

SIZE VARIATION OF MIGRANT BALD EAGLES AT GLACIER NATIONAL PARK, MONTANA

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ABSTRACT.—We measured morphological variables on 303 migrating Bald Eagles (*Haliaeetus leucocephalus*) at Glacier National Park, Montana (GNP), during 1977–88. Based on results of a concurrent migration study, most of the eagles we measured were from summering areas in the Northwest Territories, Canada. Eagles were classified by plumage as juvenile, subadult, or adult. Feather lengths differed among plumage classes in all variables, but only the eighth and ninth primaries and tail differed (decreased with age) among all three plumage classes in both sexes. We found no differences in beak depth among the three plumage classes of either sex. Masses did not differ among age classes of either sex of eagles with empty crops. The length of the exposed culmen did not differ between adult eagles at GNP and a southern Colorado wintering area. Culmen length, beak depth, and length of hallux did not differ between adult eagles at GNP and museum study skins from Canada, Alaska, and the northern U.S.

KEY WORDS: *Haliaeetus leucocephalus*; *Bald Eagle*; *morphology*; *measurements*; *migration*.

Variación de tamaño de Águilas Calvas migratorias en el Parque Nacional Glacier, Montana

RESUMEN.—Medimos las variables morfológicas de 303 Águilas Calvas (*Haliaeetus leucocephalus*) en el Parque Nacional Glacier, Montana, durante 1977–88. Con base en los resultados del estudio sobre su migración encontramos que la mayoría de las águilas medidas eran de territorios de reproducción del noroeste de Canadá. De acuerdo al plumaje, las águilas fueron clasificadas como juveniles, subadultas o adultas. La longitud de las plumas y variables analizadas fue diferente entre clases, pero sólo la octava y novena rémige primaria y la cola disminuyeron su longitud con la edad en las tres clases de plumaje y en los dos sexos. No se encontró diferencia en la profundidad del pico entre clases y sexos. La masa corporal no fué diferente entre edades y sexos sin contenido estomacal. La longitud del cúlmen, profundidad del pico y longitud del halux no difirió entre águilas adultas del Parque Nacional Glacier y pieles de museo de Canadá, Alaska y el norte de Estados Unidos.

[Traducción de César Márquez]

Morphology of Bald Eagles (*Haliaeetus leucocephalus*) is known to vary with age and sex (Bortolotti 1984a). Females generally are larger than males from similar latitudes (Stalmaster 1987). Bald Eagles of northern natal origin are, on average, larger and heavier than those from the south (Palmer 1988). Measurements of Bald Eagles have been described from western and northern North America by Imler and Kalmbach (1955), Harmata (1984), Bortolotti (1984a), Gargelton et al. (1985), and others. The purpose of

our paper is to report morphological and mass measurements of migrant Bald Eagles captured during autumns 1977–88 in Glacier National Park, Montana (GNP). Size measurements of Bald Eagles from the Mackenzie-Intermountain Flyway (McClelland et al. 1994) have not previously been reported.

STUDY AREA AND METHODS

Our study was conducted at GNP (approximately 48°30'N, 114°00'W) in northwestern Montana. Spawning kokanee salmon (*Oncorhynchus nerka*) attracted migrating eagles to the site each fall during the project. During a concurrent migration study, 30 of 31 transmitter-equipped eagles summered in the northeastern half of Canada's Mackenzie River Basin, primarily in the North-

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west Territories (latitudes of eagle locations ranged from 54°17'–65°35'N, averaging about 62°) (McClelland et al. 1994). This was the probable natal region of the eagles we measured.

We used McCollough's (1989) three broad categories to classify eagles: juvenile (juvinal plumage), subadult (basic plumages I, II, and III), and adult (basic IV and definitive plumages). We measured the following variables (methods in Bortolotti [1984a, 1984b] and Garcelon et al. [1985]): wingspan (WSpan), unflattened wing chord (WnCh); eighth (EPr), ninth (NPr), and tenth (TPr) primary feathers; tail length measured on a central tail feather (Tail); length of exposed culmen without the cere (CILn); beak depth at the leading edge of the cere (BDp); narrowest tarsal thickness frontal (NTTF) and lateral (NTTL); length of hallux claw (HalCl) (we report both left and right measurements because both were used in our sex identification model); outer claw (OCl), middle claw (MCl), inner claw (ICl); and mass (Mass). Only undamaged and apparently fully emerged feathers were included in our analyses. We palpated the crop area on each eagle and qualitatively assessed each as empty (no food detected), full (crop distended and firm), or partially full (conditions not fitting the previous two categories). We included only eagles with empty crops in analysis of mass.

Sexes were identified with a formula (using CILn and both HalCls) derived from Bortolotti's (1984a) and Garcelon et al.'s (1985) models. This derivation was explained in detail in McClelland et al. (1994). We tested for differences among the three plumage classes within each gender using ANOVA, followed by Fisher's Least Significant Difference method ($\alpha = 0.05$) for individual comparisons when the overall ANOVA was significant. Power ($1 - \beta$) of ANOVAs was estimated at $\alpha = 0.05$, where observed differences were the alternatives to hypothesized differences of zero. The ANOVAs should be treated with some caution since the measurements were used to classify by sex before age class comparisons were made. With some variables, the power to detect differences was low because of a relatively small sample size of adults.

Stalmaster (1987) and others have summarized morphological measurements of Bald Eagles from other geographic areas. We restrict comparisons to migrant adult eagles that were primarily from northern natal areas (studies by Bortolotti [1984a] and Harmata [1984]). Means from our study are compared to means from those studies using two-sample unpooled *t*-tests. Immature plumage classes have been grouped variously in research projects; therefore, we did not attempt inter-study comparisons with our two immature age classes.

RESULTS AND DISCUSSION

We measured 303 Bald Eagles: 201 juveniles (123 males, 77 females, and one of unknown sex), 77 subadults (37 males, 40 females), and 25 adults (9 males, 15 females, and one of unknown sex). In each plumage class, variables tended to be larger in females than in males (Table 1). Pat-

terns generally were consistent with Bortolotti's (1984a) previous descriptions. Feather lengths decreased from juvenile to adult in both males and females ($\bar{x} = 9.8$ and 8.7%, respectively). Differences in EPr, NPr, and Tail lengths were significant among all three plumage classes in both sexes (Table 1). Bill, tarsus, and talon measurements tended to increase with age, but less markedly than the feather length decreases. For example, Tail mean in males decreased by 16.1% from juvenile to adult, whereas CILn and BDp increased by 1.8%. BDp in females increased only 1.4%. Bortolotti (1984a) and Garcelon et al. (1985) both used BDp in their sex determination models. We found no differences in BDp among the three plumage classes of either sex. However, the power to detect differences was relatively low because of the small sample size in the adult age class (Table 1).

We recorded full crops in 16% of subadults and adults, and 12% of juveniles. Overall, some food was detected in 33% of crops. Considering only eagles with empty crops, mean masses tended to be greater for adults than for juveniles (4% in males and 5% in females). However, differences were not significant (Table 1). Stalmaster (1987) attributed generally lower masses in young eagles to incomplete bone calcification and muscle development. Some adults may have larger masses due to omental fat (Harmata pers. comm.).

CILn did not differ between adult eagles at GNP and a southern Colorado wintering area (Harmata 1984) (Table 2). CILn, BDp, and HalCl did not differ ($\alpha = 0.05$) between adult eagles at GNP and museum study skins from Canada, Alaska, and the northern U.S. (Bortolotti 1984a) (Table 2). Tail and WSpan of male and female adult Bald Eagles at Harmata's (1984) study area (37°30'N, 1375 km south of GNP), were significantly longer than our values. Harmata tracked several of his eagles to nest areas near 55°13'N, roughly 1100 km south of the farthest north nest site we documented for a GNP adult eagle. Based on latitudinal variation in size (Brown and Amadon 1968), we might have expected feather measurements taken by Harmata to have been shorter than ours. Some differences in size measurements among studies may be attributable to subtle variations in measurement techniques. For example, the amount of stretch exerted during wingspan measurement is

Table 1. Sex and plumage class variation in size of Bald Eagles at Glacier National Park, Montana. Mass is in kg and all other measurements are mm.

VARIABLE	PLUMAGE CLASS	N	MALES						
			$\bar{x}(\pm SD)^a$		RANGE	F	P > F	POWER ($\alpha = 0.05$)	
WSpan	Ad	9	1952	(88.00)	(AB) ^b	1800–2100	4.96	0.008	0.804
	Sub	35	1966	(61.13)	(B)	1840–2090			
	Juv	124	2007	(85.44)	(A)	1810–2370			
WnCh	Ad	7	569	(20.64)	(A)	540–596	20.41	<0.001	0.999
	Sub	33	583	(18.00)	(A)	560–617			
	Juv	121	601	(17.87)	(B)	570–654			
EPr	Ad	7	430	(16.86)	(A)	409–457	23.37	<0.001	0.999
	Sub	30	445	(17.41)	(B)	411–481			
	Juv	121	461	(17.07)	(C)	405–520			
NPr	Ad	7	400	(11.77)	(A)	387–417	18.13	<0.001	0.999
	Sub	31	417	(15.94)	(B)	377–446			
	Juv	121	429	(15.40)	(C)	402–496			
TPr	Ad	7	306	(11.76)	(A)	289–322	13.22	<0.001	0.997
	Sub	32	334	(26.52)	(B)	297–450			
	Juv	121	338	(17.06)	(C)	295–405			
Tail	Ad	9	284	(14.75)	(A)	265–307	90.91	<0.001	0.999
	Sub	36	306	(22.16)	(B)	274–380			
	Juv	124	339	(14.70)	(C)	305–393			
CIN	Ad	9	51.0	(1.63)	(A)	47.7–53.0	1.05	0.354	0.231
	Sub	37	50.2	(1.69)	(A)	47.7–54.7			
	Juv	124	50.1	(1.90)	(A)	46.0–54.6			
BDp	Ad	2	32.8	(0.92)	(A)	32.1–33.4	0.21	0.814	0.08
	Sub	3	32.5	(1.40)	(A)	31.0–33.8			
	Juv	20	32.2	(1.31)	(A)	30.0–35.1			
NTTF	Ad	7	17.4	(1.26)	(A)	15.1–19.0	1.23	0.296	0.264
	Sub	27	16.6	(1.08)	(A)	15.1–19.3			
	Juv	100	16.8	(1.14)	(A)	13.5–17.9			
NTTL	Ad	8	15.0	(1.53)	(A)	13.5–18.4	0.91	0.403	0.206
	Sub	32	14.4	(1.03)	(A)	13.0–17.3			
	Juv	122	14.6	(1.22)	(A)	11.1–17.9			
HalClleft	Ad	9	40.1	(1.49)	(AB)	37.7–42.0	3.71	0.027	0.674
	Sub	36	39.8	(1.21)	(B)	37.6–42.4			
	Juv	124	39.1	(1.61)	(A)	36.0–44.2			
HalClright	Ad	9	40.2	(1.37)	(A)	38.5–42.1	3.58	0.030	0.657
	Sub	35	39.8	(1.46)	(A)	37.0–43.0			
	Juv	124	39.1	(1.67)	(B)	35.8–45.0			
OCl	Ad	7	28.4	(1.00)	(A)	27.3–29.7	2.76	0.066	0.539
	Sub	36	28.1	(1.33)	(A)	23.3–31.3			
	Juv	124	27.6	(1.29)	(A)	24.5–34.2			
MCl	Ad	9	32.9	(1.29)	(A)	30.0–34.0	9.45	<0.001	0.978
	Sub	36	32.9	(1.23)	(A)	31.0–36.1			
	Juv	124	31.9	(1.31)	(B)	29.3–36.0			
ICl	Ad	9	39.5	(1.71)	(A)	36.0–42.3	1.11	0.333	0.242
	Sub	36	39.1	(1.80)	(A)	33.2–42.5			
	Juv	123	38.8	(1.84)	(A)	33.4–46.4			
Mass	Ad	6	4.30	(0.37)	(A)	3.8–4.8	0.66	0.516	0.159
	Sub	21	4.22	(0.31)	(A)	3.8–5.2			
	Juv	90	4.14	(0.43)	(A)	3.2–5.1			

^a Within a given variable, means followed by the same letter are not different, based on Fisher's LSD ($\alpha = 0.05$).

^b With some variables, the power to detect differences was relatively low because of small sample size; e.g., in this case juveniles are different from subadults but not from adults.

Table 1. Continued.

FEMALES						
<i>N</i>	$\bar{x}(\pm SD)^a$	RANGE	<i>F</i>	<i>P</i> > <i>F</i>	POWER ($\alpha = 0.05$)	
15	2047 (58.39) (A)	1940-2130	11.14	<0.001	0.991	
39	2071 (63.61) (A)	1930-2220				
75	2118 (68.31) (B)	1940-2290				
15	599 (7.81) (A)	583-613	37.36	<0.001	0.999	
36	615 (17.80) (B)	580-665				
70	631 (12.98) (C)	605-662				
13	447 (10.18) (A)	433-462	30.73	<0.001	0.999	
34	464 (19.90) (B)	429-546				
69	479 (13.24) (C)	447-510				
15	420 (8.97) (A)	409-434	21.48	<0.001	0.999	
36	434 (22.02) (B)	385-495				
70	447 (13.13) (C)	415-479				
14	331 (14.44) (A)	312-369	9.54	<0.001	0.978	
34	348 (20.62) (B)	313-403				
70	351 (12.78) (B)	320-384				
15	300 (12.14) (A)	281-334	121.10	<0.001	0.999	
40	318 (18.28) (B)	285-358				
76	353 (13.82) (C)	308-380				
15	56.0 (2.19) (A)	51.0-59.9	8.42	<0.001	0.961	
40	55.2 (1.58) (A)	51.7-59.0				
76	54.2 (1.71) (B)	50.3-59.2				
5	35.7 (1.96) (A)	34.0-39.1	0.38	0.690	0.102	
3	35.8 (1.29) (A)	34.7-37.2				
13	35.2 (0.94) (A)	33.2-36.6				
13	19.6 (1.18) (A)	17.7-21.4	5.17	0.007	0.817	
29	18.5 (1.17) (B)	15.6-21.0				
60	18.5 (1.06) (B)	16.2-20.7				
15	17.0 (1.27) (A)	13.8-18.9	2.28	0.107	0.455	
37	16.3 (1.15) (B)	12.2-17.9				
74	16.4 (1.00) (AB)	14.0-18.7				
14	45.2 (1.63) (A)	42.3-48.0	15.30	<0.001	0.999	
40	44.5 (1.42) (A)	41.5-47.8				
76	43.3 (1.39) (B)	40.4-46.5				
15	44.7 (2.33) (A)	38.6-48.3	11.08	<0.001	0.991	
40	44.5 (1.64) (A)	40.5-49.0				
76	43.1 (1.64) (B)	39.4-46.8				
15	31.5 (1.31) (A)	29.5-34.1	13.05	<0.001	0.997	
38	31.3 (1.25) (A)	29.0-34.2				
76	30.2 (1.28) (B)	27.5-32.9				
15	36.3 (1.63) (A)	33.9-39.1	17.32	<0.001	0.999	
40	35.7 (1.93) (A)	27.0-39.1				
76	34.4 (1.71) (B)	28.5-38.8				
15	44.1 (1.13) (A)	42.3-46.6	22.25	<0.001	0.999	
40	43.5 (1.42) (A)	38.2-46.0				
76	42.2 (1.22) (B)	39.6-45.6				
12	5.14 (0.36) (A)	4.5-5.8	2.28	0.109	0.451	
23	5.05 (0.45) (A)	4.3-6.2				
49	4.90 (0.41) (A)	4.0-5.8				

Table 2. Size measurements of migrant adult Bald Eagles measured at Glacier National Park, Montana (GNP), compared with study skins from Canada, Alaska, and the northern U.S. (Bortolotti 1984a) (B in table), and migrant eagles at San Luis Valley, Colorado (Harmata 1984) (H in table). Mass is in kg; all other units are mm.

VARIABLE	SEX	GNP		N	B		N	H	
		N	$\bar{x}(\pm SD)$		$\bar{x}(\pm SD)^a$	$\bar{x}(\pm SD)^a$			
WSpan	M	9	1952 (88.00)				17	2010	(54.0)*
	F	15	2047 (58.39)				17	2140	(57.0)***
WnCh	M	7	569 (20.64)	21	570 (12.89)		17	574	(14.0)
	F	15	599 (7.81)	14	629 (6.87)***		17	605	(14.0)
Tail	M	9	284 (14.75)	20	255 (10.67)***		17	301	(11.0)**
	F	15	300 (12.14)	14	289 (16.07)		17	317	(11.0)***
EPr	M	7	430 (16.86)	21	407 (15.18)**				
	F	13	447 (10.18)	13	452 (16.18)				
CILn	M	9	51.0 (1.63)	21	50.8 (1.42)		17	50.4	(2.0)
	F	15	56.0 (2.19)	14	57.2 (1.41)*		17	55.4	(2.0)
BDp	M	2	32.8 (0.92)	18	32.2 (1.07)				
	F	5	35.7 (1.96)	12	36.9 (1.63)				
HalCl	M	9	40.1 (1.49)	20	39.8 (1.42)				
	F	14	45.2 (1.63)	13	45.7 (1.93)				
Mass	M	6	4.30 (0.37)				17	4.74	(0.7)*
	F	12	5.14 (0.36)				17	5.32	(0.7)

^a Differences from GNP based on unpooled *t*-tests: $\alpha = 0.1^*$; 0.05^{**} ; 0.001^{***} .

subjective and may influence the result by several cm. Although Bortolotti (1984b) and Garcelon et al. (1985) found high levels of confidence in the repeatability of measurements within their studies, there may be greater variation between studies.

About 25% of the eagles we measured had feathers that were incompletely emerged. Molt in northern Bald Eagles generally is limited to late spring, summer, and early fall (McCullough 1989). Bortolotti and Honeyman (1985) suggested that molt in adult Bald Eagles in Saskatchewan continues well into the autumn. Harmata captured migrant eagles 2–5 mo later than we did. We believe this added time for growth of new feathers could have partially accounted for the longer feathers in Colorado. Wear between winter and spring might then produce slightly shorter feather measurements on summer territories. Alternatively, one might argue that wear between fall and winter should have produced shorter measurements in the Colorado wintering area compared to our fall measurements. Some differences in feather lengths among studies may be partly an artifact of time of year of measurements.

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LITERATURE CITED

- BORTOLOTTI, G.R. 1984a. Sexual size dimorphism and age-related size variation in Bald Eagles. *J. Wildl. Manage.* 48:72–81.
- . 1984b. Criteria for determining age and sex of nestling Bald Eagles. *J. Field Ornithol.* 55:467–481.
- AND V. HONEYMAN. 1985. Flight feather molt in breeding Bald Eagles in Saskatchewan. Pages 166–178 in J.M. Gerrard and T.N. Ingram [Eds.], *The Bald Eagle in Canada*. Proc. of Bald Eagle Days, 1983. White Horse Publishing, Winnipeg, Manitoba, Canada.
- BROWN, L.H. AND D. AMADON. 1968. *Eagles, hawks and falcons of the world*. Country Life Books, Feltham, Middlesex, U.K.
- GARCELON, D.K., M.S. MARTELL, P.T. REDIG AND L.C. BUOEN. 1985. Morphometric, karyotypic, and laparoscopic techniques for determining sex in Bald Eagles. *J. Wildl. Manage.* 49:595–599.
- HARMATA, A.R. 1984. Bald Eagles of the San Luis Valley, Colorado: their winter ecology and spring mi-

- gration. Ph.D. dissertation, Montana State Univ., Bozeman, MT U.S.A.
- IMLER, R.H. AND E.R. KALMBACH. 1955. The Bald Eagle and its economic status. USDI, Fish and Wildl. Serv., Circular No. 30. Washington, DC U.S.A.
- MCCLELLAND, B.R., L.S. YOUNG, P.T. MCCLELLAND, J.G. CRENSHAW, H.L. ALLEN AND D.S. SHEA. 1994. Migration ecology of Bald Eagles from autumn concentrations in Glacier National Park, Montana. *Wildl. Monogr.* 125:1-61.
- MCCOLLOUGH, M.A. 1989. Molting sequence and aging of Bald Eagles. *Wilson Bull.* 101:1-10.
- PALMER, R.S. [Ed.]. 1988. Handbook of North American birds. Vol. 4. Diurnal raptors, Part 1. Yale Univ Vail-Ballou Press, Binghamton, NY U.S.A.
- STALMASTER, M.V. 1987. The Bald Eagle. Universe Books, New York, NY U.S.A.

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