Journal of Archaeological Science: Reports 29 (2020) 102096

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

# Bird bones from Trou de Chaleux and the human exploitation of birds during the late Magdalenian in Belgium

Quentin Goffette[a,*], Mietje Germonpré[a], Christine Lefèvre[b], Jonathan Brecko[c], Eric Goemaere[a], Veerle Rots[d]

[a] Royal Belgian Institute of Natural Sciences, Directorate Earth and History of Life, rue Vautier 29, B-1000 Brussels, Belgium
[b] Muséum national d'Histoire naturelle, UMR 7209 Archéozoologie, Archéobotanique: sociétés, pratiques et environnements, rue Buffon 55, F-75005 Paris, France
[c] Royal Belgian Institute of Natural Sciences, Scientific Heritage Service, rue Vautier 29, B-1000 Brussels, Belgium
[d] Chercheur Qualifié du FNRS, TraceoLab/Prehistory, University of Liège, Place du 20-Août 7 (Bât. A4), B-4000 Liège, Belgium

ARTICLE INFO

*Keywords:*
Archaeozoology
Belgium
Birds
Late Magdalenian
Subsistence

ABSTRACT

The Trou de Chaleux is a cave site located in Belgium. It delivered a rich late Magdalenian material culture constituted mainly of lithic artefacts but also including bone industries and figurative art. This paper presents the results of the analysis of the large collection of bird remains recovered by E. Dupont in 1865, which was yet unstudied from taphonomical and archaeozoological perspectives. In addition to the taxonomic identification, surface alterations were investigated based on a macro- and microscopic analysis, including an analysis of wear traces and elementary composition. Special attention is devoted to the presence of human modifications such as disarticulation or butchering marks, traces of heating, presence of colourants and traces of bone working. The taphonomic history of the bird assemblage is reconstructed and the use of birds by humans characterized, as well as their importance in past human activities. We also discuss evidence for seasonal exploitation and for reconstructing the local environment and integrate our results with evidence from other Magdalenian assemblages from north-western Europe. At Trou de Chaleux, birds were used for food, as raw material for bone working and for symbolic purposes. The exploitation of avian products was intense, and species have been used for several purposes such as the raven and snowy owl having been exploited both for food and for symbolic reasons. Large bird bones were used as raw material to produce artefacts, but the use-wear analysis did not evidence unambiguous traces related to the use of the objects produced. Despite several limiting factors, the bird material from Trou de Chaleux considerably increases the knowledge of past human exploitation of birds during the late Magdalenian in north-western Europe.

## 1. Introduction

Like other animal species, birds were part of the ecosystems in which Prehistoric hunter-gatherers were living and which they exploited. The small size and low weight of most bird species, defining them as part of the small-game, can make them less desirable for food than larger and heavier mammals that yield more meat for a lesser hunting effort. However, small-game was exploited. Documenting the importance and the reasons behind the exploitation of birds helps in understanding complex human behaviour during Prehistory by defining subsistence strategies, as the exploitation of small-game can result from various environmental and human factors such as demographic pressure, need for specific raw material or cognitive abilities (Stiner et al., 2000; Müller, 2004; Laroulandie, 2009).

An increasing number of Upper Palaeolithic bird bone assemblages have been studied and published for southern and central Europe (e.g. Bochenski et al., 2009; Bullinger and Müller 2006a,b; Laroulandie, 2000, 2003; Morel and Müller 1997; Wertz et al., 2015; Wertz et al., 2016), highlighting that birds were exploited for food (meat and eggs) but also as raw material for craft (feathers and bones), and sometimes for non-utilitarian purposes. In contrast, little is known about bird exploitation in north-western Europe. Hence, documenting the use of birds in this area is essential to highlight geographic variation or shared trends in human behaviour (Laroulandie, 2004).

Up to now, in north-western Europe, Magdalenian bird bone assemblages were studied in detail only for the sites of Andernach-Martinsberg and Gönnersdorf in Germany (Street and Turner, 2016), Pincevent (David et al., 2014) and Verberie in France (Mignard, 2015).

* Corresponding author.
*E-mail address:* qgoffette@naturalsciences.be (Q. Goffette).

https://doi.org/10.1016/j.jasrep.2019.102096
Received 13 August 2019; Received in revised form 6 November 2019; Accepted 12 November 2019

Bird bone assemblages dating to periods from the Upper Palaeolithic other than the Magdalenian are even scarcer. At Pincevent, the few bird bones recovered indicate use as raw material for bone working, while at Verberie birds were used for food. At the two German sites, birds were used for food and for utilitarian and symbolic purposes. In spite of the critical location of Belgium between the German and French sites and the recovery of bird remains in karstic cavities for more than a century (e.g. De Wilde et al., 2011; Deville and Gautier, 1997; Dupont, 1873), no detailed analysis of Palaeolithic avifauna had been undertaken.

Here, we present the results of the analysis of the large collection of bird remains recovered by E. Dupont, a geologist at the University of Liège, at Trou de Chaleux, Belgium, a major late Magdalenian site. Although it had never been studied from taphonomical and archaeozoological perspectives, some cut marks had already been detected on bird bones by Dupont, which were highlighted by red markings. In addition, the taxonomic identifications of several scholars (Charles, 1998; Dupont, 1873; Lambrecht, 1933; Wolf, 1938–41) were summarized in Tyrberg's reviews of bird remains in Pleistocene assemblages of the Palaearctic (Tyrberg, 1998, 2008): *Anser fabalis*, *Anas* sp., *Haliaeetus albicilla*, *Falco tinnunculus*, *Lagopus lagopus*, *Lyrurus tetrix*, *Tetrao urogallus*, *Bubo scandiacus*, *Bubo bubo*, *Asio otus*, *Turdus pilaris*, *Garrulus glandarius* and *Corvus corax*.

The goals of the present work are: 1) to define the taphonomic history of the bird assemblage and to identify anthropogenic traces; 2) to characterize the use of birds by humans and 3) to evaluate the importance of birds in human activities. The taphonomic part is essential prior to any further discussion about the use of birds by humans, as it is unlikely that the avian assemblage from Trou de Chaleux has been accumulated by humans alone. Bird assemblages from caves are notoriously difficult to interpret as they may result from the action of different taphonomic agents, such as small carnivores, birds of prey and potentially humans (e.g. Andrews, 1990; Laroulandie, 2000). Distinguishing between these different agents is a difficult process, which is further complicated by the fact that a single assemblage may have been accumulated by several agents. In most cases, when no trace is present, attribution to a precise accumulator is impossible.

## 2. Presentation of the site

The Trou de Chaleux cave has delivered the richest late Magdalenian assemblage in Belgium, including large collections of lithic and bone industries as well as figurative art (Dewez, 1987; Dupont, 1873; Otte, 1994). It is located on the right bank of the river Lesse (Fig. 1), a tributary of the river Meuse, in a Carboniferous limestone cliff at an altitude of 115 m (Otte, 1994). In 1865, Dupont (1873) excavated one major archaeological layer inside the cave and found a large number of skeletal remains from mammals – many displaying cut marks and anthropogenic breakage – birds, and fish and numerous Magdalenian artefacts. New excavations were undertaken at the end of the 20th century on the terrace in front of the cave. M. Otte and colleagues unearthed remains of a Magdalenian occupation, including a mammal assemblage but apparently, no bird remains were discovered here (Otte, 1994). Detailed reviews on the excavations at Trou de Chaleux can be found in Otte (1994) and Charles (1998). Dewez (1987) presents an exhaustive analysis of the Magdalenian artefacts, including tools and ornaments.

Several AMS dates are available, with calibrated ages ranging from 15,733 cal BP to 14,134 cal BP (Table S1), situating the main deposit of the mammal assemblage from Trou de Chaleux, identified by Dupont as the '1er niveau ossifère' (Fig. S1), at the transition of Greenland Stadial-2 to Greenland Interstadial-1 (Bølling-Allerød Interstadial); the beginning of the latter interstadial starts at about 14,7 ka (Rasmussen et al., 2014, Table 1). The stratigraphic work performed by Dupont was meticulous for that time and the more recent excavations positively verified the chronological homogeneity of the Magdalenian layer.

However, part of the mammal assemblage is clearly much younger, as attested by a radiocarbon dated prehistoric pig humerus with cut marks (OxA-4193: 3060 ± 85 BP) (Charles, 1998). Some chronological heterogeneity among the bird material is also highlighted by the presence of six bones of the chicken (*Gallus gallus* f. domestica; see Supplementary Material, p. 10), which obviously represents a more recent intrusion, as the oldest specimens recovered in Belgium only date back to the Late Iron Age or to the beginning of the Roman period (e.g. Van Neer and Lodewijckx, 1992). It is possible that other bird remains are also intrusive, but it is impossible to ascertain without absolute dating. However, the large collection of lithic material, including more than 3000 artefacts, is characteristic of the late Magdalenian (Dewez, 1987) and the analysis of the mammal remains only detected 'The presence of a relatively small proportion of intrusive specimens…' (Charles, 1998). Although it cannot be excluded that bird remains with anthropogenic modifications are not late Magdalenian, some of the bird taxa exploited (see below), such as snowy owl (*Bubo scandiacus*) or ptarmigans (*Lagopus* sp.) are clearly associated with arctic environments consistent with an attribution to the late Magdalenian.

The three best represented mammals are horse, fox, and muskox (Charles, 1998; Germonpré, 1997). Bones of horse, reindeer, red deer, muskox and brown bear show anthropogenic modifications (Charles, 1998). The species mainly exploited by the Magdalenian inhabitants of Trou de Chaleux was the horse. Partly butchered horse carcasses were brought to the cave and carved up at the site for meat, marrow, tendons, and ligaments. The same treatment was applied to the reindeer and the muskox carcasses (Charles, 1998). Foxes were skinned, and their meat filleted (Charles, 1998). Several canines from fox and bear display an anthropogenic perforation of the root (Charles, 1998; Germonpré and Hämäläinen, 2007; Germonpré et al., 2013); they were probably used by the Magdalenian people as ornaments (Van Wetter, 1920).

## 3. Material and methods

This study includes all the bird remains recovered at Trou de Chaleux during the excavation of E. Dupont in 1865 and stored at the Royal Belgian Institute of Natural Sciences, Brussels (RBINS). Although no sieving was performed, the recovery of small anatomical elements such as quadrate and carpal bones indicates that the hand-collection during the excavation was very careful. The recovery of 83 posterior phalanges of birds the size of a ptarmigan or smaller is a strong indication that the recovery of small elements was not perfunctory. Moreover, the excavators did not make any obvious selection among the material and even the smallest, unidentifiable, bone splinters were kept. However, small elements are more likely to have been lost during the excavation than the larger ones.

Most of those bones were exhibited to the public at the Museum of Natural Sciences, which was founded in 1846. For this purpose, in 1904 the bones were immobilized with organic glue on green cardboards, which were displayed on larger plaster trays designed to be stored in the rooms of the museum. This hampered any proper study as the bones could not be removed. To perform the present study, we carefully detached the bones from their support, but no attempt was made to clean the bones, which explains the traces of glue visible on some of the pictures presented below.

Taxonomic identifications were performed with the help of the modern reference collections of the RBINS and of the Royal Museum for Central Africa, Tervuren (RMCA) and of the Muséum national d'Histoire naturelle, Paris (MNHN). The existing literature dealing with the identification of certain bird groups was also used (see Supplementary material 1). In some cases, fragments without diagnostic features could not be attributed to a species and were therefore identified at a higher taxonomic rank. The taxonomy followed is that of the IOC World Bird List (Gill and Donsker, 2017) and, for domestic taxa, that of Bohlken (1958, 1961). To quantify the material, we used Number of Identified

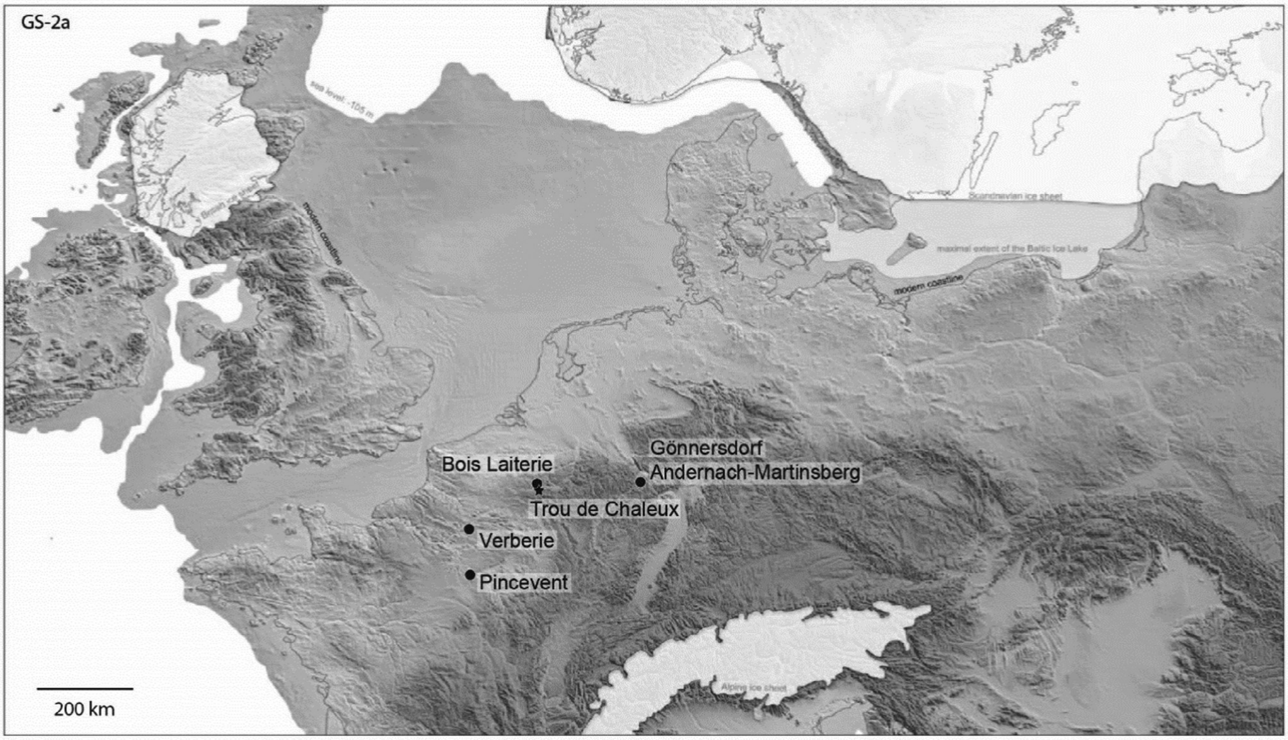


**Fig. 1.** Map of the sites cited in the text. Modified from Map GS-2a created by Grimm (2013): online archive of the Monrepos Archaeological Research Centre and Museum for Human Behavioural Evolution. http://www.monrepos-rgzm.de/tl_files/monrepos/content/projektarchiv/downloads/NW-Eu%2010W-25E%2045-60N%20-105m%20SW%20GS-2a%20map%204.jpg (accessed 18 December 2017).

Specimens (NISP), Minimum Number of Individuals (MNI) and Minimum Number of Elements (MNE). The MNE was calculated without considering the lateralisation of the elements (Lyman, 1994).

To evaluate the ages of the birds, we used the four categories proposed by Serjeantson (2009). These are 'adult' for a bone at adult size, with fully grown extremities and not porous; 'subadult' for a bone at adult size but still slightly porous; 'immature' for a bone more than half ossified and 'very young' for a bone half-ossified or less. The medullar cavity of every broken bone was examined in search of medullary bone, the presence of which is indicative of a mature female bird. Medullary bone begins to develop before the laying period, that is during spring and early summer, and disappears progressively afterwards, although traces are sometimes found until the moulting period (e.g. Van Neer et al., 2002). Sexual dimorphism is significant in orders such as the Strigiformes, and the measurements of some elements allowed us to attribute them to one or the other sex.

The fragmentation of the material was recorded for the long bones by considering the number of complete specimens for each element (see Table 2). The portion of the bones preserved was recorded but not treated in detail here.

Skeletal representation was assessed in two different ways, firstly by calculating the percentage survivorship (Brain, 1969, 1976) of coracoid, scapula, humerus, ulna, radius, carpometacarpus, femur, tibiotarsus and tarsometatarsus (100 × (MNEe)/MNI × (number of times e occurs in a complete skeleton)), *e* being an anatomical element. Secondly, the wing-to-leg ratio was calculated (wing bones/(wing bones + leg bones)), where wing bones = humerus + radius + ulna and leg bones = femur + tibiotarsus + tarsometatarsus (Ericson, 1987), using both the MNE and the NISP. We evaluated the significance of the difference in the abundance of wings versus leg bones by using a Chi-square test. Ratios involving other anatomical parts were not used because axial skeletal fragments are either rare (e.g. skull, sternum) or not identified to the species level (vertebrae and most of the pedal phalanges).

Each bone was examined under a binocular microscope (magnification 6.5–50 ×) with oblique light to record the following surface modifications: tooth marks, digestion damage (Andrews, 1990; Bochenski and Tomek, 1997; Fernandez Jalvo and Andrews, 2016), weathering, root etching (present or not), breaks, disarticulation or butchering marks, traces of burning, presence of colourants and traces of bone working. Tooth or beak marks have been described (pits or punctures, isolated or multiple, morphology) and their location on the bone has been recorded (Fernandez Jalvo and Andrews, 2016). Digestion marks have been recorded (Andrews, 1990) and localized on the bones. Weathering was assessed by looking at the presence of linear cracks at the surface of the bones (Behrensmeyer, 1978). Different characteristics of the breaks were observed (angle, morphology of the outline, aspect of the edge) to verify whether they were broken fresh or dry (Fernandez Jalvo and Andrews, 2016; Villa and Mahieu, 1991). Peculiar kinds of breaks described in the literature as disarticulation marks left by humans have been sought after, such as notches in the fossa olecrani and wrenches of medial condyles on humerus, peculiar breakages of the olecranon of the ulna, resulting from the disarticulation of the elbow, or peeling marks (Laroulandie 2002, 2005; Laroulandie et al., 2008). Peeling marks correspond to superficial flaking of the bone surface resulting from a break made by bending the bone (Laroulandie, 2000). The morphology, direction, and position of the cut marks have been recorded.

We discuss evidence for seasonal exploitation and for reconstructing the local environment and we integrate our results with evidence from other Magdalenian assemblages from north-western Europe.

Some specimens have been scanned using the microCT scanners of the RBINS Scientific Heritage Service's digitization facility, RX EasyTom microCT (RX solutions, Chavanod, France; http://www.rxsolutions.fr) and a XRE UniTom microCT, (XRE, Ghent, Belgium; https://xre.be/) in order to illustrate properly some of their features or to verify the identification of cut marks. Cross-sections of cut marks have been performed using the surface curve function in GOM Inspect

**Table 1**
Bird species identified at Trou de Chaleux. Taxa marked with an asterisk are intrusive.

| | Taxon | NISP | | MNI | | Human modifications | | Use |
|---|---|---|---|---|---|---|---|---|
| | | *N* | % | *N* | % | *NISP* | *%NISP* | |
| | **Anseriformes** | | | | | | | |
| 1 | Whooper swan (*Cygnus cygnus*) | 1 | 0.2 | 1 | 1.2 | 1 | 2.9 | Bone working (needles) |
| 2 | Mute swan (*Cygnus olor*) | 1 | 0.2 | 1 | 1.2 | 1 | 2.9 | – |
| 3 | *Anser* goose (*Anser* sp.) | 18 | 3.5 | 6 | 7.4 | 12 | 35.3 | Feathers, bone working (tubes) |
| | Undet. goose (*Anser* sp./*Branta* sp.) | 5 | 1.0 | 1 | 1.2 | 1 | 2.9 | Feathers, bone working (tubes) |
| 4 | Long-tailed duck (*Clangula hyemalis*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 5 | Red-breasted merganser (*Mergus serrator*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 6 | Common scoter (*Melanitta nigra*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 7 | Common teal (*Anas crecca*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| | Anatinae size of common teal (*Anas crecca*) | 1 | 0.2 | – | 0.0 | – | – | – |
| | Anatinae size of common scoter (*Melanitta nigra*) | 2 | 0.4 | – | 0.0 | – | – | – |
| | Anatinae size of Northern shoveler (*Spatula clypeata*) | 1 | 0.2 | – | 0.0 | – | – | – |
| | Anatinae size of mallard (*Anas platyrhynchos*) | 3 | 0.6 | – | 0.0 | 1 | 2.9 | Meat |
| | Undet. duck | 6 | 1.2 | – | 0.0 | – | – | – |
| | Undet. large Anseriformes | 1 | 0.2 | – | 0.0 | – | – | – |
| | **Galliformes** | | | | | | | |
| 8 | Grey partridge (*Perdix perdix*) | 37 | 7.2 | 8 | 9.9 | – | – | – |
| 9 | Willow ptarmigan (*Lagopus lagopus*) | 10 | 1.9 | 7 | 8.6 | – | – | – |
| 10 | Rock ptarmigan (*Lagopus muta*) | 12 | 2.3 | 7 | 8.6 | – | – | – |
| | Undet. ptarmigan (*Lagopus* sp.) | 77 | 15.0 | – | 0.0 | 7 | 20.6 | Meat |
| 11 | Black grouse (*Lyrurus tetrix*) | 9 | 1.7 | 2 | 2.5 | – | – | – |
| 12 | Western capercaillie (*Tetrao urogallus*) | 2 | 0.4 | 1 | 1.2 | – | – | – |
| 13 | *Domestic chicken (*Gallus gallus* f. domestica) | 6 | 1.2 | 2 | 2.5 | – | – | – |
| | Undet. Galliformes | 48 | 9.3 | – | 0.0 | – | – | – |
| | **Gaviiformes** | | | | | | | |
| 14 | Black-throated/Red-throated loon (*Gavia arctica/stellata*) | 2 | 0.4 | 1 | 1.2 | 1 | 2.9 | Bone working (needles) |
| | **Accipitriformes** | | | | | – | – | – |
| 15 | Undet. buzzard (*Buteo* sp.) | 2 | 0.4 | 1 | 1.2 | – | – | – |
| 16 | Short-toed snake eagle (*Circaetus gallicus*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 17 | cf. Golden eagle (*Aquila* cf. *chrysaetos*) | 1 | 0.2 | 1 | 1.2 | 1 | 2.9 | Claw |
| | **Falconiformes** | | | | | | | |
| 18 | Common kestrel (*Falco tinnunculus*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| | Falcon size of common kestrel (*Falco tinnunculus*) | 4 | 0.8 | – | 0.0 | – | – | – |
| | **Gruiformes** | | | | | | | |
| 19 | Corncrake (*Crex crex*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| | **Charadriiformes** | | | | | | | |
| 20 | Plover (*Pluvialis* sp.) | 2 | 0.4 | 1 | 1.2 | – | – | – |
| | Charadriidae size of Eurasian golden plover (*Pluvialis apricaria*) | 1 | 0.2 | – | 0.0 | – | – | – |
| 21 | Northern lapwing (*Vanellus vanellus*) | 2 | 0.4 | 1 | 1.2 | – | – | – |
| 22 | cf. whimbrel (cf. *Numenius phaeopus*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 23 | Godwit (*Limosa* sp.) | 6 | 1.2 | 2 | 2.5 | – | – | – |
| | cf. godwit (*Limosa* sp.) | 6 | 1.2 | – | 0.0 | – | – | – |
| 24 | Common snipe (*Gallinago gallinago*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| | Scolopacidae size of common snipe (*Gallinago gallinago*) | 1 | 0.2 | – | 0.0 | – | – | – |
| 25 | Common/arctic tern (*Sterna hirundo/paradisaea*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| | **Columbiformes** | | | | | | | |
| 26 | Pigeon size of rock pigeon (*Columba livia*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| | **Strigiformes** | | | | | | | |
| 27 | Snowy owl (*Bubo scandiacus*) | 15 | 2.9 | 5 | 6.2 | 6 | 17.6 | Meat, claws |
| 28 | Tawny owl (*Strix aluco*) | 3 | 0.6 | 2 | 2.5 | – | – | – |
| 29 | Short-eared owl (*Asio flammeus*) | 3 | 0.6 | 1 | 1.2 | – | – | – |
| | **Passeriformes** | | 0.0 | | | | | |
| 30 | Northern raven (*Corvus corax*) | 9 | 1.7 | 5 | 6.2 | 3 | 8.8 | Meat, toes |
| 31 | Corvidae size of Western jackdaw (*Coloeus monedula*) | 10 | 1.9 | 4 | 4.9 | – | – | |
| 32 | Eurasian skylark (*Alauda arvensis*) | 2 | 0.4 | 2 | 2.5 | – | – | – |
| 33 | Common starling (*Sturnus vulgaris*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 34 | Undet. thrush (*Turdus* sp.) | 13 | 2.5 | 4 | 4.9 | – | – | – |
| 35 | cf. Northern wheatear (*Oenanthe* cf. *oenanthe*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 36 | White-throated dipper (*Cinclus cinclus*) | 1 | 0.2 | 1 | 1.2 | – | – | – |
| 37 | Pine grosbeak (*Pinicola enucleator*) | 2 | 0.4 | 1 | 1.2 | – | – | – |
| | Passeriformes size of Eurasian skylark (*Alauda arvensis*) | 17 | 3.3 | – | 0.0 | – | – | – |
| | **Total identified** | **355** | **68.9** | **81** | **100** | **34** | **100** | – |
| | **Unidentified bird remains** | **160** | **31.1** | **–** | **–** | **–** | **–** | **–** |
| | **Total** | **515** | **100** | **81** | **100** | **34** | **100** | **–** |

**Table 2**
Trou de Chaleux. Fragmentation of bird long bones. NISP is the total number of identified specimens for each element, Complete represents the number of complete specimens for each element.

| Long bone | Anserinae | | Anatinae | | *Perdix perdix* | | *Lagopus* sp. | | Charadriiformes | | *Bubo scandiacus* | | *Corvus corax* | | Other Passeriformes | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *NISP* | Complete | *NISP* | Complete | *NISP* | Complete | *NISP* | Complete | *NISP* | Complete | *NISP* | Complete | *NISP* | Complete | *NISP* | Complete |
| Coracoid | 1 | 1 | 1 | 1 | 0 | – | 5 | 5 | 2 | 2 | 2 | 0 | 0 | – | 1 | 1 |
| Scapula | 0 | – | 0 | – | 0 | – | 1 | 1 | 1 | 1 | 1 | 0 | 0 | – | 0 | – |
| Humerus | 6 | 0 | 3 | 0 | 1 | 0 | 19 | 9 | 5 | 0 | 6 | 0 | 3 | 1 | 14 | 7 |
| Ulna | 10 | 0 | 4 | 0 | 7 | 0 | 7 | 1 | 3 | 0 | 0 | – | 1 | 0 | 0 | – |
| Radius | 4 | 0 | 2 | 0 | 0 | – | 0 | – | 0 | – | 1 | 0 | 0 | – | 9 | 0 |
| Carpometacarpus | 0 | – | 1 | 0 | 16 | 4 | 21 | 11 | 1 | 0 | 1 | 0 | 0 | – | 4 | 3 |
| Femur | 0 | – | 1 | 1 | 1 | 0 | 5 | 2 | 0 | – | 1 | 0 | 0 | – | 2 | 0 |
| Tibiotarsus | 0 | – | 1 | 0 | 2 | 0 | 4 | 1 | 3 | 0 | 1 | 0 | 1 | 0 | 12 | 1 |
| Tarsometatarsus | 1 | 0 | 3 | 3 | 8 | 1 | 30 | 22 | 2 | 0 | 0 | – | 4 | 2 | 5 | 2 |
| *Total long bones* | *22* | *1* | *16* | *5* | *35* | *5* | *92* | *52* | *17* | *3* | *13* | *0* | *9* | *3* | *47* | *14* |

(https://www.gom.com/3d-software/gom-inspect.html) and converting it into vectors using Inkscape (https://inkscape.org/en/). To investigate pigment deposits, uncoated material was examined using the SEM (FEI Quanta 200, 23 kV, spot size 6–7) and the EDS spectroscopy (EDAX: Apollo 10 SDD silicon drift detector) available at the Mineralogical Laboratory of the Geological Survey of Belgium.

Calibration of radiocarbon dates has been made with OxCal v.4.3.2. (Bronk Ramsey 2009, 2017) and the IntCal13 atmospheric curve (Reimer et al. 2013) (95.4% probability).

## 4. Results and comments

At Trou de Chaleux, the bird remains include 515 fragments representing at least 37 taxa, for a minimum of 81 individual birds present. Compared to the remains of mammals larger or similar in size to the hare recovered at the site (NISP = 3659, excluding the unidentified specimens; Charles, 1998), the avian remains represent 8.8% of the total. In terms of MNI, the proportion of birds reaches 41.3% (MNI for the large mammals is 115; Charles, 1998).

### *4.1. Taxonomic composition*

Compared to the taxa previously identified (Tyrberg, 1998, 2008), not all were positively identified during the present study (Table 1). This is partly due to greater caution about taxonomic attributions for certain groups such as the Anseriformes or Passeriformes (more information about the determinations can be found in Supplementary material 1).

Based on the new identifications, three orders account for the majority of the remains, namely Galliformes, Passeriformes, and Anseriformes, with the Galliformes being the most numerous both in terms of NISP and MNI, with respectively 56.6% and 33.3% of the total (Fig. 2).

Among the Galliformes, the ptarmigans are the most frequent and include both the rock ptarmigan (*Lagopus muta*) and the willow ptarmigan (*Lagopus lagopus*). Grey partridge (*Perdix perdix*) is the second most abundant taxon. Two larger species of Tetraonidae are also present, the Western capercaillie (*Tetrao urogallus*) and the black grouse (*Lyrurus tetrix*).

The remains of Passeriformes belong predominantly to small species, such as thrushes (*Turdus* sp.) or smaller taxa such as the Eurasian skylark (*Alauda arvensis*), the pine grosbeak (*Pinicola enucleator*) (Fig. 3A) or the white-throated dipper (*Cinclus cinclus*; Fig. 3B). Other Passeriformes species identified correspond to medium-sized corvids and to the Northern raven (*Corvus corax*).

Among Anseriformes, geese and ducks are almost equally represented in terms of NISP. Most of the duck taxa correspond to diving species, namely red-breasted merganser (*Mergus serrator*), common scoter (*Melanitta nigra*) and the long-tailed duck (*Clangula hyemalis*). A

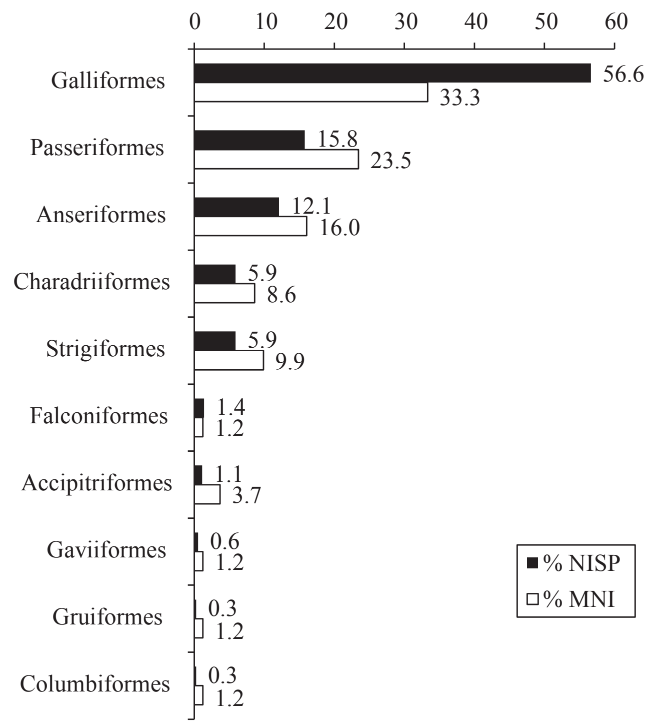


**Fig. 2.** Taxonomic spectrum of the birds from Trou de Chaleux, based on the Number of Identified Specimens (NISP = 355) and the Minimum Number of Individuals (MNI = 81).

dabbling duck, the common teal (*Anas crecca*), is also present. In addition, the mute swan (*Cygnus olor*) and the whooper swan (*Cygnus cygnus*) are identified.

Charadriiformes are mainly represented by waders, namely godwits (*Limosa* sp.), a probable whimbrel (cf. *Numenius phaeopus*), plovers (*Pluvialis* sp.), Northern lapwing (*Vanellus vanellus*) and common snipe (*Gallinago gallinago*). A bone of a common or arctic tern (*Sterna hirundo/paradisaea*) is also present.

Strigiformes are dominated by the snowy owl, but two smaller species are also identified, the short-eared owl (*Asio flammeus*) and the tawny owl (*Strix aluco*).

Diurnal birds of prey include a falcon species comparable in size to the common kestrel (cf. *Falco tinnunculus*), a buzzard (*Buteo* sp.), an eagle the size of the golden eagle (*Aquila* cf. *chrysaetos*) and the short-toed snake eagle (*Circaetus gallicus*; Fig. 3C). The latter species has not been frequently recorded among Late Pleistocene deposits (Tyrberg, 1998, 2008). Whether this bird is part of a local, extinct, breeding population or a migrant is unclear. Today, the species breeds mainly around the Mediterranean but also in regions with a continental climate

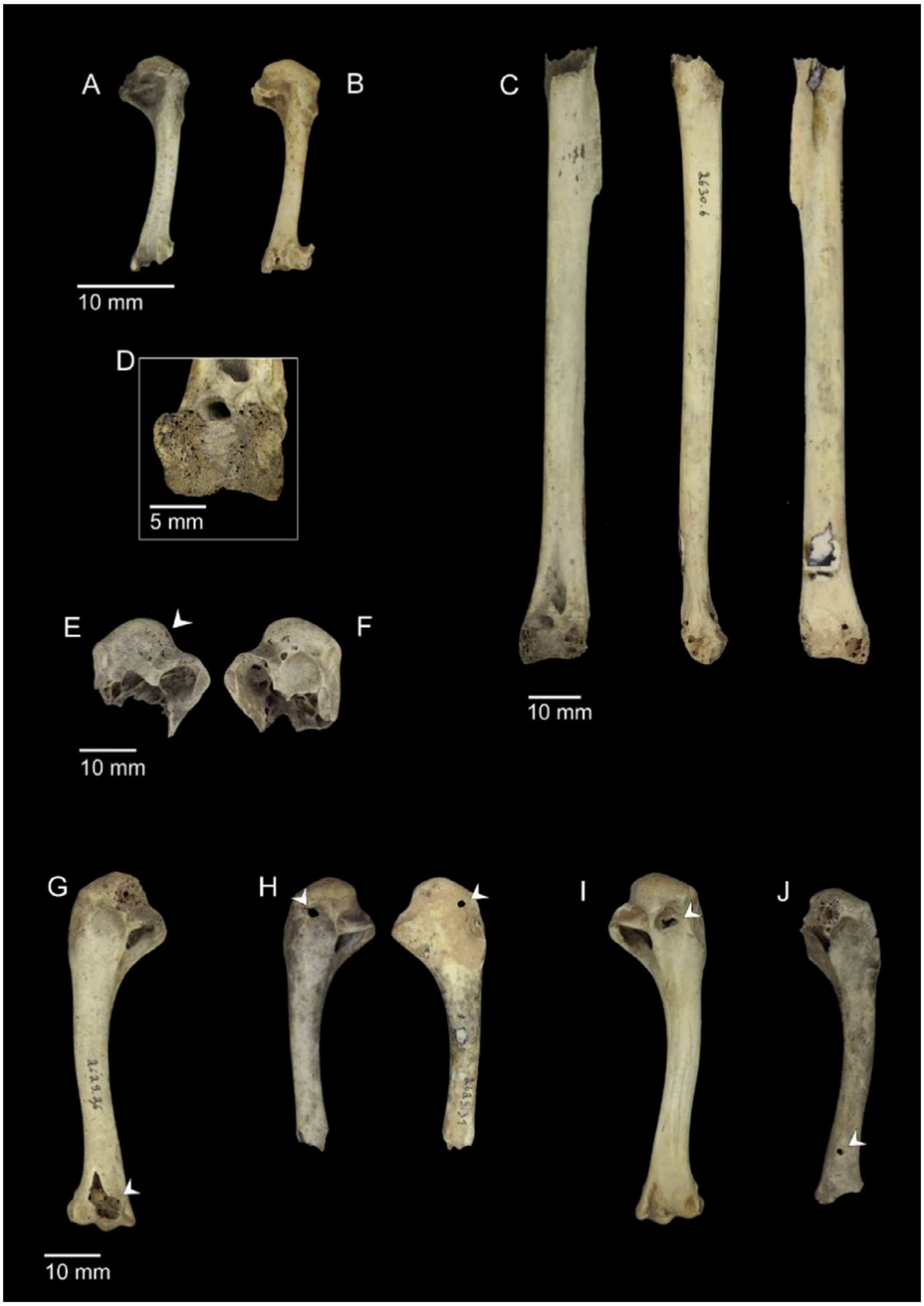


**Fig. 3.** Trou de Chaleux. A. Pine grosbeak, right humerus (IRSNB Av145); B. White-throated dipper, right humerus (IRSNB Av131); C. Short-toed snake eagle, left tibiotarsus (IRSNB Av157); D. Western capercaillie, left tibiotarsus with traces of digestion, detail view (IRSNB Av158); E-F. Black grouse, left (E. IRSNB Av147) and right (F. IRSNB Av146) humeri with peculiar breakage pattern and traces of digestion; G. Ptarmigan left humerus with a notch in the fossa olecrani (IRSNB Av138); H. Ptarmigan left humerus with bilateral puncture (IRSNB Av140); I. Ptarmigan right humerus unilateral puncture, this specimen also displays cut marks on the distal extremity (IRSNB Av142); J. Ptarmigan right humerus with unilateral puncture (IRSNB Av144).

(Cramp, 1980).

Gaviiformes are represented by a small-sized species, either the black-throated (*Gavia arctica*) or the red-throated loon (*Gavia stellata*), and the Gruiformes by the corncrake (*Crex crex*).

Columbiformes include a species the size of the rock dove (*Columba livia*), which could not be identified to species level.

### 4.2. Age and sex of the birds

Almost all the bird remains are from adult individuals, except 17 bones from juvenile or immature birds of the following taxa (summary in Table S2): goose (*Anser* sp.), ducks, probable whimbrel, snowy owl, Northern raven, corvids the size of the Western jackdaw (*Coloeus monedula*) and Eurasian skylark. No bones of very young birds were recovered, perhaps because of preservation issues linked to their greater fragility than the more ossified bones.

Indications regarding the sex are scarce. Two tibiotarsi probably coming from the same female Western capercaillie are filled with medullary bone. No other element contained medullary bone. Based on measurements, one femur corresponds to a female red-breasted merganser and two humeri and a posterior phalanx come from at least one female snowy owl and a femur comes from a male (see Supplementary material 1).

### 4.3. Climate and environment

Among the avifaunal spectrum, some species are characteristic of a cold environment such as snowy owl, ptarmigans and pine grosbeak, which are mainly found today in arctic or subarctic regions (e.g. Fennoscandia) or, in the case of rock ptarmigan, in mountainous areas acting as interglacial refugia (Stewart et al., 2010). Other taxa, such as the loon, whooper swan, red-breasted merganser, common scoter, godwits and plovers are also expected as breeding species in a cold environment. In contrast, several species are today characteristic of more temperate climates, such as the grey partridge and the tawny owl. However, avian species found today in distinct habitats frequently occur together in Pleistocene assemblages, e.g. ptarmigans and grey partridge (Tyrberg, 1991).

Most of the bird taxa from Trou de Chaleux are typical of an open landscape. In particular, snowy owl, grey partridge, common kestrel, Eurasian skylark, short-eared owl and corncrake favour tundra, steppes or grasslands. They are regularly found associated in Pleistocene assemblages as inhabitants of the Mammoth steppe which covered much of Eurasia during glacial periods (Tyrberg, 1991). A few species are characteristic of forested environments, such as the Western capercaillie and the tawny owl. In the absence of radiocarbon dates, it remains unclear whether those taxa represent more recent intrusions, like the chicken, or should be interpreted as indicators of the presence of forested area in the surroundings of the cave, as part of the transitional landscape characterizing the Late Glacial at the onset of the Holocene (Damblon, 1994; Verbruggen, 1999). Trou de Chaleux is situated in a valley environment, which appears suitable for the persistence of forested patches during cold periods. Indeed, the presence of the pine grosbeak, a cold-tolerant species needing trees to breed, suggests that forests were indeed present during the Late Glacial (Cramp and Perrins, 1994). The white-throated dipper is obviously an inhabitant of the Lesse valley since it lives along clean rocky streams and is still present in this valley today. A high proportion of bird species favouring ponds or large water bodies is recorded, including ducks, geese, swans, loons and waders.

The presence of bones of immature or subadult individuals of snowy owl, goose, ducks, whimbrel, Northern raven and skylark is a strong indication that they formerly bred around the cave, further supporting the reconstruction of the local environment of the cave based on those taxa.

### 4.4. Taphonomic analysis

Overall, the preservation of the bones is good, and the impact of post-depositional processes is limited. Strong root etching is rare (NISP = 9), calcite encrustation is absent and none of the bones display the effects of water (abrasion, polishing or rounding). Eight bones present fine linear cracks at the surface, which indicate that the bones suffered some limited weathering before they were embedded in the sediment. Four of them also display anthropogenic traces (Figs. 4E, 5A, 6A and B). Despite good conditions of preservation, the fragmentation of the material is high and only 83 long bones (33.1%) are complete (Table 2). The bones of snowy owl, geese and swans are the most fragmented. By contrast, more than half of the bones of ptarmigans are complete, which contrasts strongly with another Galliformes, the grey partridge, in which the bones are much more fragmented (14.3% of the long bones are complete). Out of the 169 broken bones, 20 (11.8%) present a straight, perpendicular fracture outline with irregular edges indicating they were fractured dry, either by trampling or sediment compaction (Villa and Mahieu, 1991). By contrast, the other 149 bone fragments have curved or spiral outlines with smooth edges typical of fractures on a fresh bone. This kind of morphology can result from the action of man or carnivores (Fernandez Jalvo and Andrews, 2016; Villa and Mahieu, 1991). Two humeri of black grouse are both broken below the proximal extremity (Fig. 3E and F), this pattern is discussed below.

In general, all skeletal elements were present in the collection, apart from the furcula and the fibula (Table 3). Elements of the head, the sternum and the pelvis are few. The lack of vertebrae and posterior phalanges in most of the taxa is probably a consequence of the identification process, as many of these elements recovered from Trou de Chaleux could not be attributed to a species. It was not possible to document skeletal representation for each species, because the NISP is frequently too low. However, the only taxa with almost all the skeletal elements represented are the ptarmigans. Although skull fragments are lacking in ptarmigans, some might be present among the remains of unidentified Galliformes.

We compared the percentage survivorship of ptarmigans and grey partridge to highlight any difference that could help to identify their taphonomic history (Fig. 7). Indeed, although these Galliformes are similar in size, the ptarmigans display cut marks indicating they were exploited by humans (see below), while grey partridge does not. Samples in other bird species or groups are too small to be compared. Ptarmigans and grey partridge show a broadly similar pattern, with carpometacarpus and tarsometatarsus being the best-preserved elements. However, in ptarmigans, the humerus is also well preserved in contrast to the grey partridge. Such patterns, where the carpometacarpus and tarsometatarsus are overrepresented, was formerly identified as a typical signature for non-human accumulators (e.g. Mourer-Chauviré, 1983), but this statement has since been challenged by several authors (Bochenski, 2005; Laroulandie, 2000; Serjeantson, 2009).

The difference in the proportion of wing and leg bones (Table S3) is significant, in terms of NISP, in grey partridge (68.6%, $\chi^2 = 4.83$, $P < 0.05$) and in swans and geese (94.1%, $\chi^2 = 13.24$, $P < 0.01$), which show more wing bones than leg bones. However, in terms of MNE, the difference is still significant in geese and swans (93.3%, $\chi^2 = 11.23$, $P < 0.01$) but not in grey partridge (67.9%, $\chi^2 = 3.57$, $P > 0.05$). This high proportion of wing bones in swans and geese is discussed below.

At Trou de Chaleux, 33 elements display damage to the cortical bone identified as digestion damage. They are the most frequent on Galliformes bones, mainly ptarmigans (n = 12), grey partridge (n = 6), black grouse (n = 1), western capercaillie (n = 2) and other unidentified Galliformes (n = 6). Other species affected are a corvid the size of the Western jackdaw (n = 2), a falcon (n = 1), a godwit (n = 1) and a goose (n = 1). Apart from the latter, of which a pedal phalanx was digested, only long bones are affected in other taxa. The dissolutions observed are light, except in the case of the capercaillie where the cortical bone of the distal epiphysis is greatly affected (Fig. 3D).

Perforations resulting from tooth or beak marks have been recorded on 14 elements. Ptarmigan is the most affected species as perforations were recorded on six proximal and one distal humeri. Other specimens affected include three proximal humeri of snowy owl, two proximal humeri of Northern raven, one articular part of a scapula of a buzzard, and one distal tibiotarsus of Western capercaillie. The perforations are multiple on three of the proximal humeri of ptarmigan, on the two proximal humeri of Northern raven and on the three proximal humeri of snowy owl. Among them, the proximal parts of a humerus of a Northern raven (Fig. 8A) and of a ptarmigan (Fig. 9E) display broad and shallow gnaw marks. In contrast, two bones of ptarmigan display very small, isolated, punctures (Fig. 3H, J). Four bones out of the 14 with perforations have first been cut by humans.

Pitting occurred at the proximal extremity of a goose ulna (Fig. 5A), in association with transverse and broad striations serrated at the base (see below).

Anthropogenic modifications have been recorded on 34 elements (6.6% of the total bird bones), coming from at least nine taxa (Table 1). These modifications will be described in further detail in the next section.

### 4.5. Anthropogenic modifications

#### 4.5.1. Burning

Despite careful examination, no trace of burning was identified on the bird material from Trou de Chaleux.

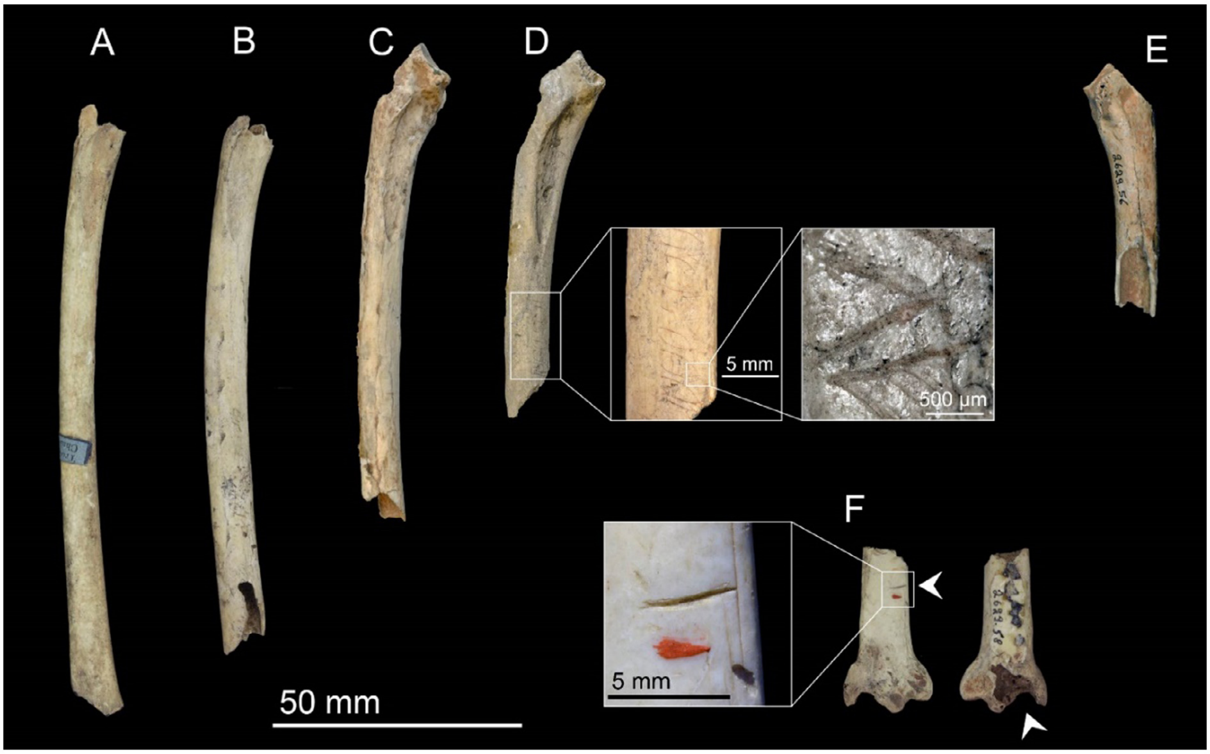


**Fig. 4.** Trou de Chaleux. Goose bones with human modifications. Left (A-D) and right (E) proximal ulnae with cut marks and peculiar breakage pattern of the proximal part. D is decorated (IRSNB Av130) (A. IRSNB Av154; B. IRSNB Av137; C. IRSNB Av148; E. IRSNB Av149). F. distal left ulna with scraping and cut marks, and a perforation on the (damaged) articular surface (IRSNB Av151).

#### 4.5.2. Breakages

Notches have been recorded in the fossa olecrani of humeri of ptarmigans (n = 4; Fig. 3G) and in geese (n = 1, Fig. 10D). Medial wrenches have been observed on the caudal surface of distal humeri of snowy owl (n = 2), mute swan (n = 1; Fig. 10A), whooper swan (n = 1; Fig. 10B), Northern raven (n = 1) and ptarmigan (n = 1, Fig. 9D). Seven proximal ulnae of geese show a similar breakage pattern, corresponding to an oblique or transversal fracture in the medio-lateral direction, in the articulation or directly below (Figs. 4A–E, 5A).

Two distal radii of geese display circular notches on the anterior side, located in the depression of the sulcus tendinosus (Fig. 6C and D; https://sketchfab.com/models/255bf206c6b049e9b30927471d420550).

Two geese ulnae present a circular hole at the distal side of the condyles ventralis ulnae. One of them has a circular perforation of about 4 mm in diameter (Fig. 5B; https://sketchfab.com/models/bd979358e9d34108939f55499ff5bf09). Although the second distal ulna is damaged, the outline of the circular perforation is still partly visible (Fig. 4F). We reproduced a similar perforation experimentally by rotation with a flint drill on a fresh distal ulna of a Herring gull (*Larus argentatus*). The operation was quickly completed and did not leave any traces on the surface of the bone around the perforation.

Finally, a talon of a snowy owl is broken distal to the articulation and the plantar border of the fracture has traces of peeling (Fig. 11E).

#### 4.5.3. Tool marks

In total, tool marks have been recorded on 27 elements, from ptarmigans (n = 7), snowy owl (n = 6), Northern raven (n = 3), loon (n = 1), goose (n = 9) and a duck (n = 1).

In ptarmigans, cut marks are present on a coracoid (Fig. 9B), five humeri (Fig. 9D–F) and a femur (Fig. 9C).

In snowy owl, fine cut marks or scraping marks are present on the shaft of five different humeri (Fig. 11A) and several fine incisions are present on the dorsal side of a coracoid (Fig. 11B).

Cut marks have been recorded on two humeri (Fig. 8A) and one tarsometatarsus of Northern raven. The almost complete tarsometatarsus bears cut marks on the medial side of the proximal extremity (Fig. 8B) and at the junction with the toes.

Fine cut marks have also been recorded on a loon humerus (Fig. 11C) and on a duck radius (Fig. S4; https://sketchfab.com/models/71e347d429fb4ab28ab8480efd0aaca5). This location is rather unusual, as this part is generally not impacted during the disarticulation or the removal of the meat (Laroulandie, 2001), but the morphology and the breadth of the incision correspond to the other cut marks observed at Trou de Chaleux. To ascertain the identification of the cut mark, we computed surface curves perpendicular to the cut mark on the 3D model extracted from the µCT slices. The profiles obtained are v-shaped and asymmetric, which is consistent with cut marks left by stone tools.

In geese, six proximal ulnae display either cut or scraping marks on the posterior edge (e.g. Fig. 5), close to the papillae remigales caudales (n = 3) and ventrales (n = 4). The papillae remigales correspond to the insertion of the ligaments tightening the large flight feathers, the secondary remiges, to the ulna (Baumel, 1993). One of them, which has previously been identified by C. Harrison as Taïga bean goose (*Anser fabalis*) and published by Charles (1995), has also been scraped and presents three longitudinal rows of bracket-like incisions (Fig. 4D; https://sketchfab.com/models/e94aa484f5084073b235831d560b3ec6). Two proximal radii of geese have been cut off transversally (Fig. 6A and B), distally to the cotyla humeralis. One of them has been scraped all over the surface and displays strong erosion on the proximal extremity (Fig. 6B). In addition, one distal radius shows a deep incision on the dorsal side of the shaft, at the level of which the bone broke off (Fig. 6D). A goose humerus presents scraping marks and the shaft was cut off transversely by ringing, above the fossa musculus brachialis.

Two elements display traces of longitudinal grooving and transversal ringing. A humerus of a loon (Fig. 10C) bears three deep

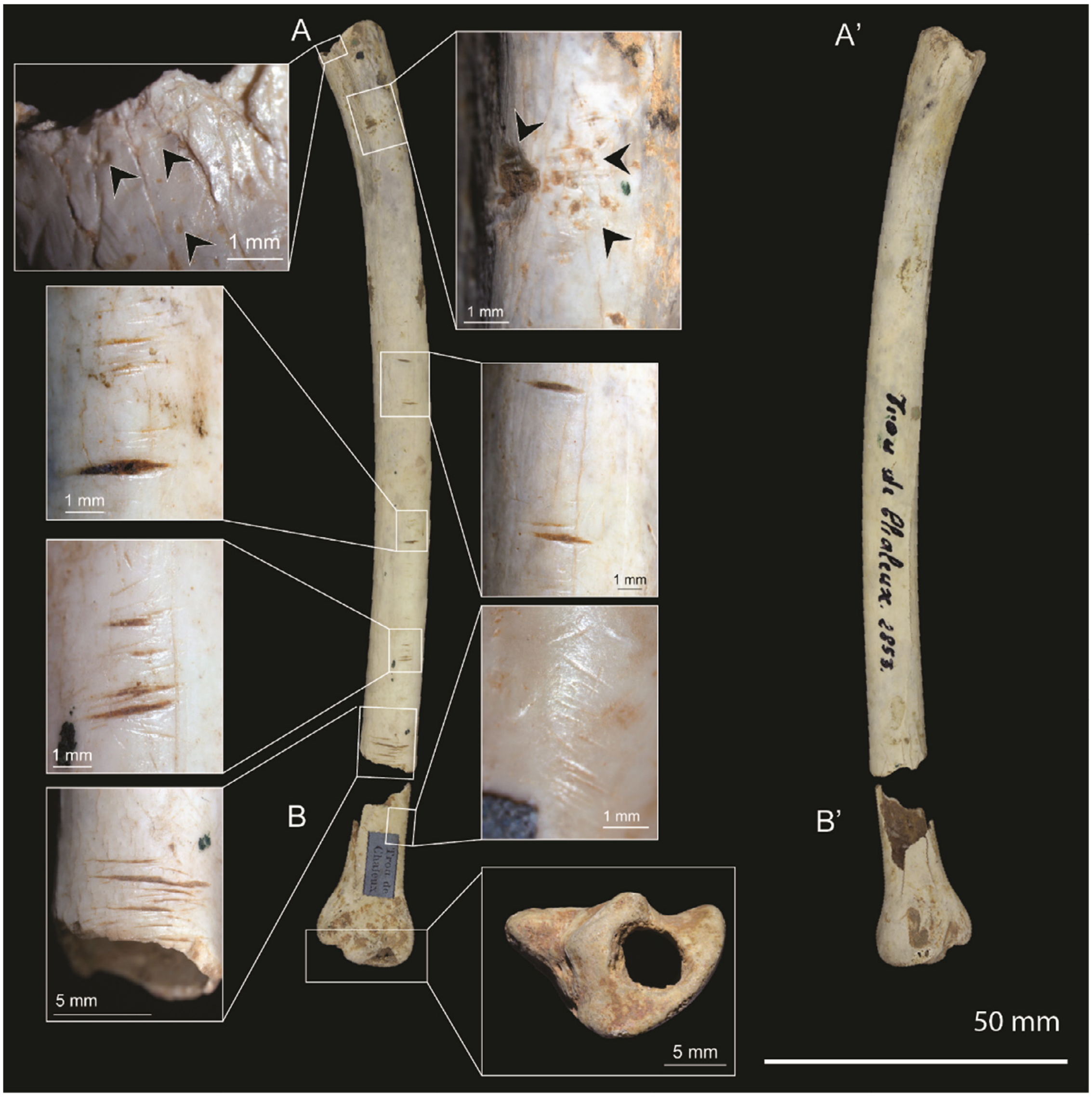


**Fig. 5.** Trou de Chaleux. A. Goose right ulna with possible human teeth marks (arrows indicate pitting) at the proximal extremity, incisions on the papillae remigales ventrales indicating the removal of the feathers and scraping marks (2853.5; A. ventral view, A'. dorsal view). B. Goose right distal ulna with scraping marks and a perforation on the articular surface (2853.4; B. ventral view, B'. dorsal view).

longitudinal grooves on the caudal side of the shaft and a fourth on the cranial side. A fifth groove was probably present in the axis of the crista deltopectoralis, which has been cut off distally. Afterwards, the shaft was cut by ringing directly below the crista, in the process of extracting five bone splinters. A distal humerus of a mute swan has been treated in a similar way (Fig. 10A). The shaft was first incised with ten deep longitudinal grooves and was then cut by ringing to produce ten bone splinters. In addition, some longitudinal incisions are present on a goose humerus (Fig. 11D), which could suggest that it was also exploited to produce bone splinters, but this remains uncertain.

#### 4.5.4. Wear traces

Three bones have been observed in search of wear traces. Two talons, one of a large eagle (Fig. 11C) and one of a snowy owl (Fig. 11D) are devoid of cut marks but display very smooth polish on the dorsal side, with groups of very fine striations. One complete goose ulna displays a very smooth shaft; the proximal extremity appears eroded (Fig. 5A). The microwear analysis identified two generations of fine striations on the surface of the shaft. First, oblique or transversal striations occurred and second, deeper striations oriented in the axis of the shaft. These striations penetrate into the deep incisions located close to the papillae remigales. No traces related to the use of this specimen have been observed.

#### 4.5.5. Pigment deposits

Some of the bones displayed ochre or reddish colour, either directly colouring the surface or as powdering sediment attached to it (e.g. Figs. 9E, 10C or S3). Red tints may appear in iron ($Fe^{3+}$) rich sediments under oxidizing conditions (Fernandez Jalvo and Andrews, 2016), which is not the case at Trou de Chaleux. Careful examination concluded that the deposits were not intentional but probably result from the encrustation of the surrounding reddish/yellowish sediment consisting of a sandy clay matrix including some muscovite detrital flakes. This interpretation is also supported by the comments made by E. Dupont (1873), who indicates that the bones were covered by a yellowish clay ground.

Nevertheless, strikingly, most of those elements with reddish tints also display human modifications. Furthermore, a perforated bear canine also displays ochre traces (Germonpré and Hämäläinen, 2007). Interestingly in this context is that in the Palaeolithic mammal

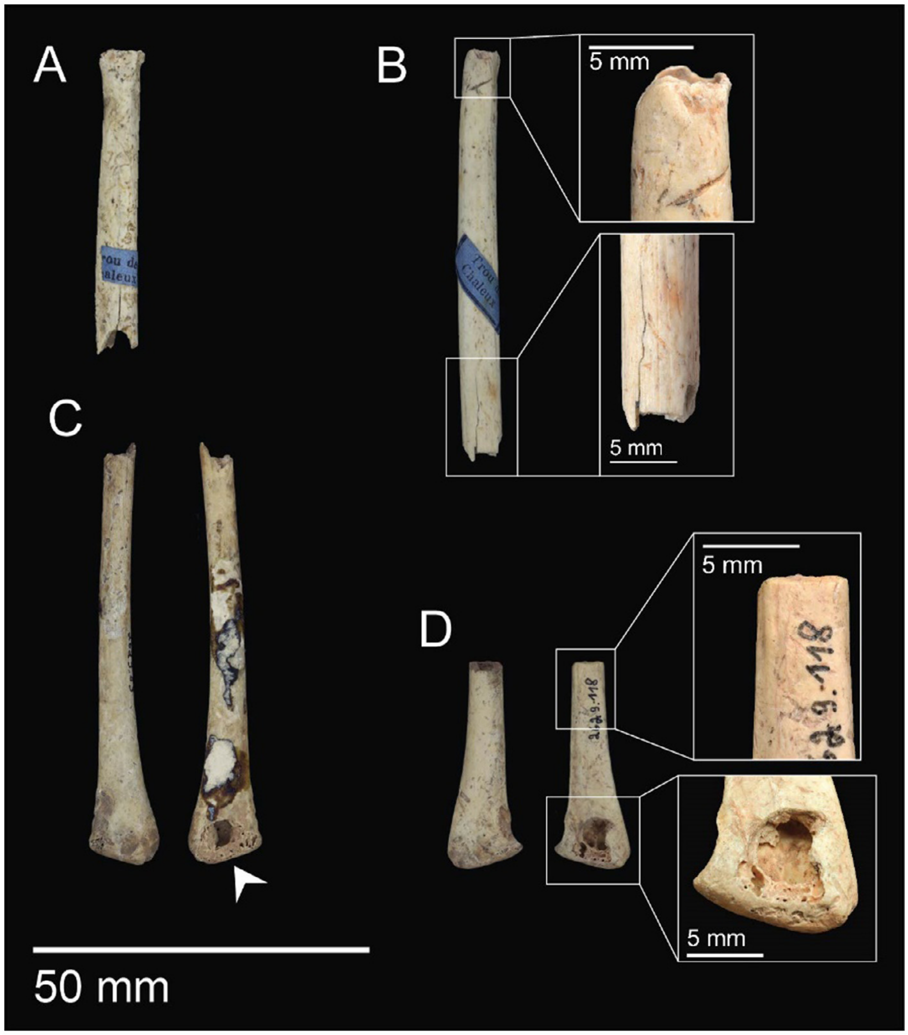


**Fig. 6.** Trou de Chaleux. Goose radii with human modifications. Proximal radius left cut off transversally (A. 1877.24), and proximal radius right cut off transversally and scraped, displaying strong use wear at the proximal extremity (B. 2853.31). Distal radii with a perforation on the anterior side, left (C. IRSNB Av152), and right displaying a deep incision on the dorsal side of the shaft (D. IRSNB Av155).

assemblage from Spy, a significant positive correlation between human-modified bones and bones with ochre traces was observed (Germonpré et al., 2013). Also, in the mammal assemblage from the first bone horizon of the Goyet cave, a clear association between human manipulated bones and bones with ochre stains was described (Germonpré, 1996). To verify the presence of ochre or hematite deposits, elementary analyses using a scanning electron microscope were performed on the more strikingly coloured bones from Trou de Chaleux. The analytical results correspond to a silty-clay sediment composed of a mixture of natural quartz and phyllosilicates (Fig. S5). The EDS spectra of the deposits are similar to those observed by the laboratory on alluvial clay sediments or loess, whose mineralogy has been verified by X-ray diffraction. In addition to quartz, they also contain illites, kaolinites, iron-rich chlorites and swelling of interstratified clay minerals as well as poorly crystallized iron oxide-hydroxide and very low proportions of amorphous Fe. Due to dehydration and maturation processes, yellow iron oxides present in the sediments can be transformed into iron oxyhydroxides and ferric iron-oxides responsible for the reddish tints, which are further accentuated when the sediment is hydrated. The iron content controlled at different points of the reddish deposits corresponds to this mineral association. The absence of a high or abnormal iron concentration indicates that neither hematite nor ochre is responsible for the visible red colour at the surface of these bones.

### 4.5.6. *Bird depiction*

An engraved ivory plate was shaped into a bird (Lejeune, 1987, figure 25, 3; ca. 4.8/2.6 cm). It was 3D scanned in the framework of this study to enhance the features on the surface, making the longitudinal incisions depicting the feathers and the groups of short, transversal, incisions evoking a mottled plumage more visible (http://virtualcollections.naturalsciences.be/virtual-collections/anthropology-prehistory/portable-paleolithic-art/trou-de-chaleux/ivory-bird).

## 5. Discussion

The bird remains found at Trou de Chaleux are numerous and come from a wide variety of species. Most of the taxa identified are ground-feeding birds (Galliformes and Passeriformes), waterfowl and waders. Potentially, all the species identified may have been exploited by humans for food. Some prey selection occurred as species smaller in size than a thrush, e.g. the size of a redpoll (*Acanthis flammea*), are almost absent. As no sieving was performed, bones of small species may have been overlooked during the excavation. However, skeletal elements smaller in size than some bones of these small species have been recovered, sometimes in high numbers. Therefore, there is no reason to believe that bones of small species would not have been collected in the field while skeletal elements smaller in size (e.g. posterior phalanges), but coming from larger species, would have been. The absence of small

**Table 3**
Number of identified specimens of each anatomical element, per species or group of birds recovered at Trou de Chaleux.

| Element | Large Anseriformes | Anatinae | *Perdix perdix* | *Lagopus* sp. | Other Galliformes | *Gavia* sp. | Diurnal raptors | *Crex crex* | Charadriiformes | *Bubo scandiacus* | Other Strigiformes | *Columba* sp. | *Corvus corax* | Other Corvidae | Other Passeriformes | Undet. Bird | Total NISP | Total % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cranium | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 | 2 | 0.4 |
| Mandibula | – | 1 | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | 3 | 0.6 |
| Quadratum | – | – | – | 1 | 2 | – | – | – | – | – | – | – | – | – | – | – | 3 | 0.6 |
| Vertebra | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 65 | 67 | 13.0 |
| Sternum | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 | 0.2 |
| Coracoid | 1 | 1 | – | 5 | 3 | – | 1 | – | 2 | 2 | 1 | – | – | – | 1 | – | 17 | 3.3 |
| Scapula | – | – | – | 1 | 1 | – | 1 | – | 1 | 1 | – | – | – | – | – | – | 5 | 1.0 |
| Furcula | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | 0.0 |
| Humerus | 6 | 3 | 1 | 19 | 4 | 1 | – | – | 5 | 6 | 2 | – | 3 | – | 14 | – | 64 | 12.4 |
| Ulna | 10 | 4 | 7 | 7 | 7 | – | 1 | 1 | 3 | – | 1 | – | – | 5 | 4 | – | 50 | 9.7 |
| Radius | 4 | 2 | – | – | 3 | – | – | – | – | 1 | – | – | 1 | – | – | 1 | 12 | 2.3 |
| Carpometacarpus | – | 1 | 16 | 21 | 1 | – | – | – | 1 | 1 | 1 | – | – | – | 4 | – | 46 | 8.9 |
| Wing phalanges | – | – | 1 | 2 | 4 | – | – | – | 3 | 1 | – | – | – | – | – | – | 11 | 2.1 |
| Carpale | – | – | 1 | 2 | 1 | – | – | – | 1 | – | – | – | – | – | – | – | 5 | 1.0 |
| Pelvis | – | – | – | 1 | 2 | – | – | – | – | – | – | 1 | – | – | – | – | 4 | 0.8 |
| Femur | – | 1 | 1 | 5 | 6 | – | 1 | – | – | 1 | – | – | – | – | 2 | 1 | 18 | 3.5 |
| Tibiotarsus | – | 1 | 2 | 4 | 12 | – | 1 | – | 3 | 1 | – | – | 1 | 2 | 10 | – | 37 | 7.2 |
| Fibula | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | 0.0 |
| Tarsometatarsus | 1 | 3 | 8 | 30 | 17 | 1 | 2 | – | 2 | – | 1 | – | 4 | 3 | 2 | – | 74 | 14.4 |
| Pedal phalanges | 2 | – | – | – | – | – | 1 | – | – | 1 | – | – | – | – | – | 83 | 87 | 16.9 |
| Element indet. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 9 | 9 | 1.7 |
| *Total* | *26* | *17* | *37* | *99* | *65* | *2* | *9* | *1* | *21* | *15* | *6* | *1* | *9* | *10* | *37* | *160* | *515* | *100* |

bird species in Magdalenian assemblages has been regularly reported (e.g. Laroulandie, 2003) although their consumption is attested on some sites, such as Monruz and Champréveyres (Switzerland) where small Passeriformes served as food (Müller, 2004). At Trou de Chaleux, the absence of small passerines is unlikely to be a consequence of recovery techniques or preservation issues as fish or micro-mammal bones and tiny skeletal pieces have been recovered during the excavation.

The complex taphonomic history of the assemblage, which results in part from predators or non-human scavengers, prevents a clear separation between the bones accumulated by humans and by other agents. Tooth or beak marks, as well as digestion marks, clearly attest the intervention of predators or scavengers. Identifying the non-human accumulators involved is difficult. The position of the isolated, very sharp, punctures observed on ptarmigan bones (Fig. 3H, J) is comparable to what has been observed in modern referential material of bird bones accumulated by birds of prey (e.g. Laroulandie, 2002; Bochenski and Tornberg, 2003). The breakage pattern of two humeri of black grouse, broken below the proximal extremity (Fig. 3E and F), also suggests the intervention of raptors, such as *Bubo* owls (Laroulandie, 2002; De Cupere et al., 2009). This is also supported by the presence of light traces of digestion. The separation is further complicated by the fact that scavenging occurred on bones discarded by humans. Similar situations have been reported at other sites, e.g. in the cave of Santa Catalina, Spain (Laroulandie, 2014). The broad and shallow gnaw marks observed on two proximal humeri, one of a Northern raven and one of a ptarmigan (Figs. 8A, 9E), could have been left by small carnivores, or by humans when removing the meat by chewing.

Different elements could document a seasonal occupation of the Trou de Chaleux, or at least exploitation of birds at a preferential time of year, such as the presence of immature bones from birds that died during the weeks following their hatch. Several of these immature bones belong to species exploited by humans at the site, such as geese, snowy owl or Northern raven. However, none of these immature bones displays human modification. In contrast, some of them have been gnawed by carnivores, which does not exclude that they were primarily consumed by humans. In the absence of clear human modifications on these immature bones, it remains uncertain whether the young birds they belonged to were exploited by man. Therefore, their presence cannot be taken as an indication of a seasonal human exploitation. Besides, two tibiotarsi probably coming from the same female Western capercaillie are filled with medullary bone, which indicates that the bird was killed around the laying period. However, the presence of strong digestion traces indicates they were digested by a predator and are therefore not indicative of human activities. None of the bones with human modifications contain medullary bone.

The presence of migratory species breeding at northern latitudes but wintering further south today, such as the whooper swan, geese, loons, waders, snowy owl or short-eared owl, suggest occupation during their breeding or migration periods. The behaviour of bird species in the past probably differed from today, but we can assume that in a colder situation the breeding grounds were further south than today (Jenkinson et al., 1984). The latitudes of the Belgian area were probably more suitable as breeding grounds than as wintering grounds for most migrating species. Although we cannot exclude that some bird bones were harvested from carcasses randomly encountered, the frequent scraping marks recorded on bones used as raw material indicate that meat, and in the case of geese, feathers, were present. This suggests that most of the bones are from birds that were actively hunted.

A series of bones carry indisputable anthropogenic traces. The species exploited at Trou de Chaleux have also been reported for many other Upper Palaeolithic sites: ducks, ptarmigans, snowy owl, swans, geese, and Northern raven. Grey partridge and ptarmigans have been exploited very frequently by Palaeolithic hunter-gatherers for food (e.g. Conard et al., 2013; Laroulandie, 2003; Wertz et al., 2016). At Trou de Chaleux, the consumption of the grey partridge is uncertain in the

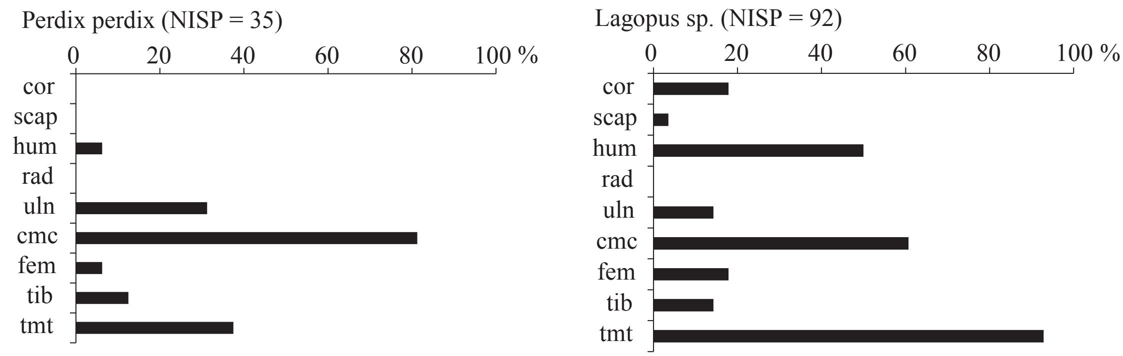


**Fig. 7.** Percentage survivorship of coracoid (cor), scapula (scap), humerus (hum), ulna (uln), radius (rad), carpometacarpus (cmc), femur (fem), tibiotarsus (tib) and tarsometatarsus (tmt) of grey partridge and ptarmigans, expressed as: 100 × (MNEe)/MNI × (number of times e occurs in a complete skeleton), *e* being an anatomical element (Brain 1969, 1976). MNE was calculated without lateralisation.

absence of butchering marks, in contrast to ptarmigans. The locations of the incisions on the bones of ptarmigan match those observed by Laroulandie (2001) during butchery and consumption experiments conducted on birds. At Trou de Chaleux, the traces correspond either to disarticulation (humeri) or to removal of the meat (coracoid, humeri and femur). Serjeantson (2009) indicates that among ptarmigan remains from Palaeolithic assemblages, the humerus and, to a lesser extent, the coracoid and the femur, are generally the skeletal elements most impacted by cut marks. There is no evidence of the exploitation of feathers or of the white feathery legs of ptarmigans, as has been suggested for other sites such as the Abri Büttenloch (Switzerland, late Magdalenian, Schibler and Sedlmeier, 1993). Today, in the Arctic, ptarmigans still represent the most frequent food taxa exploited by hunter-gatherers and not only is the meat consumed, but also the plant content of the digestive tract (Vaughan, 2010). A duck was also used as food at Trou de Chaleux.

Other species with traces of disarticulation are the Northern raven and the snowy owl. In these two species, they were observed on the humerus and the coracoid. In the case of the snowy owl, the consumption of the meat is attested by numerous traces of cutting and scraping. Since these bones do not appear to have been subsequently used for bone working, the hypothesis of meat consumption seems more likely than the one of cleaning before the bones are used as raw material. The consumption of the snowy owl was highlighted at several Magdalenian sites such as Bois-Ragot, Faustin, Isturitz and Morin, where butchering marks are sometimes associated with cooking (Laroulandie, 2016 and references therein). On these sites, cut marks are mainly recorded on the humerus, which is the most affected bone at Trou de Chaleux. Ethnography also indicates the occasional or regular consumption of the snowy owl by different groups of recent hunter-gatherers in the Arctic or subarctic regions, such as at Sandwich Bay or at the Yukon-Kuskovim Delta (Cooke, 1916; Potapov and Sale, 2013).

Butchering marks similar to those observed on snowy owl bones were also recorded on bones of the Northern raven. According to Laroulandie (2001), the fine cuts on the humeri could correspond both to the disarticulation process and to the removal of the meat. Consumption of meat of Northern raven has sometimes been proposed, for example for the Gravettian occupation of Pavlov (Bochenski et al., 2009). In Arctic populations, the Northern raven occupies a crucial place within the myths. Oosten and Laugrand (2006) indicate that '… in many respects the raven is responsible for society but without being part of it. As a predator and a scavenger, it is often associated with

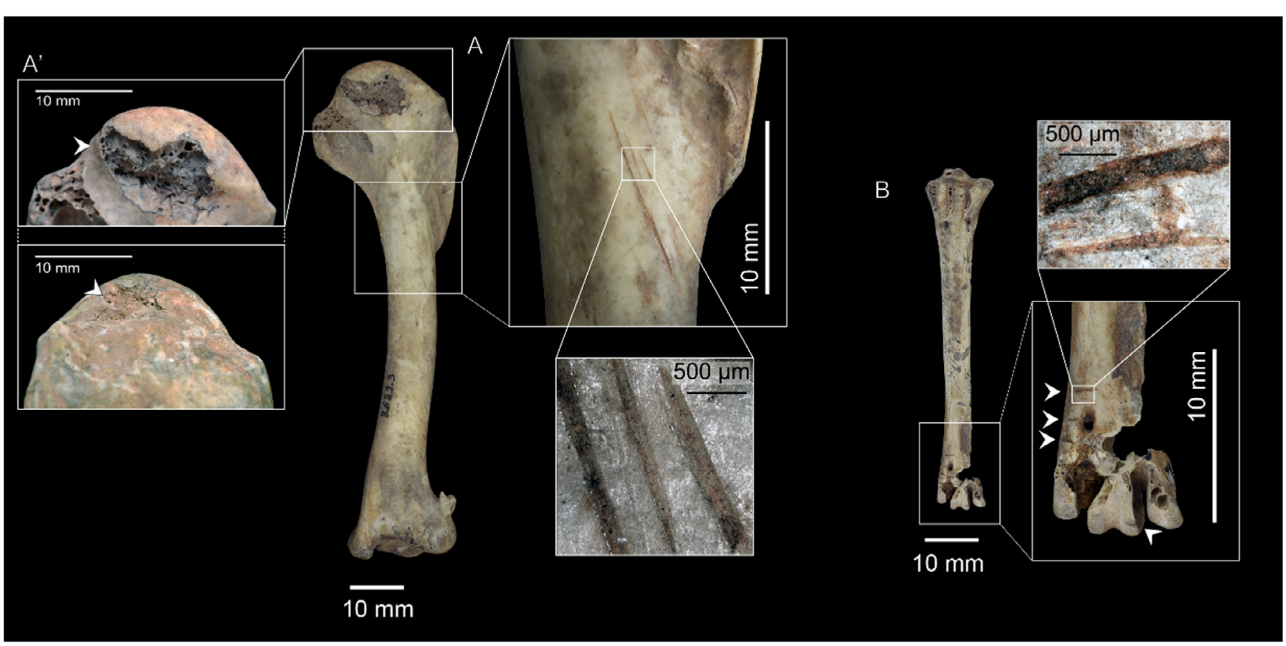


**Fig. 8.** Trou de Chaleux. Northern raven bones with cut marks. A, right humerus with cut marks indicating removal of meat and gnawing marks, having possibly be made by humans (IRSNB Av132, A'. details of the possible gnawing marks, caudal view above, cranial view below,); B. left tarsometatarsus with indication of removal of the phalanges (IRSNB Av153).

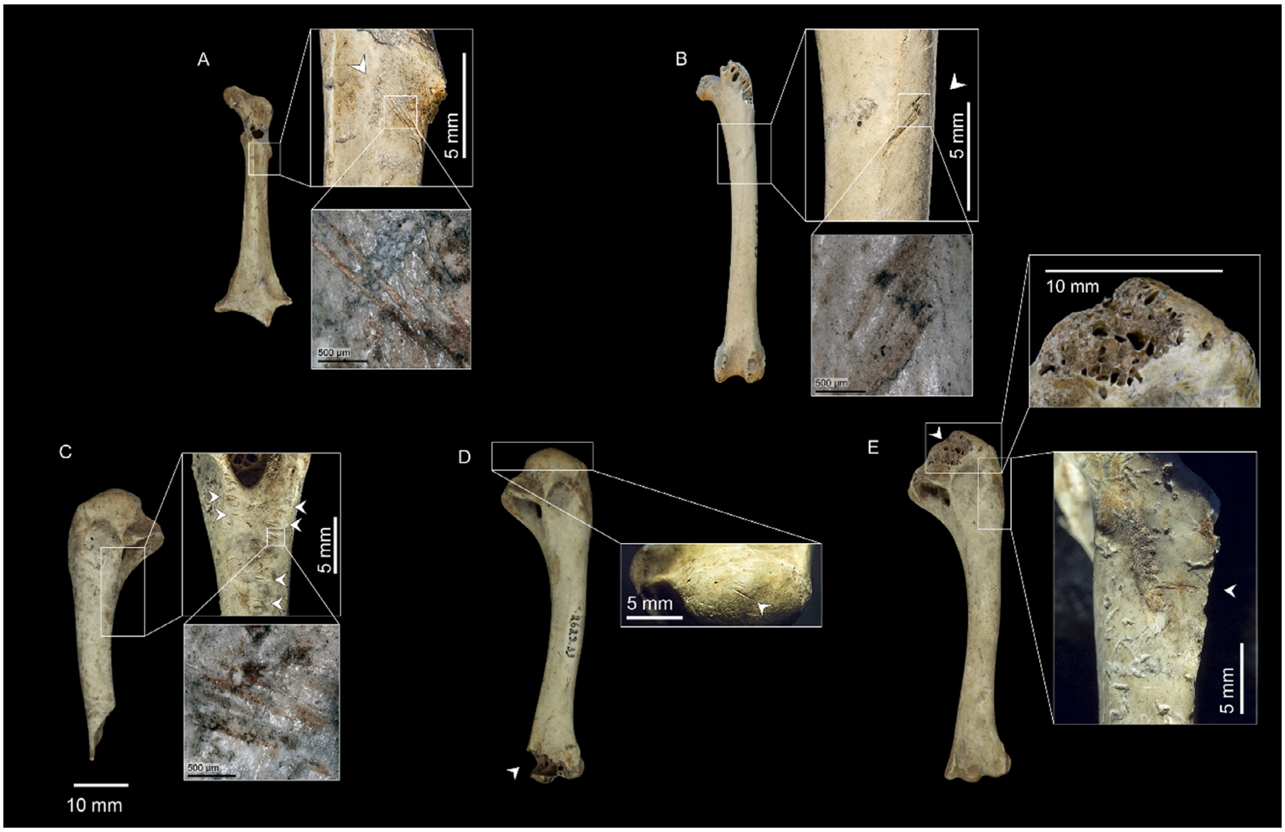


**Fig. 9.** Trou de Chaleux. Ptarmigan bones with cut marks.; A. left coracoid (IRSNB Av134); B. left femur (IRSNB Av156); C. left humerus (IRSNB Av139); D. right humerus with a medial wrench (IRSNB Av141); E. right humerus with gnaw and cut marks (E. IRSNB Av143).

eating dirt, excrement and human flesh, and yet it created light, enabling people to see and invented tattooing, enabling women to marry'. Although it is not eaten by modern Inuit populations, it is not forbidden by tradition to kill it (Laugrand and Oosten, 2015). The use of Northern raven skins is well-documented ethnologically, especially in the Inuit tradition, where it serves as the first garment for children. Sometimes, the feet alone are used as amulets (Oosten and Laugrand, 2006). Without doubt, Northern raven also played a special role in prehistoric societies, which is highlighted by the relationship that existed between this scavenger bird, among others, and Neanderthals (Finlayson and Finlayson, 2016). This is also supported by the interpretation based on the material from Gönnersdorf where some remains of Northern raven, such as the head of a Northern raven probably deposited complete, suggest symbolic uses (Street and Turner, 2016). The removal of the toes from a tarsometatarsus at Trou de Chaleux probably also reflects non-utilitarian purposes (Fig. 8B). Several traits of the Northern raven are remarkable, such as the completely black plumage, a characteristic that is shared by very few other birds in the Arctic environment, and its call. Northern raven has a very large repertoire of vocalizations, sometimes very peculiar (see, for example, https://www.xeno-canto.org/430488; http://www.xeno-canto.org/368993 or https://www.xeno-canto.org/430170) and can even mimic the human voice in captivity (Ratcliffe, 1997). As scavengers, Northern ravens would certainly have been attracted to kill- or butchery sites used by prehistoric humans during meat procurement. Northern ravens can congregate in very large numbers, sometimes in hundreds around carcasses. Such concentrations and the proximity to human activities could have facilitated their capture by prehistoric hunters. Indeed, kill- and butchering sites as well as food leftovers around human settlements were, as in the present day, certainly attractive for Northern ravens.

At Trou de Chaleux, humans paid special attention to geese. The elements recovered come mostly from the wings, while the rest of the carcass is almost absent. This overrepresentation of the bones of the wings suggests a specific collection, curation, and transport of these elements. Given the large amount of meat yielded by geese, it would be astonishing that it was not eaten but mostly partial skeletons were brought to the cave, in the form of bones of the wings. The peculiar breakage pattern observed on seven proximal geese ulnae could have occurred during the disarticulation of the elbow. A similar breakage pattern is documented for smaller species, e.g. on ptarmigan ulnae from La Vache (Laroulandie, 2005) or on black grouse ulnae from Fumane Cave (Fig. S5A–C in Peresani et al., 2011), which in both cases is interpreted as having been left by humans, the latter by Neanderthals. Although the breakage pattern observed at Trou de Chaleux does not necessarily result from human activities, the fact that those seven ulnae display other anthropogenic traces supports that this pattern is anthropogenic. Peeling marks are expected to occur during this process (Laroulandie, 2005), but none was observed on the ulnae from Trou de Chaleux.

Among the goose ulnae from Trou de Chaleux, two yielded evidence of the removal of feathers, as attested by incisions located precisely next to the papillae. The incisions observed are in a position comparable to those produced during the experimental removal of large raptor flight feathers (compare to Romandini et al., 2016, Fig. 8A5–A9). The observation of the fine striations resulting from the cleaning of the surface of one of the ulnae from Trou de Chaleux (Fig. 5A) shows that they penetrate inside the deep transversal incisions, which supports that they indeed result from the extraction of feathers and are not, in this case, part of a decoration. The deep incisions at the distal end of this bone are thought to result from the removal of the feather rather than sawing the bone because they are aligned with the other incisions and because no ringing was performed. It is possible, however, that the deep incision at the distal end created a weakness where the bone broke during the manufacturing process or during use but the fracture, which


**Fig. 10.** Trou de Chaleux. A, Mute swan right humerus incised longitudinally and displaying ringing traces designed for extracting ten bone splinters (2853.1); B, Whooper swan right humerus (IRSNB Av133); C, Loon proximal right humerus with reddish tints incised longitudinally and displaying ringing traces designed for extracting five bone splinters (2853.3); D, Goose distal right humerus cut off, with a notch and deep cut mark through the fossa olecrani (2853.2).

occurred when the bone was still quite fresh, did not initiate in the incision. Other striations located at the proximal extremity are shallow, associated with pits and present a serrated base, suggesting gnawing marks from human incisors (Fernandez Jalvo and Andrews, 2016). Their location at the extremity suggests they could be related to the use of the object rather than with the consumption of the meat. Consequently, this artefact could have been used with the proximal part in the mouth, such as a straw. We propose that the final product was intended to preserve the distal extremity, which was pierced, as reconstructed in Fig. 5A-B. This assumption is reinforced by the discovery of more complete examples from other sites such as Bois Laiterie, Belgium (Lopez Bayon et al., 1997) and La Vache, France (Delporte, 1993). Another goose ulna has been scraped and intentionally engraved with bracket-like incisions, more than 60, organised in three rows (Fig. 4D) to form a decoration.

A peculiar breakage pattern was also observed on the anterior side of two distal geese radii, where notches are present (Fig. 6C and D). They are suspected to result from the contact with the protruding processus extensorius of the carpometacarpus, during the forced stretching of the wrist joint by hand. Indeed, no tool marks were observed on the sides of the perforation which could indicate an intentional perforation. Two proximal and one distal radii have been cut off (Fig. 6A and B, D), probably to remove the articular extremities in order to create tubes. Indeed, the two proximal portions of radius shaft have been intensively scraped after they were cut off, as the cut marks are eroded (Fig. 6A and B). One goose humerus was cut by ringing, also probably for producing a tube.

Indications of feather removal found on ulnae could indicate that wings were primarily gathered for this purpose, but the length of the wing bones and their almost perfectly circular section also make them desirable as raw material. The humerus, ulna, and radius have been scraped and cut to produce tubes.

The production of tubular objects, sometimes decorated, is frequently reported at Magdalenian sites (e.g. Averbouh, 1993; Laroulandie, 2000, pp. 86-90). The bones of large birds were mainly used for that purpose, such as those of geese, swans (*Cygnus* sp.), large raptors, cranes (*Grus* sp.), etc. However, the aim of this production is unclear. None of the ulnae from Trou de Chaleux has any perforation on the shaft that could indicate production of flutes, which, however, does not exclude a use as aerophones. Indeed, the presence of tubes made of portioned radii and ulnae of geese is reminiscent of the much younger two-piece artefacts comprising a tube made from the shaft of a radius inserted in a tube of an ulna, both of swan (*Cygnus* sp.), recovered from a Middle Neolithic grave at Ajvide, Gotland. It has been proposed that these two-piece artefacts could be aerophones (Rainio and Mannermaa, 2014). Other hypotheses generally proposed for Upper Palaeolithic tubular objects include needle cases, straws or blowing tubes. The possible teeth marks at one extremity of a goose ulna at Trou de Chaleux suggest that it was held in the mouth. A specific selection of radius and ulna has been observed in different French Magdalenian sites (Laroulandie, 2016), but they concern the snowy owl. Why geese were specifically selected at Trou de Chaleux is unclear, but this could relate to their behaviour. At present, outside the breeding season, these birds gather in large flocks, sometimes totalling tens of thousands of individuals, to graze on continental or coastal plains (Cramp and Simmons, 1977). This behaviour is broadly similar to that of large gregarious herbivores, such as the horses or the reindeer, which were intensely hunted during the Palaeolithic. Moreover, Anseriformes have a specific moulting strategy. At the end of the summer, all the flight feathers (remiges) are lost at once to be replaced, which prevents them from flying. While the females rear the young, males generally gather on large water bodies to moult. Their capture is therefore made easier.

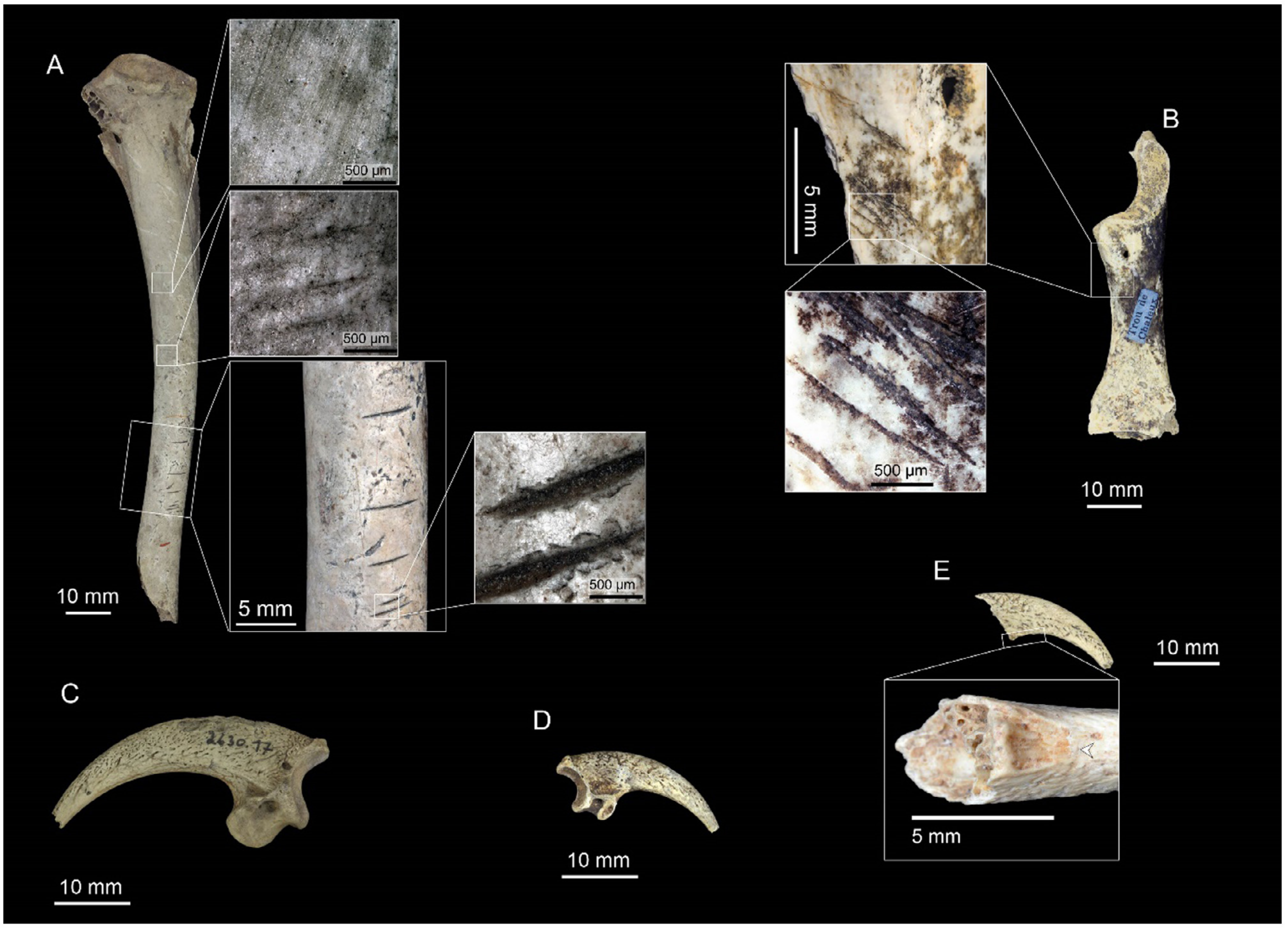


**Fig. 11.** Trou de Chaleux. A-B, D-E, Snowy owl bones. Humerus right (A, IRSNB Av135) and coracoid (B, 2853.7) with cut marks. D, talon with wear on the dorsal side (2853.23); E, talon with distinctive breakage (2853.24). C, Eagle talon with wear on the dorsal side (IRSNB Av159).

Ethnological observations indicate that under such conditions, a hunt led by Samoyedic people of Kolgueyev Island, European Russia, in the late 19th century led to the capture of several thousands of geese in one day. Interestingly, the geese were slaughtered by breaking their necks and then stored by dozens in caches covered with layers of turves, as a store for winter (Trevor-Battye, 1895). Geese represent a highly predictable, seasonal resource, easy to hunt and providing a substantial amount of meat and grease. Since they consume large quantities of plants, it is possible that their stomach contents have also been sought after, as it is ethnologically attested for ptarmigans (Vaughan, 2010). In addition, like other birds, they also yield raw material in the form of feathers, tendons, and bones.

At Trou de Chaleux, talons of a large eagle and of snowy owl were used and probably worn as an ornament, as suggested by the wear traces observed. This also means that the keratin sheath was either taken off or fell off during the use of the object. Today, eagle populations show low densities in the wild and eagles are generally scarce among the avifauna (Morin and Laroulandie, 2012). This, together with the absence of other bone elements of large eagles, suggests that the claw was specially brought into the cave and indicates a specific interest in raptor claws. The broken claw of snowy owl (Fig. 11E) could have been damaged during the extraction process, as suggested by the peeling traces observed. Fractures of this type were not produced during experimental removal of raptor claws (Romandini et al., 2014). However, a transversal fracture similar to the one observed at Trou de Chaleux is present on a claw with cut marks from Santa Catalina (Laroulandie 2014, Fig. 6e, left), although it breaks closer to the middle of the claw in the specimen from Santa Catalina. No more detail is given about this specimen and it is unclear whether this kind of fracture results from the disarticulation process or not.

The extraction of splinters from bones of large birds at Trou de Chaleux was probably aimed at producing needles, as more than thirty of these have been recovered. The species used are the whooper swan, the loon and perhaps the mute swan. The latter two possess remarkable calls (whooper swan: http://www.xeno-canto.org/476065; black-throated loon: http://www.xeno-canto.org/340741) and are integral parts of the myths of current Arctic populations, especially the loon (Vaughan, 2010; Mishler and Ridington, 2013). At Trou de Chaleux, bones of other animals have also been exploited to produce splinters, including mammals the size of the hare which display the same type of modifications (Saccasyn della Santa, 1946). Laroulandie (2000) also mentions the use of bones of lagomorphs to produce needles at the site of Mas-d'Azil, France, which were originally identified as bird bones (Chollot, 1964, pp. 340-341). It thus appears that any animal species, avian or not, of medium size, has been exploited to produce needles. The most critical criterion seems to be that the raw material possesses a hollow cavity and a relatively thick, resistant cortical bone. The extraction of bone splinters is attested in other late Magdalenian sites such as Petersfels in Germany (Berke, 1987), Champréveyres and Monruz in Switzerland (Bullinger and Müller, 2006; Müller et al., 2013; Leesch, 1997) or Santa Catalina in Spain (Laroulandie, 2014). In the site of Monruz, swan (*Cygnus* sp.) and loon (*Gavia* sp.) bones have been used, as at the Trou de Chaleux.

Although comparative sites for Belgium are few, the Magdalenian site of Bois Laiterie, which is dated to the Bölling phase (about 15,000 cal BP; Straus, 1997) and located about twenty kilometres away from Trou de Chaleux, has delivered two objects comparable to those uncovered at Trou de Chaleux. One is a fragment of the shaft of a radius of a large bird, probably a greylag goose (*Anser anser*; Lopez Bayon et al., 1997). The object's surface was scraped, and two deep, parallel incisions are located on the distal part. Oblique cut marks on the central portion are interpreted as resulting from the extraction of the feathers. This element is reminiscent of the four modified fragments of radius from Trou de Chaleux. In addition, a distal fragment of the ulna of a large Anseriformes, perhaps the greylag goose, presents a circular perforation on the articular surface of the distal extremity, identical to the two distal fragments from Trou de Chaleux. The element from Bois Laiterie suggests that the pierced ulnae from Trou de Chaleux were indeed fragments of longer objects, probably involving (almost) complete ulna. Bois Laiterie also delivered two fragments of needles, interpreted as being made of bird bone (Lopez Bayon et al., 1997). Other bird remains in Bois Laiterie (n = 174) include taxa also recorded at Trou de Chaleux. The most frequent are the willow grouse (n = 45), the Western jackdaw (n = 15) and small passerines (n = 21), but geese, ducks, waders, grey partridge and owls are also represented (Deville and Gautier, 1997). With the exception of the two elements previously described, all the bird remains of Bois Laiterie are interpreted as intrusive, in the absence of human modification. In Bois Laiterie, horse, reindeer, and ibex were the principal taxa hunted by Magdalenian people for food procurement (Gautier, 1997).

Outside Belgium, the nearest Magdalenian sites where bird remains have been analysed in detail are those of Verberie and Pincevent in the Paris Basin, which are located respectively 150 and 250 km to the south-west of Trou de Chaleux. Pincevent (between 15,500 and 13,000 cal BP; Debout et al., 2014) yielded only four bird remains, including three bones exploited as raw material: a tibiotarsus of a European shag (*Phalacrocorax aristotelis*) and an unidentified fragment used to extract bone splinters and another long bone of a large bird sawn-off transversally. The last fragment possibly comes from a vulture (David et al., 2014). The bird material from Verberie (between 15,900 and 13,900 cal BP; Enloe and Audouze, 2010) is richer, with 59 fragments identified out of 68 for a minimum of 15 individuals (Mignard, 2015). In decreasing importance, bones of duck, goose, Galliformes and Charadriiformes are identified. Birds in Verberie have only been exploited for food as indicated by the scattered cut and scraping marks. Only a radius from a goose has been more intensely scraped (Mignard, 2015).

Further to the east, the Magdalenian sites of Gönnersdorf and Andernach-Martinsberg are two open-air sites located close to each other, located at about 200 km distance to the east from Trou de Chaleux, at approximately the same latitude. They were occupied around 15,600 cal BP (Street and Turner, 2016), which make them partially contemporary to Trou de Chaleux and present many similarities in the exploitation of animals. First, as in Trou de Chaleux, horses were the most frequently hunted mammals. Excepting a gull species (*Larus*? sp.), all the bird taxa identified in the German assemblages were also recovered in Trou de Chaleux: snowy owl, goose (*Anser* sp.), swan (*Cygnus* sp.), Northern raven and ptarmigan.

Other similarities include the interest paid to the wing bones of geese and swans, which are the only bones present for these taxa at Andernach-Martinsberg and Gönnersdorf, and the selection of feet of Northern raven and claws of large diurnal raptors. For Andernach-Martinsberg and Gönnersdorf, it has been proposed that the feet and claws of Northern raven were separated from the rest of the skeleton at the same time as the skin and wings and remained attached to the skin. Noteworthy is that the bones of Northern raven present at Trou de Chaleux are essentially the same as those found in pits 77 and 83 of Gönnersdorf, except for scapula, femur and coracoids, which are absent from Trou de Chaleux (Street and Turner, 2016, Figs. 9 and 10). The hypothesis proposed for Gönnersdorf of extraction of the skin with the phalanges still attached, could be transposed to Trou de Chaleux as a tarsometatarsus shows cut marks indicating the extraction of the toes from the rest of the foot, possibly still attached with the skin.

As for supply strategies, the only taxon for which remains of virtually the entire skeleton are present is ptarmigan. Whole carcasses were probably brought into the Trou de Chaleux cave to be consumed. This contrasts with the sites of Andernach-Martinsberg and Gönnersdorf where a strong selection among skeletal elements occurred, favouring the wing and pectoral bones (Street and Turner, 2016). In the case of other species identified at Trou de Chaleux, it is difficult to specify the acquisition strategies given the low number of remains. As it has been stated for the Anseriformes of Gönnersdorf and Andernach-Martinsberg, the prevalence of wing bones is likely to result from an off-site selection of these elements, which were specifically brought to the Trou de Chaleux cave, instead of in-situ processing of the carcasses (Street and Turner, 2016). In the case of Trou de Chaleux, it is possible that the wings were kept complete, brought to the site and then exploited as raw material, both for feathers and bones. In historical times, geese have frequently been exploited for the supply of feathers, including for fletching arrows (e.g. Hardy, 1992). It is unclear whether the presence of a tarsometatarsus and two pedal phalanges at Trou de Chaleux results from the occasional supply of complete animals, or if they result from the action of other carnivores.

## 6. Conclusion

Despite several limiting factors, such as the accumulation by different taphonomic agents and some recent intrusions, the analysis of the bird material from Trou de Chaleux considerably increases our knowledge of past human exploitation of birds during the late Magdalenian in north-western Europe. At Trou de Chaleux, birds were used for food, as raw material for bone working and for symbolic purposes. Although they contributed far less to the meat supply than mammals in terms of meat weight, the total number of individuals of birds still attains half of the mammals indicating a significant involvement in catching birds, even if passive hunting techniques like nets, snares or traps may have been used for the small to medium size birds. However, larger species like geese, swans and particularly the eagle or snowy owl are likely to have necessitated more effort. The exploitation of avian products was exhaustive, and species have been used for several purposes such as the Northern raven or snowy owl having been exploited both for food and for symbolic reasons. Bones sometimes show superimposition of traces resulting from different activities, such as the geese ulnae from which the feathers were extracted and subsequently used as raw material for bone working. Although large bird bones were used as raw material to produce artefacts, the use-wear analysis did not evidence unambiguous traces related to the use of the objects produced.

The exploitation of birds at Trou de Chaleux shows several similarities to the German sites of Gönnersdorf and Andernach-Martinsberg, such as the possible use of the Northern raven for symbolic purposes and a strong selection of the wing bones of geese. In addition, both the German sites and Trou de Chaleux yielded bird depictions in portable art, which supports further the importance of birds in the symbolic life of the late Magdalenian population of north-western Europe. At a regional level, the exploitation of wing bones of geese was also reported at Bois Laiterie. The exploitation of snowy owl and eagle talons, the reliance on medium-sized Galliformes for food and the use of bones of large birds have been observed in many other Magdalenian sites. However, although geese bones have also been used occasionally elsewhere as raw material for bone working, the strong interest in goose wings seems a recurrent phenomenon rather restricted to north-western Europe.

## Acknowledgements

We wish to thank Arturo Morales (Universidad Autónoma de Madrid) for the loan of comparative specimens, Eric Dewamme (RBINS) for taking some of the pictures and Thierry Leduc (RBINS) for helping with the elementary analysis. The contribution of Quentin Goffette to this paper partly took place within the framework of a convention between the Royal Belgian Institute of Natural Sciences and the Service Public de Wallonie (SPW, DGO-4). We are also grateful to Annelise Folie and Patrick Semal, the curators of the palaeontology and the anthropological collections respectively, for helping us in accessing and handling the specimens. Finally, we want to thank all the reviewers for their constructive suggestions, which greatly improved the quality of this manuscript and Sheila Hamilton-Dyer, Southampton, for assistance with English language.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2019.102096.

## References

Andrews, P., 1990. Owls, Caves and Fossils: Predation, Preservation and Accumulation of Small Mammal Bones in Caves, with an Analysis of the Pleistocene Cave Faunas from Westbury-Mendip, Somerset. Natural History Museum, London, UK.

Averbouh, A., 1993. Fiches tubes et étuis, in: Camps-Fabrer, H. (Ed.), Fiches typologiques de l'industrie osseuse préhistorique, Cahier VI: Eléments récepteurs, Treignes, pp. 99–113.

Baumel, J.J., 1993. Handbook of avian anatomy: nomina anatomica avium. Publications of the Nuttall Ornithological Club 23.

Behrensmeyer, A.K., 1978. Taphonomic and ecologic information from bone weathering. Paleobiology 4, 150–162.

Berke, 1987. Archäozoologische Detailuntersuchungen an Knochen aus südwestdeutschen Magdalenien-Inventaren, Archaeologica Venatoria, Tübingen (Urgeschichtliche Materialhefte 8).

Bochenski, Z.M., 2005. Owls, diurnal raptors and humans: signatures on avian bones. In: O'Connor, T. (Ed.), Biosphere to Lithosphere. New studies in vertebrate taphonomy. Oxbow Books, Oxford, pp. 31–45.

Bochenski, Z.M., Tomek, T., 1997. Preservation of bird bones: erosion versus digestion by owls. Int. J. Osteoarchaeol. 7, 372–387.

Bochenski, Z.M., Tomek, T., Wilczyński, J., Svoboda, J., Wertz, K., Wojtal, P., 2009. Fowling during the Gravettian: the avifauna of Pavlov I, the Czech Republic. J. Archaeol. Sci. 36, 2655–2665.

Bochenski, Z.M., Tornberg, R., 2003. Fragmentation and preservation of bird bones in uneaten food remains of the Gyrfalcon Falco rusticolus. J. Archaeol. Sci. 30, 1665–1671.

Bohlken, H., 1958. Zur Nomenklatur der Haustiere. Zoologischer Anzeiger 160, 167–168.

Bohlken, H., 1961. Haustiere und zoologische Systematik. Zeitschrift für Tierzüchtung und Züchtungsbiologie 76, 107–113.

Brain, C.K., 1976. Some principles in the interpretation of bone accumulations associated with man. In: Isaac, G.L., McCown, E.R. (Eds.), Human origins: Louis Leakey and the East African evidence. W. A Benjamin Inc, Menlo Park, pp. 97–116.

Brain, C.K., 1969. The contribution of Namib Desert Hottentots to an understanding of australopithecine bone accumulations. Scientific Papers ofthe Namib Desert Research Station 33, 13–22.

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. Radiocarbon 51 (1), 337–360.

Bronk Ramsey, C., 2017. Methods for summarizing radiocarbon datasets. Radiocarbon 59 (2), 1809–1833.

Bullinger, J., Müller, W., 2006b. Les éléments de parure. In: Bullinger, J., Leesch, D., Plumetaz, N. (Eds.), Le site magdalénien de Monruz, 1. Premiers éléments pour l'analyse d'un habitat de plein air, Service et musée cantonal d'archéologie, Neuchâtel (Archéologie neuchâteloise 33), pp. 149–165.

Bullinger, J., Müller, W., 2006a. L'industrie osseuse. In: Bullinger, J., Leesch, D., Plumetaz, N. (Eds.), Le site magdalénien de Monruz, 1. Premiers éléments pour l'analyse d'un habitat de plein air, Service et musée cantonal d'archéologie, Neuchâtel (Archéologie neuchâteloise 33, pp. 139–147.

Charles, R., 1995. A new Late Upper Palaeolithic engraving from the Trou de Chaleux, Province of Namur. Notae Praehistoricae 15, 123–125.

Charles, R., 1998. Late Magdalenian chronology and faunal exploitation in the North-Western Ardennes, Oxford.

Chollot, M., 1964. Musée des Antiquités Nationales – Collection Piette – Art mobilier préhistorique. Edition des Musées Nationaux, Paris.

Conard, N.J., Kitagawa, K., Krönneck, P., Böhme, M., Münzel, S.C., 2013. The Importance of fish, fowl and small mammals in the Paleolithic diet of the Swabian Jura, Southwestern Germany. In: Clark, J.L., Speth, J.D. (Eds.), Zooarchaeology and Modern Human origins: human hunting behavior during the Later Pleistocene. Springer, Netherlands, Dordrecht, pp. 173–190.

Cooke, W.W., 1916. Labrador bird notes. Auk 33, 162–167.

Cramp, S., 1980. The Birds of the Western Palearctic. Volume II: Hawks to Bustards. Oxford University Press, Oxford, New York.

Cramp, S., Perrins, C.M., 1994. The Birds of the Western Palearctic. Volume VIII: Crows to finches. Oxford University Press, Oxford.

Cramp, S., Simmons, K.E.L., 1977. The Birds of the Western Palearctic. Volume I: Ostriches to Ducks. Oxford University Press, Oxford, New York.

Damblon, F., 1994. Les dépôts tourbeux et l'histoire de la végétation sur le plateau des Hautes-Fagnes (Belgique). Annales de la Société Géologique de Belgique 117, 259–276.

David, F., Enloe, J., Mourer-Chauviré, C., Bignon-Lau, O., 2014. La faune: espèces chassées, consommées ou utilisées. In: Julien, M., Karlin, C. (Eds.), Un automne à Pincevent. Le campement magdalénien du niveau IV20 (Mémoire de la Société Préhistorique Française 57) Paris, pp. 78–81.

De Cupere, B., Thys, S., Van Neer, W., Ervynck, A., Corremans, M., Waelkens, M., 2009. Eagle owl (*Bubo bubo*) pellets from Roman Sagalassos (SW Turkey): distinguishing the prey remains from nest and roost sites. International Journal of Osteoarchaeology 19 (1), 1–22. https://doi.org/10.1002/oa.965.

De Wilde, B., 2011. Les oiseaux, les anoures et les gastéropodes terrestres de la grotte Walou. In: Draily, C., Pirson, S., Toussaint, M. (Eds.), La grotte Walou à Trooz (Belgique). Fouilles de 1996 à 2004. Volume 2: Les sciences de la vie et les datations. Service public de Wallonie, Namur, pp. 61–65.

Debout, G., Valentin, B., Leesch, D., Bodu, P., Dumarçay, G., Schoch, W., Thiébault, S., 2014. Pincevent et la chronologie du Magdalénien septentrional. Nouveaux éléments au débat. In: Julien, M., Karlin, C. (Eds.), Un automne à Pincevent. Le campement magdalénien du niveau IV20, Société préhistorique française, Paris, pp. 49–60.

Delporte, H., 1993. L'art mobilier de la grotte de La Vache: premier essai de vue générale. Bulletin de la société préhistorique française 90, 131–136.

Deville, J., Gautier, A., 1997. The avifauna of La grotte du Bois Laiterie. In: Otte, M., Straus, L.G. (Eds.), La grotte du Bois Laiterie. ERAUL 80. Liège, pp. 25–64.

Dewez, M., 1987. Le Paléolithique supérieur récent dans les grottes. de Belgique Louvain-la-Neuve.

Dupont, E., 1873. L'Homme pendant les âges de la pierre dans les environs. de Dinant-sur-Meuse, Bruxelles.

Enloe, J.G., Audouze, F., 2010. The Magdalenian site of Verberie (Le Buisson Campin): an overview. In: Zubrowe, E., Audouze, F., Enloe, J.G. (Eds.), The Magdalenian Household. State University of New-York, New-York, Unraveling Domesticity, pp. 15–21.

Ericson, P.G.P., 1987. Interpretations of Archaeological Bird Remains: a taphonomic Approch. J. Archaeol. Sci. 14, 65–75.

Fernandez Jalvo, Y., Andrews, P., 2016. Atlas of Taphonomic Identifications. Springer.

Finlayson, S., Finlayson, C., 2016. The birdmen of the Pleistocene: On the relationship between Neanderthals and scavenging birds. Quat. Int. 421, 78–84.

Gautier, A., 1997. The macromammal remains of la Grotte du Bois Laiterie. In: Otte, M., Straus, L.G. (Eds.), La grotte du Bois Laiterie. ERAUL 80. Liège, pp. 177–196.

Germonpré, M., 1996. Preliminary results on the mammals of the Magdalenian upper horizon of Goyet (Belgium). Notae Preahistoricae 16, 75–85.

Germonpré, M., 1997. The Magdalenian upper horizon of Goyet and the late Upper Palaeolithic recolonisation of the Belgian Ardennes. Bulletin de l'Institut royal des Sciences Naturelles de Belgique, Série Sciences de la Terre 67, 167–182.

Germonpré, M., Hämäläinen, R., 2007. Fossil bear bones in the Belgian upper paleolithic: the possibility of a proto bear-ceremonialism. Arctic Anthropol. 44, 1–30.

Germonpré, M., Udrescu, M., Fiers, E., 2013. The fossil mammals of Spy. Anthropol. Praehistorica 123, 298–327.

Gill, F., Donsker, D., 2017. IOC World Bird List (v 7.1).

Grimm, S.B., 2013. Resilience and reorganisation of social systems during the Weichselian Lateglacial in North-West Europe. An evaluation of the archaeological, climatic, and environmental record. Dissertation. Johannes Gutenberg University, Mainz.

Hardy, R., 1992. Longbow: A Social and Military History. Patrick Stephens Ltd., Sparkford.

Jenkinson, R.D.S., Gilbertson, D.D., Sutherland, S., 1984. Changes in European geese and duck migration patterns during the Quaternary. In: Jenkinson, R.D.S., Gilbertson, D.D. (Eds.), In the shadow of extinction: a Quaternary archaeology and palaeoecology of the lake, fissures and smaller caves at Cresswell Crags SSSI. Nottinghamshire and Derbyshire County Councils.

Lambrecht, K., 1933. Handbuch der Paläornithologie, Berlin.

Laroulandie, V., 2002. Damage to Pigeon long bones in pellets of the Eagle Owl *Bubo bubo* and food remains of Peregrine Falcon *Falco peregrinus*: zooarchaeological implications. In: Bochenski, Z.M., Bochenski, Z., Stewart, J.R. (Eds.), Proceedings of the 4th Meeting of the ICAZ Bird Working Group, Krakow, Poland, 11-15 september 2001. Acta Zoologica cracoviensia 42 (special issue), Institute of Systematics and Evolution of Animals. Polish Academy of Sciences, Krakov, Poland, pp. 331–339.

Laroulandie, V., 2003. Exploitation des oiseaux au Magdalénien en France: état des lieux. In: Costamagno, S., Laroulandie, V. (Eds.), Mode de vie au Magdalénien: Apports de l'archéozoologie/Zooarchaeological insights into Magdalenian lifeways. Actes du colloque 6.4 du XIVe Congrès du l'UISPP, Liège, Belgique, 2-8 septembre 2001. BAR n° 1144. Archaeopress. British Archaeological Reports, Oxford, United Kingdom, pp. 129–138.

Laroulandie, V., 2016. Hunting fast-moving, low-turnover small game: the status of the snowy owl (*Bubo scandiacus*) in the Magdalenian. Quat. Int. 414, 174–197.

Laroulandie, V., Costamagno, S., Cochard, D., Mallye, J.-B., Beauval, C., Castel, J.-C., Ferrié, J.-G., Gourichon, L., Rendu, W., 2008. Quand désarticuler laisse des traces : le cas de l'hyperextension du coude. Annales de Paléontologie 94, 287–302.

Laroulandie, V., 2000. Taphonomie et archéozoologie des oiseaux en grotte : applications aux sites paléolithiques du Bois-Ragot (Vienne), de Combe Saunière (Dordogne) et de la Vache (Ariège), Sciences de l'Homme et Société. Université Sciences et Technologies - Bordeaux I, Bordeaux.

Laroulandie, V., 2001. Les traces liées à la boucherie, à la cuisson et à la consommation d'oiseaux. Apport de l'expérimentation, in: Bourguignon, L., Ortega, I., Frère-Sautot, M.-C. (Eds.), Préhistoire et approche expérimentale. Editions Monique Mergoil, Montagnac.

Laroulandie, V., 2004. Exploitation des ressources aviaires durant le Paléolithique en France: bilan critique et perspectives, in: Brugal, J.-P., Desse, J. (Eds.), Petits animaux et sociétés humaines. Du complément alimentaire aux ressources utilitaires. XXIVe rencontres internationales d'archéologie et d'histoire d'Antibes. Éditions APDCA, Antibes, pp. 163-172.

Laroulandie, V., 2005. Bird exploitation pattern: the case of Ptarmigan Lagopus sp. in the Upper Magdalenian site of La Vache (Ariège, France), in: Grupe, G., Peters, J. (Eds.), Feathers, grit and symbolism. Birds and humans in the ancient Old and New Worlds. Proceedings of the 5th Meeting of the ICAZ Bird Working Group, Munich, 26-28 July 2004 (Documenta Archaeobiologiae 3), Rahden, pp. 165–178.

Laroulandie, V., 2009. De la plume à l'œuf : exploitation des ressources aviaires au Magdalénien dans le Sud de la France, in: Fontana, L., Chauvière, F.X., Bridault, A. (Eds.), In search of Total Animal Exploitation. Cases Studies in Upper Palaeolithic and Mesolithic. Proceedings of the XVth UISPP World Congress, Lisbon, 4-9 September 2006, Session C 61, J. & E. Hedges, Oxford, pp. 71–89.

Laroulandie, V., 2014. Traitement et utilisation des ressources aviaires au Taridglaciaire dans la grotte de Santa Catalina, in: Berganza Gochi, E., Arribas Pastor, J.L. (Eds.), La cueva de Santa Catalina (Lekeitio, Bizkaia). I - La intervención arqueológica. Restos vegetales, animales y humanos. Diputación Foral de Bizkaia, Bilbao, pp. 297–330.

Laugrand, F., Oosten, J., 2015. Hunters, predators and prey: Inuit perceptions of animals. Berghahn, New York, Oxford.

Leesch, D., 1997. Hauterive-Champréveyres, 10. Un campement magdalénien au bord du lac de Neuchâtel. Cadre chronologique et culturel, mobilier et structures, analyse spatiale (secteur 1), Musée cantonal d'Archéologie, Neuchâtel (Archéologie neuchâteloise 31).

Lejeune, M., 1987. L'art mobilier paléolithique et mésolithique en Belgique. CEDARC, Treignes.

Lopez Bayon, I., Straus, L.G., Leotard, J.-M., Lacroix, P., Teheux, E., 1997. L'industrie osseuse du Magdalénien du Bois Laiterie. In: Otte, M., Straus, L.G. (Eds.), La grotte du Bois Laiterie. ERAUL 80. Liège, pp. 257–277.

Lyman, R.L., 1994. Vertebrate Taphonomy. Cambridge University Press, Cambridge.

Mignard, M., 2015. L'exploitation des oiseaux à Verberie. Quelle place pour l'avifaune dans les stratégies de subsistance magdaléniennes? Unpublished Master Thesis. , University of Paris I, Panthéon Sorbonne, pp. 93.

Mishler, C., Ridington, R., 2013. The Blind Man and the Loon: The Story of a Tale. University of Nebraska Press, Lincoln.

Morel, P., Müller, W., 1997. Hauterive-Champréveyres, 11. Un campement magdalénien au bord du lac de Neuchâtel. Étude archéozoologique, Musée cantonal d'Archéologie, Neuchâtel (Archéologie neuchâteloise 23).

Morin, E., Laroulandie, V., 2012. Presumed symbolic use of diurnal raptors by Neanderthals. PLoS One 7, e32856.

Mourer-Chauviré, C., 1983. Les oiseaux dans les habitats palé olithiques: gibier des hommes ou proies des rapaces? in: Grigson, C., Clutton-Brock, J. (Eds.), Animal and Archaeology: 2. Shell Middens, Fishes and Birds. British Archaeological Reports, International Series 183, Oxford, pp. 111-124.

Müller, W., 2004. One horse or a hundred hares? Small game exploitation in an Upper Palaeolithic context, in: Brugal, J.-P., Desse, J. (Eds.), Petits animaux et sociétés humaines. Du complément alimentaire aux ressources utilitaires. XXIVe rencontres internationales d'archéologie et d'histoire d'Antibes, Antibes, pp. 231–240.

Müller, W., Leesch, D., Chiquet, P., 2013. Le site magdalénien de Monruz. 3, Acquisition, traitement et consommation des ressources animales. Office du patrimoine et de l'archéologie de Neuchâtel, Hauterive.

Oosten, J., Laugrand, F., 2006. The bringer of light: the raven in Inuit tradition. Polar Rec. 42, 187–204.

Otte, M., 1994. Le Magdalénien du Trou de Chaleux (Hulsonniaux, Belgique). ERAUL 60. Liège.

Peresani, M., Fiore, I., Gala, M., Romandini, M., Tagliacozzo, A., 2011. Late Neandertals and the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane Cave 44 ky B.P., Italy. Proc. Natl. Acad. Sci. 108, 3888–3893.

Potapov, E., Sale, R., 2013. The Snowy Owl. T & AD Poyser, London.

Rainio, R., Mannermaa, K., 2014. Bird calls from a Middle Neolithic burial at Ajvide, Gotland? Interpreting tubular bird bone artefacts by means of use-wear, sound analysis, and ethnographic analogy. In: Ikäheimo, J., Salmi, A.-K., Äikäs, T. (Eds.), Sounds like theory. XII Nordic theoretical archaeology group meeting in Oulu 25-28.4.2012, pp. 85–100.

Rasmussen, S.O., Bigler, M., Blockley, S.P., Blunier, T., Buchardt, S.L., Clausen, H.B., Cvijanovic, I., Dahl-Jensen, D., Johnsen, S.J., Fischer, H., Gkinis, V., Guillevic, M., Hoek, W.Z., Lowe, J.J., Pedro, J.B., Popp, T., Seierstad, I.K., Steffensen, J.P., Svensson, A.M., Vallelonga, P., Vinther, B.M., Walker, M.J.C., Wheatley, J.J., Winstrup, M., 2014. A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: refining and extending the INTIMATE event stratigraphy. Quat. Sci. Rev. 106, 14–28.

Ratcliffe, D., 1997. The raven. A natural history in Britain and Ireland. T & A D Poyser, London.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., HattŽ, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M., van der Plicht, J., 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55 (4).

Romandini, M., Peresani, M., Laroulandie, V., Metz, L., Pastoors, A., Vaquero, M., Slimak, L., 2014. Convergent evidence of eagle talons used by Late Neanderthals in Europe: a further assessment on symbolism. PLoS One 9, e101278.

Romandini, M., Fiore, I., Gala, M., Cestari, M., Guida, G., Tagliacozzo, A., Peresani, M., 2016. Neanderthal scraping and manual handling of raptors wing bones: evidence from Fumane Cave. Experimental activities and comparison. Quaternary Int. 421, 154–172.

Saccasyn della Santa, E., 1946. Aiguilles à chas et pendeloques du Paléolithique supérieur de la Belgique. Bulletin de la Société Royale Belge d'Anthropologie et de Préhistoire 57, 12–51.

Schibler, J., Sedlmeier, J., 1993. Die Schneehuhn- und Schneehasenknochen aus dem Abri Büttenloch (Ettingen BL, Schweiz). Ein Beitrag zur Kenntnis der Jagdbeutenutzung im Spätmagdalénien. Archäologisches Korrespondenzblatt 23, 15–35.

Serjeantson, D., 2009. Birds. Cambridge University Press, Cambridge.

Stewart, J.R., Lister, A.M., Barnes, I., Dalén, L., 2010. Refugia revisited: individualistic responses of species in space and time. Proc. R. Soc. B 277, 661–671.

Stiner, Mary C., Munro, Natalie D., Surovell, Todd A., 2000. The tortoise and the hare: small-game use, the Broad-Spectrum Revolution, and Paleolithic demography. Curr. Anthropol. 41, 39–79.

Straus, L.G., 1997. La grotte du Bois Laiterie: the site, stratigraphy, chronology and excavations. In: Otte, M., Straus, L.G. (Eds.), La grotte du Bois Laiterie. ERAUL 80. Liège, pp. 25–64.

Street, M., Turner, E., 2016. Eating crow or a feather in one's cap: the avifauna from the Magdalenian sites of Gönnersdorf and Andernach-Martinsberg (Germany). Quat. Int. 421, 201–218.

Trevor-Battye, A., 1895. Ice-bound on Kolguev: a chapter in the exploration of Arctic Europe to which is added a record of the natural history of the island. A. Constable, Westminster.

Tyrberg, T., 1991. Arctic, Montane and Steppe birds as Glacial relicts in the West Palearctic. Ornithologische Verhandlungen 25, 29–49.

Tyrberg, T., 1998. Pleistocene birds of the Palearctic: a catalogue. Cambridge, Mass. : Nuttall Ornithological Club, Cambridge, Mass.

Tyrberg, T., 2008. Pleistocene birds of the Palearctic http://web.telia.com/~u11502098/pleistocene.pdf.

Van Neer, W., Lodewijckx, M., 1992. Faunaresten uit de late IJzertijd, Romeinse periode en late middeleeuwen te Wange (gem. Landen, prov. Brabant). Archeol. Vlaanderen 2, 55–64.

Van Neer, W., Noyen, K., De Cupere, B., Beuls, I., 2002. On the use of endosteal layers and medullary bone from domestic fowl in archaeozoological studies. J. Archaeol. Sci. 29, 123–134.

Van Wetter, G., 1920. Les origines de la parure aux temps paléolithiques. Mémoires de l'Académie royale de Belgique, Classe des Beaux-Arts 1, 1–170.

Vaughan, R., 2010. In search of Arctic birds. Bloomsbury, London.

Verbruggen, C., 1999. Quaternary palaeobotanical evolution of Northern Belgium. Geol. Belgicavolume 2, 99–110.

Villa, P., Mahieu, E., 1991. Breakage patterns of human long bones. J. Hum. Evol. 21, 27–48.

Wertz, K., Wilczyński, J., Tomek, T., 2015. Birds in the Pavlovian culture: Dolni Vestonice II, Pavlov I and Pavlov II. Quat. Int. 359, 72–76.

Wertz, K., Wilczyński, J., Tomek, T., Roblickova, M., Oliva, M., 2016. Bird remains from Dolni Vestonice I and Predmosti I (Pavlovian, the Czech Republic). Quat. Int. 421, 190–200.

Wolf, B., 1938-41. Fossilium Catalogus. I: Animalia. Fauna fossilis cavernarum I-III (pars. 82, 87, 92), s'Gravenhage.