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Avian Taphonomy at Bluefish Caves, Yukon, Canada

Lauriane Bourgeon[1,2] and Rolfe D. Mandel[1]

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ABSTRACT. A recent analysis of the mammal bones from Bluefish Caves (northern Yukon Territory, Canada) suggests that modern humans visited the site on several occasions for short-term hunting activities as early as 23,500 calibrated years BP. Here we apply taphonomic methods to the avian remains recovered from the caves. Seventeen genera of birds are identified in the assemblage, including 450 ptarmigan individuals (*Lagopus lagopus* and *Lagopus muta*). We discuss paleoenvironmental implications and show that carnivores and birds of prey (e.g., foxes, Snowy Owls) were likely responsible for most of the accumulation and modification of avian remains. Human intervention, however, is reported on one Snow Goose bone and possibly on ptarmigan bones.

Keywords: Beringia; Bluefish Caves; late Pleistocene; early Holocene; bone modifications; bird remains; ptarmigan; Snow Goose

RÉSUMÉ. Une analyse récente des ossements de mammifères des Grottes du Poisson-Bleu (nord du Territoire du Yukon, Canada) suggère que les hommes modernes ont visité le site à plusieurs reprises pour des activités de chasse de courte durée dès 23 500 années calibrées avant le présent. Des méthodes d’analyses taphonomiques sont ici appliquées aux restes aviaires retrouvés dans les grottes. Dix-sept genres d’oiseaux sont identifiés, dont 450 lagopèdes (*Lagopus lagopus* et *Lagopus muta*). Nous discutons des implications paléoenvironnementales et suggérons que les carnivores et les oiseaux de proie (comme le renard et le harfang des neiges) sont probablement responsables de la majeure partie de l’accumulation et de la modification des restes aviaires. Une intervention humaine est toutefois signalée sur un os d’oie des neiges et peut-être également sur des restes de lagopède.

Mots-clés : Béringie; Grottes du Poisson-Bleu; Pléistocène tardif; Holocène précoce; modification des os; restes aviaires; lagopède; oie des neiges

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INTRODUCTION

The literature describes paleoenvironments in Beringia (e.g., eastern Siberia, Alaska, and the Yukon Territory) as being highly productive during the late Pleistocene (ca. 30,000–11,000 calibrated years before present [cal BP]), accommodating a rich faunal diversity in a mosaic of steppe–tundra vegetation (Hopkins et al., 1982; Guthrie, 1990; Yurtsev, 2001; Hoffecker and Elias, 2007; Blinnikov et al., 2011; Harington, 2011; Zazula et al., 2006). That environment certainly played a significant role in modern human dispersals and subsistence strategies (Hoffecker et al., 2020, 2023).

From ca. 32,000 cal BP until possibly 26,000 cal BP, the archaeological record from the Yana River sites in the Siberian Arctic indicates that hunter-gatherers relied upon a variety of large and small game, including horse, caribou, hare, and birds (Pitulko et al., 2004; Pitulko et al., 2017). A recent taphonomic study of Bluefish Caves, in the northern Yukon Territory, suggests that humans entered the Western Hemisphere sometime during the Last Glacial Maximum (LGM, ca. 21,000 cal BP) and that they hunted horse, caribou, and wapiti until at least 12,000 cal BP (Bourgeon et al., 2017; Bourgeon, 2018; Bourgeon and Burke, 2021; but see also Krasinski and Blong, 2020). Archaeological sites post-dating 15,000 cal BP that occur east and west of the Bering Strait provide a better understanding of subsistence economies of Beringian foragers and confirm the use of a wide range of mammals, fish, and birds (Mochanov, 1977; West, 1996; Yesner, 2001; Endacott, 2008; Easton et al., 2011; Holmes, 2011; Yesner et al., 2011; Pasda, 2012; Potter et al., 2013; Lanoë and Holmes, 2016; Halffman et al., 2020).

Unlike the bones of large mammals, bird bones often make up a small proportion of faunal assemblages and tend to be given less attention in archaeological studies. Unfortunately, the recovery of avian remains largely depends on environmental conditions in which specimens are buried, as well as excavations procedures (i.e., a 4 mm mesh sieve is usually recommended; Serjeantson, 2009). However, even when sediments are properly sieved and bones are well preserved, identification problems may arise

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[1] Kansas Geological Survey, University of Kansas, 1930 Constant Avenue, Lawrence, Kansas 66047, USA
[2] Corresponding author: lbourgeon@ku.edu

due to limited morphological differences among avian taxa. Nevertheless, the study of archaeological bird remains can provide valuable information regarding paleoenvironments and bird–human interactions (Serjeantson, 2009).

Ethnographic studies (e.g., Nelson, 1902; McClellan, 1975; Emmons, 1991; Sinclair et al., 2003; Vuntut Gwitchin First Nation and Smith, 2010; Kuhnlein and Humphries, 2017) and archaeological records have widely documented the significance of birds to human communities living in northern latitudes. In Beringia, researchers have reported large collections of bird remains from the late Pleistocene and early Holocene (ca. 15,000–8000 cal BP) at Dyuktai Cave in eastern Siberia (Zelenkov et al., 2008) and at Broken Mammoth (Yesner, 2001, 2007), Swan Point (Lanoë and Holmes, 2016), Trail Creek Caves (Pasda, 2012), and Lime Hills in Alaska (Endacott, 2008). At Bluefish Caves, McCuaig-Balkwill and Cinq-Mars (1998) reported preliminary observations of migratory bird bones (N = 846), providing limited paleoenvironmental information and insight into human paleodiets. Here we perform a taphonomic study of the entire bird assemblage (N = 7113), including non-migratory birds. We propose a refined taxonomic list of the avian assemblage and discuss paleoenvironmental implications. Finally, we identify taphonomic processes responsible for observed bone modifications and explore the role of human and non-human predators in the use of bird resources at the site.

Bluefish Caves

The Bluefish Caves (67°09’N, 140°45’W) are in the northern Yukon Territory of Canada, about 54 km southwest of the Vuntut Gwitchin village of Old Crow and about 250 m above the middle course of the Bluefish River (Fig. 1). The site consists of several small cavities, up to 30 m^3 in volume, formed at the base of a Devonian limestone ridge (Cinq-Mars, 1979, 1990; Morlan and Cinq-Mars, 1982; Cinq-Mars and Morlan, 1999; Harington and Cinq-Mars, 2008). From 1977 to 1987, Jacques Cinq-Mars (Archaeological Survey of Canada) and colleagues conducted archaeological excavations within, and in front of, three main cavities, named Cave I, Cave II, and Cave III (code Borden MgVo-1, MgVo-2, and MgVo-3, respectively). All sediments were dry-sieved using a 3 mm mesh (Cinq-Mars, 1979). The excavated surface areas of caves I, II, and III are approximately 40 m², 58 m², and 10 m², respectively. The lithic and faunal collections are curated at the Canadian Museum of History in Gatineau, Quebec, Canada.

The cavities contain sedimentary deposits that are 30 cm to 2 m thick. However, most of the deposits are about 1 m thick. Cinq-Mars and colleagues identified four major stratigraphic units in the rock shelters, which they designated as A through D from the bottom of the stratigraphic sequence to the top (Cinq-Mars, 1990; Cinq-Mars and Morlan, 1999; Harington and Cinq-Mars, 2008). Unit A is weathered limestone bedrock comprising the floors of the caves. Above Unit A is Unit B, a package of loess as much as 1 m thick. Unit C, which consists of a dense concentration of humus mixed with cryoclastic debris, overlays Unit B. A thin layer of modern humus and plant litter (Unit D) caps the stratigraphic sequence.

Researchers have determined radiocarbon ages for bone samples from Unit B (Cinq-Mars, 1979, 1990; Morlan and Cinq-Mars, 1982; Youngman, 1993; Burke and Cinq-Mars, 1996, 1998; Martindale et al., 2016; Bourgeon et al., 2017). The dates indicate that the loess aggraded between about 30,000 and 11,000 cal BP. According to the pollen records from Cave I (Cinq-Mars, 1979) and Cave II (Ritchie et al., 1982), the loess started to accumulate under full-glacial conditions of the Duvanny Yar interval. During that time, the site was surrounded by dry, herbaceous tundra vegetation, and a glacial lake formed in the Old Crow, Bell, and Bluefish River basins (Hughes, 1972; Morlan, 1980; Lauriol et al., 2010). The upper portion of Unit B aggraded during late glacial conditions and corresponds to the Birch interval, which began about 14,000–13,500 ^{14}C BP (ca. 16,000 cal BP) (Cinq-Mars, 1979; Hopkins et al., 1982; Ritchie et al., 1982).

In all three caves, Unit B yielded thousands of vertebrate remains. According to Bourgeon (2018), the number of identified mammal specimens (NISP) in caves I and II is 2710 and 1683, respectively. The mammal spectrum is very diverse and typical of the mammoth steppe fauna (Guthrie, 1990); it includes medium and large ungulates, such as woolly mammoth, horse, steppe bison, and caribou (Bourgeon, 2018), as well as smaller species, such as lagomorphs and rodents (Morlan, 1983, 1989). Predators include large carnivores (i.e., brown bear, steppe lion, wolf, Arctic and red fox) and small carnivores (i.e., ermine, least weasel, Beringian ferret, American marten and short-faced skunk) (Youngman, 1993; Harington and Cinq-Mars, 2008). Birds, fish, and amphibian species were also identified (McCuaig-Balkwill and Cinq-Mars, 1998; Harington and Cinq-Mars, 2008). Unit C in all caves had significantly fewer faunal remains (Cinq-Mars, 1990).

Cinq-Mars and colleagues recovered cultural materials from Unit B in caves I and II consisting of chert artifacts and human-modified bones (Cinq-Mars, 1979, 1990; Morlan and Cinq-Mars, 1982; Cinq-Mars and Morlan, 1999). They reported about a hundred stone artifacts, including microblade cores, microblades, core tablets, burins, burin spalls, and small flakes. Flint microflakes measuring about 1–3 mm were also recovered from sieved and bulk sediment samples from Unit B in all three caves. These microflakes may indicate that tool flaking, retouching, and stone tool use occurred in situ (Cinq-Mars, 1979, 1990; Cinq-Mars and Morlan, 1999). Subsequent research by Bourgeon and colleagues confirmed butchery marks, initially observed by Morlan and Cinq-Mars (1982), on a variety of mammal bones from caves I and II (N = 14 bones with definitive cut marks, N = 24 bones with probable cut marks), including horse, caribou, and wapiti (Bourgeon et al., 2017; Bourgeon, 2018; Bourgeon and Burke, 2021). Two additional specimens from Cave II show evidence of

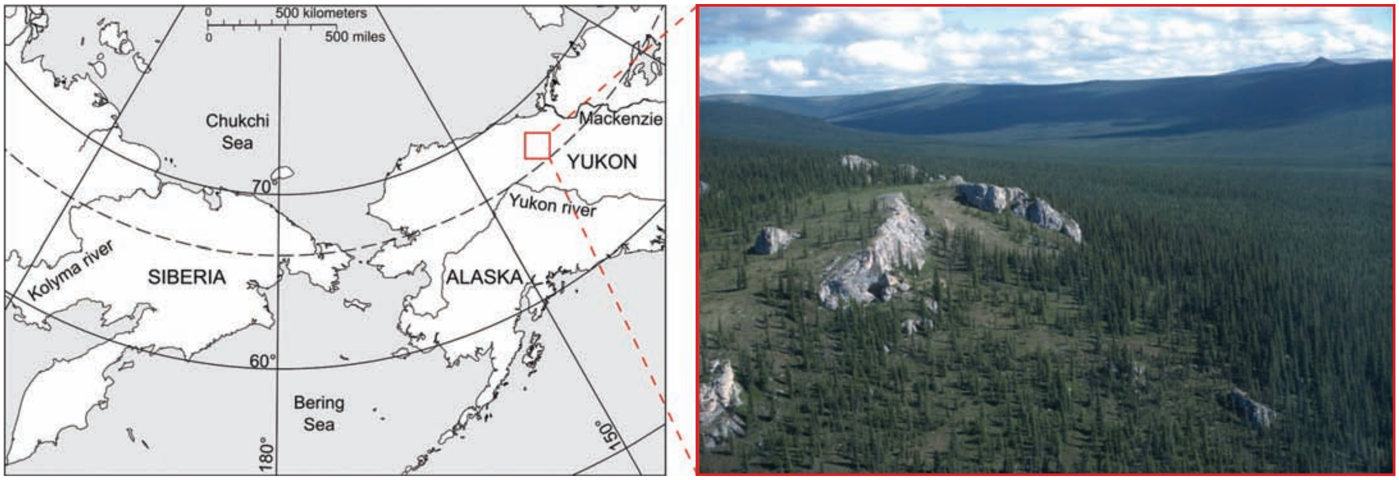

FIG. 1. Map and aerial view of Bluefish Caves. Photo: Government of Yukon.

a proboscidean bone-flaking technology (Bourgeon, 2021; Cinq-Mars and Morlan, 1999). Bourgeon et al. (2017) obtained new AMS radiocarbon dates from ultra-filtered bone collagen on six samples with definitive evidence of butchery. The results indicate that humans occupied the caves on several occasions between 23,500 and 12,000 cal BP (Bourgeon et al., 2017).

MATERIAL AND METHODS

Excavation methods and screening at Bluefish Caves contributed to the recovery of a large quantity of small vertebrate remains, including thousands of avian bones. Archival records curated at the Canadian Museum of History provide information on the stratigraphic provenance (Units B or C) of most of the remains. In some instances, however, the exact provenance is unknown (Table 1). We established taxonomic and anatomical identifications using modern comparative skeletons housed at the Cornell University Museum of Vertebrates, Lab of Ornithology (Ithaca, NY). We adapted the taxonomic nomenclature from the IOC World Bird List (Gill et al., 2021). Age estimation was based on relative bone porosity. Bones with a porous texture were considered to belong to an immature bird (Serjeantson, 2009).

We systematically attributed each specimen to a size category: Category 1 includes all small Passeriformes and Charadriiformes (e.g., swallow, sandpiper; 0–20 cm long on average); Category 2 includes larger Passeriformes and Charadriiformes (e.g., robin, plover, curlew; 20–30 cm long on average); Category 3 is mostly composed of Galliformes (e.g., ptarmigan) and birds of similar size (e.g., Harlequin Duck, Northern Hawk Owl; 30–45 cm long on average); and Category 4 consists in larger birds, over 45 cm in length (e.g., American Widgeon, Rough-legged Hawk, Snowy Owl, Snow Goose).

When possible, we identified bones to family or species. Due to the large size of the collection and very close morphological similarities between species, we did not attempt to identify bones from Category 1, except in a few cases (fully complete and well-preserved specimens). To distinguish grouse and ptarmigan species, we used metric data on the best represented anatomical elements (i.e., carpometacarpus and tarsometatarsus) in accordance with Watson and Ledogar (2019) and Stewart (1999, 2007) (see also Supplementary Text). Identification of the Northern Curlew (*Numenius borealis*), a species McCuaig-Balkwill and Cinq-Mars (1998) suggested was present among specimens from Bluefish Caves, was problematic due to the paucity of skeletons in modern osteological collections and because the species is listed as endangered under the US Endangered Species Act. Due to travel restrictions related to the Covid-19 pandemic, we used photographs from the Museum of Comparative Zoology at Harvard University to identify the species.

To estimate the relative abundance of taxa and skeletal remains, we used the number of identified specimens (NISP), the minimum number of elements (MNE), and the minimum number of individuals (MNI) based on laterality, as well as the skeletal survival rate calculated as follows: $\%\ \text{survival}_e = (\text{MNE}_e \times 100)/(\text{Number of elements}_e \text{ in one skeleton} \times \text{MNI})$ (Lyman, 1994).

To describe the degree of bone fragmentation, we recorded the completeness of the shaft circumference according to Bunn (1983): O = complete; C = more than half of the total circumference; and (= less than half of the total circumference. We analyzed long bone fragments (e.g., coracoid, humerus, radius, ulna, carpometacarpus, femur, tibiotarsus, tarsometatarsus) from size categories 2, 3, and 4 to distinguish fresh and dry fractures using the fracture freshness index (FFI) defined by Outram (2001) following earlier work by Johnson (1985) and Villa and Mahieu (1991). For every bone shaft fragment, we awarded a score of 0–2 to three criteria (i.e., fracture angle, surface texture, and outline) for a total range of 0–6. Bones with a FFI score of 6 imply that post-depositional processes were responsible for the pattern of bone fragmentation. In

Table 1. Taxonomic list of birds identified at Bluefish Caves (NISP).

	Cave I			Cave II			Cave III		
	Unit B	Unit C	Uncertain	Unit B	Unit C	Uncertain	Unit B	Unit C	Uncertain
ANSERIFORMES									
Anatinae	2	0	1	0	1	0	0	0	0
Anser caerulescens	0	0	0	0	0	1	0	0	0
Histrionicus histrionicus	0	0	1	0	2	0	0	0	0
cf. *Histrionicus histrionicus*	0	0	3	0	0	0	0	0	0
cf. *Mareca americana*	0	0	1	0	0	0	1	0	1
Total	2	0	6	0	3	1	1	0	1
CHARADRIIFORMES									
Calidris sp.	0	0	1	0	0	0	0	0	0
cf. *Numenius borealis*	0	0	0	0	0	0	2	0	1
Pluvialis sp.	8	0	3	1	0	1	0	0	0
Pluvialis cf. *dominica/fulva*	1	0	1	0	0	0	0	0	0
Pluvialis cf. *squatarola*	0	0	0	1	0	0	0	0	0
cf. *Tringa solitaria*	1	0	1	1	0	0	0	0	0
Species indeterminate	5	0	2	2	0	0	0	0	1
Total	15	0	8	5	0	1	2	0	2
GALLIFORMES									
Lagopus	2819	13	834	121	16	19	194	1	113
Total	2819	13	834	121	16	19	194	1	113
PASSERIFORMES									
Acanthis cf. *flammea/hornemanni*	0	0	0	0	0	0	1	0	1
Catharus cf. *guttatus/minimus*	1	0	0	0	0	0	0	0	0
cf. Hirundinidae	419	12	92	8	0	4	16	0	4
cf. *Poecile*	1	0	0	0	0	0	0	0	0
Plectrophenax nivalis	1	0	0	0	0	0	0	0	0
Sayornis cf. *saya*	0	0	1	0	0	0	0	0	0
cf. *Sayornis*	0	0	3	0	0	0	0	0	0
Spizella cf. *arborea/passerina*	0	0	0	1	0	0	0	0	0
Turdus migratorius	0	0	0	0	1	0	0	0	0
Species indeterminate	541	28	15	0	1	5	1	0	0
Total	963	40	111	9	2	9	18	0	5
STRIGIFORMES									
Bubo cf. *scandiacus*	0	0	0	0	0	0	2	0	1
Surnia ulula	0	0	0	1	0	0	0	0	0
Total	0	0	0	1	0	0	2	0	1
ACCIPITRIFORMES									
Buteo lagopus	0	0	0	0	0	0	0	0	1
Buteo sp.	1	0	0	0	0	0	1	0	2
Total	1	0	0	0	0	0	1	0	3
Total NISP		4812			187			344	
Total unidentified		1473			203			94	
Total bird remains		6285			390			438	

contrast, an FFI score of 0 indicates fresh bone breakage (Outram, 2001).

To help identify the accumulating agent(s), and according to compiled data from Bocheński (2005), we calculated the following ratios (based on the NISP) for the most abundant taxon: (1) the percentage of complete long bones, (2) the ratio of the wing (humerus, ulna, carpometacarpus) to leg (femur, tibiotarsus, tarsometatarsus) elements, (3) the ratio of core (sternum, pelvis, scapula, coracoid) to limb (humerus, ulna, radius, carpometacarpus, femur, tibiotarsus and tarsometatarsus) bones, and (4) the proportion of proximal (scapula, coracoid, humerus, femur, tibiotarsus) to distal (ulna, radius, carpometacarpus, tarsometatarsus) elements.

We conducted taphonomic observations of bone surfaces using an Olympus SZ51 microscope (zoom 0.8x – 4x). We recorded non-human modifications for each specimen from size categories 2, 3, and 4, including weathering (stages 0, 1, or 2; Bocheński and Tomek, 1997), abrasion, black manganese oxide coating, root etching, and rodent gnawing (score of 0 = absent; 1 = low impact; or 2 = high impact) (Morlan, 1980; Hill, 1982; Andrews, 1990; Fisher, 1995; Fernandez-Jalvo and Andrews, 2016).

Carnivores, diurnal raptors, owls, and humans may have specific feeding behaviors and produce different taphonomic signatures. Damages from carnivore gnawing on bird bones can be heavy (Mallye et al., 2008; Castel et al., 2011; Krajcarz and Krajcarz, 2012; Rodríguez-Hidalgo et al., 2016) and indicated by the presence of pits, punctures, scores, and crenulated edges (as defined by Binford, 1981). Birds of prey use their beak and talons to disarticulate carcasses. Beak marks are often located near the articular ends and have an irregular square or triangular form, or a zigzag outline (Laroulandie, 2002, 2005a; Serjeantson, 2009; but see also: Armstrong and Avery, 2014). Traces of digestion may look like the effects of weathering processes in soils (Bocheński and Tomek, 1997); we therefore recorded these as follows: 0 = absent, 1 = probable, 2 = definitive.

We examined specimens of all size categories for signs of human bone modifications. Cut marks made by stone tools are usually straight, thin, and deep, with a V-shape profile (Shipman, 1981; Olsen and Shipman, 1988; Lyman, 1994; Fisher, 1995; Bello and Soligo, 2008; Domínguez-Rodrigo et al., 2009; Boschin and Crezzini, 2012; Fernández-Jalvo and Andrews, 2016). Their location and orientation on the bone can be linked to butchery tasks, as described in the ethnographical, archaeological, and actualistic literature (Laroulandie, 2000, 2001, 2005b). We took photographs and measurements of potential human bone modification using a Zeiss Axiovision SE64. One specimen (MgVo-2, E2.4.1), previously studied (Bourgeon, 2018), was photographed and measured using an Olympus DSX-100.

Birds can be dismembered without using tools; hence other forms of human modifications were documented (Laroulandie, 2005a). The breakdown of the distal portion of the humerus can be a consequence of the dismembering of the elbow by overextension. It may result in a light squashing of the fossa olecrani, a hole with or without an adhering flake, or a notch with a medial wrench (Laroulandie, 2005a). Since neither raptors nor carnivores use this technique to dismember their prey, such bone modifications are considered strong evidence of human intervention (Laroulandie, 2005a; Laroulandie et al., 2008). Furthermore, peeling is a superficial flaking of the bone that occurs during fragmentation by bending of fibrous material (White, 1992). Traces of peeling display roughened surfaces with parallel grooves and are more commonly observed on long bone ends (e.g., ulna; Laroulandie, 2000; Serjeantson, 2009). Finally, experimental studies on ptarmigan bones show that human teeth can leave pits and punctures that may be distinguishable from carnivore gnawing and beak marks (Laroulandie, 2005a). Damaged long bones usually exhibit a unique hole near the ends (in rarer cases, the shaft is also affected, or multiple holes are displayed). Tooth marks are generally round to oval and 1–5 mm long. Adhering fragments are frequently attached to the edge and longitudinal fissures may be observed (Laroulandie, 2005a).

RESULTS

Taxonomic Representation

We examined a total of N = 7113 bones. Cave I has the largest concentration of bird remains (N = 6285, representing about 27% of the whole faunal assemblage for that cavity) compared to caves II and III (N = 390 and N = 438, respectively, representing less than 5% of the whole bone assemblage for each cavity). According to the Canadian Museum of History archival records, most of the identified specimens (78%) were recovered from Unit B (i.e. loess), while only 1% was reported from Unit C (i.e., humus). Bones from unknown stratigraphic provenance represent 21% of the NISP.

We identified about 75% of the avian bones to the order level (Fig. 2). The taxonomic list is relatively similar to previous identifications from McCuaig-Balkwill and Cinq-Mars (1998) (Table 1). In contrast, 22% of the bones from caves I and III, and 52% from Cave II could not be taxonomically identified and were only referred to as birds (Fig. 2). Taphonomic processes may explain the high frequency of unidentified specimens in Cave II, as described below.

Galliformes (subfamily: Tetraoninae) is the main order, accounting for 58% of the whole bird bone assemblage (NISP = 4130). Specimens were distributed throughout the entire humus and loess deposits at all three caves. Based on the relative abundances of the carpometacarpi and tarsometatarsi, we estimate that the MNI for Galliformes is 450: MNI = 412 in Cave I; 20 in Cave II; 18 in Cave III. Based on measurements of those bone elements, it is worth noting that: (1) the Bluefish Caves specimens compare favorably to the Willow Ptarmigan (*Lagopus lagopus*) and the Rock Ptarmigan (*Lagopus muta*) (Fig. S1, S2 and S3); and (2) we observed slightly different limb proportions between the ancient and modern specimens (Fig. S4, Tables S1 and S2), as discussed in Supplementary Text. Remains of Galliformes also include about 70 immature bones (MNI = 8).

Passeriformes are the second most abundant order in all three caves (NISP = 16%) and are represented principally by Hirundinidae, which McCuaig-Balkwill and Cinq-Mars (1998) found in various levels throughout the humus (Unit C) and loess (Unit B). Charadriiformes (NISP = 0.5%) are mostly represented by plovers (*Pluvialis*). Based on photographs from the Museum of Comparative Zoology, we may be able to attribute two coracoids and one phalanx excavated from the loess of Cave III to the Northern Curlew (*Numenius borealis*). A direct comparison with modern skeletons is needed to confirm this identification. Anseriformes (NISP = 0.2%) include one Snow Goose (*Anser caerulescens*) and a few ducks. Finally, Strigiformes and Accipitriformes (NISP = 0.2%) include the Northern Hawk Owl (*Surnia ulula*), the Snowy Owl (*Bubo scandiacus*), and the Rough-legged Hawk (*Buteo lagopus*). In the present study, we did not confirm the presence, previously identified by McCuaig-Balkwill and Cinq-Mars (1998), of the Red-tailed Hawk (*Buteo jamaicensis*).

Relative Frequency of Skeletal Remains From Ptarmigans

We only considered analysis of the frequency of skeletal remains of the most abundant taxon, i.e., *Lagopus*. All

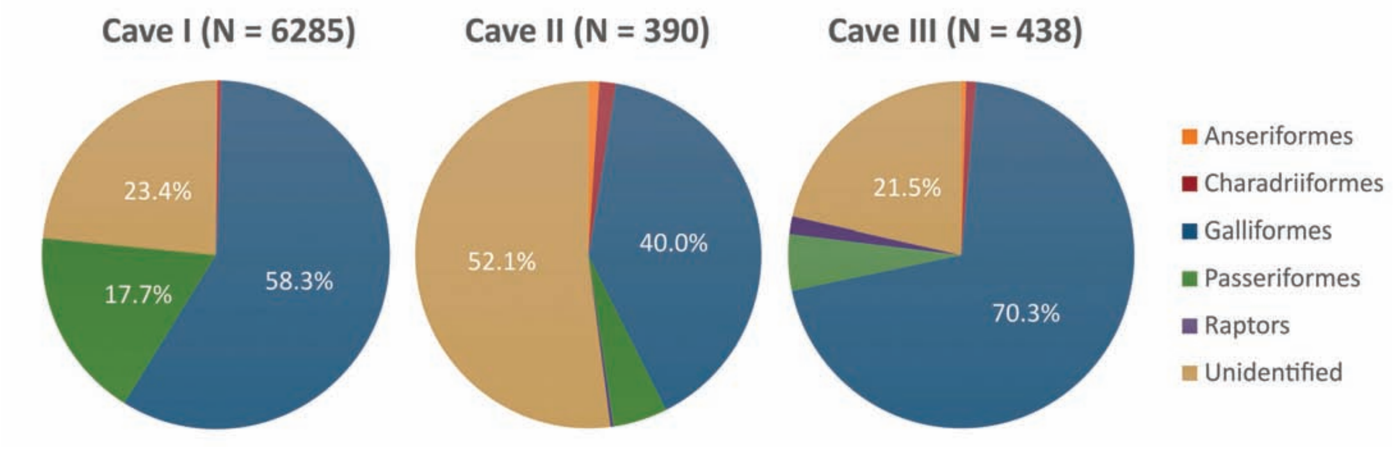

FIG. 2. Relative frequency of bird remains identified at Bluefish Caves (% NISP).

bones composing the ptarmigan skeleton are present, but in varying proportions (Fig. 3). The axial elements are underrepresented and highly fragmented. The ribs are extremely rare. Long bones (comprising 46% of the total NISP) mostly include the carpometacarpus and tarsometatarsus, which are often complete or almost complete. The next most abundant elements are the tibiotarsus (mainly distal portion), ulna (proximal and distal), radius (mostly distal) and, to a lesser degree, the humerus (proximal and distal), femur (mostly distal), and scapula and coracoid (proximal portions).

Breakage Patterns

We identified a total of N = 3913 long bones (excluding size category 1) in the avian assemblage. Of these, N = 1447 (37%) were complete or near complete. The materials from caves I and III have a lower degree of fragmentation (respectively, 40% and 23% of long bones are complete or near complete) compared to Cave II (11%).

We performed analyses of breakage patterns on N = 1151, N = 51, and N = 89 long bone fragments from caves I, II, and III, respectively (Fig. 4). Caves I and III have relatively similar representations: more than 80% of the long bone shafts display complete circumferences, and approximately 60% of the specimens were broken when fresh. In contrast, 63% of the bones from Cave II have complete shaft circumferences and 39% exhibit fresh fractures.

Taphonomic Analysis

We recorded non-human bone modifications on N = 5840 remains, i.e., 82% of the bird material (Fig. 5). The impact of weathering and root etching was low on the skeletal assemblages from caves I and III, with no more than 20% of the bones showing damage from such processes. These observations contrast with the bone assemblage from Cave II, which has been affected by weathering (about 40% at stage 1) and strongly modified by root etching (identified on 60% of the bones and completely covering bone surfaces in 24% of cases). Unfortunately, bone weathering and root etching make it difficult to detect other alterations. We identified signs of slight sedimentary abrasion in the form of small scratches and abraded edges on 46%, 14%, and 37% of the bones from caves I, II, and III, respectively. We observed manganese oxide coatings in small proportions (scattered black dots on bone surfaces) on bones from caves II and III, but 38% of the bird remains from Cave I are blackened on more than half of the bone surface.

We observed one or two pits on N = 57 specimens (N = 51, 2, and 4 from caves I, II, and III, respectively). We observed notches on N = 31 specimens (N = 29, 1, and 1 from caves I, II, and III, respectively). We mostly identified the pits and notches on long bones from size category 3 (cf. ptarmigans), and their shape may be associated with raptor beak or talon marks. We recorded heavier damage in the form of crenulated edges and multiple pits, punctures, and scores on N = 269 specimens (N = 230, 18, and 21 from caves I, II, and III, respectively). Small carnivores (e.g., foxes, mustelids) may have produced those marks. We recorded no evidence of rodent gnawing on any of the bones. We observed definitive traces of digestion on 8%, 14%, and 15% of the material from caves I, II, and III, respectively.

None of the avian bones show traces of burning. However, evidence of butchery was observed on a Snow Goose scapula from Cave II (Fig. 6), as previously reported by McCuaig-Balkwill and Cinq-Mars (1998) and later confirmed and illustrated by Bourgeon (2018). Multiple short, deep, and overlapping cuts are obliquely oriented on the shaft, near the proximal end of the scapula. The striae have a clear V-shape profile. Measurements (i.e., depth and ratio between the breadth at the top and the breadth at the bottom of the mark) obtained on two profile cross-sections perpendicular to the direction of the striae fall within the range of measurements reported for cut marks made by stone tools (Bourgeon, 2018: Appendices 77 and 79). Morphological and morphometrical criteria reported for that specimen are not consistent with marks produced by natural

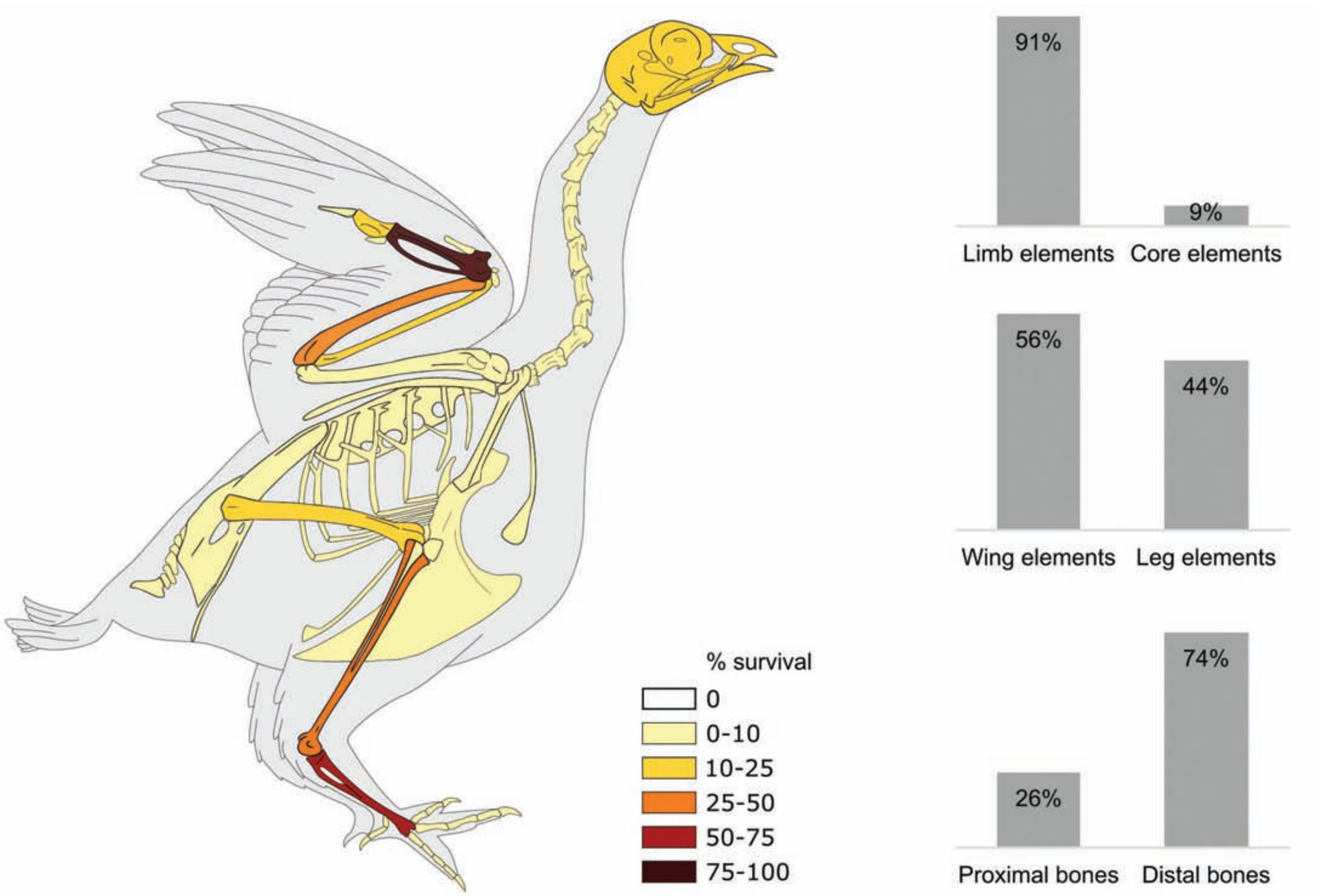

FIG. 3. Skeletal representation of the ptarmigan assemblage from all three caves. Template from ArcheoZoo.org/Michel Coutureau (Institut national de recherches archéologiques), in collaboration with Véronique Laroulandie (Centre national de la recherche scientifique).

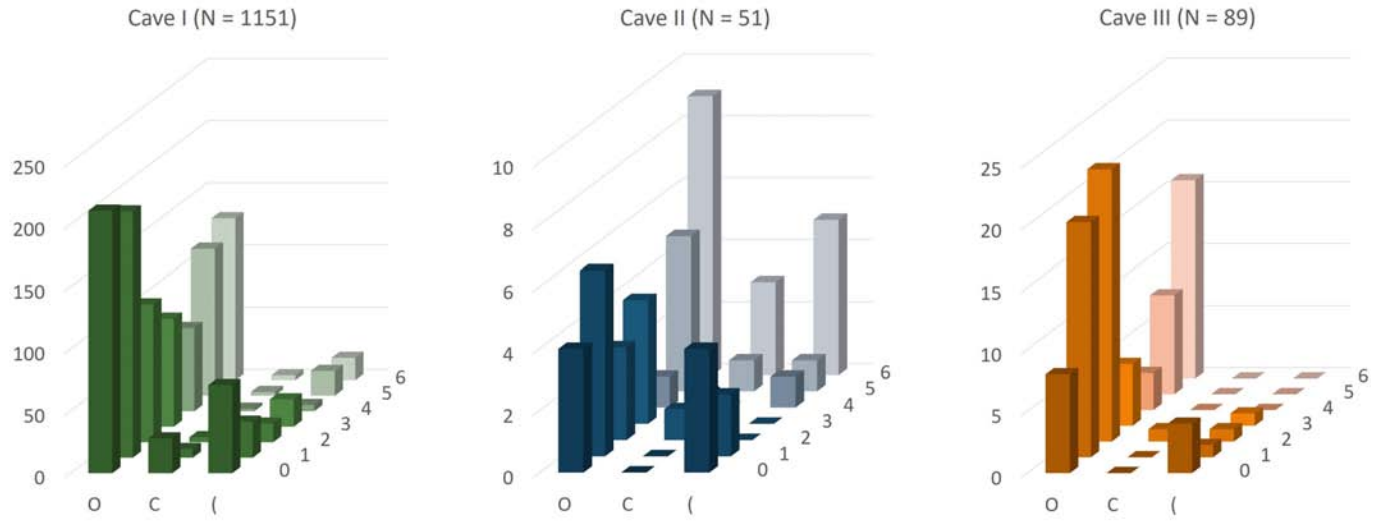

FIG. 4. Avian long bone fragmentation patterns. Y-axis: number of specimens; X-axis: shaft circumference (according to Bunn, 1983); Z-axis: fracture freshness index (according to Outram, 2001).

processes (e.g., sedimentary abrasion, carnivore gnawing). The color inside the striae resembles the external surface of the bone, indicating that they were not created recently (e.g., trowel marks). Based on archaeological observations and experimental butchering of partridge (Laroulandie, 2000; Sánchez Marco and Cacho Quesada, 2010), the marks

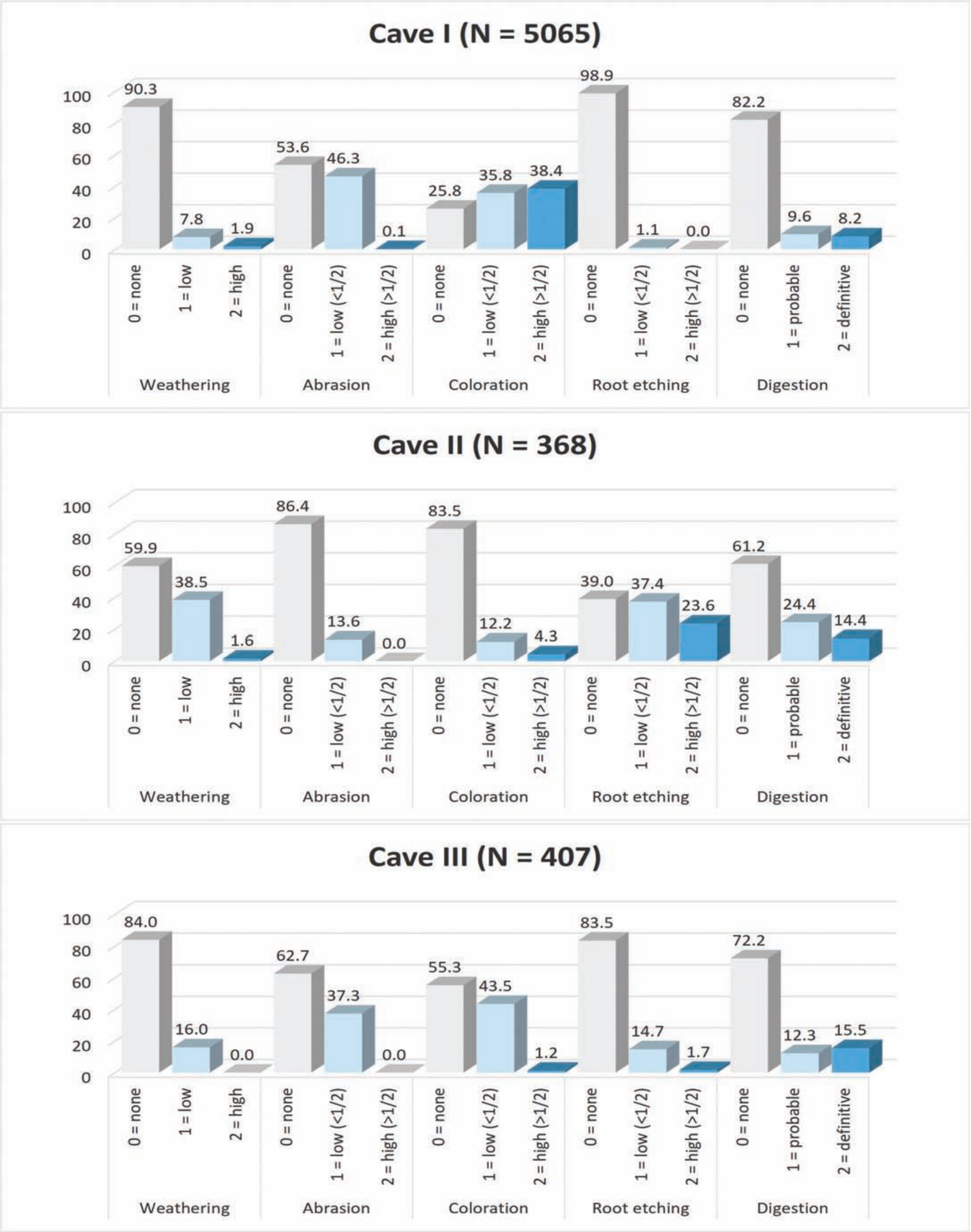

FIG. 5. Percentages of natural damage observed on the bird remains.

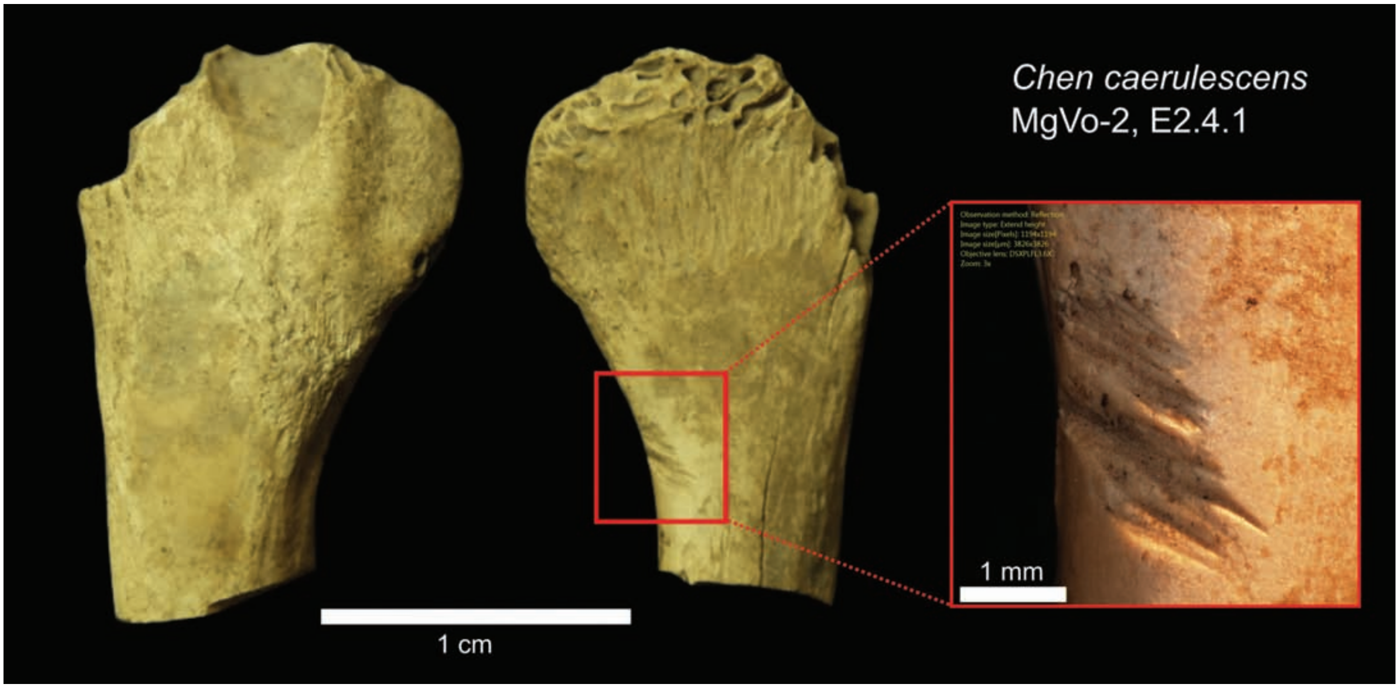

FIG. 6. Filleting marks on a Snow Goose scapula. Bluefish Cave II, specimen number E2.4.1. Photo: ©Bourgeon, 2018.

observed on the Snow Goose scapula are consistent with anthropogenic marks produced when cutting the muscles attached to the lateral side of the scapula.

We observed other modifications on ptarmigan remains that can potentially be assigned to human activity (Table 2). Five long bones bear isolated deep, short grooves obliquely oriented on the shaft (Figs. 7A–D), and one proximal phalanx of a major digit exhibits a shallow striation. We recorded scraped edges with chatter marks (i.e., ripples caused by the scraping agent bouncing on the bone surface) on a carpometacarpus (Fig. 7E) and a tarsometatarsus (Fig. 7F). The isolated striae cannot be confidently attributed to butchery. Chatter marks, however, have been frequently associated with the manufacture of mammal bone artifacts using stone tools (Newcomer, 1974; Olsen, 1984; Olsen and Shipman, 1988), and cuts and scrapes on distal bird bones have been described elsewhere as the result of the removal of wing and leg feathers (e.g., Serjeantson, 2002; Laroulandie, 2004; Peresani et al., 2011; Pedergnana and Blasco, 2016; Romandini et al., 2016; Blasco et al., 2019). These striae, therefore, could possibly be attributed to human activities.

At least 14 ulnae display superficial flaking of the proximal or distal ends (Figs. 8A, 8B) that may correspond to peeling, although there is no sign of fragmentation by bending as described by Laroulandie (2000) or Serjeantson (2009). Nevertheless, the fibrous texture suggests the tearing and removal of tendons or ligaments, and it is possible that this sort of peeling was produced by humans during the process of disarticulating the wings without fracturing the bone (Laroulandie, 2005a). Birds of prey, however, can also use their beak and claws to hold and disarticulate a carcass (Serjeantson, 2009).

The distal end of a humerus exhibits a large puncture covering the fossa olecrani (Fig. 8C). Its shape is irregular and grossly rectangular, measuring 6.02 mm long and 5.34 mm wide in its largest dimensions. The damage may be attributed to the disarticulation of the elbow by overextension, as described by experimental and archaeological observations (Laroulandie, 2005a, b; Laroulandie et al., 2008), although the shape of the comparative specimens is less irregular and more circular.

Finally, the shaft of an ulna bears a unique lozenge-shaped perforation associated with a longitudinal crack (Fig. 8D). The adhering flake measures 4.07 mm long and 2.03 mm wide and may represent a human tooth mark, as described by Laroulandie (2001, 2005a). Although beak marks can have an irregular square form and are more often located near articular ends, we cannot fully exclude birds of prey as a potential agent in the modification of that specimen.

DISCUSSION

General Observations

Cave I yielded a larger avian assemblage than caves II and III. Cave III, however, was only partially excavated (ca. 10 m^2). Caves I and II were fully and similarly excavated (i.e., 40 and 58 m^2, respectively, with all sediments dry-sieved using a 3 mm mesh) (Cinq-Mars, 1979), so the low abundance of bird bones in Cave II is noteworthy.

The percentages of taxonomic identification and the taphonomic observations we report in the present study are generally like those reported on the mammal bones from

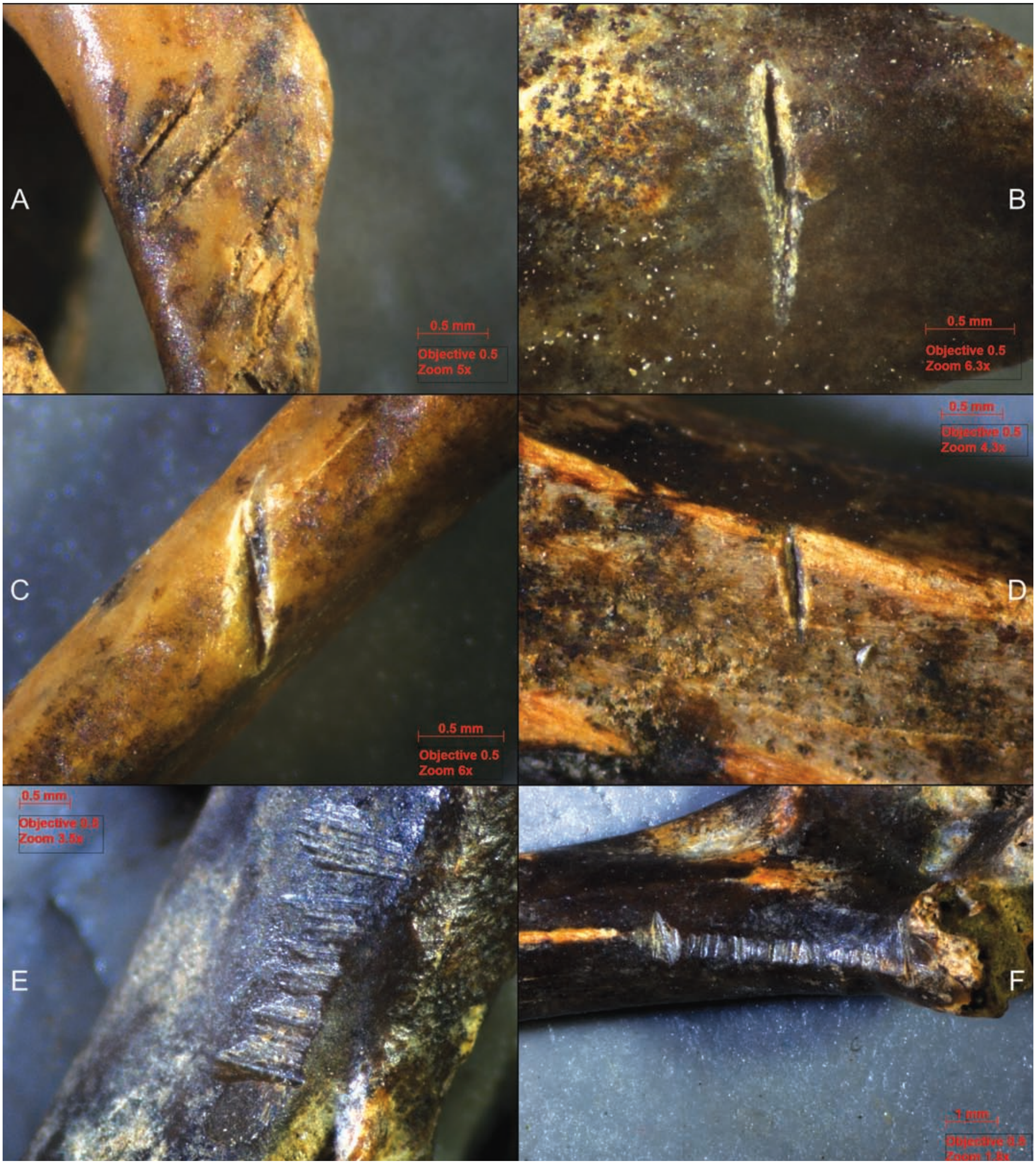

FIG. 7. Potential butchery marks on ptarmigan bones. (A) 85. Misc.199; (B) H6.4.2; (C) T2.20.87; (D) T3.21.43; (E) I6.G.23; (F) H5(e).4.3.

caves I and II (Bourgeon, 2018). Interestingly, we found that the percentages of identified bones for both classes of vertebrates are two times higher in Cave I (Aves: 77%; mammals: 23%) than in Cave II (Aves: 48%; mammals: 12%). This disparity may be related to taphonomic processes being more destructive in the latter. Plant roots have completely dissolved the surfaces of 25% of the bird bones from that cavity (current study), and the same holds true for the mammal remains (Bourgeon, 2018). It is likely that the bones from Cave II were not buried as quickly or as deeply as those in Cave I, making them more susceptible to weathering and root etching. Also, long-bone breakage

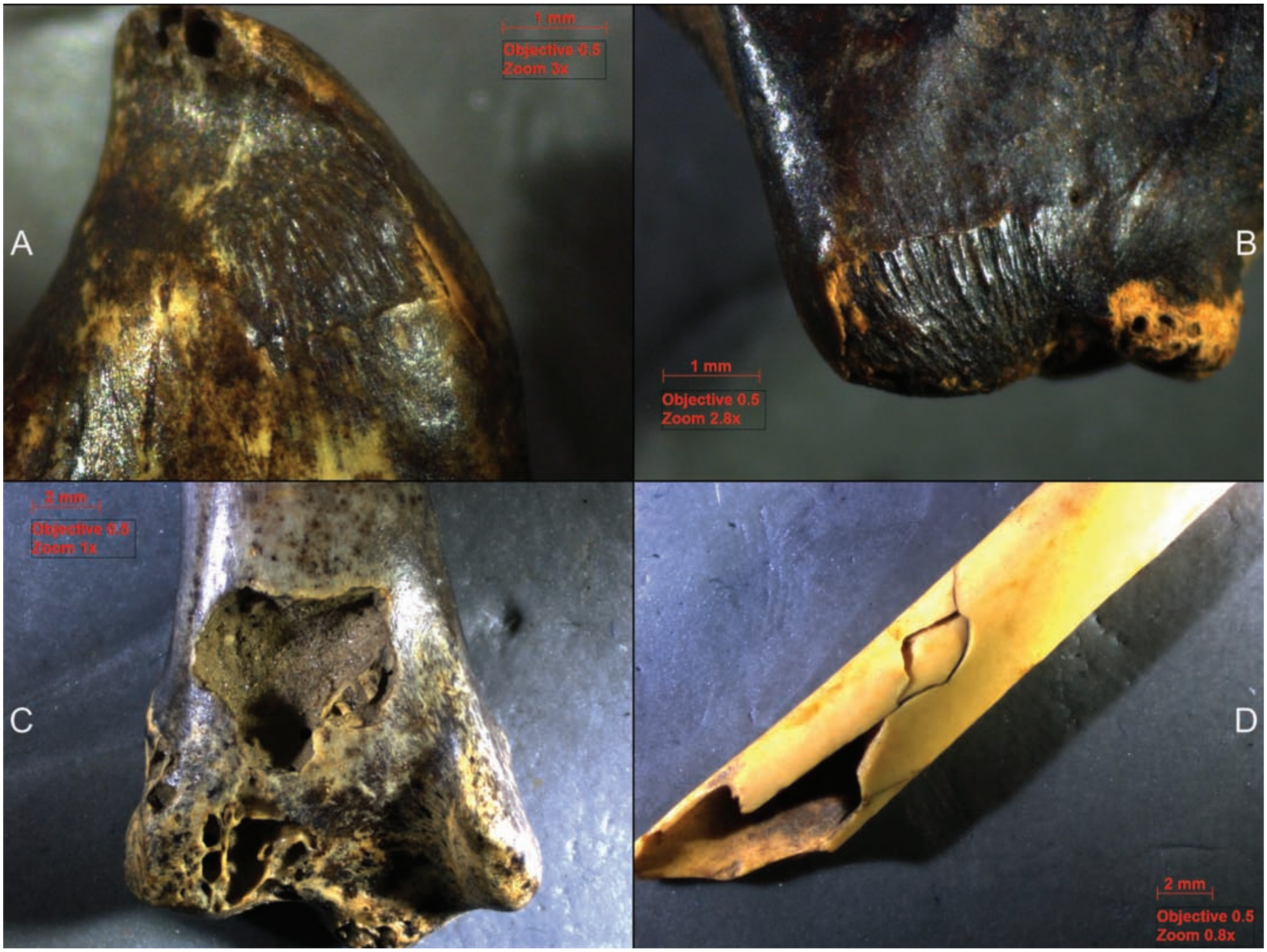

FIG. 8. Potential disarticulation and human tooth marks on ptarmigan bones. (A) T2.23.14; (B) D7.19.95; (C) I7.G.2; (D) D5.1.52.

patterns indicate that the avian material from Cave II was subjected to more post-depositional processes (e.g., rockfall, trampling) than the avian material from the other two caves (Fig. 4), thereby limiting taxonomic identification of specimens and interpretation of bone modifications.

Despite the above-mentioned taphonomic alterations, we attributed approximately 20 avian taxa to family or species levels (Table 1). In addition to about 30 small and large mammal taxa identified elsewhere (Harington and Cinq-Mars, 2008; Bourgeon, 2018), it is apparent that the taxonomic spectrum of Bluefish Caves is highly diversified and suggests a late Pleistocene environment with a relatively high level of productivity.

Who Brought the Birds into the Caves?

In the present study, we identified migratory and non-migratory birds at Bluefish Caves. While ptarmigans and the Northern Hawk Owl are nowadays common, year-round residents of northern Yukon Territory, many migratory birds (e.g., waterfowl, shorebirds, some passerines, and the Rough-legged Hawk) only appear during the breeding season (i.e., spring, summer) (Sinclair et al., 2003). In contrast, the Snowy Owl breeds today far north of the Arctic Circle and may be seen in northern Yukon during the winter (Cornell Lab of Ornithology, 2019). These migration patterns, however, may have been different during the late Pleistocene.

Many bird species nest in caves or on rock ledges and eventually die of natural causes. This is the case for some swallows, which were abundant at Bluefish Caves. The presence of other species identified in the avian assemblage (e.g., ptarmigans and waterfowl) raises questions about the cause of death and origin of bone accumulation.

Natural Origins

Bluefish Caves represent palimpsest deposits, and it is therefore not possible to confidently identify the agent(s) responsible for the bird bone formation. The presence of digested bones, scores, crenulated edges, pits, and punctures on the bird bones suggests mixed origins implicating mammalian carnivores and raptorial birds.

Potential mammalian carnivores at Bluefish Caves include wolves, foxes, and mustelids. Foxes, in particular, prey on lagomorphs and birds, including Galliformes, creating avian assemblages with a non-negligeable frequency of gnawed (> 20%) and digested (5–15%) bones (Mallye et al., 2008; Castel et al., 2011). These small canids (i.e., *Vulpes lagopus* and *Vulpes vulpes*) were abundant at Bluefish Caves and may have used the site as a den during the spring and summer (Bourgeon, 2018), hence participating in the accumulation of the bone remains. The relatively low percentage of avian bones with tooth marks (< 5%), however, suggests that foxes were not the main and only predator of birds at the site.

Raptorial birds (e.g., Rough-legged Hawk, Northern Hawk Owl, Snowy Owl) were also present in northern Yukon Territory and likely contributed to the accumulation of hundreds of lemmings and voles in the rock shelters (Morlan, 1983, 1989). When rodents are scarce, however, raptors may shift to alternative prey, such as birds (see, for example: Nybo and Sonerud, 1990; Baales, 1992; Potapova, 2001; Pokrovsky et al., 2014). This is the case for the Snowy Owl, which is well known for preying on ptarmigan in the Arctic tundra (Andrews, 1990; Baales, 1992; Bocheński, 1997; Potapova, 2001; Royer et al., 2019). Despite the palimpsest nature of the deposits, we hypothesize that owls were one of the main accumulators of the numerous ptarmigans we identified at Bluefish Caves. First, we recorded a low proportion of digested or punctured ptarmigan bones, which is consistent with moderate damages usually created by owls, in contrast with hawks and eagles, for which the degree and frequency of digestion tend to be higher (Bocheński, 1997, 2005; Royer et al., 2019; Wertz et al., 2021). Second, owls produce pellets in which the share of whole bones varies between 30% and 60% (Bocheński, 2005). The proportion of complete long bones from Bluefish Caves (46%) is in that range. Third, the proportion of wing to leg bones we calculated for ptarmigans at the site is characterized by a slight predominance of wing elements (56%) and fits the owls' pellet category.

Other indices, such as the proportion of proximal to distal parts from long bone fragments and the proportion of core to limb elements, are to be considered with caution. At Bluefish Caves, the ptarmigan bone assemblage is characterized by a relative abundance of carpometacarpi, tarsometatarsi, and distal tibiotarsi, indicating that it may have been affected by density-mediated attrition, since these elements of the gallinaceous skeleton have the densest bone mineral density (Dirrigl, 2001). The high frequency of distal elements, however, may also result from pellets of owls. Compared with proximal elements, carpometacarpi and tarsometatarsi are often overrepresented in assemblages created by owls, (e.g., humerus, femur) (Mourer-Chauviré, 1975; Baales, 1992; Bocheński, 1997, 2005). This is because owls swallow and regurgitate distal bones whole, while they first crush, and eventually regurgitate the proximal, meat-rich bones in the form of unidentifiable splinters (Baales, 1992).

TABLE 2. Potential human bone modifications observed on ptarmigan remains. For location: P = proximal; S = shaft; D = distal. Bones are from Unit B (loess), except when marked by an asterisk (* = provenance uncertain).

Cave	Spec. nb.	Location	Observations/Interpretations	Figure
I	D7.19.95	Ulna, D	Peeling/Disarticulation?	8B
I	T2.23.14	Ulna, P	Peeling/Disarticulation?	8A
I	T2.22.132	Ulna, D	Peeling/Disarticulation?	
I	T2.21.96	Ulna, P	Peeling/Disarticulation?	
I	C5/C6.1.20*	Ulna, P	Peeling/Disarticulation?	
I	C5/C6.1.20*	Ulna, D	Peeling/Disarticulation?	
I	C5/C6.1.20*	Ulna, D	Peeling/Disarticulation?	
I	C5/C6.1.20*	Ulna, P	Peeling/Disarticulation?	
I	D5.1.46	Ulna, D	Peeling/Disarticulation?	
I	D5.1.46	Ulna, D	Peeling/Disarticulation?	
I	D6.A.2*	Ulna, D	Peeling/Disarticulation?	
I	D6(NE).1.1	Ulna, P	Peeling/Disarticulation?	
I	D6.18.2	Ulna, P	Peeling/Disarticulation?	
III	85.MISC.212*	Ulna, D	Peeling/Disarticulation?	
I	I7.G.2	Humerus, D	Perforation/Disarticulation?	8C
I	D5.1.52	Ulna, S	Perforation/Tooth mark?	8D
I	H5(e).4.3	Tarso., S	Scraping marks/ Skinning-Defeathering?	7F
I	I6.G.23	Tarso., D	Scraping marks/ Skinning-Defeathering?	7E
I	H6.4.2	Ulna, S	Striae/Filleting?	7B
I	T2.20.87	Fibula, S	Striae/Filleting?	7C
I	I6.G.23	Tarso., D	Striae/Skinning-Defeathering?	
I	G7/8.6.4	Phalanx	Striae/Skinning-Defeathering?	
I	T3.21.43	Tarso., S	Striae/Skinning-Defeathering?	7D
III	85.Misc.199*	Carpo., S	Striae/Skinning-Defeathering?	7A

Human Interventions

Cut marks on a Snow Goose scapula from Bluefish Cave II (Fig. 6), which were first observed by McCuaig-Balkwill and Cinq-Mars (1998) and later re-examined by Bourgeon (2018), indicate that humans may have played a role in the accumulation of the waterfowl in the caves. Snow geese live near lakes, ponds, and streams. They breed in the Arctic tundra during the summer season and migrate south during the winter (Cornell Lab of Ornithology, 2019). Hence, it is likely that humans acquired their prey during the warm season. The date of human intervention, however, is less certain. The specimen was found at the edge of a bedrock wall, just outside the dripline, in a mixed deposit of rubbly humus and loess, about 35–40 cm below surface (Canadian Museum of History, Archives, Jacques Cinq-Mars funds, box 7, file 15). Submitted for radiocarbon dating in 2007, the bone provided a young age of 7780 ± 60 ^{14}C BP (Beta-126870; Martindale et al., 2016) and may represent a human presence at Cave II during the early Holocene, although no information was ever published to certify the validity of the dating result.

We observed potential anthropogenic modifications (i.e., in the form of striations, scraping marks, peeling, and perforations) on *Lagopus* remains, and it is possible that humans contributed, to some degree, to the accumulation of ptarmigans at the site. This land bird must have been available year-round in the Bluefish Caves area, providing an important source of food during times of hunger (Nelson, 1902; Owen, 2005), as well as feathers for clothing and in the manufacture of hunting tools (McClellan, 1975; Emmons, 1991; Sinclair et al., 2003; Dove et al., 2005). For the Vuntut Gwitchin First Nation, on whose lands the Bluefish Caves are located, ptarmigan is highly valued, along with waterfowl and caribou (Vuntut Gwitchin First Nation and Smith, 2010). Although Bourgeon (2018) documented evidence of butchery on waterfowl and caribou bone from Bluefish Caves, the anthropogenic origin of the modified ptarmigan bones remains uncertain.

At other Beringian archaeological sites, researchers have recorded high frequencies of Tetraoninae and Anatidae remains, with or without anthropogenic modifications. In eastern Siberia, cut marks were observed on Anatidae bones from Dyuktai Cave (< 15,000 cal BP), while the origin of ptarmigans at the site is less clear and may represent a mixed type of accumulation (human and non-human) (Zelenkov et al., 2008). In Alaska, at Broken Mammoth CZ3 and CZ4 (14,000 – 13,000 cal BP) and Swan Point CZ3 (12,500 – 11,500 cal BP), ptarmigans, ducks, and geese played an important role in humans' diet (Yesner, 2001, 2007; Holmes, 2011; Potter et al., 2013). Similar taxa were reported in high numbers in Stratum 3 (13,000 – 8000 cal BP) at Lime Hills Cave, suggesting that substantial avian prey was available for the inhabitants of the site, though no cut marks were found on the bird remains (Endacott, 2008). Furthermore, Trail Creek caves 2 and 9 (< 15,000 cal BP) yielded a rich collection of avian remains dominated by waterfowl and ptarmigans. Acknowledging the importance of the latter as a valuable source of carbohydrates and vitamin C, Pasda (2012:76) concluded that human intervention at the site is "undoubtedly possible, but there is no evidence visible on the bird bones."

As other researchers have pointed out (e.g., Laroulandie, 1998; Steadman et al., 2002; Pasda, 2012), the absence of physical evidence does not necessarily mean that humans were not consuming avian species. First, many birds (unlike large mammals) can be easily transported intact to another site (e.g., a base camp) for processing and consumption, leaving little to no evidence of capture at the kill site. This could be the case at Bluefish Caves, which has been interpreted as a short-term hunting shelter (Bourgeon et al., 2017; Bourgeon and Burke, 2021). Second, land birds like ptarmigans can be snared, and their entrails and flesh are sometimes eaten raw (Turner and Murdoch, 1894; Nicolaysen, 1980; Wein et al., 1996; Owen, 2005; Kuhnlein and Humphries, 2017). Finally, processing small game does not always require tools. Such acquisition and consumption methods, therefore, leave no impact marks, butchery marks, or traces of burning.

Paleoenvironmental Considerations

Birds at Bluefish Caves represent different habitats: wetlands (e.g., waterfowl), open grasslands (e.g., shorebirds, Snow Bunting, Rough-legged Hawk), tundra (e.g., ptarmigan, Snowy Owl), and woodlands (e.g., American Robin, Northern Hawk Owl) (Cornell Lab of Ornithology, 2019). Unfortunately, the stratigraphic provenience of many identified bones is unclear and remains problematic in reconstructing the paleoenvironments. A few bones were found in the humus or rubbly humus (Unit C) (CMH, Archives, Jacques Cinq-Mars funds) and include some swallows, a Harlequin Duck, and an American Robin (Table 1), all present in the Yukon today (Lepage, 2021). Birds from Unit B are more numerous compared to Unit C, and some of the remains that were recovered during the 1978 excavation of the south trench inside Cave I can be directly studied in relation to the pollen diagram established from that trench (Cinq-Mars, 1979). Although bones of ptarmigans and swallows were reported throughout the whole deposit (from the humus to Level 28, about 160 cm deep), a higher frequency of ptarmigans, passerines, and shorebirds occurs in Levels 14 to 23 (85 – 135 cm below surface), which corresponds to an increase in *Betula* pollen. The development of a shrub tundra and warmer climatic conditions after the LGM likely attracted more avian species into the Yukon Arctic. Similarly, at the Broken Mammoth site, Yesner (2001) noted that the dissolution of the Bering land bridge and the retreat of the North American ice sheets progressively allowed the re-establishment of the North Pacific flyway, leading to increased avian diversity in interior Alaska during the Birch interval.

Interestingly, measurements of *Lagopus* bones from the loess of Bluefish Caves (Unit B) show subtle differences from modern populations (Supplementary Text). The tarsometatarsi, in particular, possess a shaft width that is like the extant specimens, but the greatest length is shorter, making the Bluefish Caves specimens more robust than their modern counterparts and reflecting greater body weight. The same tendency has been demonstrated at other late Pleistocene sites from western Europe to eastern Siberia (Mourer-Chauviré, 1975; Potapova, 1986; Bocheński and Tomek, 1994; Stewart, 1999, 2007; Zelenkov et al., 2008; Stewart and Jacobi, 2015). Some researchers suggest that climatic and vegetational shifts are the most significant factors leading to body size changes (Stewart, 1999; Stewart and Jacobi, 2015). The greater body weight of Pleistocene grouse and ptarmigan is likely due to the high carrying capacity of the steppe-tundra. As the environment shifted after the Last Glacial Period, certain birds, along with many megafaunal species, underwent a reduction in body size (Stewart, 1999; Stewart and Jacobi, 2015).

CONCLUSION

The results of this study provide new information about the composition of the faunal assemblage of Bluefish Caves. The avian representation, together with the mammalian spectrum (Bourgeon, 2018; Harington and Cinq-Mars, 2008), indicate that the late Pleistocene environments at Bluefish Caves were biologically productive. Palynological and paleontological data from Cave I further suggest that the avian diversity likely increased during the Birch interval.

Ptarmigans, ducks, and geese constitute a highly valued source of food and raw material for people living in northern regions, and archaeological evidence in Beringia shows that these species played an important role in humans' subsistence strategies since the late Pleistocene. At Bluefish Caves, one Snow Goose specimen exhibits evidence of butchery, but its age remains uncertain. Although we observed bone modifications on ptarmigan as well, we could not confirm their anthropogenic origins. In sum, our taphonomic study shows that carnivores and birds of prey were likely the main accumulating and modifying agents of the avian remains at Bluefish Caves.

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