species relatively resistant to cold temperatures, in the caves it preferably chooses the areas near the entrance; hibernacula are usually located in very humid environments (humidity between 80 to 100%) and with quite low temperatures ranging between 2-5 and 10 °C, but it has been observed to survive for even a few days with temperatures of -3.5 °C (Mitchell-Jones et al. 1999; Agnelli et al. 2004).

The distribution and ecology of *P. macrobullaris* is less known, though the use of the habitat is supposed to be similar to *P. auritus*, with a preference for slightly lower altitudes; in Italy this species occurs in almost all northern regions (Spitzenberger et al. 2003; Agnelli et al. 2004).

Genus *Barbastella* Gray, 1821

Barbastella barbastellus (Schreber, 1774)

Pl. 1, fig. 18

Material: nine distal portions of humeri.

Description and remarks. Both the morphology and the dimensions of our material (Tab. 7) agree with those of the extant species.

B. barbastellus is known as a fossil from various localities as old as the early Pleistocene from Central and Eastern Europe. During the late Pleistocene it is recorded in Spain, France, Germany, Austria, Poland, former Czechoslovakia, former Yugoslavia, Bulgaria, Ukraine, Russia (Sevilla & Chaline 2004; Salari & Di Canzio 2009 with references) and in Italy at Borgio, Isola di Palmaria and Grotta Polesini (Fig. 2 with references).

The current distribution includes most of Europe, except the northernmost regions, Turkey, the Caucasus, Morocco, the Canary Islands and, perhaps, Senegal. In Italy this species occurs in almost all the territory (Horáček et al. 2000; Agnelli et al. 2004).

A nemoral species, it is relatively microthermal species, preferring the hilly and wooded areas of low and medium mountains, often in the proximity of wetlands. In summer, shelters are mainly found in buildings occasionally in hollow trees or even in caves. Winter refuges are found in cavities both natural and artificial, but also sometimes in buildings and hollow trees, with humidity values under 70% and temperatures of 0-8 ° C, reaching extremes of up to -16 °C (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

Family Miniopteridae Dobson, 1875

Genus *Miniopterus* Bonaparte, 1837

Miniopterus schreibersii (Kuhl, 1817)

Pl. 1, figs 19 - 20

Material: one sub-intact skull, 6 mandibles two of which are fragmentary, 2 humeri and 266 distal portions of humeri

	Caverna delle Arene Candide					Grotta della Madonna		Grotta Continenza		Today	
	N	min	max	mea	s.d.	N	min-max	N	min-max	min-max	
Miniopterus schreibersii											
M3-M3	1			6.1						5.4-6.6	b
C-M3	1			6.3						5.6-6.3 5.7-6.1	a b
M1-M3	1			3.4						3.1-3.2	d
L. mandible	4	10.6	11.0	10.8	0.16					10.4-11.4	b
c-m3	6	6.0	6.4	6.3	0.16					6.1-6.5	b
m1-m3	6	3.6	3.8	3.7	0.12					3.5-3.7	d
L. humerus	2	26.3	26.8	26.6	0.35			1	25.2		
Bd humerus	268	2.6	2.8	2.7	0.08	1	2.8	3	2.8	~ 2.7	c

Tab. 8 - Arene Candide Cave, "M" layers, late Pleistocene, Chiroptera: osteometric measurements (in mm) and comparison with living (measurements from a- Agnelli et al. 2004, b- Benda et al. 2003, c- Felten et al. 1973, and d- Storch 1974, Sicily only) and lateglacial *M. schreibersii* (measurements from Salari & Di Canzio 2009 and Salari in press).

Description and remarks. Both the morphology and size are similar to living *M. schreibersii*. The measurements of teeth are close to the higher values of variability observed in the extant specimens of the species, and the length values of the humeri are slightly larger the values obtained for the same species in Grotta Continenza (Tab. 8).

M. schreibersii fossils are known since the early Pleistocene in various localities in Central Europe; it is recorded in the late Pleistocene of Spain, France, Hungary, former Yugoslavia, Romania, Bulgaria, Greece, Malta, Russia, Armenia, Azerbaijan, Israel (Terzea 1986; Sevilla & Chaline 2004; López-García 2008; Sevilla et al. 2008; Salari & Di Canzio 2009 with references) and in Italy at Isola di Palmaria, Grotta del Broion, Covoli di Velo, Grotta Continenza, Grotta Polesini, Grotta Breuil, Riparo Salvini, Grotta di Castelcivita, S. Maria di Agnano, Grotta della Madonna and around Alghero (Fig. 2 with references).

The present range of *M. schreibersii* s.l. comprises all populations living from Southern Europe and Morocco to sub-Saharan Africa, Madagascar and through Southern Asia to New Guinea, Solomon Islands and Australia; such a distribution can be labelled South Palaearctic and Pantropic within the Old World (Horáček et al. 2000). In Italy this species occurs throughout to the whole country (Agnelli et al. 2004).

As a species of strict Mediterranean affinities, and typically cave-dwelling, it is found mainly linked to environments not anthropised or at most scarcely modified by man, clearly preferring karstic areas, but also occurring in a variety of both forested and open habitats (herbaceous formations, including steppe). The temperature and relative humidity of the caves in which they find refuge normally range between 4-12 °C and 70-98% in the case of winter roosts, and between 11-19 °C and 57-91% in the summer roosts (Mitchell-Jones et al. 1999; Lanza & Agnelli 2002).

Results and discussion

The "M" layers of Arene Candide Cave yielded a total number of 1,284 identified specimens, referable to at least 579 individuals (Tabs. 1 and 2). This material is clearly a natural thanatocoenosis represented by the bones of bats that probably died due to low temperatures or to the lack of subcutaneous fat reserves during hibernation (the absence of juvenile remains excludes a thanatocoenosis built under a breeding colony). During late Glacial, the Arene Candide Cave hosted a diversity of bats, with *M. blythii* as the dominant species in the assemblages, with percentages ranging between 58.5% and 73.1% if number of remains is considered and between 42.6% and 63.1% considering number of individuals. The next most abundant species is *M. schreibersii*, as the auxiliary species in the assemblage with a gradual increase from M5 to M1 in the percent both in the number of remains 5.6% to 26.1% and of individuals 9.5% to 29.3%. The four rhinolophid species and *B. barbastellus* appear as accidental species, and finally, the remaining eight taxa occur occasionally along the "M" series.

The majority of taxa present in the fossil assemblage are troglophilous (11 taxa, 73.3%), in a higher proportion compared to the bats currently distributed in Western Liguria (12 taxa, 63.2%) (Tab. 9). The fossil assemblage also includes some taxa that roost not only in caves but also in other refuges, those more distinctly anthropophilous and those that frequent rocky environments are not represented (Tab. 9; Fig. 3).

According to the environmental conditions of the hibernacula of the species present in the fossil assemblage, varying conditions during the winter may be in-

Tab. 9 - Arene Candide Cave, "M" layers, Chiroptera: comparison between Late Pleistocene taxa from Arene Candide Cave and current bat fauna from Finale Ligure territory (Finale Ligure 2007) and Western Ligurian Alps (Calvini 2005), and schematic synthesis of some ecological features of the bats.

Taxon	**Arene Candide fossil**	**Finale Ligure today**	**Western Ligurian Alps today**	**Hibernacula**	**Foraging environment**	**Zoogeographical patterns**
Rhinolophus ferrumequinum	X	X	X	caves	mixed	Mediterranean s.l.
Rhinolophus euryale	X	X	X	caves	woods	Mediterranean s.s.
Rhinolophus mehelyi	X			caves	woods	Mediterranean s.s.
Rhinolophus hipposideros	X	X	X	caves	mixed	Mediterranean s.l.
Myotis myotis	X	X	X	caves	woods	Mediterranean s.l.
Myotis blythii	X	X	X	caves	open	Mediterranean s.l.
Myotis bechsteinii			X	hollow trees, caves	woods	Nemoral
Myotis capaccinii	X	X		caves	woods	Mediterranean s.s.
Myotis daubentonii	?		X	caves	forests	Boreal
Myotis emarginatus	X		X	caves	various	Mediterranean s.l.
Myotis mystacinus s.l.	X		X	caves	various	Nemoral
Myots nattereri	?		X	caves	woods	Nemoral
Myotis sp. (little size)	X					
Hypsugo savii			X	buildings, caves	various, anthropophilous	Mediterranean s.s.
Pipistrellus kuhlii			X	buildings, rock fissures	various, anthropophilous	Mediterranean s.s.
Pipistrellus nathusii			X	rock fissures, buildings	woods	Nemoral
Pipistrellus pipistrellus			X	buildings, hollow trees	woods, anthropophilous	Mediterranean s.l.
Pipistrellus pygmaeus			X	hollow trees, buildings	various, anthropophilous	Nemoral ?
Nyctalus lasiopterus	X			hollow trees	forests	Nemoral
Nyctalus leisleri			X	hollow trees	woods	Nemoral
Nyctalus noctula	X			hollow trees	forests	Nemoral
Plecotus auritus s.l.	X		X	hollow trees, caves	forests	Boreal
Barbastella barbastellus	X		X	caves	forests	Nemoral
Miniopterus schreibersii	X	X		caves	various	Mediterranean s.s.
Tadarida teniotis			X	rock fissures	rocky	Mediterranean s.s.
Total	15	7	19			

ferred for Arene Candide Cave (or at least for the surrounding area of excavation) during the late Glacial. Temperatures and humidity in a cave, in fact, vary depending on the size of the cavity, its morphology, and number of openings and orientation of the entrance or the entrances. In large caves a variety of microclimates can be observed, and each bat species chooses the roosting places that better meet its preferences within the cave. However, the temperature seems to have increased from 7-8 °C in M5 to 11-12 °C in M4, from then onwards, to have remained nearly constant; there might have been however some cold events (one winter? a multiannual cycle?) considering the presence of *N. noctula*, *B. barbastellus*, *P. auritus* s.l. and *N. lasiopterus* at certain levels. Considering the presence of *M. schreibersii* and *B. barbastellus*, which prefer roosts that do not exceed a 70% in humidity, the values for this parameter must have not reached saturation; on the other hand,

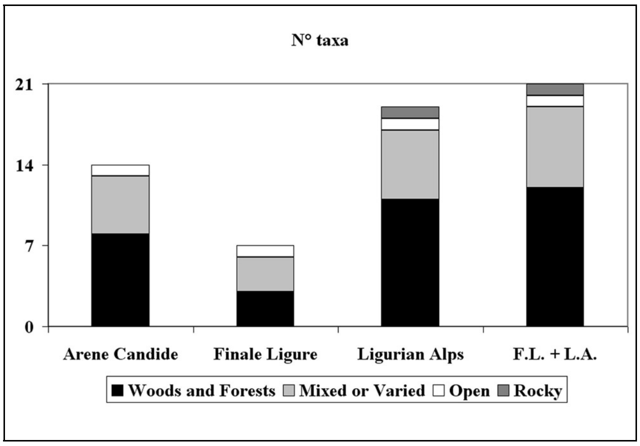


Fig. 3 - Late Pleistocene taxa of bats recorded in the "M" horizon of Arene Candide Cave and extant bat fauna in the Finale Ligure territory (F.L.) and Western Ligurian Alps (L.A.) and a composite of these two regions, for the foraging environment (see Tab. 9).

other species present in the assemblage, such as *R. mehelyi* favour roosts with humidity values close to saturation (97-100%). The levels in which are present taxa that preferably roost in hollow trees (*N. lasiopterus*, *N. noctula*, *P. auritus* s.l.) might also be considered to indicate climatic deterioration or at least particularly cold winters.

Concerning the palaeoenvironment that might be inferred from the bat assemblage, taking in account habitat preferences and palaeoenvironmental indications, *M. blythii* as the dominant species, is linked to open grassland and steppes, avoiding both the dry and denuded areas as well as any type of woodland and forest. *M. schreibersii* and *R. ferrumequinum* frequent a variety of environments, from forest to open landscapes; the former also found in steppe habitats, the latter in areas close to wetlands. On the other hand, *R. mehelyi*, *R. euryale*, *B. barbastellus* and *M. capaccinii* occur preferably in wooded areas, including those developed in the vicinity of wetlands or watercourses. Considering these preferences, Fig. 4 shows the changes in the relative percentages along the successive levels of the different taxa, grouped according to foraging environment: these changes show that variations mainly concern the species that frequent a variety of environments or open spaces, whereas forest-dwelling species show a slight but gradual increase from M5 to M2, followed by a reduction at M1.

Figures 5 and 6 show that the bat assemblage is largely dominated by the Mediterranean species (both sensu lato and sensu stricto), while the presence of nemoral and especially boreal species is negligible. Considering the number of the taxa, the Mediterranean s.s. species increase in the assemblage from under a 30% in M5 to more than a 40% in M4, mainly at the expense of the Mediterranean s.l. species, to remain later on stable; but if we consider the number of individuals a continuous increase is observed (14% in M5, 29% in M4, 36% in M3 and more than 40% in M2-1), especially in M4, due to the occurrence of *R. euryale* and *R. mehelyi* and to a significant increase of *M. schreibersii*.

If we analyse the relation between human presence in the cave and the richness of the bat tanathocoenosis, it is important to point out that is not common to find remains of bats in sites where humans are the mainly responsible for the accumulation of animal bones. These small flying mammals are in fact wild and are not commensal to humans, frequently abandoning the caves when human occupation is important, and never return. It does not seem reasonable to consider the bats were used as food supply or other purposes. As to the possibility of having been prey to Strigiform birds, it must be pointed out that generally bat remains in the pellets of these birds represent values under a 1% since they feed mainly on rodents, small birds and insectivores (Chaline et al. 1974; Kowalski 1990, 1995; Vernier 1993; Obuch 1998, 2006; García et al. 2005). However, even the Strigiform birds abandon the caves occupied by humans. The skeletal remains described in this paper, therefore, constitute an autochthonous thanatocoenosis, and evidently records time intervals during which the cave was rarely frequented or even unoccupied by humans.

Thus, the variation in bat representation along the sequence is, in fact, almost inversely correlated to large mammal abundance, except in level M3 (the large mammals preserved in the "M" layers were predominantly introduced into the cave by man (Alhaique 1994; Cassoli & Tagliacozzo 1994) and fully specular to evidences of human activity on the bones of these large mammals (Fig. 7). Alternation between cave occupation by bats and humans may have taken place during several years, or might have been seasonal (probably from late spring to early autumn, humans were occupying the cave, and from late autumn to early spring, the bats). The maximum of bat abundance recorded in M1 is perhaps due to the absence of humans in the cave during the time interval, between the latest Epigravettian occupations and the later first Neolithic attendances.

Conclusions

In the "M" layers of the Arene Candide Cave 15 taxa, belonging to 6 genera and 3 families of bats have been identified (Tabs. 1, 2), contributing with new data that increase our knowledge on the history of the bat fauna of Italy. All the taxa identified in this locality are currently distributed in northern Italy, except for *R. mehelyi* and *N. lasiopterus*. The first species is a cave-dwelling bat particularly sensitive to human disturbance, presently limited in its distribution to Sardinia and Sicily and possibly in Campania (Feola et al. 2003; Agnelli et al. 2004). The second is a typical forest-dwelling species that roosts almost exclusively in hollow trees, at present is only recorded in Tuscany and Sicily (Agnelli et al. 2004). Being these species linked to a certain extent to forested areas, their records might indicate a reduction of forest (for natural or human causes) in Western Liguria and in great part of the Italian territory during the Holocene. Moreover, the specific habitat requirements of *N. lasiopterus*, which largely seem to depend on the development of mature forests, where hollow trees may provide for its day roosts, are probably responsible for the low densities and the present patchy distribution that characterize this species, in spite of its relatively wide geographical range.

Particularly interesting the presence in the assemblage of certain taxa, such as *M. capaccinii*, *M. mystacinus* s.l., *P. auritus* s.l. and *N. lasiopterus*.

M. capaccinii is found in several late Pleistocene sites from Central-Southern Italy, invariably represented by few remains, whereas in Northern Italy and in the remaining western Palaearctic it is quite rare (Salari & Di Canzio 2009 with references). Considered a good indicator of wetland habitats, it shows in the Arene Candide Cave the same abundance patterns observed for *Alces alce,* a large deer typical of woodland or forest environment near to wetlands, rivers and lakes (Cassoli & Tagliacozzo 1994).

In the late Pleistocene *M. mystacinus* is reported at various European sites, while in Italy it is only present in Grotta Breuil and probably at Covolo di Trene (Salari & Di Canzio 2009 with references). However, due to the great morphological similarities between the two species, it is possible that some of these fossils belong to its cryptic species *M. aurascens*, a species up to now without a fossil record.

P. auritus s.l. is relatively common in various localities of Europe of Late Pleistocene age, particularly in Central and Eastern Europe, whereas in Italy until now was only known from Grotta di Pozzo and the Isola di Palmaria (Salari & Di Canzio 2009 with references).

Finally, a new record of the greater noctule adds new information for the understanding of the discontinuous distribution of this forest species, that presents a very poor record and always with few remains, in Spain (López-García 2008, López-García et al. 2009), France (Desclaux & Defleur 1997), Bulgaria (Popov 2000) and in Italy at Punta Padrebellu (Alghero, Sardinia) (Kotsakis 1987). The humerus of *N. lasiopterus* found at the Arene Candide Cave reinforces the indication that this species was commonly distributed during the Late Pleistocene in the north of the western Mediterranean basin.

The relative richness of bone remains of Chiroptera from the "M" layers are without doubt evidence of particular moments in which humans had abandoned the cave or made a seasonal use of it, particularly during the summer, since the assemblages lack juvenile specimens and thus represent thanatocoenoses originated during hibernation. Additional interpretations concerning the microclimate of the cave (at least the surrounding area of excavation) are inferred from the particular requirements of the species represented in the assemblage. Thus, the humidity had near to constant values close to saturation, whereas the temperature increased from values around 7-8 °C in M5 to 11-12 °C in M4, then remained relatively constant, albeit with some punctual fluctuations around these values.

The foraging environments preferred by the species identified in the assemblage also provide information to infer characteristics of the environment surrounding the cave during the final stages of the Pleistocene, outlining a composite landscape with extensive steppes and prairies, together with groves and water bodies. The interpretations inferred from the more stenoic bat species represented in the assemblage agree mostly with the results obtained from the study of the bird fossils in the locality (Cassoli 1980). Thus, the bat assemblage is dominated by species of Mediterranean affinities, an increase in the Mediterranean s.s. taxa is observed from a 14% in M5 to a 29% in M4 and then gradually increasing to values over a 40% in M2-1 (Figs. 5 and 6); among the bird fossils of the "M" horizon, the taxa of temperate climate are represented by less than a

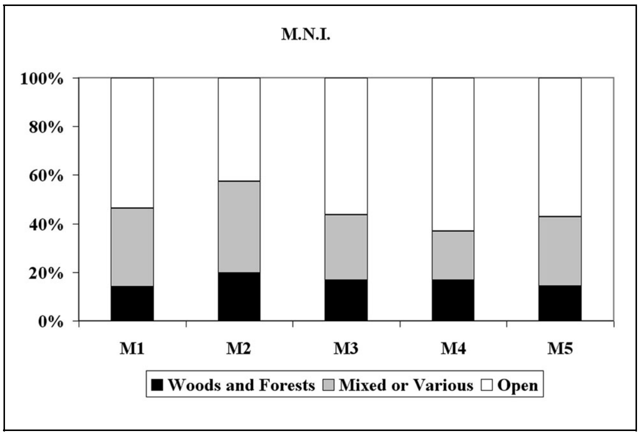


Fig. 4 - Arene Candide Cave, "M" layers, late Pleistocene: percent ratio of the Chiroptera (MNI) according to foraging environment (see Tab. 9).

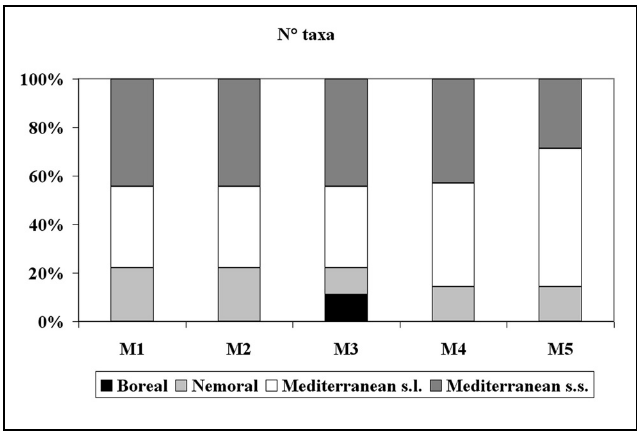


Fig. 5 - Arene Candide Cave, "M" layers, late Pleistocene: percent ratio of the Chiroptera (n. taxa) according to zoogeographic patterns (see Tab. 9). Boreal: species related to the coniferous (taiga) and mixed forests; Nemoral: species reaching maximal abundance in the temperate deciduous forests; Mediterranean s.l.: species related with thermoxerophile forests and steppe, that essentially extends their ranges beyond limits of the Mediterranean; Mediterranean s.s.: species related with thermoxerophile forests and steppe, with ranges centred within the Mediterranean basin (Horáček et al. 2000).

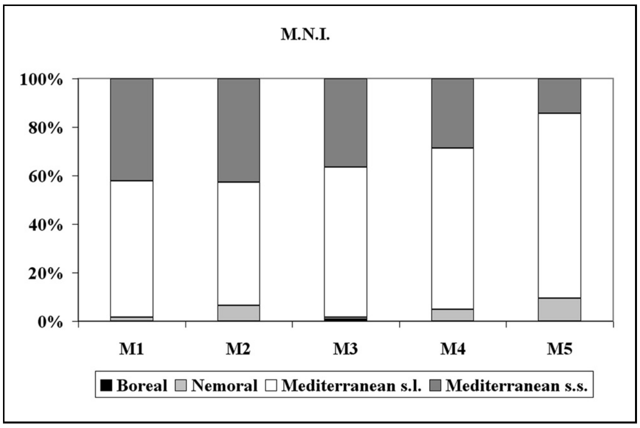


Fig. 6 - Arene Candide Cave, "M" layers, late Pleistocene: percent ratio of the Chiroptera (MNI) for the zoogeographic patterns (see Fig. 5 caption).

15% in M5 increasing to more than a 50% in M4 and then rising gradually to a 75% in M1. Excluding the species linked to marine and rocky environments, forest species increase regularly from M5 to M1, differing with the bats in the reduction observed in M1 after a moderate but progressive increase in forest species from M5 to M2 (Fig. 4).

The thermic indexes calculated by Cassoli (1980) also show a cold event in M3 layer agreeing with the occurrence of *P. auritus* s.l., the single boreal taxon in the sequence and coinciding with the single presence of *Gulo gulo* (large mustelid typical of the arctic and alpine regions of northern Palaearctic) among the large mammals (Cassoli & Tagliacozzo 1994). The variations of these indexes, finally, shows a gradual overall increase from lower temperatures indicating "cold" climate (in M5, referred to the end of Dryas II cold stage) to temperatures that might be described as "slightly cooler than temperate climate" (in M2-1, referred to the end of Allerød interstadial and the initial Dryas III cold stage), a trend that agrees with the progressive increase of *M. schreibersii* and to some extent of *R. mehelyi* and *R. euryale* and the simultaneous decrease of *B. barbastellus*.

The analysis of bat assemblages indicate the passage from cold and partially arid conditions in the lower part (M5, referred to the end of Dryas II cold stage) to conditions nearly similar to the present ones in the middle and upper part of the sequence. The environmental conditions are moderately forested in the middle part (M4-2, referable to Allerød interstadial) and moderately arid in the upper part of the "M" horizon of the Arene Candide Cave (M1, referred to the initial Dryas III cold stage). These data agree with the results of the palaeontological studies on large mammals and birds.

Acknowledgments. I am grateful to the "Istituto Italiano di Paleontologia Umana" of Rome which allowed the access to the fossils, and to Paloma Sevilla for the useful suggestions that improved the quality of the manuscript. I thank also, for their support, Tonino Tagliacozzo, Raffaele Sardella, Carmelo Petronio, Francesca Cinquina, and particularly Tassos Kotsakis for the useful discussions on the bats systematic.

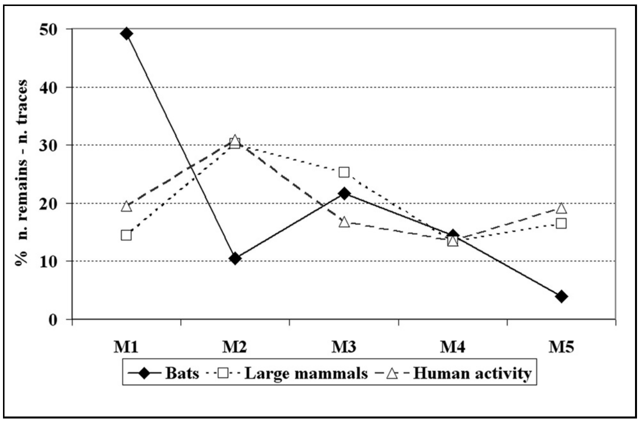
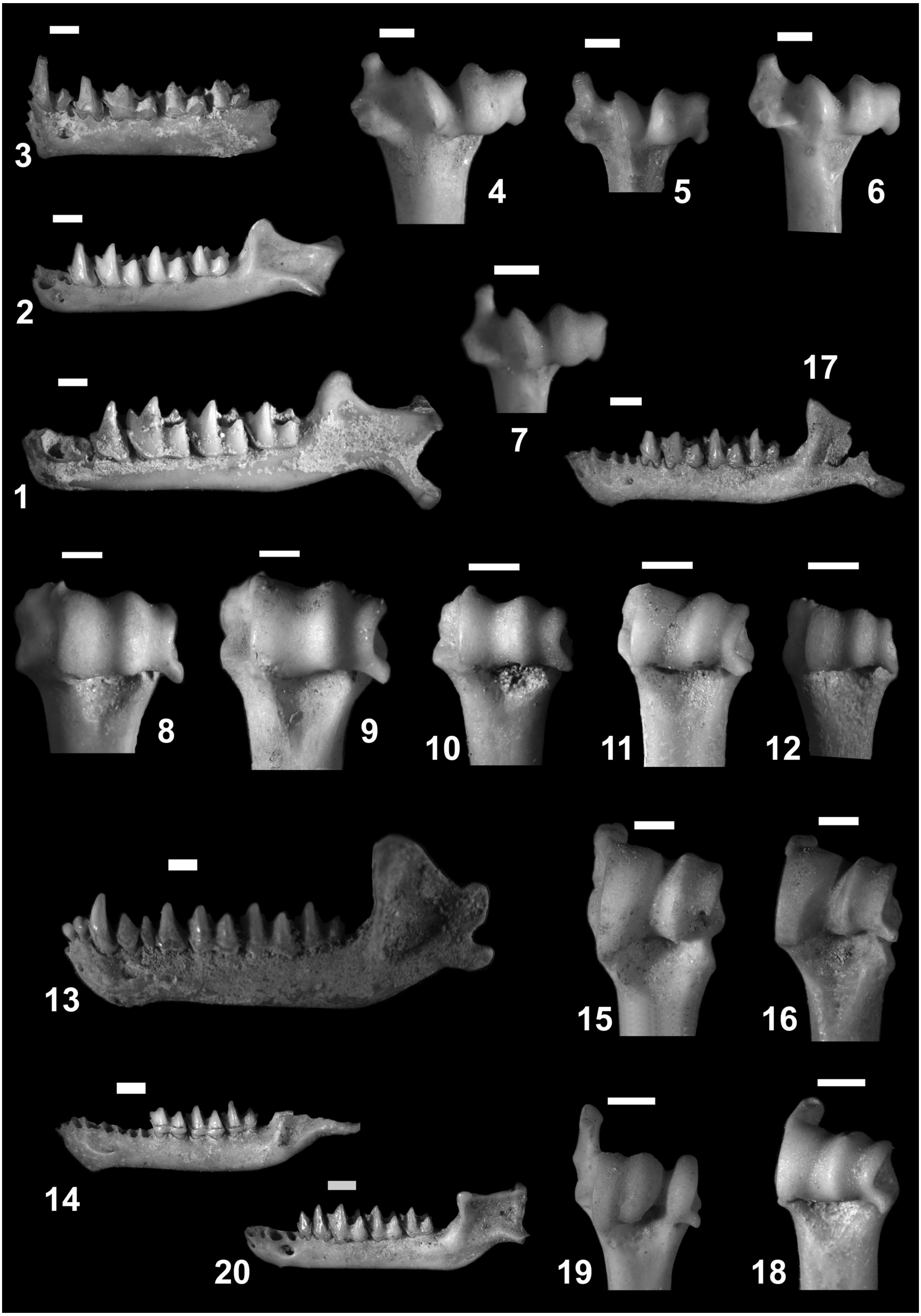


Fig. 7 - Arene Candide Cave, "M" layers, late Pleistocene: relation between the identified number of remains (NR) of large mammals (Cassoli & Tagliacozzo 1994), number of large mammal with traces of human activity (Alhaique 1994) and identified number of bat remains (NR). Identified NR of large mammals: 5,220; n. traces of human activity: 411; identified NR of bats: 1,284.

PLATE 1

Fig. 1 - *R. ferrumequinum*, mandible; Fig. 2 - *R. euryale*, mandible; Fig. 3 - *R. mehelyi*, mandible; Fig. 4 - *R. ferrumequinum*, humerus; Fig. 5 - *R. euryale*, humerus; Fig. 6 - *R. mehelyi*, humerus; Fig. 7 - *R. hipposideros*, humerus; Fig. 8 - *M. blythii*, humerus; Fig. 9 - *M.myotis*, humerus; Fig. 10 - *M. capaccinii*, humerus; Fig. 11 - *M. emarginatus* (or *M. daubentonii* or *M. nattereri*), humerus; Fig. 12 - *M. mystacinus* s.l., humerus; Fig. 13 - *M. blythii*, mandible; Fig. 14 - *M. emarginatus*, mandible; Fig. 15 - *N. lasiopterus*, humerus; Fig. 16 - *N. noctula*, humerus; Fig. 17 - *P. auritus* s.l., mandible; Fig. 18 - *B. barbastellus*, humerus; Fig. 19 - *M. schreibersii*, humerus; Fig. 20 - *M. schreibersii*, mandible. Scale bars = 1 mm.


3
4
5
6
2
17
1
7
8
9
10
11
12
13
15
16
14
20
19
18

REFERENCES

Agnelli P., Martinoli A., Patriarca E., Russo D., Scaravelli D. & Genovesi P. (Eds) (2004) - Linee guida per il monitoraggio dei Chirotteri: indicazioni metodologiche per lo studio e la conservazione dei pipistrelli in Italia. *Quad. Conserv. Nat.*, 19, 216 pp., Min. Ambiente - Ist. Naz. Fauna Selvatica.

Alhaique F. (1994) - Taphonomic study of the faunal remains from the "M" and "P" layers of the Arene Candide (Savona, Italy). *Quat. Nova*, 4: 263-295.

Angelone C., Bedetti C., Coppola D., Kotsakis T. & Pavia M. (2004) - Fossil micromammals and birds of S. Maria di Agnano (Apulia, Southern Italy): a systematic and palaeocological overview. Giornate di Paleontologia 2004, Abstracts: 6, Bolzano, 21-23 Maggio 2004.

Argenti P., Kotsakis T. & Sabatini F. (2008) - *Myotis dasycneme* in a Latest Pleistocene bat assemblage of Cittareale Cave (Rieti, Latium, Central Italy). *Geol. Rom.*, 41: 117-123.

Bartolomei G. (1966) - Diagramma microfaunistico con *Sicista* della Grotta della Ferrovia nella "Gola della Rossa" del Fiume Esino presso Jesi (Ancona). *Ann. Univ. Ferrara*, N.S., IX, 4(5): 69-75.

Benda P. & Ivanova T. (2003) - Long-eared bats, genus *Plecotus* (Mammalia: Chiroptera), in Bulgaria: a revision of systematic and distributional status. *Časopis Národního muzea, Řada přírodovědná*, 172: 157-172.

Benda P., Ivanova T., Horáček I., Hanák V., Červený J., Gaisler J., Gueorguieva A., Petrov A. & Vohralík V. (2003) - Bats (Mammalia: Chiroptera) of the Eastern Mediterranean. Part 3. Review of bat distribution in Bulgaria. *Acta Soc. Zool. Bohem.*, 67: 245-357.

Benda P. & Tsytsulina K. A. (2000) - Taxonomic revision of *Myotis mystacinus* group (Mammalia: Chiroptera) in the western Palearctic. *Acta Soc. Zool. Bohem.*, 64(4): 331-398.

Bietti A. (1987) - Some remarks on the new radiocarbon dates from the Arene Candide Cave (Savona, Italy). *Hum. Evol.*, 2(2): 185-190.

Bietti A. (1994) - A re-examination of the lithic industries of the P layers (1940-42 excavations) of the Arene Candide Cave (Savona, Italy). Discussion and general conclusion. *Quat. Nova*, 4: 341-370.

Bietti A. & Molari C. (1994) - The Upper Pleistocene deposit of the Arene Candide Cave (Savona, Italy): general introduction and stratigraphy. *Quat. Nova*, 4: 9-27.

Bon M., Piccoli G. & Sala B. (1991) - I giacimenti quaternari di vertebrati fossili nell'Italia nord-orientale. *Mem. Sci. Geol.*, 43: 185-231.

Bona F., Zorzin R., Accordino M. & Mazzi R. (2006) - Prime considerazioni paleoambientali sui depositi pleistocenici della grotta inferiore dei Covoli di Velo (VR - Italia). Giornate di Paleontologia 2006, Abstract: 12, Trieste, 8-11 giugno 2006.

Brunner G. (1958) - Nachtrag zur Breitenberghöhle bei Gössweinstein (Ofr.). *N. Jb. Geol. Paläont. Mh.*, 1958: 500-517.

Calvini M. (2005) - I Chirotteri delle Alpi Liguri. 24 pp., Provincia di Imperia.

Capasso Barbato L. & Kotsakis T. (1986) - Les chiroptères du Pléistocène supérieur de la Grotte de Monte Cucco (Italie Centrale). *Geol. Rom.*, 25: 309-316.

Cardini L. (1941) - Ricerche paletnologiche nella Caverna delle Arene Candide. *Arch. Antr. Etnol.*, 70: 110-119.

Cardini L. (1946) - Gli strati mesolitici e paleolitici della Caverna delle Arene Candide. *Riv. St. Liguri*, 12: 3-11.

Cardini L. (1955) - Scavo nella Grotta delle Arene Candide (Savona). *Quaternaria*, 2: 277-279.

Cardini L. (1980) - La necropoli mesolitica delle Arene Candide (Liguria). *Mem. Ist. It. Paleont. Um.*, 3: 9-31.

Cardini L. (1994 - Ed. M. Taschini) - Le industrie dei livelli Mesolitici e Paleolitici della Caverna delle Arene Candide (Savona). *Quat. Nova*, 4: 29-78.

Cardini L. & Bidditu I. (1967) - L'attività scientifica dell'I.I.P.U., I, Liguria: Caverna delle Arene Candide. *Quaternaria*, 9: 370-374.

Cassoli P.F. (1980) - L'avifauna del Pleistocene superiore delle Arene Candide (Liguria). *Mem. Ist. It. Paleont. Um.*, 3: 155-234.

Cassoli P.F. & Tagliacozzo A. (1994) - I macromammiferi dei livelli tardopleistocenici delle Arene Candide (Savona, Italia): considerazioni paleontologiche e archeozoologiche. *Quat. Nova*, 4: 101-261.

Chaline J., Baudvin H., Jammot D. & Saint Girons M.-C. (1974) - Les proies des rapaces. Petits Mammifères et leur environnement. 135 pp., Doin, Paris.

Cigna A.A., Giorcelli A. & Tozzi (1967) - Ricerche speleologiche nelle isole Palmaria, del Tino e del Tinetto. *Mem. Rass. Spel. It.*, 8: 1-66.

Csorba G., Ujhelyi P. & Thomas N. (2003) - Horseshoe Bats of the World (Chiroptera: Rhinolophidae). 160 pp., Alana Book, Bishop's Castle.

Desclaux E. & Defleur A. (1997) - Étude préliminaire des micromammifères de la Baume Moula-Guercy à Soyons (Ardèche, France). Systématique, biostratigraphie et paléoécologie. *Quaternaire*, 8: 213-223.

Di Canzio E. & Petronio C. (2001) - Osservazioni sulla fauna a vertebrati pleistocenici della Grotta Cola (Abruzzo, Aquila). *Boll. Soc. Paleont. It.*, 40(1): 105-114.

Felten H., Helfricht A. & Storch G. (1973) - Die Bestimmung der europäischen Fledermäuse nach der distalen Epiphyse des Humerus. *Senckenberg. Biol.*, 54: 291-297.

Feola A., Dondini G., Santangelo M. & Vergari S. (2003) - Primi dati sulla chirotterofauna del Parco Nazionale del Cilento - Vallo di Diano (Campania). In: Prigioni C., Meriggi A. & Merli E. (Eds) - IV Congresso Italiano di Teriologia. *Hystrix, It. J. Mamm.*, (n.s.) supp. 2003: 154.

Finale Ligure (2007) - Piano Urbanistico Comunale, Descrizione Fondativa - Assetto Ambientale, Allegato al Capitolo 1: specie animali e vegetali di elevato interesse presenti sul territorio finalese. (www.comunefinaleligure.it).

García A.M., Cervera F. & Rodríguez A. (2005) - Bat predation by long-eared owls in Mediterranean and temperate regions of Southern Europe. *J. Rapt. Res.*, 39 (4): 445-453.

Hanák V., Benda P., Ruedi M., Horáček I. & Sofianidou T. S. (2001) - Bats (Mammalia: Chiroptera) of the Eastern Mediterranean. Part 2. New records and review of distribution of bats in Greece. *Acta Soc. Zool. Bohem.*, 65: 279-346.

Horáček I., Hanák V. & Gaisler J. (2000) - Bats of the Palearctic Region: a taxonomic and biogeographic review. In: Woloszyn B.W. (Ed.) - Proceedings of the VIIIth EBRS, 1: 11-157, Krakow.

Jullien R. & Pillard B. (1969) - Les insectivores et les chiroptères découverts sur le sol de la cabane acheuléenne du Lazaret. In: de Lumley H. (Ed.) - Une cabane acheuléenne dans la grotte du Lazaret (Nice). *Mém. Soc. Préhist. Fr.*, 7: 95.

Kotsakis T. (1987) - Les chiroptères du Pléistocène supérieur des environs de Alghero (Sardaigne, Italie). *Geol. Rom.*, 26: 103-108.

Kotsakis T. (1991) - Late Pleistocene fossil microvertebrates of Grotta Breuil (Monte Circeo, Central Italy). *Quat. Nova*, 1: 325-332.

Kowalski K. (1990) - Some problems of the taphonomy of small mammals. In: Fejfar O. & Heinrich H.D. (Eds) - International Symposium on Evolution, Phylogeny and Biostratygraphy of Arvicolids (Rodentia, Mammalia): 285-296, Geological Survey, Praha.

Kowalski K. (1995) - Taphonomy of bats (Chiroptera). *Geobios*, M.S., 18: 251-256.

Lanza B. (1959) - Chiroptera Blumenbach, 1779. In: Toschi A. & Lanza B. (Eds) - Fauna d'Italia, vol. IV, Mammalia: Generalità, Insectivora, Chiroptera: 187-473, Calderini, Bologna.

Lanza B. & Agnelli P. (2002) - Chirotteri, Chiroptera Blumenbach, 1779. In: Spagnesi M. & De Marinis A.M. (Eds) - Mammiferi d'Italia. *Quad. Conserv. Nat.*, 14: 44-142, Min. Ambiente - Ist. Naz. Fauna Selvatica.

López-García J.M. (2008) - Late Pleistocene small mammals from Abric Romaní (Barcelona, Spain), *Ann. Univ. Ferrara - Mus. Sci. Nat.*, Vol. spec. 2008: 105-110.

López-García J.M., Sevilla P. & Cuenca-Bescós G. (2009) - New evidence for the greater noctule bat (*Nyctalus lasiopterus*) in the Late Pleistocene of western Europe. *C. R. Palevol*, 8: 551-558.

Masini F. & Abbazzi L. (1997) - L'associazione di mammiferi della Grotta di Castelcivita. In: Gambassini P. (Ed.) - Il Paleolitico di Castelcivita, culture e ambiente: 33-59, Electa, Napoli.

Menu H. & Sigé B. (1971) - Nyctalodontie et myotodontie, importants caractères de grade évolutifs chez les chiroptères entomophages. *C. R. Acad. Sci. Paris*, 272: 1735-1738.

Miller G.S. (1912) - Catalogue of the mammals of Western Europe (Europe exclusive of Russia). 1019 pp., British Museum (Nat. Hist.), London.

Mitchell-Jones A.J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. & Zima J. (1999) - The atlas of European mammals. 484 pp., Academic Press, London.

Obuch J. (1998) - Zastúpenie netopierov (Chiroptera) v potrave sov (Strigiformes) na Slovensku. *Vespertilio*, 3: 65-74.

Obuch J. (2006) - Subfosílna a subrecentná potrava sovy obyčajnej (*Strix aluco*) vo Velkej Fatre. In: Adamec M. & Urban P. (Eds) - Výskum a ochrana cicavcov na Slovensku VII - Research and protection of mammals in Slovakia VII: 225-235, Banská Bystrica.

Petronio C. & Sardella R. (1998) - Remarks on the stratigraphy and biochronology of the Late Pleistocene deposit of Ingarano (Apulia, Southern Italy). *Riv. It. Paleont. Strat.*, 104: 287-294.

Popov V.V. (2000) - The small mammals (Mammalia: Insectivora, Chiroptera, Lagomorpha, Rodentia) from Cave 16 (North Bulgaria) and the paleoenvironmental changes during the Late Pleistocene. In: Ginter B., Kozłowski J.K. & Laville L. (Eds) - Temnata Cave. Excavation in Karlukovo Karst Area, Bulgaria: 159-240, Jagellonian University Press, Cracow.

Popov V.V. & Ivanova T.I. (2002) - Comparative craniometrical analysis and distributional patterns of medium-sized horseshoe bats (Chiroptera: Rhinolophidae) in Bulgaria. *Folia Zool.*, 51: 187-200.

Radmilli A.M. (1974) - Gli scavi nella Grotta Polesini a Ponte Lucano di Tivoli e la più antica arte nel Lazio. 131 pp., Sansoni, Firenze.

Ruedi M., Arlettaz R. & Maddalena T. (1990) - Distinction morphologique et biochimique de deux espèces jumelles de chauves-souris: *Myotis myotis* (Bork.) et *Myotis blythi* (Tomes) (Mammalia; Vespertilionidae). *Mammalia*, 54: 415-429.

Salari L. (2004) - Contributo alla conoscenza dei resti ossei dei chirotteri. *Grotte e dintorni*, 8: 45-54, Museo Speleologico Franco Anelli.

Salari L. (2009) - Nota preliminare sui chirotteri tardopleistocenici della Caverna delle Arene Candide (Finale Ligure, Savona). 6° Convegno Nazionale di Archeozoologia, Abstracts: 15, Parco dell'Orecchiella, 21-24 maggio 2009.

Salari L. (in press) - I chirotteri del Tardoglaciale e Olocene antico della Grotta del Santuario della Madonna a Praia a Mare (Calabria, Italia meridionale). *Atti Mus. Civ. St. Nat.*, Trieste.

Salari L. & Di Canzio E. (2009) - I chirotteri del Pleistocene superiore e Olocene antico di alcune grotte dell'Italia centro-meridionale. *Boll. Mus. Civ. St. Nat. Verona - Geol.-Paleont.-Preist.*, 33: 3-25.

Salari L., Petronio C. & Kotsakis T. (in press) - Early Pleistocene bats from Pirro Nord (Apulia, Southern Italy). *Palaeontographica*.

Sevilla García P. (1988) - Estudio paleontologico de los quirópteros del Cuaternario español. *Paleont.i Evol.*, 22: 113-233.

Sevilla García P. (1989) - Quaternary fauna of bats in Spain: palaoecologic and biogeographic interest. In: Hanák

V., Horáček I. & Gaisler J. (Eds) - European Bat Research 1987: 349-355, Charles University Press, Praha.

Sevilla P. & Chaline J. (2004) - The fossil Middle Pleistocene bats from the Cave of Aldène (Hérault, France). *Zona Arqueol.*, 4 (Miscel. homen. Emiliano Aguirre, II - Paleont.): 592-602.

Sevilla P. & Lopez-Martinez N. (1988) - Comparative systematic value between dental and external/skeletal features in Western European Chiroptera. *Mém. Mus. Nat. Hist. Nat. Paris*, S.C., 53: 255-266.

Sevilla P., Fernández-Jalvo Y., King T. & Yepiskoposyan L. (2008) - New excavations at Azokh Cave (Ngorno Karabagh, Caucasus). First results on the study of the fossil bats. XXIV Jornadas Sociedad Española de Paleontología, Resúmenes: 203-204, Colunga, 15-18 de octubre de 2008.

Sondaar P.Y., De Boer P.L., Sanges M., Kotsakis T. & Esu D. (1984) - First report on a paleolithic culture in Sardinia. *Brit. Arch. Rep.*, I.S., 229: 29-59.

Spitzenberger F., Strelkov P. & Haring E. (2003) - Morphology and mitochondrial DNA sequences show that *Plecotus alpinus* Kiefer, Veith, 2002 and *Plecotus microdontus* Spitzenberger, 2002 are synonyms of *Plecotus macrobullaris* Kuzjakin, 1965. *Nat. Croat.*, 12 (2): 39-53.

Spitzenberger F., Strelkov P.P., Winkler H. & Haring E. (2006) - A preliminary revision of the genus *Plecotus* (Chiroptera, Vespertilionidae) based on genetic and morphological results. *Zool. Scripta*, 35(3): 187-230.

Storch G. (1974) - Quartäre Fledermaus-Faunen von der Insel Malta. *Senckenberg. Lethaea*, 55: 407-434.

Tata C. & Kotsakis T. (in press) - Early Pleistocene bats from Gargano Peninsula (Apulia, Southern Italy). *Acta Chiropt.*

Terzea E. (1986) - Chronologie des faunes pléistocènes supérieures du sud-ouest de la Roumanie. *Trav. Inst. Spéol. Émile Racovitza*, 25(1): 85-101.

Topál G. & Tusnadi G. (1963) - Data for craniometric investigation of *Myotis myotis* Borkh. and *Myotis oxygnathus* Montic. in Hungary. *Ann. Hist. Nat. Mus. Nat. Hung.*, 55: 543-549.

Tozzi C. (1969) - Segnalazione di una grotta con fauna fossile a Borgio (Savona). *Atti Soc. Tosc. Sci. Nat.*, Mem. A, 74(1): 195-2008.

Tozzi C. (1970) - La Grotta di S. Agostino (Gaeta). *Riv. Sci. Preist.*, 25: 3-87.

Trizio I., Preatoni D., Chirichella R., Mattiroli S., Nodari M., Crema S., Tosi G. & Martinoli A. (2005) - First record of the Alpine Long-Eared Bat (*Plecotus macrobullaris* Kuzjakin, 1965) in Lombardy (Northern Italy) revealed by DNA analysis. *Ann. Mus. Civ. Sc. Nat. Brescia*, 34: 171-175.

Vernier E. (1993) - Predazione di chirotteri da parte del Barbagianni (*Tyto Alba*) in Italia. *Hystrix, It. J. Mamm.*, n.s., 5 (1-2): 105-107.

Zhuowei T. & Kotsakis T. (2008) - Tardiglacial micromammals of Riparo Salvini (Latium, Central Italy). *Geol. Rom.*, 41: 125-132.