Chancellor, R.D., B.-U. Meyburg & J.J. Ferrero eds. 1998
Holarctic Birds of Prey
ADENEX-WWGBP

Morphometric features characterizing Flight Properties of Palearctic Eagles.

Wolfgang Kirmse

ABSTRACT

Wing proportions were investigated in the following ten eagle species: *Aquila chrysaetos*, *clanga*, *heliaca*, *nipalensis*, *pomarina*; *Circaetus gallicus*; *Haliaeetus albicilla*; *Hieraaetus fasciatus* and *pennatus*; *Pandion haliaetus*. From photos of these eagles flying with fully stretched wings and seen just from below were taken the following measures: length of the whole wing and of the handwing, plane of the whole wing and of the handwing. By using literature data of the real handwing length the real length and plane values of the wing were calculated. The wing proportions concerning the length relation of handwing to armwing and the plane relation of these wing portions and further the body weight and wing loading are presented in 5 diagrams. These demonstrate specific positions of each species within the measure relations corresponding partly to known flight properties. The functional significance of some morphometric features concerning flight and hunting strategy remains still uncertain.

INTRODUCTION

The evolution of different raptor species, their ecofunctional specialization, is mainly based on differing hunting strategies. The flight properties enabling a certain hunting strategy must in turn be based on morphometric relations mainly concerning proportions of the wing and their relation to body mass. Certainly the flight silhouette of a raptor contains the expression of its life style to a high degree. This paper is a further attempt to decode some of the morpho-functional significance of wing proportions in 10 palearctic eagles in a similar way used formerly in bird hunting falcons

(Kirmse 1989). The eagle species investigated are: *Aquila chrysaetos*, *clanga*, *heliaca*, *nipalensis*, *pomarina*; *Circaetus gallicus*; *Haliaeetus albicilla*; *Hieraaetus fasciatus and pennatus*; *Pandion haliaetus*.

METHOD

The wing proportions were recorded using photos of the ten species in flight with fully spread wings (gliding or soaring) seen just from below. The photos used are numbers 12 lower, 14 upper, 15 lower left, 16 lower, 18 lower left, 21 centre, 22, 23 upper, 25, 26, 28 lower, published by Porter *et al.* (1978). For *Hieraaetus fasciatus* was used fig. 97 right in Glutz von Blotzheim *et al.*(1971). From the pictures were taken the following measurements:

length of the whole wing and of the handwing, plane of the whole wing and of the handwing (Fig. 1). These relative measures allow the expression of length- and plane-relations (indices). But also absolute measures can be derived from the relative ones using the figures of handwing length given in literature. In this way by relational equations the real length of the whole wing was calculated:

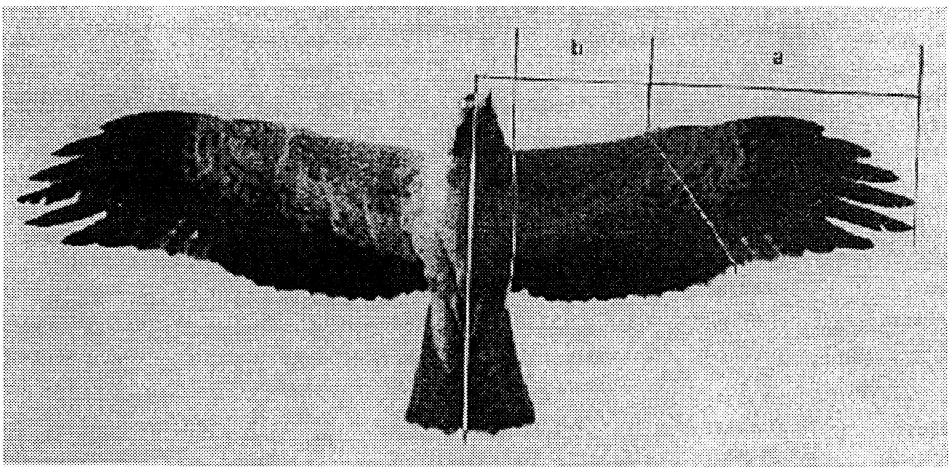
length of handwing on picture/ length of whole wing on picture = real length of handwing (given)/ real length of whole wing (to be found).

The real wingplane was found the same way:

square of winglength on picture/ plane of wing on picture = square of

---

Figure 1. Flight photo of a Booted Eagle (*Hieraaetus pennatus*) demonstrating the way of measuring lengths and planes: length of a handwing, b armwing taken rectangular to the body length axis. Straight lines across the wing are the borderlines of both wingplanes.



real winglength/ real wingplane (to be found).

The wingplane on picture was measured using a planimeter. The mean values of the length of handwing and of the body weight in both sexes, as given in Table 1, are derived from the figures published by Weick (1980).

The individuals on the photos are of unknown sex, that is why sexspecific wing proportions could not be regarded and are missing in the index relations. The length of the whole wing was calculated according to the

---

Fig.2 Each two points in the diagram connected by one line represent measures of one species,the lower left point of the male, the upper right of the female. The letters at the line connecting the points are abbreviations of latin species names: *A.ch. Aquila chrysaetos, A.c. Aquila clanga, A.h. Aquila heliaca, A.n. Aquila nipalensis, A.p. Aquila pomarina, C.g. Circaetus gallicus, H.a. Haliaeetus albicilla, H.f. Hieraaetus fasciatus, H.p. Hieraaetus pennatus, P.h. Pandion haliaetus.* Further remarks see text.

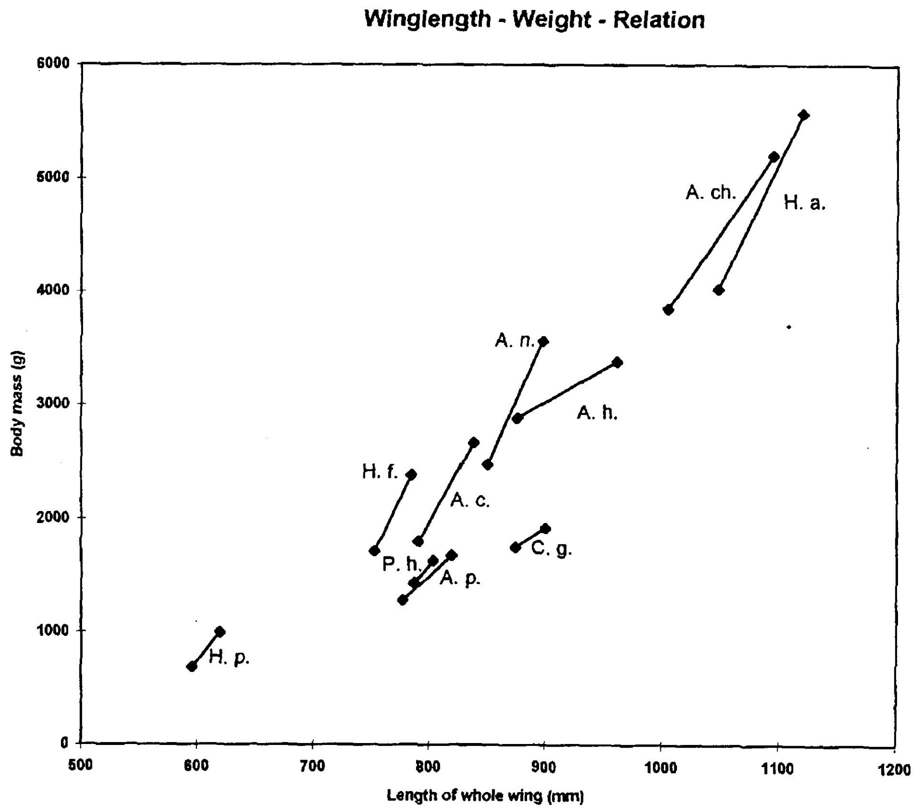
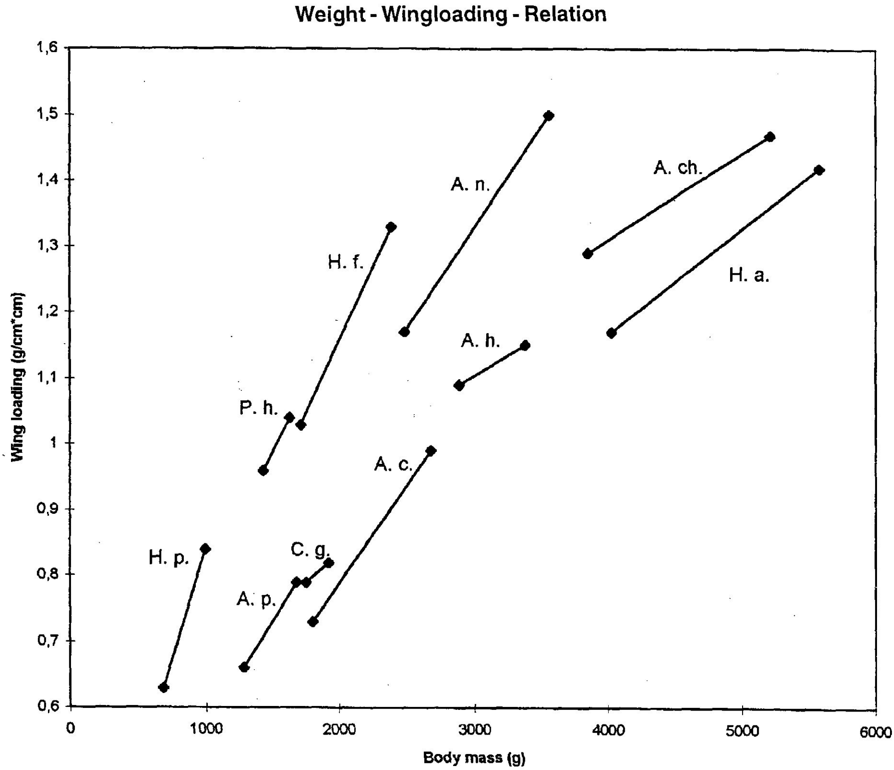


Figure 3 Symbols as in Fig.2. For further explanation see text.



sexspecific real handwingdata cited in Tab. 1. This calculated sex difference of winglength may be somewhat different to the real one.

RESULTS.

The correlation between the calculated length of the whole wing and the body mass is given in Table 1 and Figure 2. The diagram shows a rather strong regression of both variables along the diagonal with some remarkable features: *Circaetus gallicus* (*C.g.*) has a very long wing for its weight in comparison e.g. with the equally weighing *Hieraaetus fasciatus* (*H.f.*). The same is valid concerning other couples of species of about equal weight such as *Aquila heliaca* (*A.h.*) and *Aquila nipalensis* (*A.n.*) or *Haliaeetus albicilla* (*H.a.*) and *Aquila chrysaetos* (*A.ch.*). *Aquila pomarina* (*A.p.*) and *Aquila clanga* (*A.c.*) have nearly the same wing length but differ considerably in body weight. Another outstanding feature is the unequal rate of rise of data correlation from the male to the female in different species. *A.h.* and *C.g.* have exceptionally low rates of rise; very high rates of rise are visible in *H.f.*, *A.n.*

and *H.a.*

It can be expected that the longer the wing in relation to body mass the less will be the wing loading. This expectation in general turns out to be correct, as visible in Figure 3 showing the data given in Table 2, but there are some exceptions: *C.g.* has a higher wing loading than *A.p.* though having the longer wing , and the Osprey (*P.h.*) has a much higher wing loading than *A.p.* whereas both have wing lengths of the same order. Again the sexspecific rate of rise of data correlation differs markedly. The steepest increase in this correlation is visible in Booted (*H.p.*) and Bonelli's Eagle (*H.f.*) and the Osprey (*P.h.*). The biggest eagles *H.a., A.ch.* and *A.h.* in this case have the least rate of rise.

The differences between the species are represented more visibly in Figure 4 after adding the index of handwing length/ armwing length as a further variable. The data are given in Table 2. This index is important as far as the handwing portion of the whole wing represents the propelling part of the wing during active flight. So it is not surprising to find the agile and dashing fliers such as Booted (*H.p.*) and Bonelli's Eagle (*H.f.*) among species

Figure 4 The index length of handwing/length of armwing is added as the third variable to the diagram of Fig.3. Symbols as in Fig.2. For further explanation see text.

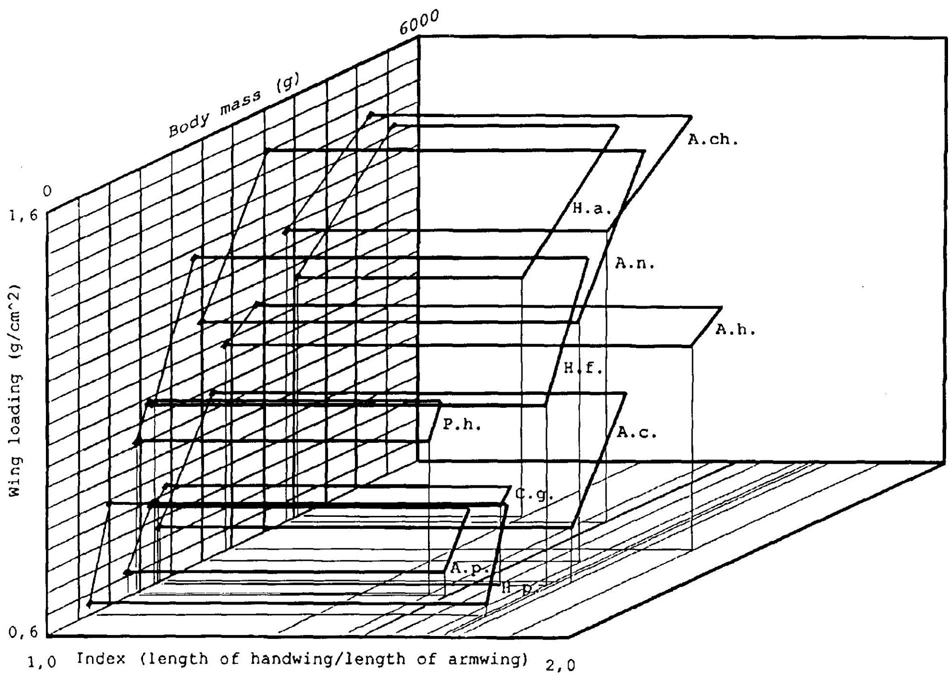


Table 1. Winglength - Weight - Relation

Length of hand wing (mm) mean values after Weick	Length of whole wing (mm) calculated	Body mass (g) mean values after Weick	Sex	Spec
380	596	683	m.	H.p.
395	620	993	f.	
464	777	1281	m.	A.p.
490	820	1677	f.	
507	791	1800	m.	A.p.
537	838	2675	f.	
548	875	1750	m.	C.g.
563	900	1919	f.	
536	850	2481	m.	A.n.
566	898	3562	f.	
582	876	2885	m.	A.h.
638	961	3383	f.	
480	787	1430	m.	H.f.
490	804	1630	f.	
485	753	1712	m.	H.f.
506	785	2386	f.	
620	1005	3850	m.	A. ch.
675	1095	5207	f.	
615	1048	4030	m.	H.a.
657	1120	5575	f.	

Table 2. Weight - Wingloading - Relation.

Body mass	Wing loading (g/cm^2)	Index (Length of handwing) /Length of armwing)	Sex	Spec.
683	0,63	1,76	m.	H.p.
993	0,84	1,76	f.	
1281	0,66	1,61	m.	A.p.
1677	0,79	1,61	f.	
1800	0,73	1,79	m.	A.c.
2675	0,99	1,79	f.	
1750	0,79	1,66	m.	C.g.
1919	0,82	1,66	f.	
2481	1,17	1,72	m.	A.n.
3562	1,5	1,72	f.	
2885	1,09	1,89	m.	A.h.
3383	1,15	1,89	f.	
1430	0,96	1,56	m.	P.h.
1630	1,04	1,56	f.	
1712	1,03	1,75	m.	H.f.
2386	1,33	1,75	f.	
3850	1,29	1,61	m.	A. ch.
5207	1,47	1,61	f.	
4030	1,17	1,43	m.	H.a.
5575	1,42	1,43	f.	

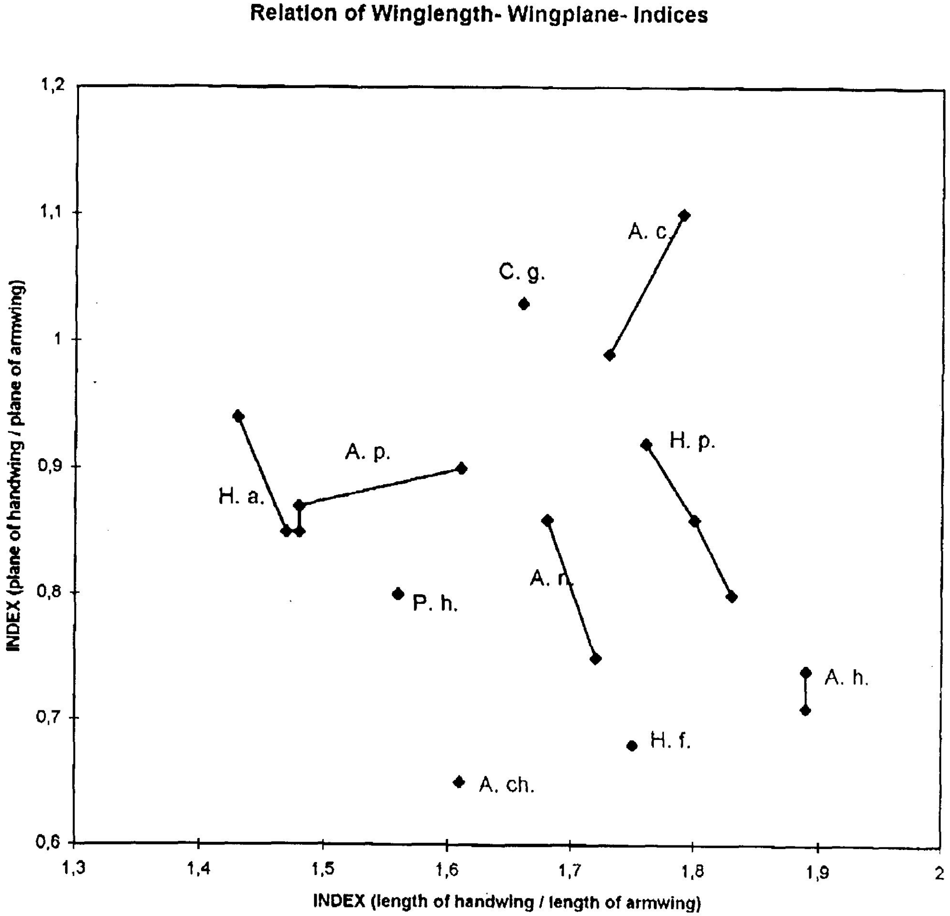
Table 3. Relation of Winglength - Wingplane - Indices

Index (length of handwing/ length of armwing)	Index (plane of handwing/ plane of armwing)	Spec
1,83	0,8	H.p.
1,8	0,86	
1,76	0,92	
1,48	0,85	A.p.
1,48	0,87	
1,61	0,9	
1,79	1,1	A.c.
1,73	0,99	
1,66	1,03	C.g.
1,68	0,86	A.n.
1,72	0,75	
1,89	0,71	A.h.
1,89	0,74	
1,56	0,8	P.h.
1,75	0,68	H.f.
1,61	0,65	A. ch.
1,43	0,94	H.a.
1,47	0,85	

with a high length index (Fig. 4). On the other hand this index decreases with increasing body mass because carrying an increased weight is more shifted to the armwing. Consequently both the largest eagles *A.ch.* and *H.a.* have lower length indices than smaller species with similar flight properties, but there remains a marked difference of that index between both eagles, characterizing the Golden Eagle (*A.ch.*) as better equipped for pursuit flight than the White-tailed Eagle (*H.a.*). However the unexpectedly very high length index of the Imperial Eagle (*A.h.*) and also the rather high index of the Greater-spotted Eagle (*A.c.*) are puzzling, because both species are known to be less agile and dashing fliers in comparison e.g. to both *Hieraaetus* species and also less than the Golden Eagle (*A.ch.*). That means there must be another relation to flight concerning the wing length index besides that of indicating higher pursuit capability.

An approach to this problem is offered by the relation of the wing plane index to the wing length index as listed in Table 3 and visible in Figure 5. In this figure the points connected by lines are not sexspecific but represent sexneutral samples of the same species. If there were a strong correlation between both variables, i.e. an increasing index of wing length would also mean a increasing index of wing plane, which seems to be probable, then the values should be arranged close to the diagonal. But contrarily the different

Figure 5 **Abbreviations of species names as in Fig.2 but points connected by a line are not sexspecific, instead they are different samples of the same species of unknown sex. For further explanation see text.**



species are located at quite scattered positions in this diagram.In spite of this some regularities are obvious: The most heavy eagles are represented closer to the lower left corner, thus there is a tendency from upper right to lower left position with increasing size, apart from some exceptions discussed further below. Another tendency just opposite to the size dependent one, i.e. from the upper left to the lower right corner, obviously concerns different flight properties. This comes out most clearly in comparing the two largest eagles and the Short-toed Eagle (*C.g.*) with Bonelli's Eagle (*H.f.*), both pairs being of similar size. The different position in the diagram means: Golden and Bonelli's Eagle both have in common a relatively long handwing but with small handwing plane in contrary to their opponents, White-tailed and Short-toed Eagles, which have a relatively shorter handwing but with large handwing plane. This alternative wing differentiation seems to be aligned with flight differentiation, either to enable quick pursuit by rapidly flapping a long but narrow handwing or alternatively to support more slow but easy glides for persistent searchflight due to a shorter but much broader handwing. Besides this basic tendency various other combinations are apparent. For example, just opposite to the size dependent tendency the Greater-Spotted Eagle (*A.c.*) has both a higher wing length index and a larger wing plane index than the Lesser-Spotted Eagle (*A.p.*) and consequently should have some similarity of flight properties to the Short-toed Eagle (*C.g.*) probably concerning quicker approach to larger and more distant prey. The Lesser-Spotted Eagle (*A.p.*) resembles more the White-tailed Eagle (*H.a.*) in this diagram despite its much lesser size. Two other two eagles of similar size, the Imperial (*A.h.*) and the Steppe Eagle (*A.n.*), are positioned differently in all diagrams but most in Figure 5. The wing length index of the Imperial Eagle is excessive for its big size and hints at flight properties resembling that of the Red Kite (*Milvus milvus*) which were positioned much more to the right of and above this diagram. The low wingplane index of *A.h.* on the other hand may indicate some capability of speedy pursuit but clearly less than in the Golden Eagle. The Steppe Eagle (*A.n.*) has a smaller wing length index in comparison with *A.h.* but more than *A.p.*, and also concerning wingplane index *A.n.* holds the centre between *A.h.* and *A.p.* Concerning flight properties the high wingloading of *A.n.* must be considered and in this respect its position in Figure 5 between *A.c.* and *A.ch.* is remarkable.

The Osprey (*P.h.*) in comparison with *A.p.* has higher wingloading, similar winglength index but lower wingplane index. This combination seems to be in favour of dives into water, and the loss of easier search flight property by the reduction of handwing plane may be compensated for by the advantage of flapping less voluminous handwings if the feathers are bedraggled with water. The Osprey as well as the similar sized *A.p.*, *C.g.* and *H.f.* each have their quite separate position in diagram 5 which in general illustrates the singularity of each species concerning morphometric specialization.

DISCUSSION

The results indicate species specific differentiation instead of species grouping concerning the flight properties of the ten eagles investigated, contrarily to the bird hunting falcons, which can be grouped into four categories of hunting strategy (Kirmse 1989). The findings allow some general conclusions in detail: Raptors capable of powerful pursuing flight have comparably short wings and a high wingloading; but not all having a high wingloading are agile hunters, e.g. not the Steppe Eagle (*A.n.*), which seems to represent a versatile compromise. The combination of a relatively long handwing (high winglength index) with a small plane (low wingplane index) indicates more reliably the capability of quick pursuing flight. The opposite combination of large handwing plane with shorter handwing length is realized in species performing persistent search flight by slow glides and even pauses in the air against the wind or by hovering as is masterfully represented by the Short-toed Eagle (*C.g.*). An increase of the handwing length in that combination seems to allow a quicker approach to more distant prey escaping. Excessive increase of handwing length in compensation for some reduction of handwing plane as represented by the Imperial Eagle (*A.h.*) may change flight properties in the direction of e.g. the Red Kite (*Milvus milvus*), provided that the wingloading were equally low, which is not the case in *A.h.* The close relatives Spotted (*A.c.*), Lesser Spotted (*A.p.*)and Steppe Eagle (*A.n.*) are remarkably separated in the diagrams which means that their flight properties are more differentiated than could be expected according to their similar appearance, and it may be that they are in process of further ecofunctional separation.

The results presented are preliminary. More data collected by using other appropriate flight photos would make the results more precise. Other features influencing flight properties are not considered here but may be of importance, e.g. the tail, concerning its shape and plane and also details of shape and outline of the wings as far as they influence aerodynamic properties as does the relative length of the handwing flight feathers (primaries). Nonetheless the relatively crude features of wing proportions used here throw some light on that functional paths the different species follow by morphometric adaptation to special hunting strategies.

ACKNOWLEDGEMENTS

I am thankfully obliged to Mr. Dieter Schille for arranging the computer graphic representation of the figures and diagrams.

REFERENCES

GLUTZ VON BLOTZHEIM 1971: Handbuch der Vögel Mitteleuropas. Bd.4 Frankfurt a.M.(1971).

KIRMSE, W. 1989: Zur interspezifischen Spezialisation der Jagdflugeigenschaften vogeljagender Falken (Falco). -Acta ornithoecologica, Jena 2 H.1,3-13.

PORTER,R.F., WILLIS,I. CHRISTENSEN, S., NIELSEN, B.P. 1978: Flight identification of european raptors. T.and A..D.Poyser, Berkhamsted (1978).

WEICK,F. 1980: Birds of prey of the world. Paul Parey, Hamburg und Berlin (1980).

Prof.Dr.Wolfgang Kirmse,
Am Bogen 43, 04277 Leipzig, Germany