Patterns of bird bone fragmentation in pellets of the Tawny Owl (Strix aluco) and the Eagle Owl (Bubo bubo) and their taphonomic implications

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Abstract. Fragmentation of bird bones in pellets of *Strix aluco* and *Bubo bubo* was studied. Each of the owl species examined showed a different pattern of damaging bones of its bird victims. The differences involve: 1 -the relative abundance of skeletal elements in pellet materials, 2 - characteristic damage to the brain case, 3 - the degree of fragmentation of various skeletal elements, 4 - the relative preservation of the proximal and distal parts of long bones, 5 - the application of different bones (in each owl species) for the calculation of the MNI. Big prey of *S. aluco* suffered more damage than small prey. In *B. bubo*, pellet materials from nest sites differed from those of non-nest sites in respect of the relative abundance of tarsometatarsi and humeri. All these differences can help in the determination of the origin of some fossil assemblages. They also provide valuable information on the ethology of killing.

Key words: taphonomy, bird bones, pellets, Strix aluco, Bubo bubo.

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I. INTRODUCTION

There are many papers analyzing patterns of bone breakage found in pellet materials and comparing them with fossil assemblages. Sometimes it is possible to identify the category of a predator or even the species responsible for the accumulation of fossil assemblages (e.g. FERNANDEZ-JALVO & ANDREWS 1992). However, most of the papers deal exclusively with mammalian prey. Owing to their fragility, bird bones are not so abundant in fossil materials as mammalian remains. It seems, however, that they, too, may be used for taphonomic purposes. To the best of our knowledge, this paper is the first that provides quantitative data on the damage to bird bones in pellets of two species of owls and points to differences which may help ascribe some fossil assemblages to one of them.

II. MATERIAL AND METHODS

Bird bones from about two-thirds of the Tawny Owl pellet material (accumulating for at least 20 years and collected by BOCHEŃSKI (1990) in the suburbs of Kraków, Poland, in June 1984), were used for this paper. The predominant prey species was *Passer domesticus*. The material used in this study contained also remains of at least 23 other bird species. It accumulated in a small wayside shrine used either as a nest site in spring or a roost out of the breeding season. Therefore, it is impossible to say which part of the material was produced by chicks and which by adult birds. Moreover, the pellets could not be clearly distinguished from uneaten remains of prey. In order to examine whether the fragmentation of bones depends on the size of victims eaten, these were divided into two categories: "small" (up to the size of *Passer*) and "big" (including *Turdus, Sturnus, Columba* and others).

Food remains of the Eagle Owl were collected by Ivan MITEV at 21 localities in NE and E Bulgaria in 1990-1993. Three of those localities were used as nest sites, so the material collected there reflects the diet of chicks and females (WAGNER & SPRINGER 1970; CRAMP 1985). The pellets from the remaining localities were produced by adult birds at their roosts. Most of the material was collected between April and September but sporadically also in winter. No division was made in respect of relative prey-size, because the material had not been determined yet. For comparisons with the Tawny Owl material the pellets from all the 21 localities were used. This seemed expedient because material of Tawny Owls also comprised remains from nest as well as roost sites.

Some pellets of the Eagle Owl were collected on Strandzha Mountain, Bulgaria. Unfortunately, a part of the material was lost and bones of only two prey taxa (*Columba* and *Perdix*) remained. For that reason that material was not included in this study; it was used only as additional, reference material.

In order to determine the fragmentation of the skeleton several categories for each skeletal element were established (Figs. 1-5) and the number of bones (fragments) in each category was counted. No distinction was made between bones of the left and the right side. For the sake of simplicity, the same categories were used for all long bones of the limbs as well as for the coracoideum, scapula and phalanx I dig. majoris. In the case of the scapula, its distal parts were counted together with the middle parts of the shaft, and the two categories were presented jointly in the category "shaft". The sternal part of the coracoideum was treated as proximal, and the scapular part – as distal.

In order to compare the relative numbers of whole and broken long bones in both these owl species, the numbers of whole bones were multiplied by two. Such a procedure was necessary because after its breakage each bone is represented by at least two pieces: a proximal and a distal. In other words, each whole bone was given two points, and each fragment of a bone one point. For further statistical analysis, points – and not the numbers of bones – were used.



Fig. 1. Categories of fragmentation of the skull in pellets of Tawny Owls and Eagle Owls: A – whole skull with beak; B – skull with beak and brain case without back part; C – brain case without back part; D – brain case; E – whole beak; F – end of beak.



Fig. 2. Categories of fragmentation of the mandibula in pellets of Tawny Owls and Eagle Owls: A – whole; B – one branch; C – articular part; D – tip of mandibula; E – middle part of branch.

The minimum number of individuals (MNI) was calculated for each bone separately. The results were presented in two ways: as numbers and as percentages of the highest value obtained for the tarsometatarsus or humerus – whichever showed the higher MNI. The MNI values would certainly have been higher, if the bones had been determined. That is why in calculating the MNI, we did not take into account the determination of bones. Neither was an attempt made to fit the proximal and distal parts together. Instead, the number of whole bones and that of proximal or distal parts of the left or right side – whichever was more numerous – were taken. Such a procedure may have slightly lowered the results but the error is believed to be the same for each kind of bone.

Chi-square test was used to examine the statistical significance of the results. In all the cases there was one degree of freedom (df=1). Although in several cases the levels of statistical significance were higher than we report, we decided to set them at 0.05 or 0.01



Fig. 3. Categories of fragmentation of the sternum in pellets of Tawny Owls and Eagle Owls: A – more than one-half of sternum with rostrum (i.e. including whole sternum); B – less than one-half of sternum with rostrum.



Fig. 4. Categories of fragmentation of the pelvis in pellets of Tawny Owls and Eagle Owls: A – synsacrum with one or two ilium-ischii-pubis bones (i.e. whole pelvis included); B – ilium-ischii-pubis bone; C – synsacrum (whole or partial); D – acetabulum region.



Fig. 5. Categories of fragmentation of long bones in pellets of Tawny Owls and Eagle Owls: A – whole bone (in carpometacarpus – os metacarpale III and IV may be missing); B – proximal part (with or without shaft); C – distal part (with or without shaft); D – shaft.

III. RESULTS

Skulls and their fragments were very numerous in the pellet material of *S. aluco*. On the contrary, in the *B. bubo* pellets, remains of skulls were seldom found (Table I). In the Eagle Owl no whole skull with its beak was found; in the Tawny Owl 7% of all skulls fell in this category (Table I: column 2). Sixteen per cent of all the skull fragments of *S. aluco* victims were characteristically damaged: the back part of the brain case up to the condylus occipitalis was missing (Table I: columns 3 and 4 jointly). Brain cases damaged in such a way formed 70% of all the brain cases which were not broken to pieces (Table I: columns 2, 3, 4 and 5 jointly). On the contrary, the brain cases of *B. bubo* victims were either undamaged or broken to pieces (Table I: columns 5 and 8). Beaks belonged to the most

Table I

Fragmentation of the skull and beak in pellets of *S. aluco* and *B. bubo* expressed as percentages of the total number of all skull fragments found (see Fig. 1). MNI [%] is the percentage of the highest value of the MNI (obtained with humerus) formed by the number of individuals estimated on the basis of a given bone

Species	Whole skull (%)	Skull with beak and brain case without back part (%)	Brain case without back part (%)	Brain case (%)	Whole beak (%)	End of beak (%)	Other fragments $(\%)$	Total of broken parts (%)	(N)	(%)
1	2	3	4	5	6	7	8	9	10	11
S. aluco (N=275)	7	11	5	0	54	18	5	93	248	96
B. bubo (N=56)	0	0	0	9	39	21	30	100	35	22

numerous fragments of skulls found in pellets of both owl species. However, their number in relation to the number of all other skull fragments (Table I: columns 2, 3, 6, 7 jointly versus 2, 3, 4, 5, 8 jointly) was significantly different in each species, ($\chi^2 = 6.04$, p<0.01).

Mandibles from the pellets of the two species examined showed one statistically significant difference: in *S. aluco* 39% of all mandibles were undamaged, while in *B. bubo* the corresponding figure was only 2% (Table II: column 2 versus 7; $\chi^2 = 27.06$, p<0.01).

Table II

Fragmentation of the mandibula in pellets of *S. aluco* and *B. bubo* expressed as percentages of the total number of all mandibular fragments found (see Fig. 2). For MNI [%] – see Table I

Species	Whole (%)	One branch (%)	Articular part (%)	Tip of mandibu- la (%)	Middle part of branch (%)	Total of broken parts (%)	MNI (N)	MNI (%)
1	2	3	4	5	6	7	8	9
<i>S. aluco</i> (N=451)	39	13	29	12	7	61	234	90
B. bubo (N=51)	2	14	35	27	22	98	22	14

In the pellet remains of *S. aluco*, the rostrum sterni was present in 81% of all the fragments of the sternum (Table III: columns 2 and 3 jointly); in *B. bubo*, other parts of the sternum, without the rostrum sterni, prevailed (58%). The difference was statistically significant ($\chi^2 = 56.30$, p<0.01).

Table III

Fragmentation of the sternum in pellets of *S. aluco* and *B. bubo* expressed as percentages of the total number of all sternal fragments found (see Fig. 3). For MNI [%] – see Table I

Species	More than 1/2 with rostrum (%)	Less than 1/2 with rostrum (%)	Fragments without rostrum (%)	MNI (N)	MNI (%)
1	2	3	4	5	6
S. aluco (N=215)	16	65	18	174	67
B. bubo (N=125)	10	33	58	54	34

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Of all pelvic fragments, the synsacrum was most numerous in the pellets of both owl species. Its proportion in *S. aluco* reached 77% and in *B. bubo* 49% (Table IV: columns 2 and 4 jointly). Fragments of the acetabulum region in *B. bubo* were 3.5 times as numerous as in *S. aluco* (Table IV: column 5).

In S. aluco and B. bubo, the degree of bone fragmentation (whole bones versus all

Table IV

Fragmentation of the pelvis in pellets of S. aluco and B. bubo expressed as percentages of the total number of all pelvic fragments found (see Fig. 4). For MNI [%] – see Table I

Species	Synsacrum with 1 or 2 ilium-ischii- pubis bones (%)	Ilium-ischii- pubis bone (%)	Synsacrum whole or partial (%)	Acetabulum region (%)	MNI (N)	MNI (%)
1	2	3	4	5	6	7
S. aluco (N=186)	20	14	57	9	144	56
B. bubo (N=114)	13	18	36	33	58	36

broken parts), expressed in points, was significantly different in 7 out of the 10 long bones (Table V: columns 7 and 8): scapula ($\chi^2 = 9.17$, p<0.01), humerus ($\chi^2 = 99.18$, p<0.01), ulna ($\chi^2 = 22.18$, p<0.01), radius ($\chi^2 = 5.27$, p<0.05), femur ($\chi^2 = 29.08$, p<0.01), tibiotarsus ($\chi^2 = 7.67$, p<0.01), tarsometatarsus ($\chi^2 = 15.71$, p<0.01). Only in the case of the coracoideum, carpometacarpus and phalanx I dig. majoris, their patterns of fragmentation did not show any statistical differences between *S. aluco* and *B. bubo*. In the Tawny Owl, whole bones outnumbered fragments as regards the humerus, ulna, radius, carpometacarpus, phalanx I dig. majoris, femur and tarsometatarsus, whereas the three remaining bones (scapula, coracoideum and tibiotarsus) were more often broken. In the Eagle Owl, five bones gained more points for the category "whole" (ulna, radius, carpometacarpus, phalanx I dig. majoris and tarsometatarsus). The remaining bones got more points for the category "broken": scapula, coracoideum, humerus, femur (difference of 3 points only) and tibiotarsus.

In both species, the total number of the proximal parts found in the material (whole bones and proximal parts) was compared with the total number of the distal parts (whole bones and distal parts) for each long bone (Table V: columns 2, 3 and 4). The relative number of both endings differed significantly between the owl species only in the case of the tibiotarsus ($\chi^2 = 5.42$, p<0.05). In this bone, proximal parts prevailed over distal (277 to 242) in the Tawny Owl, while in the Eagle Owl distal parts outnumbered the proximal (150 to 121).

Fragmentation of long bones in pellets of *S. aluco* and *B. bubo* expressed as percentages of the total number of all long-bone-fragments found (see Fig. 5). In scapula: distal part and shaft are shown jointly in the category "shaft". In coracoideum: proximal = sternal, distal = scapular. Columns 7 and 8 show points used for statistical analysis (for explanation – see "Material and Methods"). For MNI [%] – see Table I

Bones/species	Whole bone	(%)	Proximal part	(%)	Distal part	(%)	Shaft	(%)	Total of broken parts	(%)	Whole bone	(points)	Total of broken parts	(points)	MN (N	VI ()	MI (%	VI b)
1	2	2	3		4		5		6	,	7		8		9		10)
<i>S. aluco</i> (N=448) SCAPULA	11		51			`	38		89		98		399		163	0.0	63	50
B. bubo (N=148)		18	2	71				11		82		54	100	121	10/	80	=	50
S. aluco (N=512) CORACOIDEUM B. hubo (N=177)	21	24	24	14	54	62	0	0	79	76	218	84	403	135	196	92	/6	58
S. aluco (N=623) HUMERUS	55	24	26	14	15	02	5	•	45		684		281		259		100	
B. bubo (N=357)		28		38		32		3		72		198		258		160		100
S. aluco (N=522) ULNA	58	1	19		21	See.	2		42		602		221		217	1019	84	100
B. bubo (N=247)	17/10]	42		29		27		2		58	10.00	208		143		112		70
S. aluco (N=345) RADIUS	58		32		10		0		42		398		146		156		60	
<i>B. bubo</i> (N=101)		47		41		12		1		53		94		54		55		34
S. aluco (N=436) CARPOMETACARPUS	77	76	8		14	•	1	2	23	24	672	260	100	12	203	101	78	63
B. bubo (N=172) S. aluco (N=165)	88	/6	9	14	2	9	0	2	12		292	200	19	42	83	101	32	05
B. bubo (n=27)		100		0		0		0	02.23	0	el.h	54	noist	0		15	atte	9
S. aluco (N=433) FEMUR	52		29		17		1		48		452		207	B G d	180		69	
B. bubo (N=192)		33		30		37		1	1	67		126		129		96		60
S. aluco (N=479) TIBIOTARSUS	24	101	34		27		15		76		228		365		141		54	
B. bubo (N=248)		17		32		44		8		83		84		206		116		72
S. aluco (N=447) TARSOMETATARSUS B. hubo (N=257)	60	74	10	5	27	19	3	3	40	26	536	378	179	68	196	154	76	96
D. DUDU (14=237)		74		5	1	10	1	2	1	20	1	510	1	50	1		1	

When only broken long bones were taken into account (Table V: columns 3 and 4), five various kinds of bones showed statistically significant differences between the numbers of proximal and distal parts in both *S. aluco* and *B. bubo*: coracoideum ($\chi^2 = 7.66$, p<0.01), humerus ($\chi^2 = 4.03$, p<0.05), carpometacarpus ($\chi^2 = 7.47$, p<0.01), femur ($\chi^2 = 10.68$, p<0.01) and tibiotarsus ($\chi^2 = 8.63$, p<0.01). In the same owls, proximal parts outnumbered the distal as regards the humerus and radius, while in the coracoideum and tarsometatarsus the distal parts were more numerous. The ulna showed almost no differences between the proximal and distal parts were more numerous than the distal in *S. aluco*, but less numerous in *B. bubo*. In the carpometacarpus, distal parts prevailed over the proximal in *S. aluco* and conversely in *B. bubo*.

The category "shaft" in long bones was never numerous; in some cases no shaft was found (Table V: column 5).

Remains of relatively big prey (of the size of *Turdus* or *Columba*) were seldom found in Tawny Owl pellets (Table VI). In general, bones of category "big" were significantly more often broken than those of category "small" ($\chi^2 = 26.33$, p<0.01). It is worth noticing that in big prey no whole element of the head and trunk was preserved.

Table VI

	Whole	bones	Broken bones			
Skeletal elements	small (N)	big (N)	small (N)	big (N)		
CRANIUM	19	0	245	11		
MANDIBULA	174	0	251	26		
STERNUM	2	0	212	1		
PELVIS	16	0	170	0		
SCAPULA	49	0	384	15		
CORACOIDEUM	102	7	390	13		
HUMERUS	337	5	278	3		
ULNA	295	6	212	9		
RADIUS	197	2	135	11		
CARPOMETACARPUS	310	9	106	11		
PHALANX I DIG. MAJ.	138	8	17	2		
FEMUR	224	2	203	4		
TIBIOTARSUS	114	0	353	12		
TARSOMETATARSUS	264	4	174	5		
TOTAL	2241 (4482)	43 (86)	3130 (3130)	123 (123)		

Number of whole and broken skeletal elements in Tawny Owl's prey of the small and big size. Figures in brackets indicate points used for statistical analysis (for explanation – see "Material and Methods") Long bones of Eagle Owls were significantly more often broken at nest sites than at roosts (Table VII, data for all skeletal elements jointly: ($\chi^2 = 13.61$, p<0.01). The differences were especially big for the coracoideum ($\chi^2 = 9.14$, p<0.01), the humerus ($\chi^2 = 19.15$, p<0.01) and the ulna ($\chi^2 = 14.65$, p<0.01).

The last columns of Tables I-V show the MNI calculated on the basis of each kind of bone and expressed as percentages of the highest value. The sequence of bones in *S. aluco*, from highest to lowest MNI values, is as follows: humerus (100%), skull (96), mandibula (90), ulna (84), carpometacarpus (78), coracoideum (76), tarsometatarsus (76), femur (69), sternum (67), scapula (63), radius (60), pelvis (56), tibiotarsus (54), phalanx I dig. majoris (32). In the case of *B. bubo*, the sequence differs considerably: humerus (100%), tarsometatarsus (96), tibiotarsus (72), ulna (70), carpometacarpus (63), femur (60), coracoideum (58), scapula (50), pelvis (36), sternum (34), radius (34), skull (22), mandibula (14), phalanx I dig. majoris (9). It is worth noting that in both species the sequences begin and end with the same bone (humerus and phalanx I dig. majoris, respectively). The biggest differences are in the case of the victims' heads (skulls and mandibles), which are at the

Table VII

Number of whole bones and all broken parts collected at nest and roost sites of Eagle Owls. Figures represent points (for explanation – see "Material and Methods"). Asterisks (*) indicate bones which were significantly more often broken at nest sites

	Ne	st	Non-nest			
Skeletal elements	whole bones (points)	total of bro- ken parts (points)	whole bones (points)	total of bro- ken parts (points)		
SCAPULA	24	49	30	72		
CORACOIDEUM *	22	63	62	72		
HUMERUS *	58	128	140	130		
ULNA *	68	76	140	67		
RADIUS	40	25	54	29		
CARPOMETACARPUS	102	21	158	21		
PHALANX I DIG. MAJ.	30	. 0	24	0		
FEMUR	50	60	76	69		
TIBIOTARSUS	50	102	34	104		
TARSOMETATARSUS	204	45	174	23		
A hada faala						
TOTAL	648	569	892	587		

top of the Tawny Owl MNI list but were poorly represented in the pellet material of the Eagle Owl. In *S. aluco*, apart from phalanx I dig. majoris, the MNI values calculated for each bone separately, were above 50%. On the contrary, in *B. bubo*, the percentages of the MNI calculated on the basis of six various bones (pelvis, sternum, radius, skull, mandibula, phalanx I dig.majoris) were below 50%.

The Eagle Owl material collected at nest sites differed significantly ($\chi^2 = 4.98$, p<0.05) from that from non-nest sites in respect of bones with the highest MNI value (Table VIII). The tarsometatarsus reached the highest numbers at nest sites, the humerus at non-nest sites. The sequence of the remaining bones differed only slightly; the axial skeleton provided the lowest MNI values in both cases. Apart from the tibiotarsus and tarsometatarsus, the MNI values calculated using other elements of the skeleton from non-nest sites were either higher than or similar to those from nest sites.

Table VIII

Comparison of the minimum number of individuals (MNI) calculated on the basis of each skeletal element at nest and roost sites of the Eagle Owl. MNI [%] is the percentage of the highest value of the MNI (obtained with tarsometatarsus at nest sites and humerus at roosts) formed by the number of individuals estimated on the basis of a given bone

	N	ÍNI	MNI			
Skeletal elements	nest (N)	non-nest (N)	nest (%)	non-nest (%)		
CRANIUM	11	24	14	24		
MANDIBULA	5	17	7	17		
STERNUM	24	30	32	30		
PELVIS	20	38	26	38		
SCAPULA	29	51	38	50		
CORACOIDEUM	34	58	45	57		
HUMERUS	59	101	78	100		
ULNA	36	76	47	75		
RADIUS	24	31	32	31		
CARPOMETACARPUS	36	65	47	64		
PHALANX I DIG. MAJ.	8	7	11	7		
FEMUR	38	58	50	57		
TIBIOTARSUS	61	55	80	54		
TARSOMETATARSUS	76	78	100	77		

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IV. DISCUSSION

Eagle Owls often decapitate their victims before eating them but their heads are not always eaten (GLUTZ VON BLOTZHEIM & BAUER 1980). That is why in our material skulls and mandibles were less numerous than the other bones. A similar conclusion has been reached also by other authors (e.g. WAGNER & SPRINGER 1970). Although S. aluco may also decapitate its prey (CRAMP 1985), it eats up the head of the prey and so both the skulls with beaks and mandibles supply reliable information on its diet. In the Tawny Owl many beaks - and in the Eagle Owl all of them - were detached from brain cases. The difference is almost certainly due to different construction of the beak in prey species. Passer domesticus, the predominant victim of our Tawny Owls, has a stout bill firmly-attached to the brain case. On the contrary, individuals of the genus Columba, which were most heavily preyed upon by our Eagle Owls, have relatively light-constructed beaks. Hence, it is not surprising that their upper and lower mandibles were more affected than those of the Tawny Owl victims. Our results correspond well with those of BOCHEŃSKI (1960); he also failed to find complete skulls in pellets of the Eagle Owl. Characteristic damage to the back part of the brain case in S. aluco victims is probably due to the ethology of killing. Similar damage to the brain case as the result of killing has also been reported for such species of owls as Athene noctua (OLES 1961; KULCZYCKI 1964) and Tyto alba (KULCZYCKI 1964). In all cases the owls hit their prey on the head with the beak. In Eagle Owls' pellets from NE Bulgaria, we found no brain cases damaged in this way. However, in our additional material from Strandzha Mountain, Bulgaria, 32% of all brain cases (which were not broken to small pieces) lacked their back parts. It indicates that the Eagle Owl may also kill birds by hitting them on the head. It seems, however, that this behaviour is much more typical of the Tawny Owl.

It seems that of the two owls examined, *B. bubo* does more damage to the trunk of its victims than does *S. aluco*: the sternum and pelvis were more often broken to small pieces by the former species than by the latter (Table III: column 4; Table IV: column 5). It is probably due to the fact that the relative size of the Eagle Owl's prey is bigger than that of the Tawny Owl's and, consequently, the Eagle Owl is not able to swallow many of its victims whole. On the other hand, the Tawny Owl has been described to swallow a Sparrow whole (CRAMP 1985). In describing damage done to mammalian bones, ANDREWS (1990) found also that a much higher degree of breakage occurs when the prey size is large relative to the size of the predator. Also BOCHEŃSKI (1960) observed that bones of smaller birds were less damaged than those of bigger species in food remains of the Eagle Owl. As our material of Eagle Owls has not been determined yet, we could compare the degree of fragmentation only between "small prey" and "big prey" for Tawny Owls (Table VI). According to expectations, the bones of big prey tended to be more often broken than those of small prey. The difference was especially distinct in the case of bigger elements that formed the axial skeleton (head and trunk).

The Eagle Owl seems to break long bones of its victims more often than the Tawny Owl (Table V). In *B. bubo*, the category "whole" prevailed only in three kinds of bones, which are relatively short and stout (carpometacarpus, phalanx I dig. majoris and tarsometatarsus). On the other hand, in the Tawny Owl the category "broken" prevailed only in

the case of very fragile bones (scapula and tibiotarsus) and the coracoideum. Although the coracoideum does not look fragile, it suffered heavy damage from both species of owls. It is probably due to the fact that its sternal part is firmly attached to the sternum, and owls -especially Tawny Owls - must break it (before or during swallowing) to make the victim a more compact lump. In the Eagle Owl material, the shoulder joint was often cut off from the victim's body but not dismembered: the scapular part of the coracoideum was attached to the proximal parts of the humerus and scapula. This corresponds well with BOCHEŃSKI's (1960) conclusion that Eagle Owls cut off the wings of their victims with their beaks rather than tear them asunder. This practice must be common to the Eagle Owl, because (contrary to the Tawny Owl) most of its victims' humeri were broken. After breakage, all parts of the wing are eaten because, in our material, the distal parts of the humerus were almost as frequent as the proximal. The radius, with its long thin shaft, is apparently a fragile bone. Nevertheless, we found surprisingly many whole radii in the pellets of both owls, which indicates that the bone is well-protected by the stout ulna. For some reasons, distal parts of legs (with tarsometatarsi) are apparently not always eaten by Tawny Owls. According to RACZYŃSKI and RUPRECHT (1974), the legs of 2 out of the 15 Sparrows fed to an adult S. aluco, were never eaten. The percentage representation for the phalanx I dig. majoris in pellets of both owl species was very low. It is difficult to say whether or not these bones were eaten or digested. They may have been detached from wings when the prey was plucked. Owls often pluck birds before eating (e.g. MÄRZ 1958; THIOLLAY 1963; GLUTZ VON BLOTZHEIM & BAUER 1980; CRAMP 1985) but nothing is known about damage done to bones during plucking. On the other hand, phalangae I dig. majoris are firmly attached to carpometacarpi, and when birds are plucked by people, the bones remain attached to the wing.

The relative preservation of proximal and distal parts differed between *S. aluco* and *B. bubo* only in the case of the tibiotarsus. A similar comparison, based exclusively on broken bones, showed more differences in frequency of the two endings, but here we must be more cautious because the samples were less numerous and the results may be more influenced by the species composition of the prey in owl diets. It seems that the preservation of each particular part of a bone depends on its construction: the stouter the ending, the more frequently it is found in pellet materials. It is worth noting that in pellets of both owls the scapular part of the coracoideum was much more numerous than the sternal part. Thus, in fossil material the relative abundance of both parts of the coracoideum may indicate its pellet origin. However, this problem calls for additional studies on the damage to the coracoideum under natural conditions (e.g. erosion).

WAGNER & SPRINGER (1970) and CRAMP (1985) have already noticed that bones in Eagle Owl pellets collected from nest sites are more often broken because female owls dismember prey and give its small pieces to their chicks. Now we can specify those observations: in general they are correct but three bones (coracoideum, humerus and ulna) suffer significantly more damage than the others (Table VII). As two of them belong to the shoulder joint, it seems that the behaviour of cutting it off, described by BOCHEŃSKI (1960), is typical rather of female owls at nest sites than of other adult owls at roost sites.

A comparison of the MNI calculated for each element of the skeleton, shows the relative importance of each bone in analyzing the pellet materials of both owl species. In the Tawny Owl, three bones (humerus, skull and mandible) reached higher values than 90% of the MNI. Similar results (without any precise figures) have also been reported by GLUTZ VON BLOTZHEIM & BAUER (1980) but the first person who used "beaks and their fragments" to calculate MNI was probably RÖRIG (1910). Consequently, it is advisable to use these three bones for this purpose. The remaining elements of the skeleton may provide some additional data on rare victims but generally their contribution to the calculation of the MNI is rather small. In our study, two bones (humerus and tarsometatarsus) provided higher values than 90% of the MNI for the whole Eagle Owl material (Tables I-V: last columns). WAGNER & SPRINGER (1970) used "four most numerous bones" to calculate MNI (femur, humerus, tarsometatarsus and coracoideum). In our study, however, the MNI values calculated on the basis of the femur and the coracoideum were only in the middle of the sequence-list including all the elements of the skeleton. According to BEZZEL et al. (1976), the tarsometatarsus provides the highest values of the MNI in eight species of the B. bubo bird victims. The values for the humerus (expressed as percentages of the highest value of the MNI) range - depending on the victim species from 25% to 81%. A precise comparison of our results with those of BEZZEL et al. (1976) is not possible because our material was not determined to species level. However, Table VIII of our paper provides a good explanation of the above-mentioned difference. It shows that the predominance of the tarsometatarsus or the humerus is strictly connected with the origin of the material (from nest sites or non-nest sites). And so the material of BEZZEL et al. (1976) must have been collected at nest sites. Our material contained pellets from both kinds of sites and that is why both bones (tarsometatarsus and humerus) provided almost equal percentages of the MNI. The predominance of tarsometatarsi over humeri (or vice versa) in fossil assemblages of pellet origin indicates whether the material accumulated at a nest site or a non-nest site.

Damage to bird bones in pellets of the Tawny Owl is different in many aspects from that of the Eagle Owl. All these differences should be sufficient to ascribe fossil assemblages to one or the other of the owl species. The fact that victims of the two species examined differ in size would make it even easier. FERNANDEZ-JALVO and ANDREWS (1992) included Tawny Owls and Eagle Owls in the same category of predators, moderately or heavily digesting the tooth enamel of small mammals. In doubtful cases, taking into account the kind of breakage of bird bones could help distinguish fossil materials accumulated by them. KORTH (1979) found that percentage representations of mammalian skeletal elements in Bubo virginianus and Tyto alba were nearly identical. Both owls showed an extremely high representation for all elements. If he had included bird bones in his study, he would probably have found more differences. Before any comparison with a fossil bird material can be done, the breakage of bird bones from pellets of other species of owls should be studied. It would be also important to study the effect of post-depositional factors (e.g.erosion) on bird bone damage. Our results indicate that studies of bird bone damage in pellet materials may provide valuable information on the taphonomy of fossil assemblages and, indirectly, on the ethology of killing.

V. FINAL CONCLUSIONS

The fragmentation of bird bones in pellet materials provides interesting information on the ethology of killing, and can be used to ascribe fossil assemblages to a certain species of owls (predator) – especially in cases where bones of mammalian prey remain untouched. Tawny Owls and Eagle Owls show different patterns of damaging their bird victims. The most characteristic features are as follows:

1. Skulls and mandibles are rare in pellets of Eagle Owls but very numerous in Tawny Owls.

2. About 70% of all recognizable brain cases of *S. aluco* victims lack the back part as the result of killing. Such damage is much less typical of *B. bubo* victims.

3. Eagle Owls tend to break bones of their bird victims more often than do Tawny Owls. It is probably due to the owl / prey size relation.

4. In S. aluco, bones of small prey are less affected by breakage than those of big prey.

5. A significant difference in preservation of the proximal and distal parts of bones was found in the tibiotarsus. Proximal parts were more numerous in pellets of *S. aluco*, distal parts in those of *B. bubo*.

6. Scapular parts of the coracoideum are much more numerous in pellets of both owls than sternal parts. The fact may be used as an evidence of the pellet origin of some fossil assemblages.

7. In S. aluco, three bones (humerus, skull, mandible) provide very good results in the calculation of the MNI.

8. In *B. bubo*, the tarsometatarsus is the best bone for the calculation of the MNI at nest sites, and the humerus - at non-nest sites. The fact may serve as an extra evidence of the nest or non-nest origin of fossil materials.

REFERENCES

ANDREWS P. 1990. Owls, Caves and Fossils. Natural History Museum Publications, London, 231 pp.

BEZZEL E., OBST J., WICKL K. H. 1976. Zur Ernährung und Nahrungswahl des Uhus (Bubo bubo). J. Orn., 117: 210-238.

BOCHEŃSKI Z. 1960. The diet of the eagle-owl Bubo bubo (L.) in the Pieniny Mts. Acta zool. cracov., 5(8): 311-333.

BOCHEŃSKI Z. Jun., 1990. The food of suburban Tawny Owls on the background of birds and mammals occurring in the hunting territory. Acta zool. cracov., 33(9): 149-171.

CRAMP S. (ed.,) 1985. Handbook of the birds of Europe, the Middle East and North Africa: the Birds of the Western Palearctic. IV. Terns to Woodpeckers. Oxford, New York. Oxford Univ. Press., 616 pp.

FERNANDEZ-JALVO Y., ANDREWS P. 1992. Small Mammal Taphonomy of Gran Dolina, Atapuerca (Burgos), Spain. J. Archeol. Sc., 19: 407-428.

GLUTZ VON BLOTZHEIM U. N., BAUER K.M. (eds.,) 1980. Handbuch der Vögel Mitteleuropas. Bd. 9. Akademische Verlagsgesellschaft, Wiesbaden, 1148 pp.

- KORTH W. W. 1979. Taphonomy of microvertebrate fossil assemblages. Ann. Carnegie Mus. Nat. Hist., 48: 235-285.
- KULCZYCKI A. 1964. Study on the make up of the diet of owls from the Niski Beskid Mts. [In Polish with English summary]. Acta zool cracov., 9(9): 529-559.
- LOWE V. P. W. 1980. Variation in digestion of prey by the Tawny Owl (Strix aluco). J. Zool., 192: 283-293.
- MÄRZ R. 1958. Der Uhu (Bubo bubo L.). Neue Brehm-Büherei, Ziemsen Verlag, Wittenberg Lutherstadt, H. 108, 48 pp.
- OLES T. 1961. Observations on the food habits in Little Owl. [In Polish with English summary]. Przegląd Zool., 5(4): 377-378.
- RACZYŃSKI J., RUPRECHT A. L. 1974. The effect of digestion on the osteological composition of owl pellets. Acta zool. cracov., 14(2): 25-38.
- Rörig G. 1910. Magen- und Gewölluntersuchungen heimischer Raubvögel. Arb. aus der Kais. Biol. Anst. f. Land- u. Forstwirtschaft, 7(4): 473-520.

THIOLLAY J.-M. 1963. Les "pelotes" de quelques Rapaces. Nos Oiseaux, 27: 124-131.

WAGNER G., SPRINGER M. 1970. Zur Ernährung des Uhus Bubo bubo im Oberengadin. Orn. Beobachter., 67: 77-94.