Variation and Sexual Dimorphism of the Size of Northern Mockingbirds' White Wing Patches

Michael J. Justice
Departments of Science and
Mathematics
Chowan College
Murfreesboro, NC 27855

Teresa C. Justice
Department of Psychology
Chowan College
Murfreesboro, NC 27855

I. Introduction

Quantitative and qualitative aspects of a visual signal are necessarily related to and constrained by numerous factors. These factors include the signal's communicative function, the natural history of the species involved, the sensory capacities of the relevant recipients, and the mechanism of signal generation. Thus, quantifying the form of and variability in a visual signal and considering these data along with natural history may provide some insight into the role of a signal in a communication system.

Northern Mockingbirds (*Mimus polyglottos*) have large white patches on dark gray wings (Fig. 1). Although the wing patches are largely hidden when perched, the behavioral contexts of their exposure suggest they function in communication. Exposure of the wing patches occurs during flight, copulation, and the execution of two displays: wing flashes (Allen 1947, Brackbill 1951, Hailman 1960, Selander and Hunter 1960) and flight displays (Derrickson and Breitwisch 1992). Wing flashes are synchronous, discontinuous, non-flight-related extensions of both wings above the horizontal. They are most often seen while the bird is foraging on the ground (Hailman 1960), but have been observed during attacks on predators as well (Hicks 1955). Flight displays are performed while singing: the bird will fly approximately 1 - 3 m upward and then slowly descend to approximately the same perch, often spiraling during both ascent and descent.

Michener (1953), using field sketches, reported that male mockingbirds are likely to have larger wing patches than females. The present study first quantified the variability and sexual dimorphism in mockingbird wing patch size, and then examined the utility of linear discriminant analysis and linear

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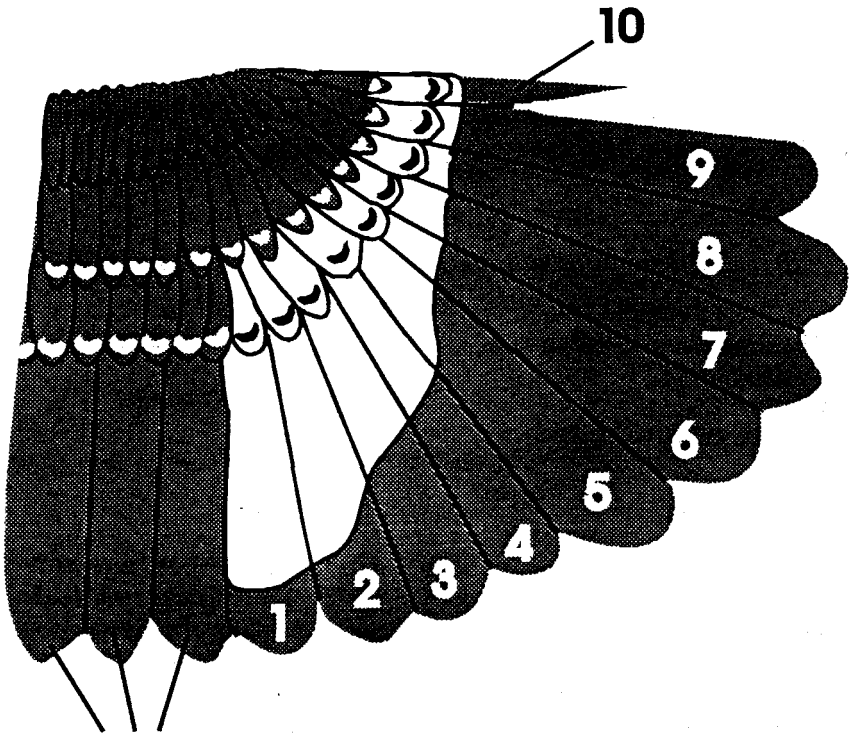
Secondaries

Fig. 1. Diagram of a typical mockingbird's white wing patch, dorsal view. The individual primaries are numbered.

regression to sex mockingbirds in the hand. Given the natural history of mockingbirds, a sexual dimorphism in wing patch size raises at least three possibilities concerning the signal function(s) of wing patch size. Specifically, wing patch size may be used in 1) sex recognition, 2) intersexual quality advertisement, and/or 3) predator deterrence: males may require a larger, more conspicuous badge of warning because they are the primary caretakers of older fledglings. These hypotheses will be considered where the data allow.

II. Methods

Subjects. Mockingbirds are medium-sized (45 - 60g; 21 - 27cm) oscines. Sexing through breeding-season sexually dimorphic behaviors is fairly easy: only males sing and only females incubate. The mockingbirds used in this study were trapped year round from a population of approximately 65 color-banded wild mockingbirds residing on the 72 ha suburban residential campus of The University of North Carolina at Greensboro (36°N 79°W). From routine monitoring of the population, mating status was known for most of the birds used in the study. Approximately 12% of the males are unmated at any one time (personal observation). This along with an apparent lack of unmated females during the breeding season indicates the study population is male-biased, as is found in other populations (Breitwisch 1989, Derrickson and Breitwisch 1992).

Morphometrics. Upon capture, the bird was first banded (if not already) and then the following measures were taken in the field, after which the bird was released. Not all measures were taken on all birds, and thus sample sizes vary slightly for the various measures. Each measure was taken with dial calipers to the nearest 0.10mm. The entire process took 15 - 25 minutes. Tarsometatarsus length was measured as the diagonal of the tarsometatarsus from the middle posterior point of the tibia-metatarsus joint to the center of the anterior lower edge of the most distal undivided scute (Baldwin *et al.* 1931). The length of each primary flight feather was measured as the chord of the feather from the anterior edge of the wrist joint to the tip, without flattening the natural curvature of the feather. Here, "wing length" is the chord of the longest primary, while "total wing length" is the sum of the chords for all 10 primaries.

Wing patch size was measured from the ventral surface of the left wing's primary flight feathers, without flattening their natural curvature. Each of the ten primaries is white by the wrist and dark gray distally (Fig. 2). Ventrally, the wing patch is comprised of all the white on the primaries except some near the wrist, which is covered by very light gray underwing coverts. Dorsally, the white near the wrist is obscured by dark gray coverts; the wing patch is comprised of a row of white primary coverts and the white on the primaries which extends beyond the coverts. On each individual primary, the border between the white and gray is often irregular and sometimes blurred (Michener 1953; personal observation). The amount of white on an individual feather was measured as the length of the chord from the wrist joint to the most distal point on the shaft where a line drawn perpendicular to the shaft across either the

inner or outer vane did not intersect any gray area (Fig. 2). Wing patch size was computed as the sum of the lengths of white on all 10 primaries. Occasionally, primary #10 did not have any white extending beyond the underwing coverts. In those instances the amount of white was the chord of the distance from the wrist to the distal edge of the underwing coverts.

One researcher (MJJ) took all morphological measurements. Because 14 birds were captured more than once, precision of the measures could be assessed. Differences between measures were negligible. The median difference (1.0mm) represents only a 2% error on a typical measure of the amount of white on a primary (approximately 50.0mm), and the modal difference (0.2mm) was considerably smaller. Also, for all primaries measured, the first measure of the amount of white was extremely highly positively correlated with the second measure (Spearman's rho = 0.96, N = 140 pairs of measures).

Statistical Analyses. Parametric statistics were used when adequate sample sizes were available and all assumptions were met. All tests were two-tailed. The linear discriminant and linear regression analyses were performed using Minitab Release 10Xtra on a mainframe processor. All other statistics were computed either by hand or with an AST PC with an Intel 486sx microprocessor using Systat Version 5.0.

III. Results

Morphometrics. All results are in mm. Mean ± SE wing patch size for males was 546.7 ± 4.7 (N = 34; range: 479.5 - 597.1) and for females was 486.0 ± 5.0 (N = 29; range: 442.5 - 564.8). Kolmogorov-Smirnoff one-sample tests for normality indicated that wing patch size was normally distributed for both males (N = 34, $P = 0.08$) and females (N = 29, $P = 0.525$). The variance in wing patch size was the same for both sexes ($F_{33,28} = 1.04$; $P > 0.20$). Males had larger wing patch sizes than females ($t = 8.76$, df = 61, $P < 0.001$; $r^2 = 0.557$). Males known to be mated had larger wing patches than males known to be unmated (mated: 558.7 ± 6.9, N = 16; unmated: 528.0 ± 10.2, N = 5; $t = 2.25$, df = 19, $0.02 < P < 0.05$, $r^2 = 0.21$).

Descriptive statistics on the amount of white on each of the 10 primary flight feathers are presented in Table 1. For each of the 10 primaries, the amount of white was significantly greater in males (all $P < 0.001$), even with the alpha level adjusted to 0.005 to compensate for the multiple t tests used. The larger wing patches in males are mainly due to males having more white on primaries 1, 2, 3, and 4 (Table 1). Within males, primaries 1, 2, 3, and 4
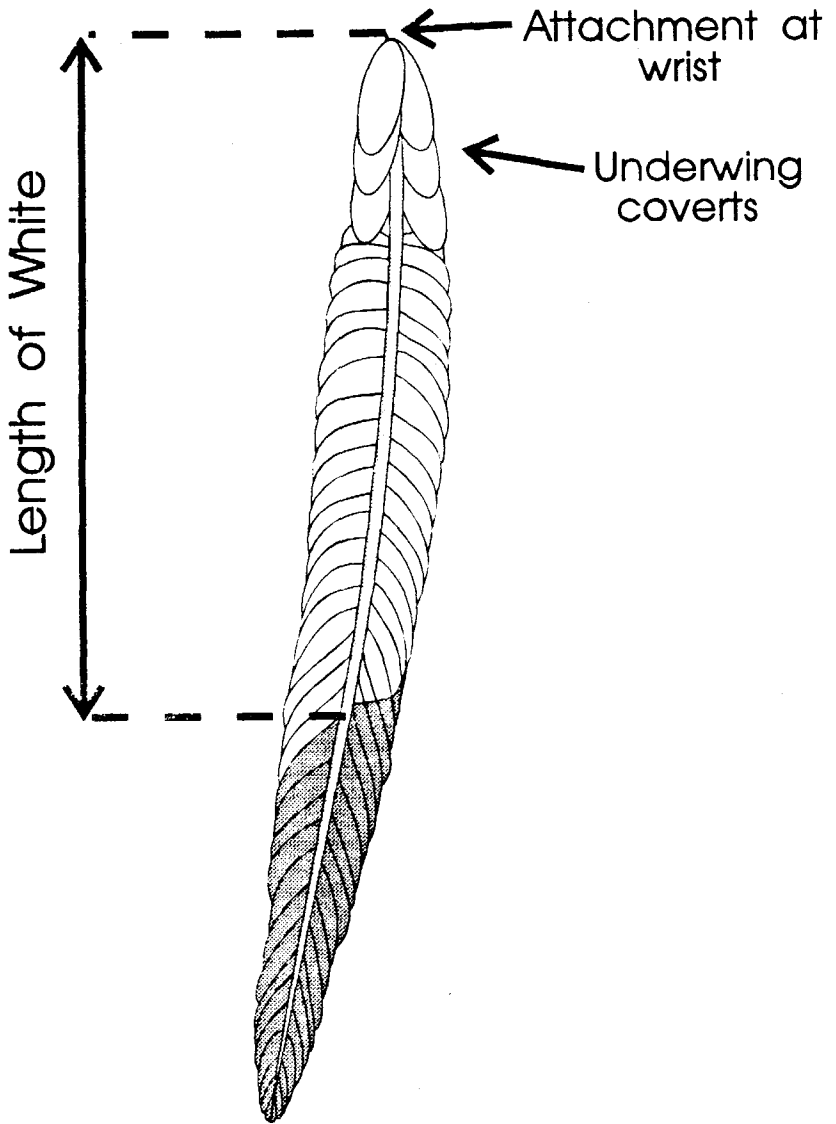
Attachment at wrist

Underwing coverts

Length of White

Fig. 2. A typical mockingbird primary, with the measure of the amount of white indicated at left.

were considerably more variable than the others (pairwise F tests, all P values < 0.001). Within females, only primaries 1, 2, and 3 were more variable than primaries 5 - 10. When the wing is extended, the variability in the white on these first few primaries would largely affect how long the wing patch appears as it extends from the 10th primary toward the secondaries (Fig. 1). Variability in the other primaries, which was considerably lower, would largely affect how wide the wing patch looks from the proximal edge of the white coverts to the distal edge of the wing patch on the primaries.

Table 1
Descriptive Statistics on the Amount of White on Each of the Ten Primary Flight Feathers. P# = Primary Number. CV = Coefficient of Variation. ♂ - ♀ = Difference in Means, Males Minus Females.

P#	Sex	*n*	Min	Max	Mean	SE	Med	CV	♂ - ♀
10	♂	34	30.6	39.5	35.11	0.35	35.2	0.058	2.58
	♀	29	30.4	38.0	32.53	0.31	32.3	0.052	
9	♂	34	43.5	55.2	47.88	0.40	47.7	0.049	3.73
	♀	30	39.4	49.4	44.15	0.41	44.1	0.051	
8	♂	34	46.6	53.2	49.55	0.27	49.6	0.032	3.27
	♀	30	42.7	51.4	46.28	0.36	46.0	0.042	
7	♂	34	47.3	56.6	51.49	0.41	50.9	0.046	3.64
	♀	30	42.8	52.8	47.85	0.41	48.1	0.047	
6	♂	34	41.5	57.9	52.85	0.52	53.2	0.057	3.69
	♀	30	44.3	55.3	49.16	0.44	48.8	0.049	
5	♂	34	49.3	59.0	52.24	0.43	51.5	0.048	4.30
	♀	30	42.0	53.5	47.94	0.48	48.1	0.055	
4	♂	34	46.4	65.0	53.63	0.78	52.7	0.085	7.43
	♀	30	38.8	50.7	46.20	0.48	46.8	0.057	
3	♂	34	47.9	78.0	65.37	1.15	64.4	0.102	12.89
	♀	30	42.5	72.6	52.48	1.27	51.3	0.133	
2	♂	34	55.5	78.2	69.53	0.87	70.2	0.073	10.02
	♀	30	47.6	72.9	59.51	0.95	59.1	0.088	
1	♂	34	58.1	77.7	69.02	0.78	68.9	0.066	8.94
	♀	30	47.6	69.9	60.08	0.87	59.6	0.079	

As in other populations (Derrickson and Breitwisch 1992 and citations within), tarsometatarsal length and wing length were both longer in males on average, with considerable overlap across the sexes. Mean ± SE tarsometatarsal length for males was 33.6 ± 0.22 (N = 26; range: 31.2 - 35.5) and for females was 32.3 ± 0.22 (N = 24; range: 30.1 - 34.7). The two sexes differed significantly (t = 4.069, df = 48, P < 0.001; r^2 = 0.256). Mean ± SE wing length for males was 111.8 ± 0.65 (N = 36; range: 103.3 - 119.7) and for females was 104.8 ± 0.66 (N = 33; range: 97.7 - 110.9). Again, the two sexes differed significantly (t = 7.563, df = 67, P < 0.001; r^2 = 0.461).

Wing patch size was correlated with wing length in males (r = 0.576, N = 34, P < 0.001) and in females (r = 0.585, N = 29, P < 0.001). However, there was no correlation between wing patch size and tarsometatarsal length in males (r = 0.072, N = 26, P = 0.727) or in females (r = 0.233, N = 22, P = 0.296).

The positive relationship between wing patch size and wing length raises the possibility that females are choosing males by body size alone, and the larger wing patch size in males may be due simply to the allometric relationship between wing patch size and body size. Thus, wing patch size divided by total wing length (multiplied by 100 for simplicity) was also compared between males and females. Mean ± SE of (wing patch size/total wing length) x 100 for males was 54.54 ± 0.4 (N = 29; range: 48.60 - 57.98) and for females was 51.61 ± 0.5 (N = 21; range: 47.93 - 57.00). Kolmogorov-Smirnoff one-sample tests for normality indicated that this variable was normally distributed for both males (N = 29, P = 0.986) and females (N = 21, P = 0.671). The variance in wing patch size was the same for both sexes ($F_{20,28}$ = 1.34, P > 0.10). Even when corrected for total wing length, males still had significantly larger wing patch sizes than females (t = 4.76, df = 48, P < 0.001; r^2 = 0.321).

Sexing Birds in the Hand. Attempts to use any combination of the measures of the amount of white on individual primaries produced multicollinearity problems, as did combinations of body size measures. Therefore, only wing length and wing patch size were used in the analyses.

Minitab produced the following linear discriminant functions:

Males: - 475.42 + (7.95)Wing length + (0.12)Wing Patch Size
Females: - 419.88 + (7.74)Wing length + (0.05)Wing Patch Size

Data collected from the bird in the hand should be entered into both of these functions; the bird should be placed in the category in which it scores highest. The linear regression function produced was

Sex = 7.5499-(0.0220*Wing Length)-(0.00712*Wing Patch Size)

with sex scored as male = 1 and female = 2. Birds scoring below 1.5 are classified as males; females score above 1.5. The standard error of the wing length coefficient was 0.01; that of the wing patch size coefficient was 0.00168. The ANOVA table for this analysis is depicted in Table 2.

Table 2
Anova Table for Regression of Wing Length and Wing Patch Size on Sex

Source	SS	df	MS	F	p
Regression	8.99	2	4.49	40.40	<< 0.0001
Residual	6.66	60	0.11		

Using either of these functions on the complete original data set, 31 out of 34 males (91.2%) and 25 out of 29 females (86.2%) were correctly classified (overall 88.9%). Thus, there is a slight tendency for these functions to misclassify females as males, although the overall proportion of correctly classified individuals is rather high. Rerunning the discriminant analysis with males assigned a prior probability of 0.52 (based on the male-biased sex ratio of approximately 1.1:1) did not improve the proportion of correct classifications. A jack-knifed cross validation on the discriminant analysis produced the same proportions of correct classifications as the validation using the entire original data set.

IV. Discussion

As stated earlier, a wing patch size dimorphism raised the possibilities that wing patch size may be involved in sex recognition, quality advertisement, and/or predator deterrence. The data presented here can certainly address the first two possibilities.

Sex Recognition. The present data suggest sex recognition is an unlikely function. Considering that there is a male-biased sex ratio and females defend the territory against other females (Derrickson and Breitwisch 1992), males with patches in the females' size range could be mistaken for females and if so would be at a considerable reproductive disadvantage, especially if they elicit territorial aggression from females. If wing patch size is a signal for sex recognition, then one would expect that most males would have wing patches considerably larger that most females' wing patches, with very little overlap in size. Instead, only 55.7% of the variation in wing patch size was explained by sex, and there was considerable overlap between the sexes. In fact, 73.2% of males are in the females' size range (the largest female wing patch was 0.62 standard deviation above the males' mean). This casts doubt on the possibility that wing patch size is primarily used in sex recognition, although it may serve to supplement other signals of sex.

Quality Advertisement. If wing patch size is an intersexual signal of male quality, then one would expect it to be 1) sexually dimorphic, as a result of long-term female choice for the largest wing patches, 2) variable among males, because it is a signal which reflects the variability in male quality, 3) related to some aspect of male quality, 4) displayed to potential mates, and 5) generally larger in mated males. Mockingbirds' wing patch size is dimorphic and variable among males. Within males, wing patch size correlated with at least one measure of body size (wing length); body size is related to success in agonistic encounters in many species (Archer 1988) and thus might be considered an aspect of male quality. Further, the flight displays are performed during song, which is used primarily for mate attraction (Derrickson and Breitwisch 1992 and citations within), and are performed much more often by unmated males compared to mated males (Breitwisch and Whitesides 1987). Thus, while song likely attracts potential mates, the accompanying flight displays may function to display the wing patches to these females. Mated males had significantly larger wing patches than unmated males, suggesting a female preference for larger patches. Taken together, these data support the hypothesis that wing patch size may be a signal of male quality to female mockingbirds.

The study of mockingbirds, and particularly of sexual selection in mockingbirds, has been dominated by an interest in their acoustical communication because of their complex song. The present research indicates that mockingbirds may have a well-developed system of intersexual visual signals as well, which should be considered in future studies of their life history and habits. Clearly, such studies would be facilitated by being able to · sex mockingbirds at the time of banding. Both the discriminant analysis and the regression analysis had rather high rates of correct classification. The regression function, however, would be easier to compute in the field or to graph for use in the field. Unfortunately, neither these functions nor the sexual dimorphism in the "length" of the wing patch can be considered as definitive tools for sexing mockingbirds in the hand because of the large amounts of overlap in wing patch size and the reasonable possibility of a misclassification of a female of above-average size. However, the discriminant and regression functions are likely to provide better resolution than univariate comparisons because of the large amounts of male-female overlap observed in all mockingbird morphometry to date.

Acknowledgments

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