



General Palaeontology, Systematics and Evolution (Vertebrate Palaeontology)

## Avian fossil assemblages at the onset of the LGM in the eastern Alps: A palaeological contribution from the Rio Secco Cave (Italy)



### *Assemblages fossiles d'oiseaux au commencement du dernier maximum glaciaire dans les Alpes orientales : une contribution paléo-écologique de la grotte du Rio Secco (Italie)*

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#### ARTICLE INFO

##### Article history:

Received 9 August 2017

Accepted after revision 24 October 2017

Available online 22 February 2018

##### Keywords:

Birds  
Late Pleistocene  
Last Glacial Maximum  
Eastern alps  
Italy  
Systematics  
Palaeoecology  
Rio Secco cave

##### Mots clés :

Oiseaux  
Pléistocène supérieur  
Dernier maximum glaciaire  
Alpes orientales  
Systématique  
Paléo-écologie  
Grotte du Rio Secco

#### ABSTRACT

The avian fossil assemblages from the late Pleistocene deposits of the Rio Secco Cave (north-eastern Italy) is presented herein. We studied the layers that date back to the end of MIS3 and the beginning of MIS2, which also contain evidence of Gravettian frequentation dated to 33.5–30 ka cal BP. The systematic analysis revealed the presence of 18 species and other supraspecific taxa that supported palaeoenvironmental reconstructions. Taxa indicate that, at the onset of LGM, site surroundings were characterised by conifer or mixed forests, open grasslands, slow-flowing water bodies and mountain meadows with rocky outcrops, as indicated by *Lagopus muta*. Today, this environment is found above the tree line (beyond 1500–2000 m) and cannot be detected near the site, located at 580 m asl. Noteworthy, is also the finding of the second Italian late Pleistocene fossil record of *Picus canus*.

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#### RÉSUMÉ

Les assemblages fossiles d'oiseaux des dépôts du Pléistocène supérieur de la grotte de Rio Secco (Nord-Est de l'Italie) sont ici présentés. Nous avons étudié les niveaux qui remontent à la fin du MIS3 et au début du MIS2, et qui contiennent aussi des preuves d'une fréquentation gravettienne datée de 33,5–30 ka cal. L'analyse systématique révèle la présence de 18 espèces et d'autres taxons supra-spécifiques, qui permettent des reconstitutions paléoenvironnementales. Les taxons indiquent qu'au début du dernier maximum glaciaire, les alentours du site étaient caractérisés par des forêts mixtes ou des forêts

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de conifères, des prairies ouvertes, des cours d'eau à faible intensité et des prairies de montagne à affleurements rocheux, comme l'indique la présence de *Lagopus muta*. Actuellement, cet environnement s'observe au-dessus de la ligne des arbres (au-dessus de 1500–2000 m) et ne peut être trouvé près du site, localisé à 580 m au-dessus du niveau de la mer. À noter qu'il est aussi le lieu de la découverte du second enregistrement fossile italien au Pléistocène supérieur de *Picus canus*.

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## 1. Introduction

Geographic distribution and phenology of birds have changed many times in the past, due to environmental, climatic, ecological and, recently, also anthropic factors, in a dynamic process which is still underway (Bruderer and Salewski, 2008; Gordo, 2007; Holm and Svenning, 2014; Jonzén et al., 2006). As bird species are often linked to particular habitats, especially concerning vegetation, fossil avifaunas give important informations about palaeoenvironment and palaeoclimate. Some authors even consider birds better paleoenvironment indicators than micromammals (Bedetti and Pavia, 2013; Serjeantson, 2009). Despite this, contributions which deal with avian fossil remains have so far been few, and this field seems to receive less attention than the study of mammal fossil remains, maybe because in many fossil assemblages the mammal remains outnumber the bird remains, and also because of the scarcity of bird skeletal comparative collections.

In this work, we present the systematic analysis of avifaunal remains of the Rio Secco Cave, from layers dating to the onset of MIS2. In Italy, several sites yielded avian remains from this period, but just a few in the area of the northern belt of the exposed Great Adriatic Plain, where the Rio Secco Cave is located (Fig. 1). Some of them lack clear quantitative or stratigraphic indications (Bon et al., 1991; Tyrberg, 1998); amongst the ones provided with datings and a reliable stratigraphy, there are Grotta di Fumane (Cassoli and Tagliacozzo, 1994) and Riparo del Broion (Gurioli et al., 2006). The layers D1d–D1e of the Fumane cave deposit, which date back to 31,75–31,43 ka 14C BP (Higham et al., 2009), provided, among the other bird taxa, *Bubo scandiacus* remains. The presence of this species indicates a colder climate. Riparo del Broion yielded from layers dated 30–32 14C ka BP (ABA), bird remains that indicate the presence of slow-flowing water bodies. During the Last Glacial Maximum, bird remains from Sandalja II (southern Istria, Croatia) also indicate colder climate conditions, like *Lagopus lagopus* and *Bubo scandiacus* (Tyrberg, 1998). Similar taxa related to colder climatic conditions, including *Bubo scandiacus*, have also been found in the Covolo di Trene in the same period (Romandini and Nannini, 2012; Tonon, 1977). During the cold phases of the LGM, the Italian peninsula, as other parts of Mediterranean Europe (Spain and Balkans) represented refugia for northern species, which moved southwards after glacial expansions (Pellegrino et al., 2014; Sanchez Marco, 2004). Furthermore, the number of bird taxa from open environments (steppe, alpine meadows, etc.), suggests an expansion of these habitats in cold stages. Even

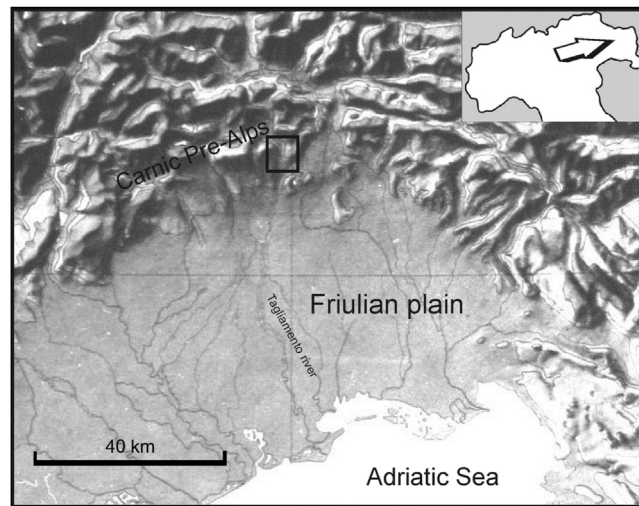
several Lateglacial sites of north-eastern Italy and Croatia yielded avian remains that have been studied and have provided numerical or taxonomic data Grotta di Veja E, in the Veneto region; Riparo Soman, Riparo Dalmeri e Riparo Cogola in the Trentino region; Grotte Verdi di Pradis in the Friuli region; Sandalja II e Ljubiceva pecina in Croazia (Fiore et al., 2015; Gala and Tagliacozzo, 2009, 2010; Oros Sršen et al., 2014; Tonon, 1983). Ljubiceva pecina, in southern Istria, provided *Lagopus lagopus* remains, indicating the permanence in this area, in the early stages of Lateglacial, of species of cold environments (Oros Sršen et al., 2014). The avian taxa identified from the other sites, whose deposits date back to the end of Lateglacial, at the Holocene boundary, mostly correspond to the current avifauna of the area.

## 2. Site and stratigraphy

The Rio Secco Cave is located at an elevation of 580 m asl on the Pradis Plateau in the eastern part of the Carnic PreAlps (Fig. 2), an orographic system of the eastern Alps dissected from north–south and west–east oriented valleys that separate mountains with peaks 2000–2300 m asl. The Pradis Plateau is 6 sq km wide and is enclosed on three sides by mountains peaking from 1148 m to 1369 m and to the south it is bounded by the foothills dissected by the Cosa stream. The plateau rises from 530 m to 590 m and faces the south to the present-day Friulian plain, which is the uppermost belt of a large plain, the Great Adriatic Plain, which emerged during the late Pleistocene and had its maximal southern expansion during the LGM (Antonoli and Vai, 2004; Shackleton et al., 1984). The shelter protects a horizontal gallery, which is almost completely filled with sediments. In 2002, a test-pit revealed the presence of prehistoric settlements. An archaeological excavation has been carried out since 2010 (Peresani et al., 2014).

The sedimentary body of the cave includes 4 stratigraphic Macro-Units, partially affected by bioturbation:

- Macro-Unit 1: includes US2 (Unità Stratigrafica-Stratigraphic Unit 2) and US3. Contains historical settlements and Neolithic/Bronze Age archaeological material;
- Macro-Unit BR1: includes US4 and US6 and is characterized by the presence of angular stones and fragments of karst limestone pavement originated by vault collapses. US4 is composed of blocks and stones with a loamy fine fraction and contains rare lithics. US6 is a thin and discontinuous layer with organic matter and micro-charcoal, rare bones, lithic implements and two hearths.



**Fig. 1.** Map of the northern Adriatic region with the position of Rio Secco Cave in the black square.

**Fig. 1.** Carte de la région Adriatique nord, avec la position de la grotte de Rio Secco dans l'encart.



**Fig. 2.** View of the Pradis Plateau with the position of Rio Secco Cave in the gorge, marked with the arrow. In the background, the alluvial plain with the Tagliamento River in the center.

**Fig. 2.** Vue du plateau de Pradis, avec la position de la grotte de Rio Secco dans la gorge, indiquée par la flèche. À l'arrière-plan, la plaine alluviale, avec la rivière Tagliamento au centre.

A preliminary analysis of mammal remains revealed the presence of *Capra ibex*, *Rupicapra rupicapra*, *Bos primigenius/Bison priscus* and *Castor fiber*. Human modifications include cut-marks and combustion on caprid shafts, on a marmot clavicle and on a *Castor fiber* scapula (Peresani et al., 2014). Charred wood from one of these hearths yielded an age of 33,480–30,020 y cal BP, assessing the placement of US6 in the early Gravettian period (Talamo et al., 2014). Macro-Unit BR1 probably covers a time span of a few millennia between the end of MIS3 and the beginning of MIS2, in a context of progressively harsher climate that peaked during the LGM (Clark et al., 2009; Monegato et al., 2017);

- Macro-Unit BR2: is a massive stone-supported breccia. It includes US4BR and a discontinuous sandy layer at the base, labeled US4sabbie. This Macro-Unit is archaeologically sterile;
- Macro-Unit BIO1: is composed of stones and loamy fine fraction and contains some Mousterian archaeological material. It includes the layers US5top, US7, US5, US8 and US9. The age of these deposits ranges from 47,940–45,840 cal BP (US5top) to more than 49,000 y BP (lower level of US7) (Talamo et al., 2014). The mammal remains from these layers belong to ungulates (*Cervus elaphus*, *Capreolus capreolus*, cf. *Alces alces*, *Rupicapra rupicapra*, *Capra ibex*, *Sus scrofa*, *Bos primigenius*);

*Bison priscus*), carnivores (*Ursus spelaeus*, *Martes martes*, *Mustela erminea*, *Meles meles*, *Vulpes vulpes*, *Canis lupus*) and to *Erinaceus europaeus* and *Lepus europaeus*. The remains of *Cervus elaphus* and *Ursus spelaeus* show human modifications (Peresani et al., 2014; Romandini et al., in press). Among the bird remains, a claw of *Aquila chrysaetos* show cut-marks (Romandini et al., 2014).

### 3. Materials and methods

In this work, we present the systematic analysis of 194 bird remains coming from Macro-Unit BR1 and Macro-Unit BR2. All sediments were excavated in 50 × 50 cm or 33 × 33 cm squares and in some cases (e.g., US4), they were removed in arbitrary levels. Bird remains have been recovered after sediments wet sieving. The amount of processed sediment is approximately 57 m<sup>3</sup> (39 m<sup>3</sup> for BR1 and 18 m<sup>3</sup> for BR2). The fossil material is stored in the Sezione di Scienze Preistoriche e Antropologiche of the Dipartimento di Studi Umanistici of the University of Ferrara. The taxonomic determinations have been based on comparisons with two modern bird skeletal comparative collections: the “Marco Pavia Ornithological Collection” (MPOC), stored at the Dipartimento di Scienze della Terra of the Torino University, and the one held at Sezione di Scienze Preistoriche e Antropologiche of the Dipartimento di Studi Umanistici of the University of Ferrara. Some specific contributions on the osteological features of single avian orders and families have also been very helpful for the taxonomic determinations (Cuisin, 1989; Erbersdobler, 1968; Janossy, 1983; Kraft, 1972; Otto, 1981; Schmidt-Burger, 1982; Tomek & Bochenski, 2000). Taxonomy follows Del Hoyo et al. (2014, 2016). Osteological terminology follows Baumel and Witmer (1993).

### 4. Taxonomical determination and ecological background

A total of 166 remains have been assigned to 31 bird taxa (Table 1). Among these, several remains have been attributed to species-level taxa and are described in detail hereafter, while other remains have been attributed to supraspecific taxa, because of their fragmentation or because of the lack of diagnostic features. The latter are not described in detail. Finally, 28 remains are left as Aves.

#### Class Aves

#### Order Galliformes

#### Family Phasianidae

#### Genus *Coturnix*

#### *Coturnix coturnix* Linnaeus, 1758

Material. One proximal right coracoid (RS320) from BR1.

Description and comparisons. *Coturnix coturnix* bones differ from those of all other western Palearctic Galliformes in size, being clearly smaller than the other species (Kraft, 1972).

Remarks. *Coturnix coturnix* currently breeds in most of Europe and winters in sub-saharan Africa (Del Hoyo et al., 2014). In Italy, it is a breeding, regular migrant and

**Table 1**

List of bird taxa from Rio Secco Cave. The numbers indicate the identified remains for each taxon.

**Tableau 1**

Liste des taxons d'oiseau de la Grotte de Rio Secco. Les numéros indiquent les restes identifiés pour chaque taxon.

Taxa	BR1	BR2
<i>Coturnix coturnix</i>	1	
<i>Perdix perdix</i>	1	1
<i>Lagopus muta</i>	3	1
<i>Tetrao urogallus</i>	1	2
<i>Lyrurus tetrix</i>	6	1
<i>Tetrao urogallus/Lyrurus tetrix</i>	1	1
Galliformes indet.	10	2
<i>Crex crex</i>	2	
<i>Fulica atra</i>		1
Rallidae indet.	3	
<i>Asio otus</i>	2	
<i>Asio flammeus</i>	2	
Strigidae indet.	1	
<i>Buteo buteo</i>	2	
<i>Picus canus</i>	1	
<i>Falco</i> sp.	1	
<i>Pica pica</i>	1	
<i>Nucifraga caryocacates</i>	1	
Corvidae indet.	8	3
Paridae indet.		1
Alaudidae indet.	1	
cf. <i>Turdus viscivorus</i>	2	
<i>Turdus</i> sp.	2	1
<i>Erithacus rubecula</i>	1	1
Muscicapidae indet.		1
<i>Prunella collaris</i>	1	
<i>Pyrrhula pyrrhula</i>	1	1
<i>Loxia curvirostra</i>		1
<i>Fringilla coelebs/montifringilla</i>	1	
Emberizidae indet.		1
Passeriformes indet.	60	31
Aves indet.	23	5
Total remains	139	55

rare wintering species. It breeds in open areas with low vegetation (Brichetti and Fracasso, 2004). This species is reported in the Palearctic since the early Pleistocene, and becomes abundant in the fossil record of the late Pleistocene of Europe (Tyrberg, 1998, 2017).

#### Genus *Perdix*

#### *Perdix perdix* Linnaeus, 1758 (Fig. 3A)

Material. One distal right tibiotarsus (RS403) from BR1 and one distal right ulna (RS375) from BR2.

Description and comparisons. The distal tibiotarsus differs from the one of the genera *Alectoris*, *Lagopus* and *Bonasa* in the width of the epiphysis (smaller than in *Lagopus lagopus*, *Alectoris rufa* and *Alectoris greca*) and in the extent of the pons supratendineum, which is clearly wider than in *Bonasa bonasia* and *Lagopus muta*. The ulna is distinguishable from that of the above-mentioned genera in being less wide distally (Kraft, 1972).

Remarks. *Perdix perdix* is a sedentary species, which is spread across most of Europe, partly because of reintroductions, also for hunting purposes (Del Hoyo et al., 2014). In Italy, it is currently a sedentary and rare breeding species, which was much more widespread in historical times. It lives in open grasslands and shrublands, preferably hilly (Brichetti and Fracasso, 2004). *Perdix perdix* is known in



**Fig. 3.** Bird remains from the late Pleistocene deposits of Rio Secco cave. A. *Perdix perdix* distal right tibiotarsus (RS403), cranial view. B. *Lagopus muta* distal left coracoid (RS335), dorsal view; C. *Lagopus muta* right tarsometatarsus (RS380), dorsal view; D. *Tetrao urogallus* distal right tibiotarsus (RS412) cranial view; E. *Lyrurus tetrix* proximal left tibiotarsus (RS352), cranial view. F. *Lyrurus tetrix* left tarsometatarsus (RS324), dorsal view. G. *Crex crex* distal left humerus (RS452), cranial view. H. *Fulica atra* right coracoid (RS 378), dorsal view. I. *Asio flammeus* left phalanx I of digit 1 (RS455), lateral view. J. *Buteo buteo* distal right tibiotarsus (RS321), cranial view. K. *Picus canus* proximal left carpometacarpus (RS315), ventral view. L. *Nucifraga caryocatactes* distal left tibiotarsus (RS325), cranial view. M. cf. *Turdus viscivorus* right carpometacarpus (RS356), ventral view. N. *Prunella collaris* maxilla (RS390), ventral view. O. *Loxia curvirostra* maxilla (RS504), dorsal view. The scale bar represents one centimetre.

**Fig. 3.** Restes d'oiseau des dépôts Pléistocène supérieur de la grotte de Rio Secco. A. Tibiotarsus droit distal (RS403) de *Perdix perdix*, vue crâniale. B. Coracoïde gauche distal (RS335) de *Lagopus muta*, vue dorsale. C. Tarsometatarsus droit (RS380) de *Lagopus muta*, vue dorsale. D. Tibiotarsus droit distal (RS412) de *Tetrao urogallus*, vue crâniale. E. Tibiotarsus gauche distal (RS352) de *Lyrurus tetrix*, vue crâniale. F. Tarsometatarsus gauche (RS324) de *Lyrurus tetrix*, vue dorsale. G. Humérus gauche distal (RS452) de *Crex crex*, vue crânienne. H. Coracoïde droit (RS378) de *Fulica atra*, vue dorsale. I. Phalange gauche I du doigt 1 (RS455) d'*Asio flammeus*, vue latérale. J. Tibiotarsus droit distal (RS321) de *Buteo buteo*, vue crâniale. K. Carpometacarpus gauche proximal (RS315) de *Picus canus*, vue ventrale. L. Tibiotarsus gauche distal (RS325) de *Nucifraga caryocatactes*, vue crâniale. M. Carpometacarpus droit (RS356) de cf. *Turdus viscivorus*, vue ventrale. N. Maxillaire (RS390) de *Prunella collaris*, vue ventrale. O. Maxillaire (RS504) de *Loxia curvirostra*, vue dorsale. La barre d'échelle représente 1 cm.

the Palearctic since the early Pleistocene, and is commonly reported in the late Pleistocene of Europe, including Italy (Tyrberg, 1998, 2017).

### Genus *Lagopus*

#### *Lagopus muta* Montin, 1781 (Fig. 3 B and C)

**Material.** One cranial portion of a left scapula (RS348), one distal left coracoid (RS335) and one shaft of a right ulna (RS368) from BR1 and one right tarsometatarsus (RS380) from BR2.

**Description and comparisons.** On average, *Lagopus muta* is slightly smaller than *Lagopus lagopus*. The distal coracoid is dimensionally compatible with both species, but the angulus medialis, which is more hook-shaped in *Lagopus muta* than in *Lagopus lagopus*, allows us to rule out this last species. The tarsometatarsus differs from the one of *Lagopus lagopus* in the clearly smaller length (Kraft, 1972). We tentatively refer the cranial portion of the scapula and the ulna shaft to *L. muta* (even if these elements are not diagnostic enough to distinguish it from *L. lagopus*), on the basis

of a high morphological correspondence with the former species.

**Remarks.** *Lagopus muta*, a mostly sedentary species, is distributed across the rocky tundra areas of high latitudes and in the mountain areas of the mid-latitudes of the boreal hemisphere (Del Hoyo et al., 2014). In Italy, it currently lives in the Alps as a sedentary and breeding species; here, it prefers meadows with some creeping shrubs and rocky grounds, above the tree line. It is mostly observed at heights between 2,300 and 2,700 m asl, but with a minimum of 1,550 and a maximum of 2,900 m asl, as this species makes altitudinal seasonal movements (Brichetti and Fracasso, 2004). This species is known in the Palearctic since the middle Pleistocene and is often reported from late Pleistocene localities. In the cold phases of the Pleistocene, it was much more widespread, also at lower heights than today (Tyrberg, 1998, 2017). It currently survives on the mountain areas of mid-latitudes as a “glacial relict” (Holm and Svenning, 2014; Tyrberg, 1991).

### Genus *Tetrao*

#### *Tetrao urogallus* Linnaeus, 1758 (Fig. 3D)

Material. One distal right tibiotarsus (RS412) from BR1, one sternum fragment (RS387) and one distal posterior phalanx (RS506) from BR2.

Description and comparisons. The size of the distal tibiotarsus fragment and the sternum fragment, which are bigger than that of other large Galliformes as *Phasianus colchicus* and *Lyrurus tetrrix*, makes these remains easily identifiable as *Tetrao urogallus* (Erbersdobler, 1968). We tentatively refer the posterior phalanx, which shows features typical of Galliformes (rounded distal epiphysis and curved and short outline), to *Tetrao urogallus* on the basis of its size.

Remarks. *Tetrao urogallus*, a mostly sedentary species, is spread across the northern Eurasia and part of the medium latitudes of Europe (Del Hoyo et al., 2014). In Italy, where it is currently a sedentary and breeding species, it lives in conifer or mixed forests of the central-eastern Alps (Brichetti and Fracasso, 2004). In the high latitudes of the boreal hemisphere, it is observed at lower heights (Cramp, 1998). Also during the late Pleistocene, as the fossil record indicates, this species was spread at lower heights than today (Holm and Svenning, 2014). *Tetrao urogallus* is reported in the Palearctic since the middle Pleistocene and is often recorded in the late Pleistocene (Tyrberg, 1998, 2017).

### Genus *Lyrurus*

#### *Lyrurus tetrrix* Linnaeus, 1758 (Fig. 3E and F)

Material. One furcula fragment (RS345), one cranial portion of a left scapula (RS337), one distal right coracoid (RS405), one proximal left tibiotarsus (RS352), one proximal right tibiotarsus (RS369) and one left tarsometatarsus (RS324) from BR1. One proximal right femur (RS486) from BR2.

Description and comparisons. This species is larger than those in the genera *Alectoris*, *Lagopus*, *Bonasa* and *Perdix*, but smaller than in *Tetrao urogallus*. The bones differ from this species and from *Phasianus colchicus* also in several morphological features (Erbersdobler, 1968). In the case of the proximal femur, the size of the epiphysis allows us to rule out *Tetrao urogallus* (Erbersdobler, 1968) and the extent and shape of the pneumatic foramina under the crista trochanteris, together with the outline of the epiphysis in proximal view, rule out *Phasianus colchicus*. The two proximal tibiotarsi can be easily separated from *Tetrao urogallus* by size (Erbersdobler, 1968); these elements differ from *Phasianus colchicus* in the protrusion in the proximal direction of the crista cnemialis cranialis, which is lower in *Lyrurus tetrrix*. The cranial portion of the scapula cannot belong to *Tetrao urogallus* on the basis of the size and differs from *Phasianus colchicus* in the presence of the pneumatic foramen between the facies articularis humeralis and the acromion. The total length of the tarsometatarsus allows us to rule out both *Tetrao urogallus* and *Phasianus colchicus* (Erbersdobler, 1968). The furcula differs from the one of *Phasianus colchicus* in the protrusion of the hypocleideum, which is less pronounced in *Lyrurus tetrrix*, while *Tetrao urogallus* can be ruled out on the basis of the size. In the case of the distal coracoid, the distance of the posterior processus

lateralis from the apex medialis allows us to rule out both *Tetrao urogallus* (in which it is greater) and *Phasianus colchicus* (in which it is smaller). In these species, the facies articularis sternalis of the coracoids also shows a different outline in sternal view, more curved in *Phasianus colchicus* than in *Lyrurus tetrrix* and straighter in *Tetrao urogallus* (Erbersdobler, 1968).

Remarks. *Lyrurus tetrrix* is mostly sedentary. In north-eastern Europe and Russia, where this species is more widespread, it mostly lives in lowland habitats, transitional between woodland and open heath, bog and steppe; in the mountain areas of the mid-latitudes, like the Alps, it survives as a “glacial relict” (Cramp, 1998; Del Hoyo et al., 2014). In Italy, it is currently a sedentary and breeding species in the Alps, where it lives in conifer or deciduous forest, also in areas with sparse vegetation or near open areas (Brichetti and Fracasso, 2004). Pleistocene fossil records suggest that this species, during cold phases, was much more widespread than today (Holm and Svenning, 2014). *Lyrurus tetrrix* is known since the early Pleistocene of the Palearctic and is quite abundant in the late Pleistocene avian fossil record of Europe (Tyrberg, Tyrberg, 2017).

## Order Gruiformes

### Family Rallidae

#### Genus *Crex*

#### *Crex crex* Linnaeus, 1758 (Fig. 3G)

Material. One distal left humerus (RS452) and one distal right ulna (RS399) from BR1.

Description and comparisons. The bone features of *Rallus aquaticus* are extremely similar to those of *Crex crex*, but, as in the case of the distal humerus and the distal ulna, *Rallus aquaticus* can be ruled out because of its smaller size.

Remarks. *Crex crex* currently breeds in most of Europe and winters in sub-saharan Africa (Del Hoyo et al., 2014). In Italy, it is a breeding (only in mountain areas of north-eastern Italy), regular migrant and irregular wintering species. It breeds in open or semi-open environments, like meadows with tall grass and moist grasslands (Brichetti and Fracasso, 2004). *Crex crex* is known in the Palearctic fossil record since the early Pleistocene (Tyrberg, 1998; Tyrberg, 2017).

#### Genus *Fulica*

#### *Fulica atra* Linnaeus, 1758 (Fig. 3H)

Material. One right coracoid (RS378) from BR2.

Description and comparisons. Within the Rallidae family, the size of this coracoid is intermediate between *Porphyrio porphyrio* and *Gallinula chloropus* and thus this remain can be determined as *Fulica atra*.

Remarks. *Fulica atra* is distributed across Europe and Asia. Part of the population winters in Africa and south-eastern Asia (Del Hoyo et al., 2014). In Italy, it is currently a sedentary and breeding, regular migrant and wintering species. This species inhabits still or slow-flowing waters (Brichetti and Fracasso, 2004). It is a species that is present in the Palearctic fossil record since the early Pleistocene (Tyrberg, 1998, 2017).

## Order Strigiformes

### Family Strigidae

### Genus *Asio*

#### *Asio otus* Linnaeus, 1758

Material. One phalanx III of digit 2 (RS331) and one indeterminate ungual phalanx (RS350) from BR1.

Description and comparisons. These two ungual phalanges have been ascribed to *Asio otus* because their proximal epiphysis, in proximal view, are less round-shaped with respect to the proximal epiphysis of the ungual phalanges of *Asio flammeus*, the most similar species from an osteological point of view.

Remarks. *Asio otus* is widespread across the mid-latitudes of the northern hemisphere (Del Hoyo et al., 2014). In Italy, it currently is a sedentary and breeding, regular migrant and wintering species. It prefers woodlands surrounded by open areas, used for hunting purposes (Brichetti and Fracasso, 2006). *Asio otus* is reported in the Palearctic since the middle Pleistocene and becomes more abundant in the late Pleistocene (Tyrberg, 1998, 2017).

#### *Asio flammeus* Pontoppidan, 1763 (Fig. 3, I)

Material. One left phalanx I of digit 1 (RS455) and one phalanx II of digit 1 (RS398) from BR1.

Description and comparisons. The left phalanx I of digit 1 shows a processus that extends in the ventral side of the proximal part of the bone. This is a typical feature of the 1st phalanx of the digit 1 of Strigidae. Among medium-sized Strigidae, it shows greater morphological correspondence with *Asio flammeus* and *Asio otus*. The specimen is attributed to *Asio flammeus* because of the stouter outline and a flatter proximal epiphysis, in lateral view, with respect to *Asio otus*. The phalanx II of digit 1 (an ungual phalanx) has been ascribed to this species because the processus present in the proximal part of the bone is wider in proximal view than in *Asio otus* and extends to a more ventral direction, in lateral view, than in *Asio otus*.

Remarks. *Asio flammeus* breeds in the high and mid-latitudes of the northern hemisphere and winters in southern North America, southern Asia and Africa (Del Hoyo et al., 2014). In Italy, it is currently a regular migrant and wintering species. It prefers wetlands, meadows, grasslands and steppes, often observed also in mountain areas (Brichetti and Fracasso, 2006). *Asio flammeus* is known in the Palearctic since the middle Pleistocene (Tyrberg, 1998; Tyrberg, 2017).

### Order Accipitriformes

#### Family Accipitridae

### Genus *Buteo*

#### *Buteo buteo* Linnaeus, 1758 (Fig. 3J)

Material. One sternum fragment (rostral area) (RS323) and one distal right tibiotarsus (RS321) from BR1.

Description and comparisons. This tibiotarsus differs from tibiotarsi of other raptors of similar size (like *Accipiter gentilis*, *Pernis apivorus*, *Circus aeruginosus*, *Milvus milvus*, *Milvus migrans* and *Aquila pennata*) especially in the central position of the canalis extensorius and of the sulcus extensorium, with a 45° inclined pons supratendineum. *Buteo lagopus* and *Buteo rufinus* tibiotarsi are similar to this remain in osteological features, but are ruled out because of their larger size, especially considering that the width of the distal epiphysis of this tibiotarsus is shorter than the

range indicated for *Buteo buteo* by Schmidt-Burger (1982). Moreover, this remain is slightly smaller than all the *Buteo buteo* tibiotarsi we used for comparison and from the literature. The sternum fragment has been ascribed to *Buteo buteo* on the basis of the morphological correspondence in the general outline of the sulcus articularis coracoideus and of the dorsal labrum, and also in the shape of the rostrum spina externa (Otto, 1981). Even the sternum fragment looks smaller than the specimens in the collection.

Remarks. *Buteo buteo* is widespread across Europe and western Asia, with part of the population wintering in sub-saharan Africa (Del Hoyo et al., 2014). In Italy, it is currently a sedentary and breeding, regular migrant and wintering species. It lives in a variety of different habitats (Brichetti and Fracasso, 2003). This species is reported in the Palearctic fossil record since the middle Pleistocene (Tyrberg, 1998, 2017).

### Order Piciformes

#### Family Picidae

### Genus *Picus*

#### *Picus canus* Gmelin, 1788 (Fig. 3K)

Material. One proximal left carpometacarpus (RS315) from BR1.

Description and comparisons. This carpometacarpus, similar in osteological features both to *Picus canus* and *Picus viridis*, is slightly smaller than the one of *P. viridis*. Moreover, the processus intermetacarpalis is in a more proximal position and the trochlea carpalis is slightly less pointed than in *P. viridis*. The other Palearctic species of Piciformes are ruled out on the basis of the size.

Remarks. *Picus canus* is distributed across the mid-latitudes of Eurasia (Del Hoyo et al., 2014). In Italy, where it lives in the eastern Alps, it is currently a sedentary and breeding, irregular migrant and irregular wintering species. It inhabits conifer, deciduous or mixed forests (Brichetti and Fracasso, 2007). *Picus canus* is known in the Palearctic fossil record since the middle Pleistocene. In the late Pleistocene, as the fossil record attests, it was mostly spread in central and eastern Europe. The Rio Secco Cave remain represents the third Italian fossil record of this species (Pavia and Insacco, 2013; Tyrberg, 1998, 2017). The first comes from the late Pleistocene deposits of the Caverna delle Arene Candide, in Liguria (Cassoli, 1980), while the second, a complete ulna dubitatively referred to *P. canus*, comes from the middle Pleistocene deposits of the Comiso area, in Sicily (Pavia and Insacco, 2013).

### Order Passeriformes

#### Family Corvidae

### Genus *Pica*

#### *Pica pica* Linnaeus, 1758

Material. One cranial portion of a right scapula (RS338) from BR1.

Description and comparisons. Slight differences in the osteological characteristics distinguish this scapula from those of other Corvids of the same size, like the species of the genus *Pyrrhocorax* and *Corvus monedula*. In detail, in this remain the acromion is clearly higher than the ventral part

of the tuberculum coracoideum: this is a typical feature of *Pica pica* scapulae (Tomek and Bochenki, 2000).

Remarks. *Pica pica* is widespread across Europe and most of Asia (Del Hoyo et al., 2016). In Italy, where it is very abundant and widespread, it is a sedentary and breeding, irregular migrant and irregular wintering species. It lives in a variety of open and wooded habitats (Brichetti and Fracasso, 2011). *Pica pica* is known in the Palearctic since the early Pleistocene. It is largely present in the European fossil record of the late Pleistocene (Tyrberg, 1998, 2017).

### Genus *Nucifraga*

#### *Nucifraga caryocatactes* Linnaeus, 1758 (Fig. 3L)

Material. One distal left tibiotarsus (RS325) from BR1.

Description and comparisons. The width of the distal epiphysis of the tibiotarsus rule out all Corvidae apart from *Nucifraga caryocatactes* and *Pica pica* (Tomek and Bochenki, 2000). The shape of the canalis extensorius and the obliquity of the pons supratendineus allow us to rule out *Pica pica*.

Remarks. *Nucifraga caryocatactes* is spread across the high and mid-latitudes of Eurasia (Del Hoyo et al., 2016). In Italy, where it only lives in the Alps, is a sedentary and breeding, irregular migrant and irregular wintering species. It inhabits conifer forests (Brichetti and Fracasso, 2011). This species is reported in the Palearctic fossil record since the middle Pleistocene (Tyrberg, 1998, 2017).

### Family Turdidae

#### Genus *Turdus*

#### cf. *Turdus viscivorus* Linnaeus, 1758 (Fig. 3M)

Material. Two right carpometacarpi (RS356 and RS411) from BR1.

Description and comparisons. The two carpometacarpi, clearly belonging to the family Turdidae on the basis of their osteological features, are tentatively referred to *Turdus viscivorus* for the large size and for a high morphological correspondence. Nevertheless, the total length of both the specimens is longer than any *Turdus viscivorus* carpometacarpus of the collection (RS411 length: 25.8 mm; RS356 length: 25.4 mm). In the European bird fossil record of the Pleistocene, several specimens of a Turdidae bigger than *Turdus viscivorus* have been reported. Some of them (only humeri and cranial remains) have even been assigned to a new species, *Meridiocichla salotti* (Louchart, 2004). Nevertheless, considering that carpometacarpi are not highly diagnostic bones (especially for Passeriformes), and considering the absence in the literature of the size range of carpometacarpi of *Turdus viscivorus*, we prefer to tentatively refer RS356 and RS411 to cf. *Turdus viscivorus* instead, rather than to other less probable taxa like *Zoothera dauma* (a big asian Turdidae, rare vagrant in Europe) or *Meridiocichla salotti* (Louchart, 2004).

Remarks. *Turdus viscivorus* is distributed across the high and mid-latitudes of Europe and western Asia (Del Hoyo et al., 2016). In Italy, it is a sedentary and breeding, regular migrant and wintering species. It lives in open wooded environments in mountain or hilly areas, where it prefers clearings used for feeding purposes (Brichetti and Fracasso, 2008). *Turdus viscivorus* is known in the fossil

record of the Palearctic since the middle Pleistocene. It is commonly reported in European late Pleistocene localities (Tyrberg, 1998, 2017).

### Family Muscicapidae

#### Genus *Erithacus*

#### *Erithacus rubecula* Linnaeus, 1758

Material. One left humerus (RS363) from BR1 and one proximal right humerus (RS 434) from BR2.

Description and comparisons. The humeri of the genera *Luscinia* and *Erithacus* show some differences from the general osteological features of the humeri of the other members of the family they belong, the Muscicapidae. The latter show, in the proximal humerus, 2 fossae, separated by a medial bar, while *Luscinia* and *Erithacus* have only the pneumo-anconeal fossa well developed, with a shallow tricipital fossa. The humerus of *Erithacus rubecula* differs from *Luscinia megarhynchos* and *Luscinia luscinia* in the smaller size and from *Luscinia svecica* in the narrower proximal epiphysis and in the absence of a rim which, from the tricipital fossa, continues up until the ventral part of the bone (Janossy, 1983).

Remarks. *Erithacus rubecula* is widespread across Europe and northern Africa (Del Hoyo et al., 2016). In Italy, it is currently a sedentary and partial breeding, regular migrant and wintering species. It lives in a variety of wooded environments (Brichetti and Fracasso, 2008). This species is reported in the Palearctic fossil record since the middle Pleistocene and is scarcely represented in the Italian Pleistocene fossil localities (Tyrberg, 1998; Tyrberg, 2017).

### Family Prunellidae

#### Genus *Prunella*

#### *Prunella collaris* Scopoli, 1769 (Fig. 3N)

Material. One maxilla (RS390) from BR1.

Description and comparisons. The general outline in dorsal view and the slight curving of the os nasale in correspondence with the nose cavity in lateral view, make this remain ascribable to the family Prunellidae. Within the family, its size rules out *Prunella modularis*, which is clearly smaller (Cuisin, 1989; Janossy, 1983).

Remarks. *Prunella collaris* is spread across the Mediterranean basin and central Asia (Del Hoyo et al., 2016). In Italy, it is currently a sedentary and breeding, regular migrant and wintering species. During the breeding season it lives in mountain areas with low cliffs, rocky slopes and alpine meadows, above the tree line (Brichetti and Fracasso, 2007). This species survives in mountain areas of mid-latitudes as a “glacial relict” (Tyrberg, 1991). This species is known in the Palearctic fossil record since the middle Pleistocene (Tyrberg, 1998, 2017).

### Family Fringillidae

#### Genus *Pyrrhula*

#### *Pyrrhula pyrrhula* Linnaeus, 1758

Material. One left humerus (RS411) from BR1 and one proximal left humerus (RS500) from BR2.

Description and comparisons. The left complete humerus is ascribed to *Pyrrhula pyrrhula* on the basis of the



total length and the morphology of the proximal epiphysis, with the medial bar extending more into the direction of dorsal side, a feature that allows us to separate this species from the other Fringillidae of the same size (Janosy, 1983). The proximal humerus is referred to *Pyrrhula pyrrhula* on the basis of the size and of the above-mentioned morphology of the proximal epiphysis.

Remarks. *Pyrrhula pyrrhula* is spread across high and mid-latitudes of Eurasia (Brichetti and Fracasso, 2013; Del Hoyo et al., 2016). In Italy, it is currently a sedentary and breeding, regular migrant and wintering species. It inhabits conifer, deciduous and mixed forests (Brichetti and Fracasso, 2013). *Pyrrhula pyrrhula* is known in the Palearctic fossil record since the middle Pleistocene (Tyrberg, 1998, 2017).

### Genus *Loxia*

#### *Loxia curvirostra* Linnaeus, 1758 (Fig. 30)

Material. One maxilla (RS504) from BR2.

Description and comparisons. The outline and morphology of the bill, with crossed tips, is the most typical feature of this species, that makes it unmistakable (Cuisin, 1989). Between the other species of the genus *Loxia*, *Loxia pytyopsittacus* and *Loxia scotica* can be ruled out because of their more robust bill and a greater size than *L. curvirostra*. *Loxia leucoptera* differs from *L. curvirostra* in being slightly smaller and in the slender bill.

Remarks. *Loxia curvirostra* is distributed across temperate and subarctic areas of the northern hemisphere (Del Hoyo et al., 2016; Brichetti and Fracasso, 2013). In Italy, it is currently a sedentary and breeding, regular migrant and wintering species, that lives in conifer forests of mountain areas (Brichetti and Fracasso, 2013). This species is reported in the Palearctic fossil record since the late Pleistocene (Tyrberg, 1998, 2017).

## 5. Discussion

The bird taxa recognized in this work all belong to the extant Italian avifauna (Brichetti and Fracasso, 2015). Taxa like *Lyrurus tetrrix*, *Tetrao urogallus*, *Picus canus*, *Nucifraga caryocatactes*, *Pyrrhula pyrrhula*, *Loxia curvirostra* indicate the presence, in the vicinity of the site, of mainly conifer or mixed forests. Taxa like *Lagopus muta* e *Prunella collaris* suggest the presence of open areas with low vegetation and rocky grounds, above the tree line. *Lagopus muta* is absent today from the area of the site. In detail, this species has been observed 12 times in Friuli-Venezia Giulia in the period between 2006–2011, but at almost 30 km further from the site and at higher heights (Guzzon et al., 2013). During the time span represented in the sediments in this study, the site, which is located at 580 m asl, was probably surrounded by a forest environment, if we consider that the minimum height reached by the tree line during LGM, in the oriental Prealps, was 7–800 m asl (Ravazzi et al., 2007). Anyway, assuming that the catchment/hunting area of the predator responsible for the accumulation of bird remains (being it a nocturnal raptor, a diurnal raptor, a carnivore or a man) is hardly wider than 30 km from the site (Serjeantson, 2009), the presence of *Lagopus muta* at

the Rio Secco Cave indicates that mountain open environments were located closer to the site, and therefore, as expected, the tree line was located at lower heights than today. The presence of these open and rocky environments is furthermore confirmed by *Capra ibex*, *Rupicapra rupicapra* and *Marmota marmota* (Peresani et al., 2014). *Perdix perdix* suggests the presence of open areas with low vegetation, while *Turdus viscivorus* indicates the presence of open wooded areas. Still or slow-flowing water bodies had to be found near the site, as the presence of *Fulica atra* indicates. This is confirmed by the remains of *Castor fiber* (Peresani et al., 2014). *Coturnix coturnix*, *Crex crex*, *Asio otus*, *Asio flammeus*, *Buteo buteo* and *Erithacus rubecula*, species that today have a migratory behaviour, could have deceased also during migration. In this phase they can be found in several environments, therefore, these taxa are not useful for paleoenvironment reconstruction purposes. *Pica pica* doesn't give any palaeoecological indication as it currently lives in a variety of different environments.

The taxa identified do not suggest any significant environmental change between the investigated layers, showing a prevalence, both in BR1 and BR2, of species typical of forest environments, in terms of the number of identified specimens and also of the number of taxa identified.

The finding of *L. muta* remains at lower heights with respect to its current altitudinal distribution suggests, as expected, the presence of a colder climate than that of the present, as we are dealing with the onset of the LGM. However, caution is required when inferring climate oscillations on the basis of changes in fossil avifauna distribution patterns. It must be taken into account that these changes can be due to a variety of different factors that are not necessarily linked to temperature shifts, such as vegetation and food availability, seasonality, precipitation trends, fluctuations of the populations, interactions with other species (potential competitors), changes in the ecology and habits of the species, and even ecological pressure due to human activities. Only strong latitudinal or altitudinal shifts in a bird species distribution, possibly supported by other evidences and by attested climate trends, should be used as a climate proxy (Bedetti & Pavia, 2001; Bedetti & Pavia, 2007; Finlayson, 2011; Tyrberg, 2010).

Of particular interest is the finding, among the bird fossil remains of this site, of a carpometacarpus of *P. canus*. This remain represents the second Italian late Pleistocene fossil record of this species and the third for Italy. This record falls inside its current Italian distribution, while the other Italian fossil records fall outside its current distribution (Cassoli, 1980; Pavia and Insacco, 2013; Tyrberg, 1998, 2017).

The results of the taphonomic analysis indicate that the responsible for the accumulation of the bird remains in the deposit were nocturnal raptors, carnivores and humans. Some nocturnal raptor species frequent caves and rocky cliffs, for breeding or resting purposes, and prey on other birds. The bones of their preys, ejected in the pellets, can show traces of digestion (rounding and thinning of the articular and broken ends, looking like a slight corrosion), or, often, they show no traces of digestion at all (Andrews, 1990; Bochenski & Tomek, 1997; Rufä et al., 2017; Serjeantson, 2009). Diurnal raptors or carnivore digestion

usually produces more severe damage on the surface of the bones because of their stronger digestive acids (Bochenski et al., 1997, 1998; Lloveras et al., 2014, 2016; Serjeantson, 2009). Furthermore, the small bones contained in owl pellets are more protected from post-depositional taphonomic modifications as they are wrapped in a matrix of fur and feathers (Serjeantson, 2009). The percentage of slightly corroded bird remains that we detected in the assemblage (11.9% of the total,  $n = 23$ ) and the amount of well preserved small Passeriformes and small rodent remains, support the hypothesis of nocturnal raptors as accumulators of at least part of the bird bones. In this avian fossil assemblage, we identified two species of Strigiformes, *Asio otus* and *Asio flammeus*. These species, however, do not usually frequent caves or rocky cliffs (Brichetti & Fracasso, 2006; Cramp, 1998), therefore they should not be considered the responsible for the accumulation of the bird bones. *Bubo bubo* could most likely be the causative agent, especially considering that some of the slightly corroded bird remains belong to *Lyrurus tetrax* and *Tetrao urogallus* (the species of the genus *Asio* feed only on smaller birds). Moreover, *Bubo bubo* is reported to prey on diurnal and nocturnal raptors (Brichetti & Fracasso, 2006; Cramp, 1998; Mikkola, 1976): this could explain the presence of *Asio otus* and *Asio flammeus* among the bird remains. The home range (i.e. hunting area) of a pair of *B. bubo* is reported to be up to 20 km<sup>2</sup>, even if some studies report that their territories may be larger (Cramp, 1998; Martínez et al., 2003). Therefore, assuming *B. bubo* as the accumulator, the bird species it brought to the site represent the environment within a range of approximately 2,5 km around the site.

We can assess that carnivores have also been responsible for the accumulation of part of the bird bones, as carnivore damages (pits, punctures, scores) and strong digestive damage have been detected, respectively, on 2.1% ( $n = 4$ ) and 1% ( $n = 2$ ) of the bird remains. Unfortunately, we do not have enough data from the taxonomical analysis of the mammal remains from these layers, yet, to infer which carnivore species could have been the possible accumulator.

Among the other natural modifications detected, manganese dioxide staining was the most common (20.6% of the total,  $n = 40$ ), followed by root marks (2.6%,  $n = 5$ ), rodent's gnawing (2.1%,  $n = 4$ ), trampling (2.1%,  $n = 4$ ), concretions (1.5%,  $n = 3$ ) and exfoliation (0.5%,  $n = 1$ ). Some of the bird remains show human modification, that will be presented in detail in a forthcoming contribution.

The pollen record from Azzano Decimo core (which is located about 40 km far from the Rio Secco Cave, in the Friulian plain) shows an increase of xerophytic plants for the time interval considered in this work, confirming the expansion of open and dry environments caused by harsher climatic conditions (Pini et al., 2009).

## 6. Conclusions

The systematic analysis of the bird remains of the Rio Secco Cave allowed palaeoenvironmental reconstructions. At the onset of the LGM, the surrounding of the cave was characterized, on the basis of the avian taxa, by the presence of different environments, such as conifer or mixed

forests, open areas with low vegetation and rocky grounds, open grasslands, open wooded areas and slow-flowing water bodies. Harsh conditions with increase of xerophytic plants, in the time interval investigated, are also indicated from the Azzano Decimo pollen core in the Friulian plain about 40 km south of Rio Secco Cave (Pini et al., 2009). This mosaic of habitats in the northern belt of the Great Adriatic Plain, that guaranteed the availability of several different resources, probably attracted early Gravettian hunter-gatherers who visited the site about 30 ka y BP. The presence of *L. muta* at low heights also suggests the presence of a climate colder than today during the time span investigated. Besides, the finding of the second Italian late Pleistocene fossil record of *P. canus* confirms the long-standing presence of this species in the mountain areas of north-eastern Italy.

This contribution represents a further step in the knowledge of paleornithocenosis, palaeoenvironment and palaeoclimate of the late Pleistocene in the eastern Alps. Moreover, this is the first systematic analysis of an avian fossil assemblage from the area of Friuli-Venezia Giulia, for a period older than the Lateglacial (Tonon, 1983) and, at the same time, supported by datings and a reliable stratigraphy. Further analyses of fossil avifaunal assemblages will give new insights about the palaeoecology and paleobiogeography of birds, the environments of the past, and even about human-bird interactions in Prehistory (Blasco and Peresani, 2016).

## Acknowledgements

Financial support to the Rio Secco Research Project is provided by the Administration of the Clauzetto Municipality and the Friuli Venezia Giulia Region and a group of public institutions (Ecomuseo delle Dolomiti Friulane "Lis Aganis", BIM Tagliamento Consortium, Pordenone Province), Foundations (Fondazione CRUP) and private companies (Friulovest Banca). M. Peresani structured the research project and directed the fieldwork; M. Romanini coordinated the fieldwork. The Rio Secco project is also co-designed by the Neanderthal Museum (A. Pastoors & G.C. Weniger) and the Universitat Rovira y Virgili at Tarragona (M. Vaquero). This study has received funding from the Torino University ex 60% Grants 2016 and 2017. We are grateful to Prof. Benedetto Sala for his help and precious suggestions, to three anonymous reviewers for constructive suggestions and to Leah Mascia for revision of the English text. Authors' contributions: M. Pe. and M. R. planned the research; L. C., M. Pa. and M. R. analyzed the data; L. C., M. Pa., M. R. and M. Pe. wrote the paper.

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