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Damage to Pigeon long bones in pellets of the Eagle Owl *Bubo bubo* and food remains of Peregrine Falcon *Falco peregrinus*: zooarchaeological implications

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Abstract. In order to find criteria for distinguishing anthropogenic from non-anthropogenic bird assemblages, a taphonomic analysis of modern Pigeon long bones collected from pellets of the Eagle Owl as well as a study of non-ingested Peregrine Falcon food remains has been conducted. Differences between pellets and non-ingested remains were noted in the skeletal part representation, fragmentation, digestion traces and beak impacts.

Key words: taphonomy, bird bones, food remains, pellets, *Bubo bubo*, *Falco peregrinus*.

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I. INTRODUCTION

Bird remains recovered from archaeological sites may have been deposited by humans, carnivores, raptors, or may have resulted from natural deaths (e. g. MOURER-CHAUVIRÉ 1983; VILETTE 1983; BRAMWELL et al. 1987; ERICSON 1987; BAALES 1992; LIVINGSTON 1989; SERJEANTSON et al. 1993; LAROULANDIE 2000). As a result, the origins of such remains must be deciphered early in any zooarchaeological analysis. Here a taphonomic analysis of modern Pigeon *Columba* sp. long bones recovered from Eagle Owl *Bubo bubo* (LINNAEUS, 1758) pellets and Peregrine Falcon *Falco peregrinus* (TUNSTALL, 1771) food remains (bones not ingested by the raptor) is presented as a contribution toward distinguishing these potential agents. Quantitative and qualitative data concerning skeletal part representation, bone fragmentation, digestion marks and beak impacts are provided. BOCHEŃSKI et al. (1993) have already carried out a study of the patterns of bird bone fragmentation and skeletal part representation in Eagle Owl pellets, but to the best of my knowledge, our study is the first to provide data on digestion traces and beak impacts.

I chose to work on Pigeon long bones for two reasons. The first one is that they were relatively numerous in the moderns collections analysed. The second reason is related to size. Pigeons are medium-size birds like the Ptarmigan and damage to bird bones has been shown to be related to the size of prey species (BOCHEŃSKI et al. 1993). Therefore, these results can be used to determine which agent is responsible for the deposition of Palaeolithic Ptarmigan remains on archaeological sites. I use long bones because they are the most common in the archaeological record.

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II. MATERIAL

The material analysed belongs to Patrick BAYLE. Eagle Owl pellets were collected in the Drôme area (South-Eastern France) from roosts and/or nest sites. More than three hundred Pigeon long bones (NISP = 321), representing a Minimum Number of Individuals of twenty-two, were studied (Table I).

The non-ingested Peregrine Falcon food remains were collected at four localities from South-Eastern France (the first two from Isère and the other two in Aveyron). For this species, more than one hundred bones (NISP = 114), representing twenty individuals, were analysed (Table I).

Table I

Pigeon long bones (NISP), Minimum Number of Elements (MNE) and percentage survival (% survival) in pellets of *Bubo bubo* and food remains of *Falco peregrinus*

Bones	*Bubo bubo*			*Falco peregrinus*		
	NISP	MNE	% survival	NISP	MNE	% survival
Coracoideum	32	22	50.0	16	15	37.5
Scapula	21	19	43.2	12	12	30.0
Humerus	46	32	72.7	37	34	85.0
Ulna	34	25	56.8	20	19	47.5
Radius	18	17	38.6	5	5	12.5
Carpometacarpus	35	34	77.3	14	14	35.0
Femur	41	27	61.4	6	6	15.0
Tibiotarsus	48	33	75.0	3	3	7.5
Tarsometatarsus	46	44	100.0	1	1	2.5
Total	321			114		

III. METHODS

To study the skeletal part representation in these samples, I calculated the percentage survival using BRAIN's equation (BRAIN 1981) [% survival of y = 100*MNEy/MNI*2 ; MNE = Minimum Number of elements; MNI = Minimum Number of Individuals].

Fragmentation of Pigeon long bones was evaluated using the percentage of whole bone (DODSON & WEXLAR 1979) [% of whole bone y = 100* number of whole bone y/total number of y].

Digestion traces were analysed under a binocular microscope at X3 to X15 magnification. In order to determine the distribution of these traces the proximal part, the distal part and the broken ends of shafts were recorded independently. I calculated the percentage areas of showing digestion traces for each bone (e. g. % of proximal part of bone y showing digestion = 100*the digested area of the proximal part of bone y /total area of the proximal part of bone y).

In order to investigate the distribution of beak impacts, the bones were divided into bone segments, as shown in Fig. 1 (see LAROULANDIE 2000 for details). For each segment the number of perforations was counted and the percentage calculated (e.g. % of segment A perforated = 100*number perforations on segment A /total area of segment A).

IV. RESULTS

Skeletal part representation

The pellet material is dominated by the tarsometatarsus, although the carpometacarpus, the distal part of tibiotarsus and the proximal part of humerus are also well represented (Table I). The percentage of wing bones as a proportion of wing and leg bones (ERICSON 1987) is 46,0. Deviation from the expected percentage (50%) is not statistically different ($Z = 0.89$, $p > 0.05$).

The humerus dominates the non-ingested Peregrine Falcon food remains. The scapula, the coracoideum and wing bones, with the exception of the radius, are more common than leg bones (Table I). The percentage of the wing bones (ERICSON 1987) is 87.7. Deviation from the expected percentage is this time statistically significant ($Z = 5.16$; $p < 0.01$).

Bone fragmentation

The frequency of whole bones in pellet material is variable when different bones are compared (Table II). Distal parts of wings and legs (tarsometatarsus and carpometacarpus) show a lesser degree of fragmentation than proximal ones.

In the Peregrine Falcon non-ingested food remains the percentage of whole bones is relatively high and approximately equal frequencies of skeletal elements occur (Table II).

Table II

Percentage of complete Pigeon long bones in pellets of *Bubo bubo* and food remains of *Falco peregrinus* (NISP = Number of Identified Specimens)

Bones (NISP)	*Bubo bubo*			*Falco peregrinus*		
	Whole bone	Fragments	% of whole bone	Whole bone	Fragments	% of whole bone
Coracoideum	4	28	12.5	11	5	68.8
Scapula	4	17	19.0	6	6	50.0
Humerus	1	45	2.2	26	11	70.3
Ulna	10	24	29.4	11	9	55.0
Radius	3	15	16.7	3	2	60.0
Carpometacarpus	20	15	57.1	9	5	64.3
Femur	3	38	7.3	4	2	66.7
Tibiotarsus	5	43	10.4	2	1	66.7
Tarsometatarsus	40	6	87.0	1	0	100.0

Digestion traces

Digestion traces have only been observed on pellet material. They are present on most of the breakage surfaces of most skeletal elements Table III). Digestion of the proximal and distal ends is generally lower than in shaft breaks (respectively : $Z = 12.2$, $p < 0.01$; $Z = 8.7$, $p < 0.01$). The scapular end of the coracoideum, the proximal ends of the humerus and the scapula are less affected by stomach acids.

Table III

Percentage of digestion of proximal ends, distal ends and shaft breakage of Pigeon long bones in pellets of *Bubo bubo*

Bones	Proximal			Distal			Breakage		
	total	dig.	% dig.	total	dig.	% dig.	total	dig.	% dig.
Coracoideum	22	5	22.7	14	5	35.7	28	27	96.4
Scapula	19	2	10.5	–	–	–	21	20	95.2
Humerus	32	9	28.1	15	8	53.3	45	42	93.3
Ulna	22	16	72.7	20	18	90.0	25	25	100.0
Radius	13	5	38.5	7	6	85.7	15	14	93.3
Carpometacarpus	31	27	87.1	24	9	37.5	15	14	93.3
Femur	16	7	43.8	27	20	74.1	39	38	97.4
Tibiotarsus	18	6	33.3	28	20	71.4	48	46	95.8
Tarsometatarsus	42	19	45.2	43	26	60.5	7	7	100.0
Total	215	96	44.7	178	112	62.9	243	233	95.9

Beak impacts

Regarding beak impacts in pellet material, the humerus shows the highest percentage of perforated segments (Table IV). Holes are located near the articular ends (Table IV). The number of beak impacts on the humerus vary between one and four near the proximal end with two being the most common (Table V). Often the impacts are on opposite parts of the bone (Fig. 2). Other long bones are less affected by this type of mechanical damage. There is generally only one hole. The radius is the only bone that shows no impacts (Table V).

Table IV

Percentage of perforated segment of Pigeon long bones in pellets of *Bubo bubo* (see Fig. 1 and Fig. 2)

Bones	% perforated segment				
	A	B	C	D	E
Coracoideum	13.6	0.0	26.7	7.1	–
Scapula	10.5	0.0	0.0	0.0	–
Humerus	65.6	40.0	0.0	7.7	40.0
Ulna	9.1	4.0	0.0	0.0	10.0
Radius	0.0	0.0	0.0	0.0	0.0
Carpometacarpus	6.5	2.9	0.0	0.0	–
Femur	0.0	0.0	0.0	4.3	3.7
Tibiotarsus	0.0	0.0	3.6	6.1	21.4
Tarsometatarsus	0.0	0.0	0.0	4.7	–

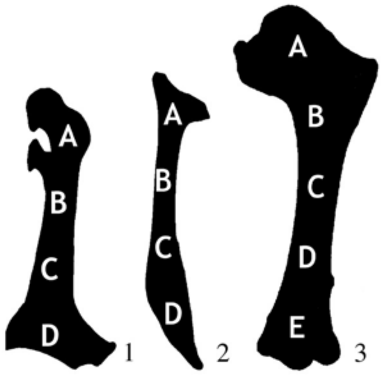

Fig. 1. Segments of bone. 1 designates the coracoideum, carpometacarpus and tarsometatarsus, 2 the scapula and 3 is used for humerus, ulna, radius, femur and tibiotarsus (see Tables IV and V).

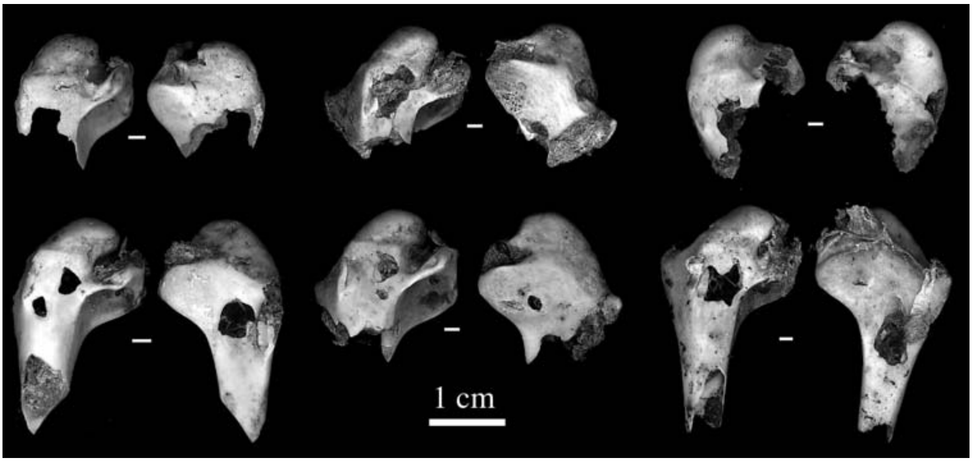

Fig. 2. Bilateral beak impact near proximal end of pigeon humerus in pellets of *Bubo bubo*.

Table V

Perforations of Pigeon long bones in pellets of *Bubo bubo* (see Fig. 1 and Fig. 2)

Bones	Number of perforated segments					Number of perforations by segment					Total number of perforated bones	Total number of perforations
	A	B	C	D	E	A	B	C	D	E		
Coracoideum	3	0	4	1	–	4	0	9	1	–	8	14
Scapula	2	0	0	0	–	4	0	0	0	–	2	4
Humerus	21	4	0	1	6	44	6	0	2	6	32	58
Ulna	2	1	0	0	2	2	1	0	0	2	5	5
Radius	0	0	0	0	0	0	0	0	0	0	0	0
Carpometacarpus	2	1	0	0	–	2	1	0	0	–	3	3
Femur	0	0	0	1	1	0	0	0	1	1	2	2
Tibiotarsus	0	0	1	2	6	0	0	1	3	6	9	10
Tarsometatarsus	0	0	0	2	–	0	0	0	3	–	2	3
Total	30	6	5	7	15	56	8	10	10	15	63	99

Excluding the radius, beak impacts on the Peregrine Falcon food remains, are present on approximately one third to one half of the shoulder girdle and wing bones (Table VI). Because bones of the leg are poorly represented, the percentage is not significant. On visual inspection holes resulting from Peregrine Falcon activity look smaller than those produced by the Eagle Owl. Half of the perforated humeri present only a single hole (Fig. 3). The other half of the humeri present between two and thirteen sets of opposing impacts generally located near the proximal ends.

Table VI

Perforations of Pigeon long bones in food remains of *Falco peregrinus* (see Fig. 3)

Bones	Number of perforated bones	% of perforated bones
Coracoideum	6	37.5
Scapula	4	33.3
Humerus	21	56.8
Ulna	2	10.0
Radius	0	0.0
Carpometacarpus	7	50.0
Femur	0	0.0
Tibiotarsus	2	66.7
Tarsometatarsus	0	0.0

Fig. 3. Beak impact on pigeon humerus in food remains of *Falco peregrinus*.

V. DISCUSSION

The skeletal part representation of Pigeon long bones in Eagle Owl pellets is not statistically different from the observations of BOCHEŃSKI et al. (1993) [$\chi^2 = 4.5$; ddl = 8; $p > 0.05$ for the nest site, $\chi^2 = 10.0$; ddl = 8; $p > 0.05$ for roost site]. I did not, however, observe a predominance of distal tarsometatarsus fragments (N = 43) over its counterpart (N = 42) as argued by these authors. BOCHEŃSKI et al. (1993, 1997, 1998) and BOCHEŃSKI & TOMEK (1994) suggested that this predominance could be used as an indicator of the pellet origin of fossil assemblages. Given our results, the latter suggestion seems unwarranted.

It is difficult to interpret the meaning of the skeletal part representation noted in the non-ingested Peregrine Falcon food remains. More observations are needed to verify if the trend observed in our study results from a sample bias. Analysis of pellet material would allow the documentation of whether there are complementary patterns in these two sources of material.

According to ERICSON (1987) the higher proportion of wing bones over leg bones would indicate a "natural decomposition". The present data shows that Peregrine Falcon may produce a pattern similar to the one recorded for the Great Black-backed Gull *Larus marinus* (LINNAEUS, 1758) [SERJEANTSON et al. 1993], Tawny Owl *Strix aluco* (LINNAEUS, 1758), Eagle Owl (BOCHEŃSKI et al. 1993), Imperial Eagle *Aquila heliaca* (SAVIGNY, 1809) [BOCHEŃSKI et al. 1997] and the Golden Eagle *Aquila chrysaetos* (LINNAEUS, 1758) [BOCHEŃSKI et al. 1999].

The lesser fragmentation of tarsometatarsus and carpometacarpus, compared to other long bones in the pellets material, may be explained by the fact that these parts do not have much meat. As a result, the raptor does not have to break them before swallowing. This is not the case for the other long bones which are rich in meat. The raptors have to reduce them before ingesting them.

The anatomical position of the bone related to meat quantity is not the only factor that determines fragmentation. As mentioned by BOCHEŃSKI et al. (1993), prey size is also an important variable. For example the fragmentation of Turtledove bones, which are smaller than Pigeon bones, is statistically less significant than fragmentation of Pigeon long bones (see LAROULANDIE 2000). To some extent prey size may explain the statistically lower percentages of whole bones obtained in this study compared with the results of BOCHEŃSKI et al. (1993) [Table VII]. Types of pellets, that is resulting from chicks or adult birds, may also explain this difference (BOCHEŃSKI et al. 1993).

Table VII

Proportion of whole bones in pellets of *Bubo bubo* in BOCHEŃSKI et al. (1993) and this study

Bones	Proportion of whole bone			
	BOCHEŃSKI et al. (1993)	This material	Z	p
Coracoideum	0.237	0.125	2.4	0.05
Humerus	0.277	0.022	5.29	0.01
Ulna	0.421	0.294	2.32	0.05
Carpometacarpus	0.756	0.571	3.76	0.01
Femur	0.328	0.073	4.98	0.01
Tibiotarsus	0.169	0.104	1.58	0.05
Tarsometatarsus	0.735	0.869	2.79	0.01

The low fragmentation of bones from non-ingested Peregrine Falcon food remains is quite similar to the percentage observed by BOCHEŃSKI et al. (1997, 1999) on Golden and Imperial Eagles.

The difference in digestion observed between shaft breaks and articular ends may be explained by in the fact that the latter are covered with cartilage which may protect the bones from stomach acids. The preservation of anatomical connections in the pellets may also contribute to this pattern. Indeed the ends that are the least affected by digestion (the scapular end of the coracoideum, the proximal ends of the humerus and the scapula) constitute the scapular girdle which is the most often preserved articulation (Fig. 4).

The differential damage caused by the beak can to some extent be explained by the capacity of the bone to record mechanical pressure. In the pellet material, the radius presents a relatively low percentage of completeness suggesting that the bone is under high pressure. However, there is no evidence of this pressure because this bone is too narrow. The proximal humerus on the other hand,

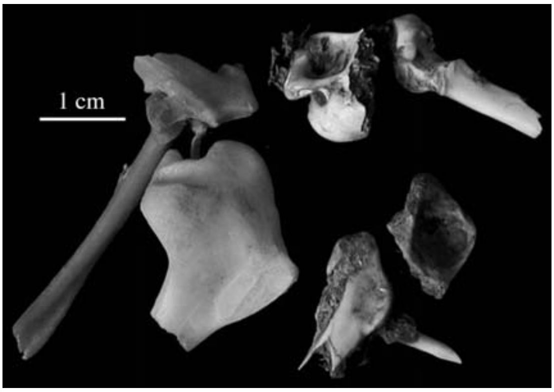

Fig. 4. Preserved scapular girdle of pigeon in pellets of *Bubo bubo*.

which is the largest part of this long bone, is the most affected. Other factors such as anatomical position may also explain differential damage.

VI. CONCLUSION

Based on modern Pigeon long bones several criteria allow the distinction of pellets of Eagle Owl from Peregrine Falcon food remains. The differences have been found in skeletal representation and fragmentation patterns, presence or absence of digestion traces, and types and numbers of beak impacts.

The next question is how to use these criteria to determine the agent causing the accumulation of fossil bird remains? In modern samples factors such as prey size and predator age can cause changes in the patterns produced by the two raptors studied here. These patterns may also overlap with those caused by other raptors. The problem is that with fossil material we have to deal with a much larger number of factors (e.g.: SCHIFFER 1987, LYMAN 1994). The specific damage produced by raptors may partly or completely disappear due to post-depositional processes such as the pressure from overlying sediments, differential survivorship, erosion and mixing of material from different origin (e. g. BOCHEŃSKI & TOMEK 1997, TRAPANI 1998, HIGGINS 1999, LAROULANDIE 2000, DIRRIGL 2001). Therefore the quantitative data presented here should be used with caution. In order to identify the accumulators and unravel the taphonomic history of bird remains the use of a combination of different criteria is necessary.

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