

BIRDS FROM THE LATE PLEISTOCENE: ENVIRONMENTAL AND CLIMATIC SCENARIOS BETWEEN THE ALPS AND THE GREAT ADRIATIC PLAIN (NORTH-EASTERN ITALY)

Lisa Carrera

Università degli Studi di Ferrara, Dipartimento di Studi Umanistici, Sezione di Preistoria e Antropologia, Ferrara, Italy
Corresponding author: L. Carrera <lisa.carrera@student.unife.it>

ABSTRACT: In this work we show the potential of bird remains as environmental and climatic proxies, reconstructing the environmental scenarios of the piedmont area of North-Eastern Italy across the MIS3/MIS2 boundary, on the basis of the fossil avifauna that we found in Rio Secco Cave (PN) and Buso Doppio del Broion Cave (VI) in the Berici Hills. The results indicate the presence of a mosaic of environments, with open and forested areas and water and rocky habitats in a context of cold climatic conditions as indicated by the finding of the cold-adapted species *Bubo scandiacus* and *Lagopus muta*.

KEYWORDS: Birds, palaeoenvironment, late Pleistocene, north-eastern Italy, Rio Secco Cave, Buso Doppio del Broion Cave

1. INTRODUCTION

Western Palearctic avifauna consists of more than 500 breeding species, each of which has very specific ecological needs and a strong link with his habitat, particularly with the type of vegetation: this aspect makes fossil avifauna a coherent palaeoenvironmental and palaeoclimatic proxy for the whole Pleistocene, as most of extant bird species are reported in the Western Palearctic since the Early Pleistocene (Tyrberg, 1998, 2008). Resident species are more useful than migratory ones for this purpose, as they live in the same habitat during the whole year. Fossil birds are also useful to infer past climatic conditions. The Pleistocene climatic oscillations have shaped, over the course of time, the range of many species, which followed the shift of their ecological niche. For instance, during cold phases, Mediterranean Europe represented a “refuge area” for arctic, subarctic and boreal species (e.g. the snowy owl, *Bubo scandiacus*) (Holm & Svenning, 2014; Sanchez Marco, 2004). The presence of these species in the fossil record of Western Palearctic mid-latitudes represents a proxy of a climate colder than present. The fossil record of other bird species, like the rock ptarmigan (*Lagopus muta*), indicates that they were more widespread and lived at lower heights than today during the cold phases, as they followed the descent of the vegetational zones. The finding of these species at low heights in the mid-latitudes, can be used with caution as a climate proxy. We point out that only evidence concerning strong latitudinal or altitudinal changes in the geographic distribution of a bird species should be considered as a climate proxy (Bedetti & Pavia, 2001; Carrera et al., 2018; Tyrberg, 2010). We can also infer past climate changes on the basis of the changes in the bird species

associations across the layers of a single deposit. This approach can be based, in detail, on the presence of a climate marker in a layer, on changes in the relative abundance of a species, or on variations in the proportion of taxa from different habitats (open, rocky, water, forest) (Bedetti & Pavia, 2007; Tomek et al., 2012). To obtain a representative result, this analysis should be applied to deposits with a high number of bird remains and a long stratigraphic sequence.

In this work, we carried out a systematic analysis of the avifaunal remains from the deposits of two Palaeolithic sites in North-Eastern Italy: Buso Doppio del Broion Cave (VI) and Rio Secco Cave (PN). In detail, we analysed the avifaunal assemblages coming from the layers referable, from both sites, to the MIS3/MIS2 boundary, in order to infer past climate and environmental characteristics of this geographic area in a context of increasingly harsher climate (Clark et al., 2009; Monegato et al., 2017). Both sites are located along the connection area between the so-called “Great Adriatic Plain”, the large plain which emerged in the northern Adriatic area during the cold phases of the Late Pleistocene (Antonioni, 2012), and the piedmont fringe (Fig. 1). The Rio Secco Cave is located on the Pradis Plateau (Eastern Carnic Pre-Alps), at an elevation of 580 m a.s.l. The plateau faces the Friulian plain to the south. The Late Pleistocene sediments cover a time span from 50 to 30 ka, with evidence of short-term Gravettian and Mousterian occupations. The layer 6, an anthropic layer contained in the Macro-Unit BR1, yielded an age of 33,480–30,020 yr cal BP, assessing its placement in the early Gravettian period (Peresani et al., 2014; Talamo et al., 2014). The Buso Doppio del Broion Cave is a cavity formed by a system of galleries which opens at 150 m a.s.l. in the eastern slope of the Berici Hills (an uplifted karst plateau isolated in the

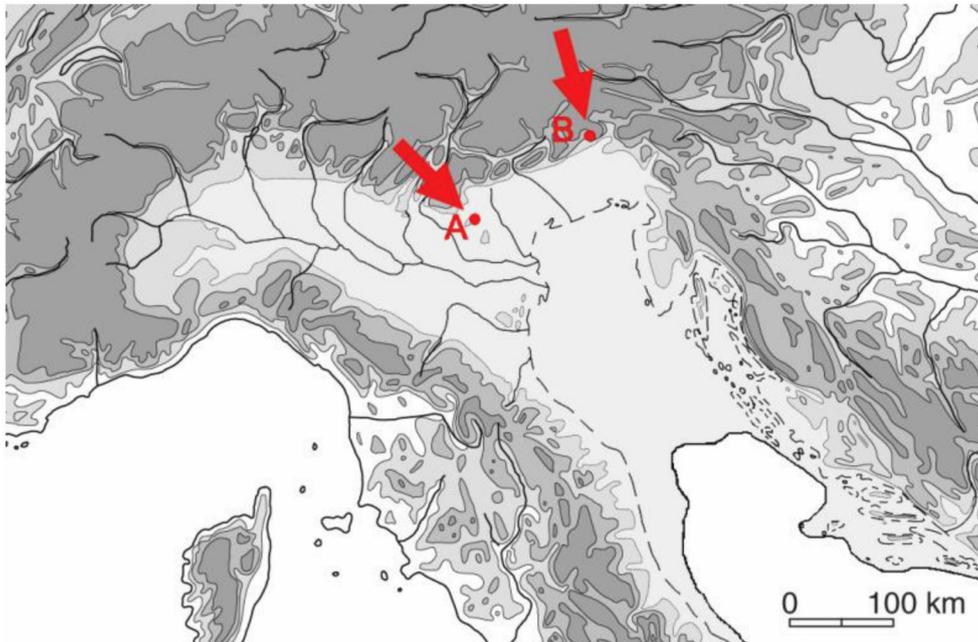


Fig. 1 - Map of Northern Italy with the geographic position of Buso Doppio del Broion Cave (A) and Rio Secco Cave (B). The light grey area indicates the extension of the Great Adriatic Plain during the time span investigated.

alluvial plain). The deposits of Buso Doppio del Broion Cave, below the upper reworked sediment, contain scanty Gravettian lithic implements. The sequence probably covers a time span including the onset of the LGM (Layer 1) and the preceding millennia, on the basis of the similarity of the lithic material to a radiocarbon dated palaeolithic site located in the proximity of the cave (Gurioli et al., 2006; Romandini et al., 2015). The archaeological excavation in these two caves is ongoing, carried out by the University of Ferrara.

2. MATERIALS AND METHODS

The systematic analysis of the avifaunal remains involved 194 avian remains from the Macro-Units BR1 and BR2 of Rio Secco Cave, and 775 bird remains from layers 1, 2, 3, 4, 5, 6, 7 of Buso Doppio del Broion Cave.

The sediments were excavated in 50 × 50 cm or 33 × 33 cm squares and then wet sieved. For the systematic analysis we used 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. The fossil material is stored in the Sezione di Scienze Preistoriche e Antropologiche of the Dipartimento di Studi Umanistici of the University of Ferrara. Bird taxonomy follows Del Hoyo et al. (2014, 2016).

3. RESULTS

We identified a great variety of bird species from the two deposits (Tab. 1). The bird taxa recognized in this work all belong to the extant Western Palearctic

avifauna. In the Rio Secco Cave bird assemblage, in detail, we identified 166 remains (85.6 %) which have been assigned to 31 bird taxa (18 species) (Carrera et al., 2018). 28 remains are left as indeterminate Aves. In the Buso Doppio del Broion bird assemblage, we identified 634 remains (81.8 %) which have been assigned to 69 bird taxa (44 species), while 141 remains are left as indeterminate Aves (Carrera et al., in press). Among the identified remains, for both assemblages, several remains have been attributed to species-level taxa and others to supraspecific taxa, because of their fragmentation or because of the lack of diagnostic features.

4. DISCUSSION AND CONCLUSION

The bird species identified allowed palaeoenvironmental and palaeoclimatic reconstructions. Among the bird taxa found at Rio Secco Cave, *L. muta* and *P. collaris* suggest the presence of open areas with low vegetation and rocky exposures close to the cave, while *P. perdix* and *C. coturnix* indicates the presence of open grasslands/shrublands. *L. tetrix*, *T. urogallus*, *P. canus*, *N. caryocatactes*, *P. pyrrhula* and *L. curvirostra* indicate the presence of conifer or mixed forests, while *F. atra* suggests the presence of slow-flowing water bodies (Cramp, 1998). *L. muta* is absent today from the area of the site, as it currently lives at higher heights, above the tree line. Its presence during the end of MIS 3 at about 580 m a.s.l. indicates that mountain open environments had to be located at lower heights, and thus it can be considered an indicator of a climate colder than the current one (Carrera et al., 2018).

The deposit of Buso Doppio del Broion Cave provided a wide range of bird species useful for palaeoenvironmental reconstructions. The presence of open habitats like grasslands, shrublands and steppe is sug-

Taxa	NR	
	Rio Secco	Buso Doppio
<i>Coturnix coturnix</i>	1	6
<i>Perdix perdix</i>	2	1
<i>Lagopus lagopus/muta</i>		1
<i>Lagopus muta</i>	4	
<i>Tetrao urogallus</i>	3	4
<i>Tetrao urogallus/Lyrurus tetrix</i>	2	4
<i>Lyrurus tetrix</i>	7	35
Galliformes indet.	12	34
<i>Aythya ferina</i>		2
<i>Aythya fuligula</i>		3
<i>Spatula querquedula</i>		2
<i>Spatula querquedula/Anas crecca</i>		12
<i>Anas platyrhynchos</i>		2
<i>Anas platyrhynchos/acuta</i>		1
<i>Anas crecca</i>		2
cf. <i>Anas crecca</i>		1
Anatidae indet.		20
<i>Apus pallidus/apus</i>		4
<i>Crex crex</i>	2	12
<i>Gallinula chloropus</i>		1
<i>Fulica atra</i>	1	
Rallidae indet.	3	5
<i>Grus grus</i>		1
<i>Tetrax tetrax</i>		1
<i>Limosa lapponica/limosa</i>		1
<i>Gallinago gallinago</i>		6
Charadriiformes indet.		2
Laridae indet.		1
<i>Surnia ulula</i>		1
<i>Athene noctua</i>		1
cf. <i>Aegolius funereus</i>		1
<i>Asio otus</i>	2	
<i>Asio otus/flammeus</i>		2
<i>Asio flammeus</i>	2	
<i>Bubo scandiacus</i>		3
Strigidae indet.	1	1
<i>Aquila chrysaetos</i>		3
<i>Accipiter gentilis</i>		3
<i>Buteo buteo</i>	2	
Accipitridae indet.		1

Taxa	NR	
	Rio Secco	Buso Doppio
<i>Picus canus</i>	1	
<i>Picus viridis</i>		1
Picidae indet.		1
<i>Falco tinnunculus</i>		4
<i>Falco vespertinus</i>		1
<i>Falco</i> sp. 1		1
<i>Falco</i> sp.	1	9
<i>Pyrhcorax pyrrhcorax</i>		2
<i>Pyrhcorax graculus</i>		11
<i>Pyrhcorax pyrrhcorax/graculus</i>		14
<i>Pica pica</i>	1	
<i>Nucifraga caryocatactes</i>	1	2
<i>Corvus monedula</i>		2
<i>Corvus corax</i>		2
<i>Corvus corone</i>		1
Corvidae indet.	11	21
Paridae indet.	1	
<i>Eremophila alpestris</i>		1
Alaudidae indet.	1	
cf. <i>Delichon urbicum</i>		1
cf. <i>Hirundo rustica</i>		5
cf. <i>Ptyonoprogne rupestris</i>		1
<i>Riparia riparia</i>		1
Hirundinidae indet.		12
<i>Tichodroma muraria</i>		5
<i>Troglodytes troglodytes</i>		1
<i>Sturnus vulgaris/unicolor</i>		4
cf. <i>Turdus viscivorus</i>	2	2
<i>Turdus viscivorus/pilaris</i>		1
<i>Turdus</i> sp.	3	3
<i>Erithacus rubecula</i>	2	1
<i>Phoenicurus ochruros</i>		1
Muscicapidae indet.	1	
<i>Prunella collaris</i>	1	3
cf. <i>Petronia petronia</i>		1
<i>Pyrhula pyrrhula</i>	2	1
<i>Chloris chloris</i>		1
<i>Loxia curvirostra</i>	1	2
<i>Fringilla coelebs/montifringilla</i>	1	
Emberizidae indet.	1	
Passeriformes indet.	91	335

Tab. 1 - Bird taxa from the Macro-Units BR1 and BR2 of Rio Secco Cave (Carrera et al., 2018) and from the layers 1, 2, 3, 4, 5, 6, 7 of Buso Doppio del Broion Cave (Carrera et al., in press). NR indicates the number of remains for each taxon.

gested by the presence of *C. coturnix*, *P. perdix*, *G. grus*, *T. tetrax*, *A. noctua*, *B. scandiacus*, *F. tinnunculus*, *E. alpestris* and cf. *P. petronia*. Other species indicate the presence of rocky cliffs and exposures, such as *A. pallidus/apus*, *A. chrysaetos*, *P. graculus*, *P. pyrrhonorax*, *C. corax*, *P. rupestris*, *T. muraria* and *P. collaris*. *T. urogallus*, *L. tetrax*, *S. ulula*, *A. funereus*, *A. gentilis*, *P. viridis*, *N. caryocatactes*, *T. troglodytes*, *P. pyrrhula* and *L. curvirostra* indicate the presence of conifer or mixed forests. Finally, a variety of water bird species such as *A. ferina*, *A. fuligula*, *S. querquedula*, *A. platyrhynchos*, *A. crecca*, *G. chloropus* and *G. gallinago*, suggests the presence of slow-flowing water bodies, wetlands or marshes near the site (Cramp, 1998).

The finding of two cold-adapted boreal species, *B. scandiacus* and *S. ulula*, both currently absent from the Italian avifauna (Brichetti & Fracasso, 2015), indicates a climate colder than present during the time span investigated. Other indications of a climate colder than present is the finding, at low heights of *L. tetrax*, *T. urogallus*, *P. graculus*, *P. pyrrhonorax* and *P. collaris*, which currently live, in the Alps, in high mountain environments only (Carrera et al., in press).

The avifaunal assemblages from both the sites provided a coherent environmental framework for the geographic area of connection between the piedmont area and the Great Adriatic Plain, constituted by a mosaic of different habitats. This frame is further supported by the results of the analysis of the pollen records from the Fimon lake deposits and the Azzano Decimo core, in the Friulian Plain (about 40 km south of Rio Secco Cave) (Pini et al., 2009, 2010). During the LGM, the landscape of the piedmont area was constituted by an extensive belt of boreal trees, while the nearby plain was characterized by large steppe habitats, dominated by *Artemisia* and juniper (Monegato et al., 2015).

Despite the richness of the Italian palaeornithological record, contributions which deal with avian fossil remains are few with respect to those concerning mammal fossil remains, maybe because of the scarcity of bird skeletal comparative collections. We hope that this field will grow in the near future, as it could provide important advances concerning the palaeobiogeography and palaeoecology of bird species and the evolution of environmental scenarios subjected to the Pleistocene climatic oscillations, with the contribution of innovative approaches such as the species distribution modeling (Svenning et al., 2011) and phylogenetics.

ACKNOWLEDGEMENTS

Research at the Rio Secco Cave and Buso Doppio Broion Cave is coordinated by Marco Peresani and Matteo Romandini respectively in the framework of projects supported by the Ministry of Culture and local institutions and promoters. We are grateful to Prof. Benedetto Sala for his help and precious suggestions, and to Ulf Johansson (Naturhistoriska riksmuseet, Stockholm, Sweden) for the loan of some crucial recent skeletons.

REFERENCES

Antonoli F. (2012) - Sea level change in Western-Central Mediterranean since 300 Kyr: comparing

global sea level curves with observed data. *Alpine and Mediterranean Quaternary*, 25, 15-23.

Bedetti C., Pavia M. (2001) - Climate and environmental changes and faunal turnover: the avifauna case history. International conference on Paleobiogeography and Paleocology, Abstract book, Piacenza, 34-35.

Bedetti C., Pavia M. (2007) - Reinterpretation of the Late Pleistocene Ingarano Cave deposit based on the fossil bird association (Apulia, South-eastern Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 113(3), 487-507.

Brichetti P., Fracasso G. (2015) - Check-list degli uccelli italiani aggiornata al 2014. *Rivista Italiana di Ornithologia*, 85, 31-50.

Carrera L., Pavia M., Romandini M., Peresani M. (2018) - Avian fossil assemblages at the onset of the LGM in the Eastern Alps: a palaeological contribution from the Rio Secco Cave (Italy). *Comptes Rendus Palevol*, 17, 166-177.

Carrera L., Pavia M., Peresani M., Romandini M. - Late Pleistocene fossil birds from Buso Doppio del Broion Cave (North-Eastern Italy): implications for palaeoecology, palaeoenvironment and palaeoclimate. *Bollettino della Società Paleontologica Italiana*, in press.

Clark P.U., Dyke A.S., Shakun J.D., Carlson A.E., Clark J., Wohlfarth B., Mitrovica J.X., Hostetler S.W., McCabe A.M. (2009) - The last glacial maximum. *Science*, 325, 710-714.

Cramp S. (1998) - The complete birds of the Western Palearctic on CD-ROM. Optimedia. Oxford University Press.

Del Hoyo J., Collar N.J., Christie D.A., Elliot A., Fishpool L.D.C. (2014) - Illustrated checklist of the birds of the world. Vol. 1: Non-passerines. Lynx Éditions, Barcelona.

Del Hoyo J., Collar N.J., Christie D.A., Elliott A., Fishpool L.D.C., Boesman P., Kirwan G.M. (2016) - Illustrated checklist of the birds of the world. Vol. 2: Passerines. Lynx Éditions, Barcelona.

Gurioli F., Cappato N., De Stefani M., Tagliacozzo A. (2006) - Considerazioni Paleontologiche, Paleoecologiche e Archeozoologiche dei livelli del Paleolitico superiore del Riparo del Broion (Colli Berici, Vicenza). In *Atti del Convegno Nazionale di Archeozoologia*, Rovereto, 5, 47-56.

Holm S.R., Svenning J.C. (2014) - 180,000 years of climate change in Europe: avifaunal responses and vegetation implications. *Plos One*, 9(4), e94021.

Monegato G., Ravazzi C., Culiberg M., Pini R., Bavec M., Calderoni G., Jež J., Perego R. (2015) - Sedimentary evolution and persistence of open forests between the south-eastern Alpine fringe and the Northern Dinarides during the Last Glacial Maximum. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 436, 23-40.

Monegato G., Scardia G., Hajdas I., Rizzini F., Piccin A. (2017) - The Alpine LGM in the boreal ice-sheets game. *Scientific Reports*, 7(1), 2078.

Peresani M., Romandini M., Duches R., Jéquier C., Nannini N., Pastoors A., Picin A., Schmidt I., Va-

- quero M., Weniger G.C. (2014) - New evidence for the Mousterian and Gravettian at Rio Secco Cave, Italy. *Journal of Field Archaeology*, 39, 401-416.
- Pini R., Ravazzi C., Donegana M. (2009) - Pollen stratigraphy, vegetation and climate history of the last 215ka in the Azzano Decimo core (plain of Friuli, north-eastern Italy). *Quaternary Science Reviews*, 28(13), 1268-1290.
- Pini R., Ravazzi C., Reimer P.J. (2010) - The vegetation and climate history of the last glacial cycle in a new pollen record from Lake Fimon (southern Alpine foreland, N-Italy). *Quaternary Science Reviews*, 29(23), 3115-3137.
- Romandini M., Bertola S., Nannini N. (2015) - Nuovi dati sul Paleolitico dei Colli Berici: risultati preliminari dello studio archeozoologico e delle materie prime litiche della Grotta del Buso Doppio del Broion (Lumignano, Longare, Vicenza). In *Atti della XLVIII Riunione Scientifica dell'IIPP*, 53-59.
- Sanchez Marco A. (2004) - Avian zoogeographical patterns during the Quaternary in the Mediterranean region and paleoclimatic interpretation. *Ardeola*, 51(1), 91-132.
- Svenning J.C., Fløjgaard C., Marske K.A., Nógues-Bravo D., Normand S. (2011) - Applications of species distribution modeling to paleobiology. *Quaternary Science Reviews*, 30(21-22), 2930-2947.
- Talamo S., Peresani M., Romandini M., Duches R., Jéquier C., Nannini N., Pastors A., Picin A., Vaquero M., Weniger G.C., Hublin J.J. (2014) - Detecting human presence at the border of the northeastern Italian Pre-Alps. *14C Dating at Rio Secco Cave as expression of the first Gravettian and the late Mousterian in the northern Adriatic region*. *Plos One*, 9(4), e95376.
- Tomek T., Bocheński Z.M., Socha P., Stefaniak K. (2012) - Continuous 300,000-year fossil record: changes in the ornithofauna of Biśnik Cave, Poland. *Palaeontologia Electronica*, 15(1), 1-20.
- Tyrberg T. (1998) - Pleistocene birds of the Palearctic: a catalogue. *Publications of the Nuttall Ornithological Club No. 27*, Cambridge.
- Tyrberg T. (2008) - Pleistocene birds of the Palaeartic. <http://web.telia.com/~u11502098/pleistocene.pdf> (Accessed on the 1st of November 2017, last updated in 2008).
- Tyrberg T. (2010) - Avifaunal responses to warm climate: the message from Last Interglacial faunas. *Records of the Australian Museum*, 62(1), 193-205.

Ms. received: April 29, 2018
Final text received: May 19, 2018

