

A Morphometric Analysis of *Accipiter* Species

Alan Kemp and Tim Crowe

ABSTRACT

Samples of up to 10 study skins for 45 of the 48 species in the genus *Accipiter* were measured for 24 dimensions of the head, wings, tail and feet. For each species and each sex within a species, the logged values of the means of each measurement were analysed by cluster and factor analysis. Two clusters were identified, large goshawks together with larger females of a few other species and the remaining smaller species. *A. ovampensis*, with its rather falcon-like proportions, was the most aberrant species. Morphometric similarities between species and subspecies were compared with their known biogeography. Similar species were allopatric or ecologically separated, but there was considerable convergence between species in different areas and between the individual sexes of different species.

INTRODUCTION

The genus *Accipiter* is the largest and one of the most homogeneous within the avian order Falconiformes, comprising 22% of the 223 species in the family Accipitridae (Amadon & Bull 1988). It was reviewed in detail by Wattel in 1973, when 43 species were recognised, but subsequent studies suggest that it consists of 48 species, including those previously in the genera *Megatriorchis* and *Erythrotriorchis* (Amadon & Bull 1988). Wattel (1973) examined patterns of geographical differentiation within the genus, based partly on traditional measurements of the bill, wing, tail and tarsus, together with dimensions of the middle toe and hind claw. The measurements were compared by univariate statistics and by transforming them to relative proportions of the wing length to minimize effects of body size. This study provided one of the first extensive morphometric analyses of an entire avian genus (Wattel 1973).

The present study is part of a series examining the systematics and morphometrics of raptors (Kemp & Crowe 1990, 1991, in press). It attempts to define morphometric similarities between species to assess the extent that phenetic characters have been used in deciding systematic relationships and may be used to define ecological similarity. A morphometric analysis of 280 of the 291 species of diurnal birds of prey (Falconiformes) indicated that smaller *Accipiter* species were most similar to *Micrastur buckleyi*, *M. ruficollis*, *M. gilvicolis*, male *Falco novaeseelandiae* and *Micronisus (Melierax) gabar*, while larger ones resembled males of *Spizaetus* spp., *Hieraetus ayresii*, *H. kienerii* and *Spizastur melanoleucus*, both sexes of *Parabuteo unicinctus* and females of *Circus maillardi* (Kemp & Crowe 1991). Although at least two groups can be recognised within the genus *Accipiter* based on morphological characters (Kemp & Crowe 1990), previous assessment of systematic relationships have been based mainly on phenetic, not necessarily phylogenetic similarities.

MATERIALS AND METHODS

Twenty-four measurements of the head (8), wing (4), legs (2), feet (8) and tail (2) (Biggs *et al.* 1978) were taken on samples of up to 10 study skins of 45 of the 48 species of *Accipiter* (Amadon & Bull 1988) and 5 distinctive subspecies. No specimens were available for *A. princeps*, *A. nanus* and *A. brachyurus*, all Australasian island endemics with restricted ranges. The distribution of measurements was bimodal for all species and subspecies (except *A. imitator*, *A. luteoschistaceus*, *A. doriae* and *A. collaris* where only one sex was represented). Larger specimens were taken to be female, smaller to be male and the samples for each sex were analysed separately.

The mean for each measurement was calculated for each sample (Table 1) and the logged values of the 96 sets of means, for all species, subspecies and sexes, were compared by centroid cluster analysis and factor analysis (Bio-Medical Data Package, BMDP). Details of the samples taken are available from A.C.K. and of the analyses from T.M.C. It should be noted that the measurements are not absolute values of the dimensions for the species concerned; rather they are indices of those dimensions as recorded from dry museum specimens by one recorder (A.C.K.).

RESULTS

The cluster analysis joined morphometrically similar species at low euclidean amalgamation distances but separated dissimilar species by their higher amalgamation distances (Fig. 1). There are two major clusters, one incorporating both sexes of the larger goshawks (11 species) together with the larger females of some smaller species (7 species), the other comprising the remaining smaller species. The most aberrant species, morphometrically, is *A. ovampensis*. The smaller species also formed two groups, one mainly males and the other larger females, although each sex of less dimorphic species occurred in the same cluster and of more dimorphic species in separate clusters.

Only one factor, out of the five specified for the analysis, was necessary to record the patterns of correlation within the data. In the orthogonally rotated factor loadings, this factor accounted for 21.7% of the variance explained. The sorted and rotated loadings for Factor 1 (Table 2) indicate that measurements of the wing, feet and bill contributed most to this factor. Gape width, an index of swallowing capacity, contributed least to the factor analysis. The list in sequence of the factor scores indicates morphometric similarities between species and sexes (Table 3). Since all members of the genus appear to be sexually dimorphic in size, the standard index of dimorphism using wing length can be compared with one derived from the factor scores (Table 4). These two measures of dimorphism are strongly correlated ($r = -0.86$, S.E. = 0.11, $P < 0.001$) although the exact sequence of species is not the same for each index of dimorphism.

DISCUSSION

The principal separation within the genus is on overall size, despite log transformation of the means to reduce this effect. That the genus is rather homogeneous is indicated by only one factor accounting for correlation of the variation. The most clearly separated clusters are females of the large goshawks (*A. gentilis*, *A. meyerianus*, *A. melanoleucus*, *A. henstii* and *A. buergerii*), males of the smallest sparrowhawks (*A. superciliosus*, *A. collaris*, *A. minullus* and *A. erythropus*) and the aberrant *A. ovampensis*. The latter has long been known for its relatively long wings, short tail and short tarsus within the genus (Wattell 1973), which may be related to more frequent falcon-like stooping than in other species (Kemp & Kemp 1975). Many of the other clusters of species or subspecies are consistent with previous analyses of the genus, such as the "gentilis" group of large goshawks and the "nisus" group of long-toed sparrowhawks (Wattell 1973).

The extent of morphometric similarity (Fig. 1, Table 3) can also be compared to the biogeographical distribution for each species (Table 1). Similar species occur allopatrically, at least when breeding, or are separated ecologically in the few instances where sympatric. This applies even to the most diverse radiation of *Accipiter* species, within the Australasian region (including Wallacea), where 20 species (42% of the genus) occur. It confirms the Gaussian pattern established by Wattell (1973), which has also been found for the genus *Falco* (Kemp & Crowe in

Table 1. Scientific names, common names and biogeographical realm of Accipiter species (after Amadon & Bull 1988) and subspecies (after Weick 1980) that were measured. Sample sizes and mean measurements used in cluster and factor analyses are presented, with the sexes separated on bimodality of the samples.

Species of Accipiter	Sex n	Measurement																IT	CT	OT	HC	IC	CC	OC																				
		BL	BD	SL	JL	JB	GL	BW	GW	SW	WL	SECL	AL	UL	TLC	TLO	TARL								HT																			
<i>A. albogularis</i> , Pied Sparrowhawk, Australasian (Solomons)																																												
	f	7	29.4	16.2	60	43	30	25	13.4	21	36	246	166	105	83	187	171	68	24	23	38	30	21.5	21.1	16.5	14.2																		
	m	5	27.0	15.1	54	37	25	22	12.1	20	32	217	147	91	71	166	157	64	22	21	36	27	19.3	18.4	15.2	12.7																		
<i>A. b. badius</i> , Shikra, Afrotropical																																												
	f	5	20.0	12.3	45	32	24	17	10.2	16	27	189	115	74	59	146	137	48	15	14	25	19	12.9	12.5	11.0	9.2																		
	m	5	17.9	11.1	41	29	22	15	8.8	14	26	174	106	71	54	132	124	44	14	13	23	17	11.4	11.0	10.0	8.4																		
<i>A. b. dussumieri</i> , Shikra, Indomalayan																																												
	f	5	22.4	13.0	50	35	25	19	10.1	17	29	208	143	90	71	169	158	54	19	18	32	23	16.4	15.7	12.4	10.8																		
	m	4	20.3	12.3	46	31	21	18	10.4	16	26	187	125	77	65	148	141	52	18	17	29	21	14.5	13.9	11.7	10.1																		
<i>A. bicolor</i> , Bicoloured Hawk, Neotropical																																												
	f	5	27.8	16.1	57	41	30	22	12.1	19	33	241	178	107	86	199	187	69	27	25	42	29	21.2	20.7	15.5	12.6																		
	m	5	23.9	13.7	49	35	25	19	10.5	16	29	212	153	94	74	168	166	59	21	20	37	25	17.1	16.5	12.6	10.6																		
<i>A. brachyurus</i> , New Britain Collared Sparrowhawk, Australasian (New Britain)																																												
<i>A. brevipes</i> , Levant Sparrowhawk, Palaearctic																																												
	f	5	22.8	13.0	49	37	27	19	10.6	19	29	235	143	94	76	176	164	51	18	16	30	23	14.6	14.3	11.2	9.6																		
	m	5	21.0	12.5	46	32	24	17	10.5	16	28	217	132	87	71	160	153	50	16	16	29	22	13.5	13.2	11.4	9.8																		
<i>A. buergeri</i> , Chestnut-mantled Goshawk, Australasian (New Guinea)																																												
	f	2	36.1	20.8	73	56	41	30	14.1	25	41	324	216	132	119	242	225	77	39	36	59	39	33.6	32.5	23.8	17.1																		
	m	3	32.5	19.6	67	48	36	28	13.6	24	38	295	192	115	106	215	207	72	32	31	53	34	29.2	28.4	21.5	14.9																		
<i>A. butleri</i> , Nicobar Sparrowhawk, Indomalayan (Nicobars)																																												
	f	1	22.3	12.6	48	34	24	20	10.9	16	32	183	133	84	63	155	141	50	20	16	28	21	14.7	13.4	11.1	9.7																		
	m	3	21.4	12.2	47	31	23	19	8.7	16	26	169	125	74	51	147	142	49	16	15	26	19	13.7	13.1	11.6	9.3																		

Species of Accipiter	Sex of	n	Measurement																								
			BL	BD	SL	IL	JB	GL	BW	GW	SW	WL	SECL	AL	UL	TLC	TLO	TARL	HT	IT	CT	OT	HC	IC	CC	OC	
<i>A. castanius</i> , Chestnut-flanked Sparrowhawk, Afrotropical																											
	f	4	22.7	13.1	51	33	25	18	10.5	18	29	182	145	82	64	165	152	58	20	18	31	22	16.6	15.8	11.2	9.6	
	m	5	19.5	11.5	43	29	22	16	8.9	15	26	156	121	71	57	137	123	53	14	15	26	18	13.0	12.6	9.3	8.0	
<i>A. cirrocephalus</i> , Australian Collared Sparrowhawk, Australasian																											
	f	5	21.3	12.5	46	32	23	17	9.9	15	26	238	150	101	77	173	176	66	19	19	37	27	16.6	16.5	12.4	10.4	
	m	5	18.3	11.3	41	28	20	13	9.4	13	24	206	133	87	67	145	154	57	16	15	32	22	13.1	13.2	10.0	8.4	
<i>A. collaris</i> , Semi-collared Hawk, Neotropical																											
	m	3	21.8	13.2	48	33	25	17	10.3	16	29	174	124	79	60	137	134	49	19	18	34	25	17.6	16.8	12.6	10.8	
<i>A. cooperi</i> , Cooper's Hawk, Nearctic																											
	f	5	28.6	16.4	59	45	33	25	12.7	21	35	263	181	116	88	222	205	71	26	24	42	30	23.2	21.6	15.0	12.8	
	m	5	23.7	14.4	54	38	27	20	11.5	18	32	235	159	102	78	198	184	63	22	21	37	25	18.8	17.8	13.4	11.0	
<i>A. dorsalis</i> , Doria's Goshawk, Australasian (New Guinea)																											
	m	2	32.7	19.0	66	48	34	27	12.7	25	39	296	213	124	111	264	241	82	31	27	46	30	28.1	26.4	19.8	15.5	
<i>A. erythrauchen</i> , Gray Moluccan Collared Sparrowhawk, Australasian (Moluccas)																											
	f	7	23.3	13.5	49	35	25	18	10.9	15	28	207	147	92	72	160	156	62	23	22	41	29	17.7	18.2	13.9	11.8	
	m	2	22.3	13.2	48	35	25	18	10.8	15	30	200	132	88	72	149	148	64	21	20	39	27	17.2	16.8	12.7	10.9	
<i>A. erythropus</i> , Red-thighed Sparrowhawk, Afrotropical																											
	f	5	19.2	11.3	42	29	20	15	9.2	13	25	171	121	75	62	127	130	47	17	15	28	21	12.9	12.9	10.5	9.1	
	m	5	16.3	9.9	36	26	20	12	7.7	12	23	147	107	64	51	112	113	44	15	14	26	19	11.3	11.4	9.1	7.9	
<i>A. f. fasciatus</i> , Brown Goshawk, Australasian																											
	f	5	30.5	17.0	65	46	34	26	13.9	23	38	304	191	124	96	242	216	82	27	25	43	31	23.8	22.1	17.2	14.6	
	m	5	28.1	16.0	61	44	32	25	11.9	21	36	288	180	121	93	229	210	80	26	24	40	29	22.3	21.3	17.9	14.9	
<i>A. f. francisii</i> , Malagasy Sparrowhawk, Madagascan																											
	f	6	22.6	13.1	50	36	26	20	10.9	18	29	171	126	77	64	153	144	53	16	16	27	21	14.6	14.0	12.2	10.5	
	m	6	20.3	12.0	45	32	22	16	9.6	16	27	159	119	69	59	136	131	50	14	14	24	18	12.8	12.6	11.0	9.5	

Species	Sex	n	Measurement																								
Accipiter			BL	BD	SL	JL	JB	GL	BW	GW	SW	WL	SECL	AL	UL	TLC	TLO	TARL	HT	IT	CT	OT	HC	IC	CC	OC	
<i>A. f. brutus/griveaudi</i> , Malagasy Sparrowhawk, Madagascar (Comores)																											
	f	5	22.3	12.3	49	43	24	18	10.8	17	29	164	119	73	58	137	134	53	17	17	28	21	14.6	14.1	12.0	10.3	
	m	5	19.5	11.1	46	32	23	18	9.7	15	27	144	108	64	53	115	112	47	15	14	25	18	12.5	11.8	10.4	8.5	
<i>A. gentilis</i> , Northern Goshawk, Palaearctic & Nearctic																											
	f	5	37.7	21.7	78	58	42	33	15.8	29	46	357	237	155	124	266	243	84	35	32	51	37	32.5	30.3	21.2	17.6	
	m	5	33.8	19.1	71	52	38	28	13.4	25	42	318	203	136	113	231	215	76	28	27	45	33	27.2	26.1	18.0	14.9	
<i>A. griseiceps</i> , Celebes Crested Goshawk, Australasian (Sulawesi)																											
	f	3	25.9	14.7	56	41	30	22	11.1	19	35	197	144	86	72	164	154	56	21	21	31	24	20.9	19.6	14.6	12.3	
	m	3	24.0	13.6	53	37	27	23	9.9	16	33	181	137	77	66	147	143	52	19	19	28	22	18.4	17.2	13.4	10.5	
<i>A. gularis</i> , Japanese Sparrowhawk, Palaearctic																											
	f	5	20.4	12.3	44	32	23	16	10.1	15	26	194	128	80	64	140	137	52	17	16	31	22	14.3	14.2	11.1	9.5	
	m	5	17.1	10.3	39	27	20	13	9.1	13	25	168	112	73	57	120	121	49	14	14	27	20	11.9	12.1	9.1	7.8	
<i>A. gundlachi</i> , Cuban Hawk, Nearctic (Cuba)																											
	f	1	31.0	17.2	61	47	33	28	14.1	25	41	280	200	108	83	245	218	72	36	34	50	38	28.2	26.1	18.2	15.9	
	m	1	25.9	15.2	59	41	31	22	13.3	22	32	237	172	107	78	213	188	68	24	23	42	30	20.6	19.5	15.3	10.7	
<i>A. haplochrous</i> , New Caledonian Sparrowhawk, Australasian (New Caledonia)																											
	f	6	27.0	15.7	57	39	28	22	13.0	20	34	237	159	102	77	180	174	66	21	21	35	26	18.6	18.5	15.0	12.4	
	m	6	24.3	13.8	52	37	27	20	11.6	18	31	205	140	93	70	157	152	60	20	18	32	23	15.7	15.7	12.4	10.5	
<i>A. hemnicogrammus</i> , Moluccan Barred Sparrowhawk, Australasian (Moluccas)																											
	f	5	30.0	16.8	60	42	30	23	12.4	19	36	247	174	106	84	215	184	74	20	20	32	25	16.7	16.5	14.3	12.2	
	m	5	27.1	15.5	55	38	28	20	10.9	17	33	215	152	92	71	190	173	62	17	18	30	23	15.0	14.9	12.9	11.0	
<i>A. henstii</i> , Madagacar Goshawk, Madagascar																											
	f	4	38.7	22.5	76	57	42	33	14.2	26	41	322	246	147	115	281	263	96	37	33	53	38	33.3	30.3	22.6	19.0	
	m	4	40.1	19.1	67	48	36	27	13.0	23	38	282	208	124	101	239	220	83	30	25	46	32	26.4	24.5	17.6	15.8	

Species of Acceptor	Sex of n	Measurement																								
		BL	BD	SL	IL	JB	GL	BW	GW	SW	WL	SECL	AL	UL	TLC	TLO	TARL	HT	IT	CT	OT	HC	IC	CC	OC	
<i>A. imitator</i> , Imitator Sparrowhawk, Australasian (Solomons)																										
	f	1	27.2	14.1	48	32	21	20	12.0	19	28	209	155	83	61	169	155	59	17	18	27	22	14.1	14.1	13.0	11.3
<i>A. luteschistaceus</i> , Blue and Gray Sparrowhawk, Australasian (New Britain)																										
	m	1	23.0	13.3	59	37	27	19	11.3	19	30	193	138	80	70	148	138	59	17	18	27	19	13.3	13.1	12.5	10.1
<i>A. madagascariensis</i> , Madagascar Sparrowhawk, Madagascan																										
	f	7	22.6	13.4	50	34	25	18	10.6	17	29	218	160	99	75	183	180	64	22	21	38	27	17.6	18.0	13.6	11.2
	m	3	18.0	10.6	41	27	19	14	8.7	14	24	173	126	76	61	140	145	54	17	16	31	21	12.3	13.0	9.7	8.0
<i>A. melanochlamys</i> , Black-mantled Goshawk, Australasian (New Guinea)																										
	f	5	29.0	16.7	59	42	30	23	13.5	22	35	251	177	104	80	195	177	68	22	22	37	28	20.6	20.0	15.5	13.3
	m	6	25.7	15.5	53	38	28	21	12.3	19	32	220	155	94	72	169	158	64	20	19	31	24	17.2	16.2	12.7	11.2
<i>A. melanoleucus</i> , Black and White Goshawk, Afrotropical																										
	f	5	36.3	21.2	70	55	40	33	14.1	24	41	337	234	146	120	256	233	84	36	31	55	38	28.5	27.4	20.4	17.0
	m	3	30.9	18.3	64	46	33	28	12.2	20	39	280	188	120	105	213	196	75	29	26	43	30	24.3	22.5	17.2	14.2
<i>A. meyerianus</i> , Papuan Goshawk, Australasian (except Australia)																										
	f	2	39.0	22.7	72	56	46	33	14.6	28	42	326	229	150	120	247	229	78	33	32	50	38	29.9	28.4	20.3	17.7
	m	2	35.7	20.9	72	51	38	30	14.2	24	40	295	200	128	103	208	198	72	29	27	45	31	27.2	25.7	18.1	15.4
<i>A. minutus</i> , Little Sparrowhawk, Afrotropical																										
	f	5	19.4	12.0	40	29	21	15	9.5	15	25	158	115	70	55	121	122	45	17	15	28	21	12.7	12.6	9.6	8.3
	m	5	16.3	10.6	36	25	19	13	7.8	12	22	140	103	60	50	105	106	39	14	13	24	17	10.6	10.5	8.5	7.4
<i>A. nanus</i> , Dwarf Sparrowhawk, Australasian (Sulawesi)																										
<i>A. nissus</i> , Eurasian Sparrowhawk, Palearctic																										
	f	5	22.5	12.8	50	35	26	18	10.4	17	29	230	149	100	78	181	174	60	20	20	39	26	16.7	17.3	12.8	10.8
	m	5	18.7	11.0	44	29	23	16	9.2	15	26	202	131	85	66	150	154	54	16	15	33	21	12.6	13.0	10.2	8.0
<i>A. n. novaezelandiae</i> , Variable Goshawk, Australasian																										
	f	5	35.9	20.6	71	52	38	30	13.0	25	39	311	222	134	96	241	230	84	31	30	49	36	29.7	27.5	20.9	18.0
	m	5	30.4	17.5	62	45	33	25	11.7	21	36	261	184	112	94	196	191	72	27	25	40	29	23.8	22.0	16.8	14.1

Species of Accipiter	Sex	n	Measurement																								
			BL	BD	SL	IL	JB	GL	BW	GW	SW	WL	SECT	AL	UL	TLC	TLO	TARL	HT	IT	CT	OT	HC	IC	CC	OC	
<i>A. rufiventris</i> , Rufous-breasted Sparrowhawk, Afrotropical																											
	f	5	22.1	13.1	48	35	24	19	11.3	17	28	234	151	100	78	184	178	56	19	19	40	26	15.9	16.2	11.8	9.9	
	m	5	19.4	11.6	43	31	22	15	10.0	15	26	202	129	84	66	151	154	52	17	15	43	22	13.2	13.3	10.1	8.6	
<i>A. soloensis</i> , Gray Frog Hawk, Palearctic																											
	f	5	20.2	11.5	44	33	24	16	10.9	16	26	198	121	75	61	143	133	43	15	14	25	18	12.2	11.8	10.5	8.6	
	m	5	19.8	11.3	44	31	22	16	10.0	15	25	186	111	73	60	135	127	43	14	13	24	18	11.6	11.3	10.1	8.5	
<i>A. striatus</i> , Sharp-shinned Hawk, Nearctic & Neotropical																											
	f	5	20.6	12.0	44	32	23	16	9.8	15	25	208	142	90	70	165	168	57	17	17	35	23	14.2	14.4	10.4	9.0	
	m	5	17.6	10.6	37	27	20	13	8.4	14	23	178	122	75	57	137	140	50	13	14	30	20	11.5	12.2	8.6	7.4	
<i>A. superciliosus</i> , Tiny Hawk, Neotropical																											
	f	5	20.9	12.5	46	31	23	15	10.4	15	27	160	114	70	60	117	117	48	19	18	32	24	16.6	15.9	12.1	10.2	
	m	5	17.8	10.9	41	29	22	13	8.7	13	24	134	95	59	48	96	96	42	14	14	25	20	13.0	12.7	9.8	8.2	
<i>A. t. tachiro</i> , African Goshawk, Afrotropical																											
	f	5	29.0	16.4	59	44	32	26	11.7	21	34	239	180	107	83	213	196	67	26	23	36	26	24.7	22.4	15.2	13.2	
	m	5	25.1	14.9	54	40	29	21	11.1	18	32	222	159	90	71	176	168	59	20	18	32	23	19.2	17.5	13.1	11.2	
<i>A. t. macroscelides</i> , African Goshawk, Afrotropical (rainforest)																											
	f	5	26.7	14.7	56	40	29	23	10.8	19	33	218	165	97	77	196	179	63	21	20	33	24	19.9	18.1	12.9	11.7	
	m	5	22.0	12.7	50	34	25	19	10.2	17	30	189	143	83	67	160	146	60	16	16	28	20	15.0	14.3	10.5	8.9	
<i>A. trinitatus</i> , Spot-tailed Sparrowhawk, Australasian (Sulawesi)																											
	f	6	21.1	11.8	46	34	25	17	9.8	15	29	164	123	72	56	143	128	53	17	16	25	19	13.2	12.6	11.1	9.7	
	m	5	20.0	11.4	46	33	24	16	9.2	16	29	155	115	67	53	136	122	53	15	15	24	18	12.1	11.8	10.4	9.2	
<i>A. trivirgatus</i> , Asian Crested Goshawk, Indomalayan																											
	f	5	29.9	16.8	66	49	36	27	12.4	22	40	264	200	119	95	217	205	72	27	26	40	30	28.2	25.0	16.4	14.4	
	m	5	26.5	15.4	60	43	32	25	11.2	20	37	229	171	100	82	192	179	66	23	23	35	27	23.7	21.4	14.5	12.6	

Species of Accipiter	Sex	n	Measurement																								
			BL	BD	SL	JL	JB	GL	BW	GW	SW	WL	SECL	AL	UL	TLC	TLO	TARL	HT	IT	CT	OT	HC	IC	CC	OC	
A. virgatus, Bestra Sparrowhawk, Indomalayan																											
	f	5	22.7	13.1	48	34	25	18	11.0	16	28	207	150	95	73	168	165	60	21	20	39	28	17.7	17.2	12.7	10.8	
	m	5	18.2	10.9	41	28	20	14	9.1	13	25	154	121	75	60	133	134	53	16	16	31	22	13.4	13.0	9.6	8.0	

Measurements (see Biggs *et al.* 1978 for details):

Head measurements: BL = bill chord, BD = bill depth, SL = skull length, JL = jaw length, GL = gape length, BW = bill width, GW = gape width, SW = skull width.

Wing measurements: WL = wing length, SECL = secondary length, AL = alula length, UL = ulna length.

Tail measurements: TLC = centre tail length, TLO = outer tail length.

Leg measurements: TARL = tarsus length, HT = hind toe length, IT = inner toe length, CT = centre toe length, OT = outer toe length, HC = hind claw chord, IC = inner claw chord, CC = centre claw chord, OC = outer claw chord.

Table 2. Matrix of factor loadings for each measurement taken (as in Biggs *et al.* 1978), orthogonally rotated and sorted in order of variance explained within each factor.

Measurement	Contribution to Factor 1
Secondary length	0.980
Inner claw chord	0.976
Hind claw chord	0.974
Inner toe length	0.974
Centre claw chord	0.973
Bill depth	0.971
Jaw length	0.971
Alula length	0.967
Hind toe length	0.967
Skull length	0.966
Outer claw chord	0.966
Bill chord	0.965
Ulna length	0.960
Jaw-bill length	0.957
Centre tail length	0.953
Gape length	0.950
Outer tail length	0.950
Wing length	0.949
Skull width	0.945
Outer toe length	0.938
Bill width	0.930
Tarsus length	0.927
Centre toe length	0.902
Gape width	0.793

Table 3. Order of estimated factor score for each species and sex.

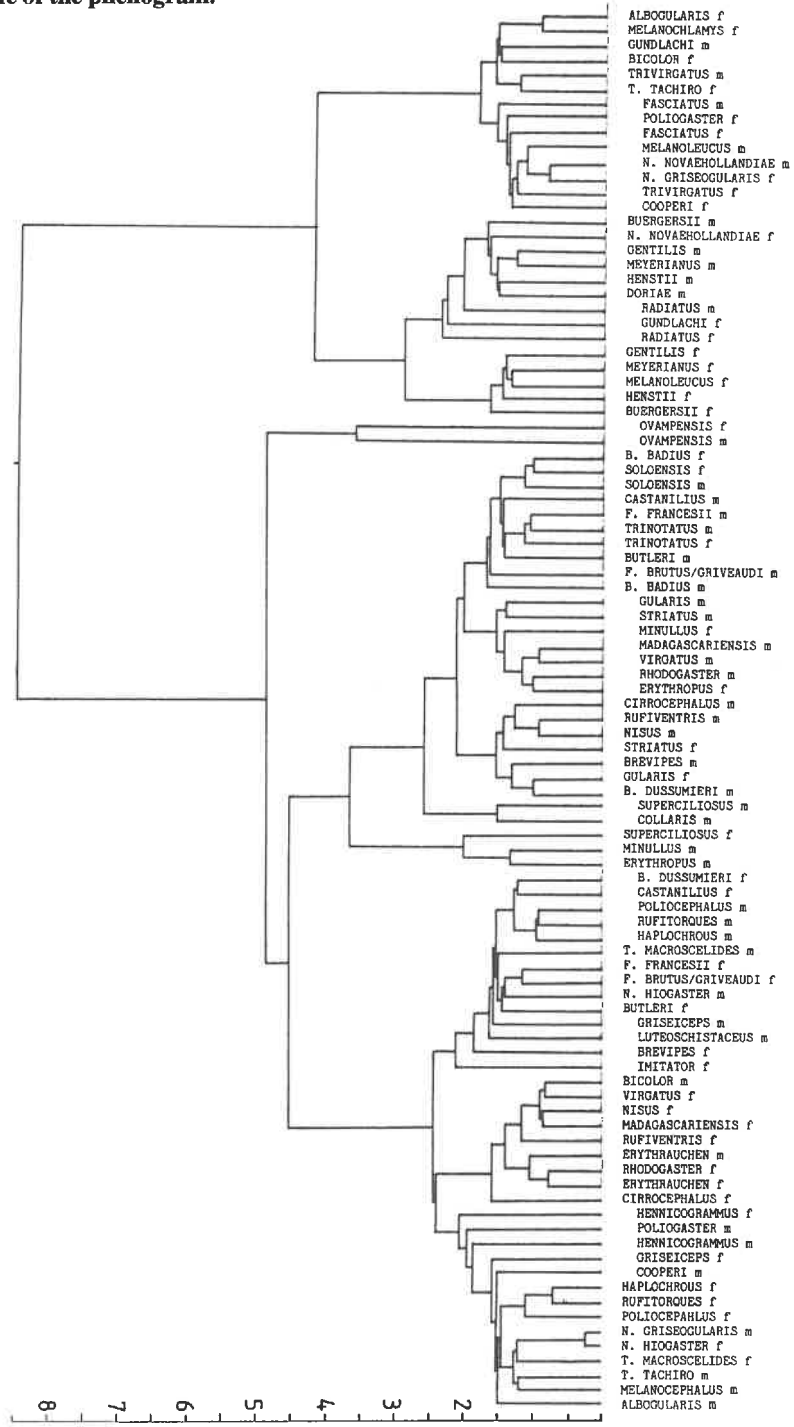
Species	Sex	Estimated factor score
<i>A. minullus</i>	m	-1.902
<i>A. erythropus</i>	m	-1.711
<i>A. superciliosus</i>	m	-1.616
<i>A. gularis</i>	m	-1.419
<i>A. b. badius</i>	m	-1.375
<i>A. striatus</i>	m	-1.370
<i>A. f. brutus/griveaudi</i>	m	-1.252
<i>A. minullus</i>	f	-1.221
<i>A. soloensis</i>	m	-1.195
<i>A. castanilius</i>	m	-1.181
<i>A. virgatus</i>	m	-1.163
<i>A. madagascariensis</i>	m	-1.142
<i>A. erythropus</i>	f	-1.118
<i>A. trinotatus</i>	m	-1.105
<i>A. f. francesii</i>	m	-1.076
<i>A. rhodogaster</i>	m	-1.030
<i>A. soloensis</i>	f	-1.009
<i>A. cirrocephalus</i>	m	-0.955
<i>A. butleri</i>	m	-0.932
<i>A. b. badius</i>	f	-0.931
<i>A. trinotatus</i>	f	-0.884
<i>A. nisus</i>	m	-0.881
<i>A. rufiventris</i>	m	-0.818
<i>A. superciliosus</i>	f	-0.803
<i>A. gularis</i>	f	-0.759
<i>A. b. dussumieri</i>	m	-0.742
<i>A. f. brutus/griveaudi</i>	f	-0.690
<i>A. brevipes</i>	m	-0.625
<i>A. ovampensis</i>	m	-0.611
<i>A. striatus</i>	f	-0.609
<i>A. butleri</i>	f	-0.565
<i>A. f. francesii</i>	f	-0.564
<i>A. t. macroscelides</i>	m	-0.555
<i>A. collaris</i>	m	-0.540
<i>A. n. hiogaster</i>	m	-0.502
<i>A. luteoschistaceus</i>	m	-0.413
<i>A. castanilius</i>	f	-0.412
<i>A. imitator</i>	m	-0.345
<i>A. rufitorques</i>	m	-0.323
<i>A. griseiceps</i>	m	-0.319
<i>A. brevipes</i>	f	-0.316
<i>A. b. dussumieri</i>	f	-0.295
<i>A. cirrocephalus</i>	f	-0.250
<i>A. erythrauchen</i>	m	-0.239
<i>A. poliocephalus</i>	m	-0.223
<i>A. haplochrous</i>	m	-0.176
<i>A. bicolor</i>	m	-0.148
<i>A. virgatus</i>	f	-0.139
<i>A. rufiventris</i>	f	-0.132
<i>A. rhodogaster</i>	f	-0.112
<i>A. nisus</i>	f	-0.067
<i>A. hennicogrammus</i>	m	-0.062
<i>A. erythrauchen</i>	f	-0.050
<i>A. poliogaster</i>	m	-0.014

Species	Sex	Estimated factor score
<i>A. madagascariensis</i>	f	0.005
<i>A. t. tachiro</i>	m	0.017
<i>A. melanochlamys</i>	m	0.037
<i>A. griseiceps</i>	f	0.117
<i>A. ovampensis</i>	f	0.144
<i>A. cooperi</i>	m	0.174
<i>A. albogularis</i>	m	0.186
<i>A. n. griseogularis</i>	m	0.188
<i>A. n. hiogaster</i>	f	0.198
<i>A. t. macrosclides</i>	f	0.215
<i>A. poliocephalus</i>	f	0.335
<i>A. haplochrous</i>	f	0.363
<i>A. rufitorques</i>	f	0.397
<i>A. hennicogrammus</i>	f	0.462
<i>A. trivirgatus</i>	m	0.551
<i>A. gundlachi</i>	m	0.572
<i>A. bicolor</i>	f	0.620
<i>A. melanochlamys</i>	f	0.622
<i>A. t. tachiro</i>	f	0.708
<i>A. albogularis</i>	f	0.709
<i>A. cooperi</i>	f	0.852
<i>A. n. novaehollandiae</i>	m	0.902
<i>A. polioaster</i>	f	0.916
<i>A. f. fasciatus</i>	m	0.949
<i>A. n. griseogularis</i>	f	0.958
<i>A. melanoleucus</i>	m	1.101
<i>A. trivirgatus</i>	f	1.120
<i>A. f. fasciatus</i>	f	1.199
<i>A. henstii</i>	m	1.383
<i>A. gundlachi</i>	f	1.392
<i>A. meyerianus</i>	m	1.421
<i>A. buergersii</i>	m	1.454
<i>A. doriae</i>	m	1.454
<i>A. radiatus</i>	m	1.492
<i>A. gentilis</i>	m	1.494
<i>A. n. novaehollandiae</i>	f	1.689
<i>A. melanoleucus</i>	f	1.901
<i>A. buergersii</i>	f	1.952
<i>A. meyerianus</i>	f	1.957
<i>A. gentilis</i>	f	2.132
<i>A. henstii</i>	f	2.136
<i>A. radiatus</i>	f	2.412

Table 4. Comparison of indices of sexual size dimorphism based on mean wing length (m/ f x 100, Table 1) and difference in factor scores (Table 3).

Species	Sexual dimorphism index	
	Wing length	Difference in factor score
<i>A. soloensis</i>	93.9	0.186
<i>A. erythrauchen</i>	96.6	0.189
<i>A. trinotatus</i>	94.5	0.221
<i>A. f. fasciatus</i>	94.7	0.250
<i>A. brevipes</i>	92.3	0.309
<i>A. butleri</i>	92.3	0.367
<i>A. griseiceps</i>	91.9	0.436
<i>A. b. badius</i>	92.1	0.444
<i>A. b. dussumieri</i>	89.9	0.447
<i>A. buergersii</i>	91.0	0.498
<i>A. f. francesii</i>	93.0	0.512
<i>A. albogularis</i>	88.2	0.523
<i>A. hennicogrammus</i>	87.0	0.524
<i>A. meyerianus</i>	90.5	0.536
<i>A. haplochrous</i>	86.5	0.539
<i>A. poliocephalus</i>	86.8	0.558
<i>A. f. brutus/griveaudi</i>	87.8	0.562
<i>A. trivirgatus</i>	86.7	0.569
<i>A. melanochlamys</i>	87.6	0.585
<i>A. erythropus</i>	85.9	0.593
<i>A. gentilis</i>	89.0	0.638
<i>A. gularis</i>	86.6	0.660
<i>A. cooperi</i>	89.4	0.678
<i>A. minullus</i>	88.6	0.681
<i>A. rufiventris</i>	86.3	0.686
<i>A. t. tachiro</i>	92.3	0.691
<i>A. n. griseogularis</i>	85.1	0.700
<i>A. cirrocephalus</i>	86.5	0.705
<i>A. rufitorques</i>	85.9	0.720
<i>A. henstii</i>	87.6	0.753
<i>A. ovampensis</i>	87.0	0.755
<i>A. striatus</i>	85.6	0.761
<i>A. bicolor</i>	88.0	0.768
<i>A. castanilius</i>	85.7	0.769
<i>A. n. novaeollandiae</i>	83.9	0.770
<i>A. t. macroscelides</i>	86.7	0.770
<i>A. n. hiogaster</i>	86.0	0.787
<i>A. melanoleucus</i>	83.1	0.800
<i>A. superciliosus</i>	83.8	0.813
<i>A. nissus</i>	87.8	0.814
<i>A. gundlachi</i>	84.6	0.820
<i>A. rhodogaster</i>	85.1	0.918
<i>A. radiatus</i>	86.2	0.920
<i>A. poliogaster</i>	83.2	0.930
<i>A. virgatus</i>	74.4	1.024
<i>A. madagascariensis</i>	79.4	1.147

Figure 1. Centroid cluster analysis of logged mean values of 24 dimensions for 45 species of *Accipiter* and five subspecies (from Table 1) using the programme BMDP. The euclidean amalgamation distance of each cluster is indicated by the scale down the side of the phenogram.



press) and which may apply to most raptorial species. However, there are no cosmopolitan or widespread *Accipiter* species that overlap geographically with many other species, as is found in the genus *Falco*.

Not all subspecies of a species cluster with the same group of species, indicating the validity of considering them as separate populations both ecologically and systematically. Furthermore, in most clusters one sex may be more similar to the opposite rather than the same sex of another species. However, each sex is not always clustered with the same set of species, suggesting that the sexes may either both be similar to their replacement species, or one may be more similar to another species-group.

This indicates the necessity to consider each sex as separate morphometric and ecological units and the problem of trying to compare the ecology of species with dimorphic sexes. Previous studies of sexual dimorphism in raptors have used either body mass or wing length as their indices of dimorphism, whereas it is well known that the sexes may also differ in proportions of various body parts, such as the head and feet. It is suggested that the factor index may be a more comprehensive reflection of sexual differences than one based only on a single dimension, such as wing length, which is itself only a correlate of body size.

ACKNOWLEDGEMENTS

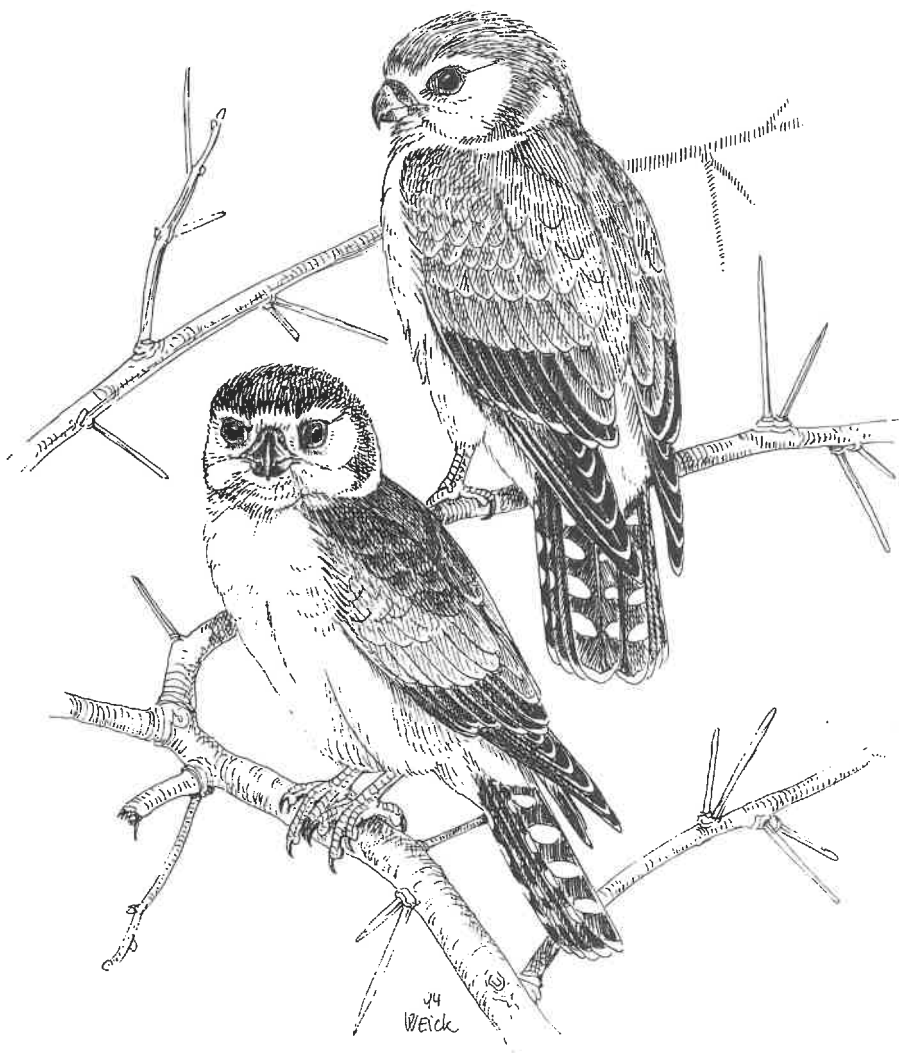
We thank Dean Amadon, Peter Colston, Meg Kemp, John Mendelsohn, the American Museum of Natural History, Frank Chapman Memorial Fund, British Museum (Natural History, Sub-department of Ornithology), Transvaal Museum, Foundation for Research Development, Council for Scientific and Industrial Research and University of Cape Town for their support.

REFERENCES

- AMADON, D. & J. BULL 1988. Hawks and owls of the world: a distributional and taxonomic list, with the genus *Otus* by Joe T. Marshall and Ben F. King. *Proceeding of the Western Foundation for Vertebrate Zoology* 3(4) : 295-357.
- BIGGS, H. C., R. BIGGS & A. C. KEMP 1978. Measurements of raptors. Pp. 77-82 in A.C. Kemp (Ed.). *Proceedings of a Symposium on African Predatory Birds*. Pretoria. Northern Transvaal Ornithological Society.
- KEMP, A.C. & T.M. CROWE 1990. A preliminary phylogenetic and biogeographical analysis of the genera of diurnal raptors. In: G. Peters & R. Hutterer (Eds.) *Vertebrates in the Tropics*. Bonn : Museum Alexander Koenig.
- KEMP, A.C. & T.M. CROWE 1991. Morphometrics of the Falconiformes : an overview. *Acta XX Congressus Internationalis Ornithologici*, Vol. 1 : 483-490.
- KEMP, A.C. & T.M. CROWE 1993 A morphometric analysis of *Falco* species. In: M. Nicholls (Ed.) *The Biology and Conservation of Small Falcons*. Canterbury: The Hawk Trust.
- KEMP, A.C. & M.I. KEMP 1975. Observations on the breeding biology of the Ovambo Sparrowhawk, *Accipiter ovampensis* Gurney (Aves: Accipitridae). *Annals of the Transvaal Museum* 29: 185-190.
- WATTEL, J. 1973. Geographical differentiation in the genus *Accipiter*. *Nuttall Ornithological Club* 13: 1-231.
- WEICK, F. 1980. *Die Greifvögel der Welt*. Berlin: Verlag Paul Parey.

Dr. Alan Kemp
Department of Birds
Transvaal Museum
P.O. Box 413
Pretoria, 0001
South Africa

Prof. Tim Crowe
Percy FitzPatrick Institute
University of Cape Town
Rondebosch, 7700
South Africa



African Pygmy Falcon *Polihierax semitorquatus*