Assessment of Body Size and Sexual Size Dimorphism in *Haliaeetus leucocephalus* (Bald Eagles) of the Chesapeake Bay

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Abstract

We measured eight morphometric parameters to characterize body size and sexual size dimorphism in *Haliaeetus leucocephalus* L. (Bald Eagle) from the Chesapeake Bay. Linear measurements, including culmen length, culmen depth, hallux length, tarsus length, wing chord, length of 8th primary, and tail length, were made from museum specimens that were exclusive to the Chesapeake Bay population. We obtained mass data from the National Wildlife Health Center's Bald Eagle necropsy program. Bald Eagles from the Chesapeake Bay showed some level of reversed sexual size dimorphism in all characters examined. Mass and tarsus length exhibited the highest dimorphism index. On average, females were more than 30% heavier than males, with a tarsus that was 17% longer. Body size for Bald Eagles in the Chesapeake Bay is larger than in southern populations and smaller than in northern populations, supporting earlier evidence of clinal variation with latitude.

Introduction

Body size has been correlated with a broad array of life history traits, including, among others, behavioral dominance, metabolism, fecundity, survivorship, home range, and migration distance (e.g., Calder 1974, Calder 1984, Peters 1986, Riess 1989). Due to its integral relationship with many biological processes, body size is an important morphological characteristic and its measure is often required to test many prominent ecological hypotheses. Body size is one of only a few parameters that represent a common currency across a wide range of disparate ecological sub-disciplines, from geographic variation on a continental scale, to limits of species coexistence within ecological communities, to foraging behavior and metabolic requirements.

Haliaeetus leucocephalus L. (Bald Eagle) is the largest avian predator in North America. Variation in body size with latitude has been well known and is the primary basis for earlier subspecies designations between southern and northern populations (American Ornithologists' Union 1957). However, most of the available body size information is focused within populations near the extremes of the breeding range. The breeding population of Bald Eagles within the Chesapeake Bay is believed to be reproductively isolated from other populations along the Atlantic Coast and elsewhere throughout North America and occupies a mid-latitude position within the species range (Byrd et al. 1990). There have been no attempts to characterize body size within this population. Here, we attempt to sample birds specifically from the Chesapeake Bay breeding population for the purpose of quantifying body size and extent of sexual dimorphism. We compare findings to other populations throughout the breeding range.

Methods

The Chesapeake Bay is an area of convergence for Bald Eagle breeding populations along the Atlantic Coast. In addition to a resident breeding population, post-nesting and subadult Bald Eagles from breeding populations in the Southeast and Northeast migrate to the Bay during specific periods of the year. In late spring and early summer, eagles migrate north from Florida and other southeastern states to spend the summer months in the Bay (Broley 1947, Millsap et al. 2002, Watts and Byrd 1999). Based on band returns and observations within communal roosts, migrant eagles appear to move into the Bay from southern populations in mid- to late May, spend the summer months, and leave during September (Broley 1947, Clark 1992, Watts and Whalen 1997). Bald Eagles from northeastern Canada and the

United States migrate southward into the Chesapeake Bay during the late fall and early winter period (Byrd et al. 1990, McCollough 1986, Stewart and Robbins 1958). These birds apparently move south in advance of large water bodies freezing over in northern latitudes, and their appearance in the Bay coincides with the movement of waterfowl into the area. Numbers increase through November and December, typically reaching a peak in January. Most northern birds are believed to have moved northward out of the Bay by mid-March.

The convergence of other breeding populations on the Chesapeake Bay makes it difficult to isolate birds from this breeding population for morphometric description. In order to overcome this problem, we screened available material by time of year. We selected periods during the annual cycle when the number of birds from other populations reaches a low. We included materials that were collected or recovered between mid March and late May or mid-September and late November. We selected materials that reflect the core of the Chesapeake Bay breeding population, including Virginia, Maryland, Delaware, southeastern Pennsylvania, and northeastern West Virginia.

We measured eight commonly used morphometric parameters to characterize body size in Bald Eagles from the Chesapeake Bay. Linear measurements were made from preserved specimens from the Natural History Museum of the Smithsonian Institution and from the Bailey-Law collection held at Virginia Polytechnic Institute and State University. Linear characters included culmen length, culmen depth, hallux length, tarsus length, wing chord, length of 8th primary, and tail length. Culmen length was measured as the chord from the distal edge of the cere to the tip of the lower mandible. Culmen depth was measured from the distal edge of the cere to the ventral surface of the lower mandible with the mandibles in the closed position. Hallux length was measured as the distance between the location where the hallux emerges from the skin and its distal end. Tarsus length was measured by palpating the proximal and distal ends of the tarsus bone in order to include the full bone length. All of the bone measurements above were made with dial calipers to the nearest 0.1 mm. In order to improve accuracy, we repeated these measurements 3 times and used an average value to represent the character. Wing chord was measured from the radial-carpal joint to the distal end of the longest primary. The length of the 8th primary was measured as the distance between where the feather inserts on the wing to the distal end. Tail length was measured as the distance between where the feather inserts on the tail and the distal end of the longest retrix. This was accomplished by inserting a metal ruler between the central retrices to the base of the feathers and measuring the longest feather. Some characters could not be measured on all individuals due to specimen condition.

Mass data were obtained from the National Wildlife Health Center's Bald Eagle necropsy program. In order to isolate the Chesapeake Bay breeding population, records were sorted according to the geographic and time-of-year constraints outlined above. In addition, only carcasses that were considered to be in good to excellent condition when weighed were included.

We calculated descriptive statistics and compared average characters for male and female samples using two-tailed t-tests for independent samples. The degree of dimorphism for each character was expressed using the dimorphism index outlined in Storer (1966).

Results

Bald Eagles from the Chesapeake Bay showed some level of sexual dimorphism in all characters examined (Table 1). Females were the larger sex in every respect and size differences were statistically significant for all characters except culmen length. The relative degree of dimorphism varied across parameters, with tarsus length and body mass exhibiting the greatest relative differences between the sexes. On average, females were more than 30% heavier than males, with a tarsus that was 17% longer. Relatively minor but statistically significant differences were found for hallux length and culmen depth. Linear measurements of flight feathers were significantly different between males and females but these characters exhibited considerable variation within gender classes.

Discussion

Clinal variation in body size with latitude has been documented for many vertebrate taxa (e.g., Allee et al. 1949, Mayr 1963). For Bald Eagles, size differences between populations near the extremes of the breeding range have been well known, with northern populations containing significantly larger individuals than southern populations (American Ornithologists' Union 1957). Body size for Bald Eagles in the Chesapeake Bay appears to fall between that reported from populations to the south and north. For example, average wing chord for males (581 mm) and females (621 mm) in the Chesapeake Bay was longer than for southern populations (529 and 577 mm) but shorter than in northern populations (589 and 640 mm; Friedmann 1950). Similarly, tail length for males and females in the Chesapeake Bay was 287 and 316 mm compared to 249 and 271 mm and 310 and 339 mm for southern and northern populations, respectively. These findings are consistent with the positive correlation between body size and latitude that has been documented for many avian species (e.g., Aldrich and James 1991, James 1970). For Bald Eagles, the underlying factors that may have lead to this pattern remain unclear.

Reversed sexual size dimorphism is a common characteristic among predatory birds that has evolved independently in

Table 1. Summary statistics for Chesapeake Bay Bald Eagle morphometric characters. Values presented are means ± 1 SE. Parenthetic values are sample sizes for males and females, respectively. All linear values are presented in mm. Mass is presented in g.

Character	Male	Female	Index[a]	t-statistic	p-value
Culmen length (14, 11)	50.4 ± 1.01	52.3 ± 0.96	1.9	1.33	ns
Culmen depth (14, 10)	33.5 ± 0.52	35.1 ± 0.33	2.3	2.39	<0.05
Hallux length (15, 12)	39.6 ± 0.96	42.3 ± 0.44	3.3	2.34	<0.05
Tarsus length (15, 12)	70.8 ± 1.62	82.8 ± 1.08	7.8	5.76	<0.001
Wing chord (15, 12)	581 ± 8.7	621 ± 7.1	3.3	3.45	<0.01
8th primary length (14, 10)	376 ± 14.1	425 ± 5.3	6.1	2.83	<0.01
Tail length (15, 10)	286 ± 9.1	315 ± 8.1	4.8	2.39	<0.05
Body mass (36, 30)	3522 ± 137.7	4630 ± 105.4	13.6	6.5	<0.001

[a] Dimorphism index (Storer 1966)

different taxa. Several hypotheses have been advanced to explain this form of dimorphism (see Mueller 1990). Some advantages of large female size include a greater capacity to produce and incubate eggs or care for young (Andersson and Norberg 1981, Lundberg 1986, Wheeler 1983) and a size advantage in competition for mates (Newton 1988, Olsen and Olsen 1987). Small males have been suggested to be more efficient foragers and providers (Andersson and Norberg 1981, Hakkarainen and Korpimaki 1991, Lundberg 1986) and superior in territorial contests and courtship displays (Safina 1984). Another line of explanation suggests that it is not absolute size but the relative asymmetry between sexes that is important. For example, female dominance may help to maintain parental roles and reduce overlap in food niches (Mueller 1986, Mueller and Meyer 1984, Smith 1982).

Bald Eagles in the Chesapeake Bay exhibit considerable size dimorphism that is detectable in nearly all of the characteristics measured here. Body mass was particularly dimorphic, with females weighing 30% more than males on average. Although the factors that have contributed to the formation and maintenance of these differences are not completely clear, several of the hypotheses outlined above could easily apply to eagles within this breeding population. Males and females serve functionally different roles during the nesting period. For example, females are behaviorally dominant and control activities on the nest surface, males provide much of the prey through the early period of brood rearing, and females perform more of the incubation, brooding, and chick provisioning duties (Markham and Watts, unpubl. data). Division of labor during the nesting cycle may have consequences for body size.

The level of dimorphism found in the Chesapeake Bay is generally consistent with birds examined in the northern portion of the breeding range (Bortolotti 1984) but varies somewhat in the details. Females were approximately 25% heavier than males in the northern portion of the range. Hard structures such as culmen and hallux appear to be relatively less divergent within the Chesapeake Bay compared to farther north based on comparison of respective dimorphism indices. However, divergence patterns for feather structures appear to be very similar between the geographic areas. Geographic variation in the relative divergence of different structures may suggest geographic differences in some of the underlying selective pressures. A range-wide evaluation of these characters may help to provide further insight into factors that may contribute to sexual dimorphism.

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