Belg. J. Zool. — Volume 122 (1992) — issue 1 — pages 123-132 — Brussels 1992

(Manuscript received on 11 March 1991)

CORRELATION BETWEEN THE WING LENGTH OF LIVING BIRDS AND MEASUREMENTS OF THEIR BONES

by

ZYGMUNT BOCHEŃSKI and ZBIGNIEW BOCHEŃSKI Jun.
Institute of Systematics and Evolution of Animals,
Polish Academy of Sciences,
Slawkowska 17, 31-016 Kraków, Poland

SUMMARY

An indirect method useful in identifying fossil and recent bird bone remains is described. In birds belonging to one group (genus, family) of similar body plan, various measurements of the bones are correlated with wing length. The latter parameter may be easily found in ornithological literature. The minimal and maximal measurements of the wing length compared with the minimal and maximal measurements of a bone, show linear arrangement in diagrams. It enables us to estimate the wing length on the basis of the size of a bone which may be helpful in determining the taxonomic position of the bone — even if the species is not represented in osteological collections.

Key words : bird, wing length, bone sizes, correlation, identification.

INTRODUCTION

Dimensions of bones play an important role in identifying fossil and contemporary bird remains. The complete data on skeletal measurement are available in literature only for a very limited number of recent bird species. Direct comparison with well-determined skeletal specimens is not always possible. There are more than 100 osteological collections in the world. However, specimens of rare birds are either well-dispersed or missing altogether (WOOD and SCHNELL, 1986). As a consequence, the comparative material for determination is sometimes hardly available. That is why it is often necessary to look for indirect methods. The purpose of this paper is to determine to what degree and in which cases the size of a bone fragment is connected with wing length (the latter parameter is commonly cited in ornithological literature). In other words, whether the size of a bone fragment can indicate the wing length which, in turn, may support the identification of the species.

MATERIAL AND METHODS

At first wing lengths of individual birds were compared with their bone measurements (the width of the distal articular part of the humerus and tibiotarsus) in the series of skeletal specimens stored at the Institute of Systematics and Evolution of Animals, Polish Academy of Sciences (ISEA). The wing length was measured before preparation from the carpal joint to the tip of the longest primary. The specimens represented two phylogenetically distant genera : *Larus* and *Corvus*. The results are shown in the diagrams (Fig. 1 A, B and 2 A, B). For each, the reduced major axis and the correlation coefficient were calculated (r between 0.93 and 0.97).

Afterwards, the same 4 species of the genus *Corvus* from Fig. 2 A and B and the same parameters were studied in a different way. The minimal and maximal measurements of the wing lengths were plotted against the minimal and maximal measurements of their bones (Fig. 3 A, B). All of those data — based on large series of individuals — were taken from literature (FERENS, 1967 ; TOMEK, in prep.). The graph of minimal versus maximal values of bone and wing parameters delivers four points so, each species is covered by one rectangle in the diagram. It should

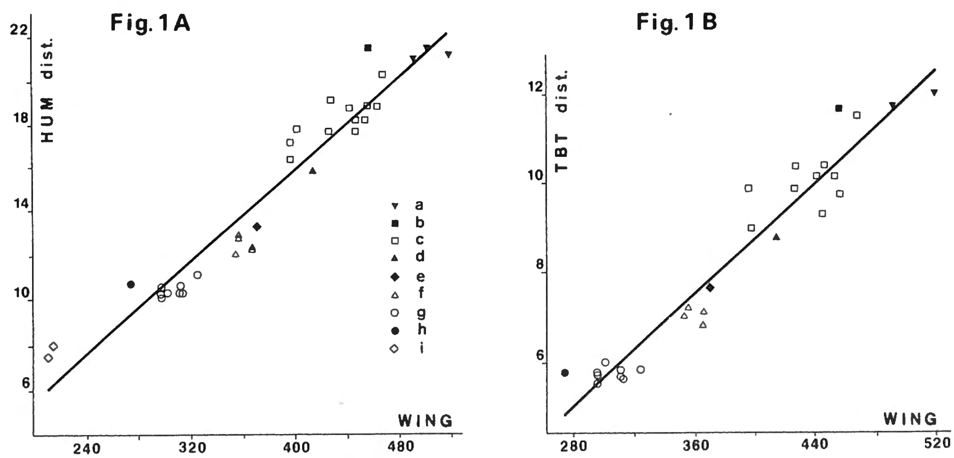
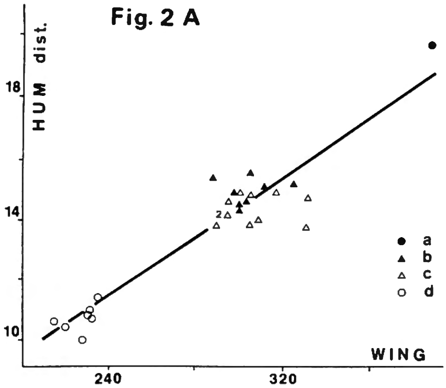


Fig. 1A. — The relationship between the wing length (WING) and the width of the distal part of the humerus (HUM dist.) in the genus *Larus*. Each point indicates one individual. Legend : a — *L. marinus* LINNAEUS, 1758 ; b — *L. hyperboreus* GUNNERUS, 1767 ; c — *L. argentatus* PONTOPPIDAN, 1763 ; d — *L. californicus* LAWRENCE, 1854 ; e — *L. delavarensis* ORD, 1815 ; f — *L. canus* LINNAEUS, 1758 ; g — *L. ridibundus* LINNAEUS, 1766 ; h — *L. pipixcan* WAGL, 1831 ; i — *L. minutus* PALLAS, 1776. Statistics : reduced major axis a = −5.61 ; b = 5.37. Correlation coefficient r = 0.97

Fig. 1B. — The relationship between the wing length and the width of the distal part of the tibiotarsus (TBT dist.) in the genus *Larus*. Legend as in Fig. 1A. Statistics : a = −4.15 ; b = 3.24 ; r = 0.97



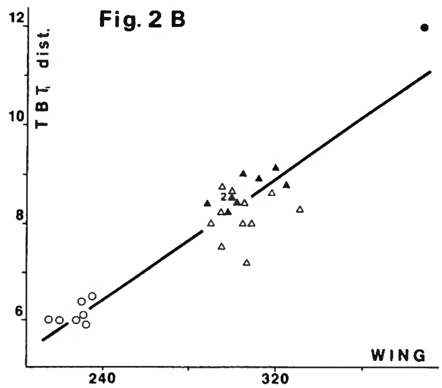
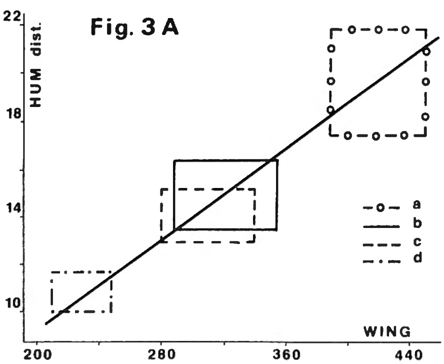


Fig. 2A. — The relationship between the wing length and the width of the distal part of the humerus in the genus Corvus. Each point indicates one individual. Legend : a — *C. corax* LINNAEUS, 1758 ; b — *C. corone* LINNAEUS, 1758 ; c — *C. frugilegus* LINNAEUS, 1758 ; d — *C. monedula* LINNAEUS, 1758. Statistics : a = −1.15 ; b = 5.18 ; r = 0.94.

Fig 2B. — The relationship between the wing length and the width of the distal part of the tibiotarsus in the genus *Corvus*. Legend as in Fig. 2A. Statistics : a = −1.52 ; b = 3.28 ; r = 0.93.



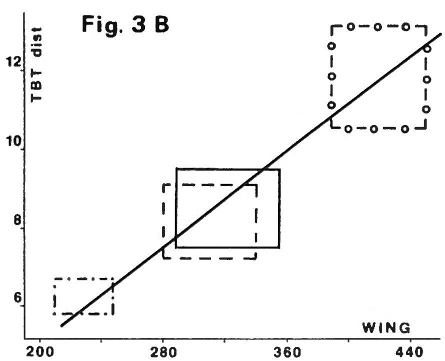


Fig. 3A. — The relationship between the wing length and the width of the distal part of the humerus in the genus *Corvus*. Each rectangle indicates the range of one species. Legend : a — *C. corax* ; b — *C. corone* ; c — *C. frugilegus* ; d — *C. monedula*. Statistics : a = −0.28 ; b = 0.05 ; r = 0.83.

Fig 3B. — The relationship between the wing length and the width of the distal part of the tibiotarsus in the genus *Corvus*. Legend as in Fig. 3A. Statistics : a = −0.98 ; b = 3.02 ; r = 0.82.

be remembered, however, that both variables (the wing and the bone measurements) are normally distributed. If we plotted the two variables against each other in a large series of individuals, we assume that we would get a figure of an elliptic shape for each species. However, due to the lack of numerous individual measurements and for the sake of simplicity, each species is covered by one rectangle (not ellipse) in the diagram. Data from literature allow us to draw rectangles of horizontal and vertical sides, *i. e.* not slanting in any way. The combinations of minimal and maximal values (*i. e.* 4 vertices of each rectangle for all species studied) were used to calculate the reduced major axis and the correlation coefficient in the same way as in the case of individual points. The high value of the correlation coefficients (3 A : r = 0.83 ; 3 B : r = 0.82) that were found using data from humerus and tibiotarsus, and the similarity of these diagrams (Fig. 3 A, B) to the previous ones (Fig. 2 A, B) indicate that the method can be used for further investigations. The area covered by individual points of each species in Fig. 2 A and B corresponds well with the area and the arrangement of the rectangles in Fig. 3 A and B. Although the correlation coefficients calculated for the vertices of the rectangles (Fig. 3 A, B) are somewhat smaller than the correlation coefficients calculated for individual points (Fig. 2 A, B), they are still statistically significant. In other words, simplified data (rectangles) can be nearly as good as individual measurements (points) in determining the correlation of the wing length and the bone dimensions. So, we compared the minimal and maximal measurements of the wing lengths (taken from literature) with minimal and maximal values of different measurements of various bones (cited in literature and taken from specimens of ISEA) in several groups of birds. The results are illustrated by means of rectangles in separate diagrams. In the case when only one skeleton (*i. e.* one bone measurement) of the species given was available, it is represented by a line segment indicating the minimal and maximal wing length. Single individuals were marked with separate points.

RESULTS

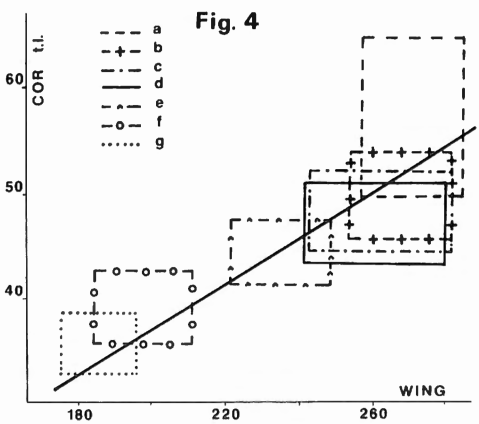
Fig. 4 shows a relationship between the length of the coracoideum and the length of the wing in European ducks from the genus *Anas* (CRAMP and SIMMONS, 1977 ; WOELFLE, 1967). All the rectangles lie approximately on the reduced major axis ; only one of the Mallard protrudes partially above the line. It is connected with the differentiation of the size of drakes in this species. It also may have happened that in the collections studied by WOELFLE (1967) some domesticated (bigger) drakes were included among the wild specimens. Probably due to this fact, the correlation coefficient is a bit lower (r = 0.70) than in the case of *Corvus* and *Larus*. It is also worth noticing that the rectangles of the Wigeon, the Gadwall and the Pintail much overlap this : is connected with the fact that these species are nearly the same size.

Similar results were also obtained when we compared the length of the carpometacarpus with the wing length in the same species of ducks.

The diagram in Fig. 5 depicts a relationship between the length of the humerus and the length of the wing in 5 species of European grouse (data from : CRAMP and SIMMONS, 1980 ; ERBERSDOBLER, 1968 ; KRAFT, 1972). The sexual dimorphism in the genera *Bonasa* and *Lagopus* is so small that both sexes are combined. On the contrary, in the genus *Tetrao,* sexes are shown separately. Although 3 various genera are presented in this diagram, all the rectangles lie again on the reduced major axis. The correlation coefficient is very high (r = 0.96).

The comparison of the wing length (CRAMP and SIMMONS, 1977) and the width of the distal articular part of the tarsometatarsus (KELLNER, 1986) is shown in European herons (Fig. 6). Although there are 9 species belonging to 7 different genera and 2 subfamilies, the rectangles lie again more or less on the reduced major axis. Only the rectangle of *Botaurus stellaris* is more aside but in spite of it the correlation coefficient is high (r = 0.88).

Similar comparison was done for two genera of the birds of prey : *Accipiter* and *Circus* (Fig. 7). In this case it is a relationship between the wing length (CRAMP and SIMMONS, 1980 ; DEMENTEV and GLADKOV, 1951 ; ISEA) and the width of the proximal part of the humerus (OTTO, 1981 ; ISEA). These two genera differ considerably in the proportions of these parameters. Moreover, rectangles of *Accipiter* show better linear arrangement than those of *Circus*. It is also reflected in the value of the correlation coefficients (r = 0.96 and 0.62 accordingly). Rectangles of 2 other



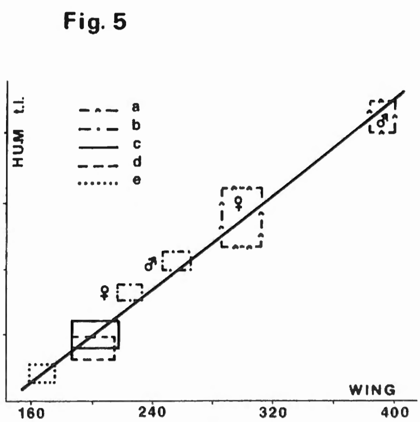


Fig. 4. — The relationship between the wing length and the total length of the coracoideum (COR t. l.) in the genus *Anas*. Each rectangle indicates the range of one species. Legend : a — *A. platyrhynchos* LINNAEUS, 1758 ; b — *A. acuta* LINNAEUS, 1758 ; c — *A. strepera* LINNAEUS, 1758 ; d — *A. penelope* LINNAEUS, 1758 ; e — *A. clypeata* LINNAEUS, 1758 ; f — *A. querquedula* LINNAEUS, 1758 ; g — *A. crecca* LINNAEUS, 1758. Statistics : a = −6.57 ; b = 0.22 ; r = 0.70.

Fig. 5. — The relationship between the wing length and the total length of the humerus (HUM t. l.) in the subfamily Tetraoninae. Each rectangle indicates either the range of one sex or of the whole species. Legend : a — *Tetrao urogallus* LINNAEUS, 1758 ; b — *T. tetrix* LINNAEUS, 1758 ; c — *Lagopus lagopus* (LINNAEUS, 1758) ; d — *L. mutus* (MONTIN, 1776) ; e — *Bonasa bonasia* (LINNAEUS, 1758). Statistics : a = −10.41 ; b = 0.35 ; r = 0.96.

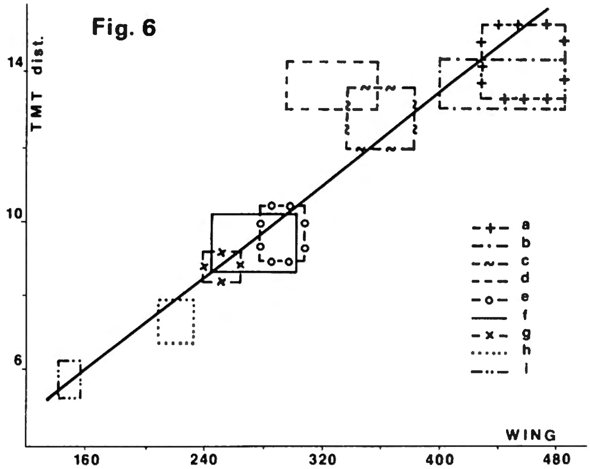


Fig. 6. — The relationship between the wing length and the width of the distal part of the tarsometatarsus (TMT dist.) in the family Ardeidae. Each rectangle indicates the range of one species. Legend : a — *Ardea cinerea* LINNAEUS, 1758 ; b — *Egretta alba* LINNAEUS, 1758 ; c — *A. purpurea* LINNAEUS, 1766 ; d — *Botaurus stellaris* (LINNAEUS, 1758) ; e — *Nycticorax nycticorax* (LINNAEUS, 1758) ; f — *E. garzetta* (LINNAEUS, 1766) ; g — *Bubulcus ibis* (LINNAEUS, 1758) ; h — *A. ralloides* (SCOPOLI, 1796) ; i — *Ixobrychus minutus* (LINNAEUS, 1766). Statistics : a = 1.22 ; b = 3.06 ; r = 0.88.

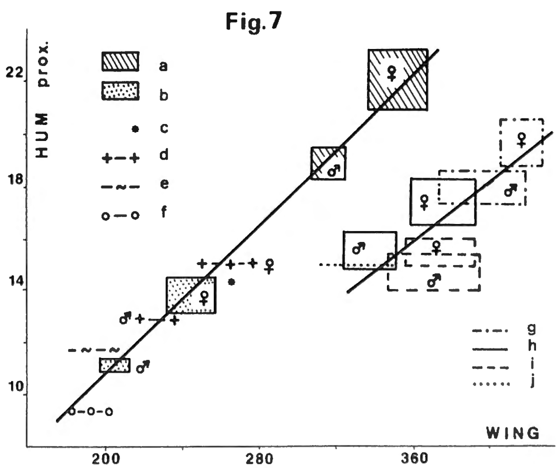


Fig. 7. — The relationship between the wing length and the width of the proximal part of the humerus (HUM prox.) in two genera : *Accipiter* and *Circus*. Each rectangle, line segment or point indicates either the range of one sex or of the whole species. Legend : a — *A. gentilis* (LINNAEUS, 1758) ; b — *A. nissus* (LINNAEUS, 1758) ; c — *A. fasciatus* (VIGORS and HORSFIELD, 1827) ; d — *A. cooperi* (BONAPARTE, 1828) ; e — *A. striatus* VIEILLOT, 1807 ; f — *A. soloensis* HORSFIELD, 1821 ; g — *C. aeruginosus* (LINNAEUS, 1758) ; h - *C. cyaneus* (LINNAEUS, 1766) ; i — *C. pygargus* (LINNAEUS, 1758) ; j — *C. macrourus* (GMELIN, 1771). Statistics : *Accipiter* a = −3.68 ; b = 7.25 ; r = 0.96. *Circus* a = −4.80 ; b — 5.76 ; r = 0.62.

species from another genus (*Buteo buteo* and *B. lagopus*) would be situated between the reduced major axes of *Accipiter* and *Circus*. For the sake of simplicity it was not shown in Fig. 7.

The species of the genus *Falco* serve as the last examples of our investigations (Fig. 8 and 9). The length of the wing (CRAMP and SIMMONS, 1980 ; FRIEDMANN, 1950 ; BROWN *et al.*, 1982 ; ISEA) was compared with the width of the distal parts of the tibiotarsus and the humerus (SOLTI, 1981 ; ISEA ; KUROCHKIN, *in lit.*). In both cases the correlation coefficient is high (tibiotarsus : r = 0.89 ; humerus : r = 0.88). It is worth noting that rectangles of *F. tinnunculus, F. subbuteo* and *F. rupicoloides* are arranged in a different way to each other in Fig. 8 (tibiotarsus) than in Fig. 9 (humerus).

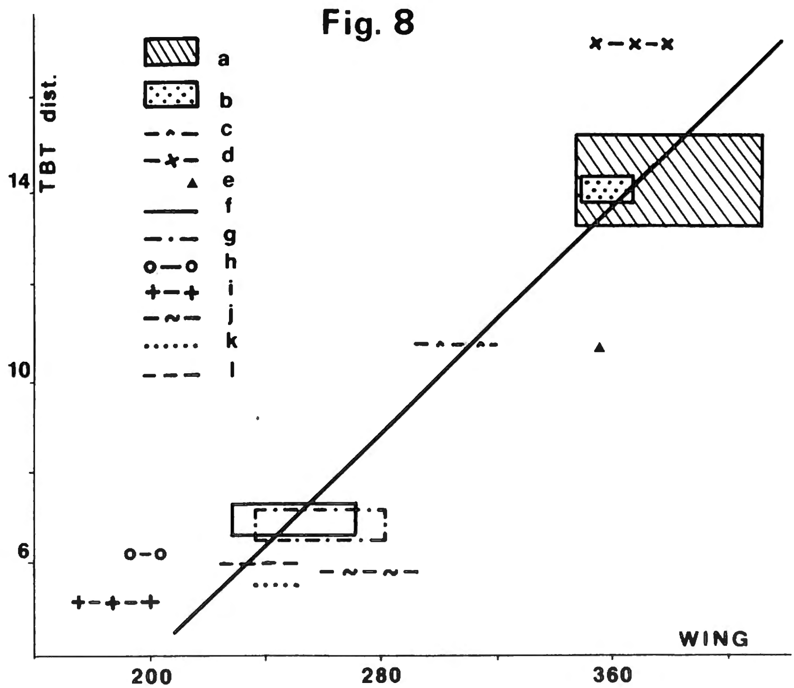


Fig. 8. — The relationship between the wing length and the width of the distal part of the tibiotarsus (TBT dist.) in the genus *Falco*. Each rectangle, line segment or point indicates either the range of one sex or of the whole species. Legend : a — *F. cherrug* GRAY, 1834 ♂♀ ; b — *F. peregrinus* TUNSTALL, 1771 ♀ ; c — *F. peregrinus* ♂ ; d — *F. rusticolus* LINNAEUS, 1758 ♂ ; e — *F. berigora* VIGORS and HORSFIELD, 1827 ♀ ; f — *F. subbuteo* LINNAEUS, 1758 ♂♀ ; g — *F. tinnunculus* LINNAEUS, 1758 ♂♀ ; h — *F. columbarius* LINNAEUS, 1758 ♂ ; i — *F. sparverius* LINNAEUS, 1758 ♂ ; j — *F. rupicoloides* SMITH, 1830 ; k — *F. vespertinus* LINNAEUS, 1766 ♂ ; l — *F. naumanni* FLEISCHER, 1818 ♂. Statistics : a = −8.20 ; b = 0.06 ; r = 0.89.

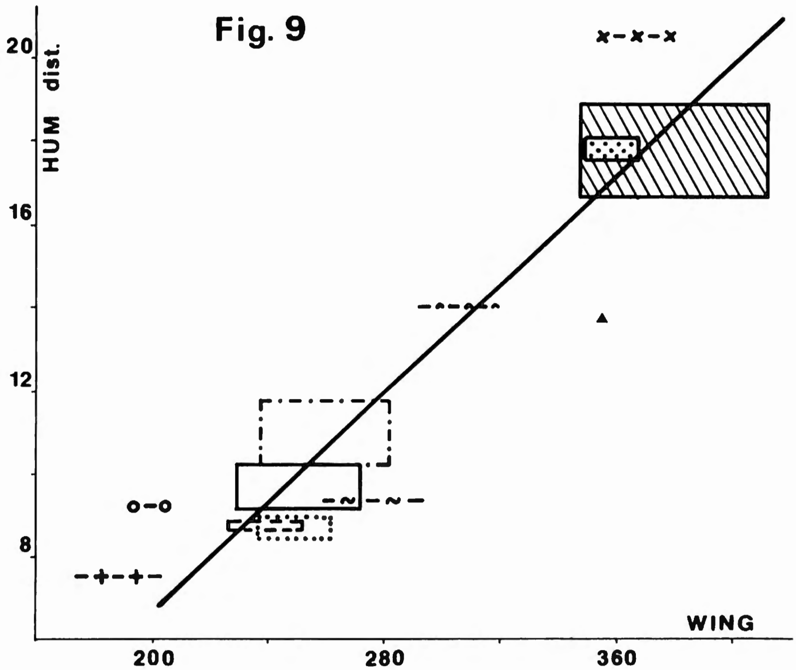


Fig. — 9. The relationship between the wing length and the width of the distal part of the humerus (HUM dist.) in the genus *Falco*. Legend : a-j as in Fig. 8 ; k — *F. vespertinus* ♂♀ ; l — *F. naumanni* ♂♀. Statistics : a = −6.53 ; b = 6.60 ; r = 0.88.

DISCUSSION

The size of a bone fragment depends on the size of a bird, its biology and also on skeletal proportions (Bocheński, 1989).

The relationships between the wing length and the bone measurements described above work to a various degree in different groups of birds. It seems for instance that the groups consisting of species differing in the shape and the length of wing (feathers) — due to their sedentary or migratory behaviour — may not show such relationships or their relationships may be weaker. Unfortunately, there are no osteometric data to prove it. Such differentiations in the shape and length of the wings are observed *e. g.* in the genus *Oriolus* (Schüz, 1971 after Kipp, 1936) or even in the subspecies of *Zonotrihia capensis* (Van Tyne and Berger, 1959 after Chapman, 1940).

If the above statement is right, shortening primaries (no changes of wing bone sizes) in sedentary birds should shift their rectangles to the left side of the reduced major axis. On the contrary, lengthening of the wing in migratory birds should shift their rectangles to the right side of the axis. The arrangement of rectangles and line segments representing partial and short distant migrants like : *Botaurus stellaris*

(Fig. 6), *Falco rusticolus, F. columbarius* and *F. sparverius* (Fig. 8 and 9) as well as the long distant migrant — *Circus pygargus* (Fig. 7) may support this theory. On the other hand, the data arrangement of sedentary *Falco berigora* and *F. rupicoloides* (Fig. 8 and 9) and a long distant migrant *Circus macrourus* (Fig. 7) does not agree with it. It should be emphasized, however, that in all the cases mentioned above, the rectangles, line segments and points were not very far from the reduced major axis. More or less linear arrangement can be seen in all the diagrams.

The arrangement of the falcon rectangles in relation to the reduced major axis (Fig. 8 and 9) was also compared with the division of the genus into subgenera (WOLTERS, 1975). It appeared that the arrangement of rectangles does not reflect the systematic division based on many characteristics.

The relationships between the wing length and the length of leg and wing skeletons were found in birds of similar biology — *i. e.* in European gulls (DINNENDAHL and KRAMER, 1957). Although the relationships of single bones and the wing length were not studied by them, the results were similar to those obtained by us in the case of the length of the coracoideum in ducks (Fig. 4) and of the humerus in grouse (Fig. 5). However, bone fragments are far more numerous than whole bones in fossil and recent bird remains. The present results indicate that well-defined measurements of bone fragments are also good for studies of proportions.

Our results only indicate the problem. However, the examples of allometric dependencies show that scaling features are essential for identification of bird bone fragments. They lead to the following practical conclusions :

1. The length of wing — characteristic for each species, dependent on the length of full grown primaries and commonly cited in literature — is, to a various degree, correlated with measurements of various parts of the skeleton (wings as well as legs).

2. The correlation of one part of a bone with the wing length is similar in species belonging to a genus or even to a family provided that the birds have the same or very similar body plan. Such a correlation may be presented by a linear arrangement of points or rectangles which may be used for calculation of a reduced major axis.

3. Having examined a relationship of the wing length and a given bone measurement (depending on the fragment which is to be identified) in a certain group of birds (based even on a part of species belonging to the group), one can estimate the wing length on the basis of the size of the bone fragment. It can be simply read from the axis on which wing length is scaled. This, in turn, leads to the identification of the species, or at least helps us to reduce the number of possibilities.

REFERENCES

BOCHEŃSKI, Z. (1989) — Problems of skeletal proportions in fossil bird research. *Fortsch. d. Zoologie*, **35** : 445-450.

BROWN, L. K., E. K. URBAN and K. NEWMAN, Eds. (1982) — *The birds of Africa. Vol. 1. Academic Press, London (521 pp).*

CRAMP, S. and K. E. L. SIMMONS, Eds. (1977) — *Handbook of the birds of Europe, the Middle East and North Africa : the birds of the Western Palearctic.* Vol. 1 : Ostrich to Ducks. Oxford Univ. Press, Oxford, London, New York (722 pp).

CRAMP S. and K. E. L. SIMMONS, Eds. (1980) — *Handbook of the birds of Europe, the Middle East and North Africa : the birds of the Western Palearctic.* Vol. 2 : Hawks to bustards. Oxford Univ. Press, Oxford, London, New York (695 pp).

DEMENTEV, G. P. and N. A. GLADKOV, Eds. (1951) — *Pticy Sovetskogo Soyuza.* Vol. 1. Sovetskaya Nauka, Moscow (659 pp).

DINNENDAHL, L. and G. KRAMER (1957) — Über grössenabhängige Änderungen von Körperproportionen bei Möwen (*Larus ridibundus, L. canus, L. argentatus, L. marinus*). *J. Orn.*, **98** : 282-312.

ERBERSDOBLER, K. (1968) — *Vergleichend morfologische Untersuchungen an Einzelknochen des postcranialen Skeletts in Mitteleuropa vorkommender mittelgrosser Hühnervögel.* Inaugural-Diss. Doktorwurde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität München (93 pp).

FERENS, B. Ed. (1967) — *Klucze do oznaczania kregowców Polski. Ptaki Aves : non-Passeriformes.* PWN, Warszawa, Kraków (414 pp).

FRIEDMANN, H. (1950) — The birds of North and Middle America. A descriptive catalog. *Bull. Smithsonian Inst.*, **50** : 1-793.

KELLNER, M. (1986) — *Vergleichend morphologische Untersuchungen an Einzelknochen des postcranialen Skellets in Europa vorkommender Ardeidae.* Inaugural-Diss. Doktorwürde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität München (221 pp).

KRAFT, E. (1972) — *Vergleichend morphologische Untersuchungen an Einzelknochen Nord- und Mitteleuropäischer kleinerer Hühnervögel.* Inaugural-Diss. Doktorwürde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität München (194 pp).

OTTO, C. (1981) — *Vergleichend morphologische Untersuchungen an Einzelknochen in Zentraleuropa vorkommender mittelgrosser Accipitridae.* Inaugural-Diss. Doktorwürde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität München (182 pp).

SCHÜZ, E. (1971) — *Grundriss der Vogelzugskunde.* Verlag Paul Parey, Berlin, Hamburg (390 pp).

SOLTI, B. (1981) — Vergleichend osteologische Untersuchungen an Skelettsystem der Falkenarten *Falco cherrug* Gray und *Falco peregrinus* Tunstall. *Vertebr. Hung.*, **20** : 75-125.

VAN TYNE, J. and A. J. BEREGER (1959) — *Fundamentals of ornithology.* Wiley, New York (624 pp).

WOELFLE, E. (1967) — *Vergleichend morphologische Untersuchungen an Einzelknochen des postcranialen Skeletts in Mitteleuropa vorkommender Enten, Halbgänse und Säger.* Inaugural-Diss. Doktorwürde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität München (203 pp).

WOLTERS, H. E. (1975) — *Die Vogelarten der Erde.* Lief. 1. Paul Parey, Hamburg, Berlin (80 pp).

WOOD, D. S. and G. D. SCHNELL (1986) — *Revised world inventory of avian skeletal specimens, 1986.* American Ornithologists' Union and Oklahoma Biological Survey, Norman, Oklahoma (296 pp).