What's with hue? An exploration of sexual dichromatism in chipping sparrows

Rachel Lee
University of Michigan Biological Station, 9133 East State St., Pellston, Michigan 49769; email: rachshao@umich.edu

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ABSTRACT

In some species of birds male and female plumage reflects differently in the UV spectrum. This "hidden" (to the human eye) form of sexual dichromatism has been uncovered through advances in reflectance spectrometry. We were interested in crown color as a potentially UV dichromatic sexually selected trait in chipping sparrows. We studied sexual dichromatism in the UV and visible spectrums, as well as correlations between crown color and morphology. In our study sample of live birds and dead museum specimens there was no statistically significant difference between males and females in the UV or visible spectrums, however there was a trend towards dichromatism in UV hue. We also found a significant correlation between male wing length and UV hue as well as a significant degree of sexual dimorphism in wing length. Previous studies relating dimorphism in wing length to sexual dichromatism may support the trend in sexual dichromatism.

Introduction

Sex-based difference in coloration, or sexual dichromatism, is a common form of dimorphism in birds. The degree of sexual dichromatism varies widely among different species (Badyaev and Hill 2003). Males typically have brighter plumage than females, and most of the attention paid to sexual dichromatism goes to species in which the males are brilliantly colored and the females appear drab or camouflaged (Kraaijeveld et al. 2003). However, many species exhibit plumage elaboration that appears in both sexes.

"Hidden" sexual dimorphism has been found in some small passerine species such as the European blue tit (*Parus caeruleus*). In these birds, male crowns reflect more in the UV range than female crowns (Andersson et al. 1998). While blue tits show significant sexual dimorphism in the amount of reflectance in the UV range (320-400nm), the amount of visible reflectance is not significantly different between the sexes. Thus, this dimorphism is "hidden" to humans, whose visual capacity only lies in the visible spectrum of electromagnetic radiation (Andersson et al. 1998). Findings such as this call into question many of the previous assumptions made about bird species that exhibit no apparent difference in coloration.

Sexual monomorphism, or the similar appearance of male and female ornamentation, is another relatively unexplored aspect of avian biology (Amundsen 2000). The traditional view of sexual selection is that females are exclusively the choosy sex and that they select for desirable traits in males. Darwin attributed similar ornamentation in males and females to "modes of inheritance", with the selected traits being transferred to females even though they have no function for them (reviewed by Amundsen 2006). The modern interpretation of this hypothesis is that female ornamentation is an indirect response to sexual selection on males, meaning that it is due to the fact that most of the genome is shared by both sexes, and that traits that are selected in males are also selected for in the population as a whole (Amundsen and Parn 2000). Recent research suggests that direct selection is acting on female ornamentation either due to males exercising some degree of choice in their partner (mate choice) or due to competition between females (female-female interactions) (Amudsen 2000). One

example of direct selection on female ornamentation is the curled wing feathers in black swans *Cygnus atratus*. Here, the degree of feather elaboration is correlated with pairing status, social dominance and indirectly, reproductive success in both sexes (Kraaijeveld et al. 2003). Similar selective mechanisms could be working on plumage coloration in other bird species that are monochromatic.

Chipping sparrows are an interesting species to study in relation to sexual selection and coloration because of their bright chestnut-colored crowns. Crown color and patterning is often subject to sexual selection in birds (Pruett-Jones, pers comm), and it is possible that the chestnut crown color in chipping sparrows is a sexually selected trait. The extent of sexual dichromatism in chipping sparrow crown color has previously only been described subjectively. Females are described in most field guides as "duller" than the males with some brown streaking in the crown (Middleton 1998). The aim of this study is to determine the degree of sexual dichromatism in chipping sparrows in both UV and visible spectra, as well as to explore the relationship between crown color and other morphological characters.

Methods

Study Species

Chipping sparrows are small passerines that are common summer residents in North America. Both sexes show similar plumage, with a bright chestnut-colored crown, distinct white superciliary stripe, black lores and eye stripe. They have traditionally been viewed as a monogamous species, but recent research has suggested that once nesting has begun, males seek extra-pair copulations with females in neighboring territories (Middleton 1998). Females do most of the incubation and brooding, while males are mostly responsible for feeding nestlings during the first three days (Middleton 1998).

Study specimens:

We captured live chipping sparrows on the University of Michigan Biological Station (UMBS) campus in Pellston, Michigan, throughout the month of July 2007. We captured the birds using song playback and mist nets, and then transported them to an office where we performed morphological measurements (weight, tarsus length, wing length, tail length, cloacal protuberance in males, and bill size). Live birds were sexed by the presence of a brood patch or cloacal protuberance. We caught twelve live birds (nine males and three females).

Our second data set consisted of museum specimens obtained from the University of Michigan Museum of Natural History (UMMNH) and the UMBS study skin collection. We received thirty total specimens from UMMNH (fifteen males and fifteen females), and five total from the UMBS collection (four males and one female). Specimens were collected over that past fifty years from sites throughout the lower peninsula of Michigan. The only morphological measurement we took on specimens was wing length.

Reflectance Spectrometry:

Five measurements were taken on each bird's crown using a USB2000 spectrometer. The PX-2 xenon light source provided light in the 320 – 700 nm range, which covers both UV and visible wavelengths (Montgomerie 2006). Spectral reflectance

was measured in relation to a Spectralon white standard and black felt dark standard. Data from the spectrometer was entered into Tiger Spectre v. 1.7, which calculated the average hue, chroma and brightness from the five readings taken on each specimen. Average hue, chroma and brightness were calculated for reflectance in the visible range, the UV range and total (both UV and visible light).

We compared the crown coloration between live and dead specimens and between dead males and dead females with a one-way ANOVA in SPSS 14.0. Correlation between crown color and morphological traits was determined using a linear regression with the morphological trait as the independent variable and color variables (hue, chroma and brightness) as the dependent variables. Sexual dimorphism in morphological traits was also determined using a one-way ANOVA test in SPSS 14.0.

Results

Live vs. dead

Our first objective was see if there was a statistically significant difference in crown color between live and dead males specimens. Nine live and 19 dead (4 from UMBS and 15 from UMMNH) chipping sparrows were measured. We found significant difference in crown hue in both the UV and visible ranges between live and dead males (see Figure 1). Significant difference was also found in UV chroma, but not visible chroma, UV brightness or visible brightness. Although some color variables showed no significant difference between the live and dead samples, the significant differences in visible chroma and hue convinced us that the live and dead samples could not be considered together, and should thus be considered two separate data sets.

Sexual Dichromatism:

We could not perform statistical analysis on sexual dichromatism in the live data set because our sample of live females (N=3) was too small. We therefore limited our analysis to dead specimens. Nineteen dead males and sixteen dead females were measured. No significant statistical difference was found in any of the color variables between males and females. However, UV hue may suggest a trend towards sexual dimorphism because it has a significance level less than 10% (p=0.059) (see Figure 2).

Morphology:

We found a significant correlation in dead male birds between UV hue and wing length from a linear regression (p=0.011, R=0.570, n=19). A statistically significant difference was found between male and female wing length using a one-way ANOVA (p=0.000). The mean wing length for males was 69.15 cm with a standard deviation of 1.96 cm, and the mean wing length for females was 66.10 cm with a standard deviation of 2.03 cm.

Discussion

Sexual Dichromatism

Chipping sparrow crowns are not sexually dichromatic in the visible spectrum. Brightness in the visible range showed very high similarity (see Table 2) between the two sexes and this finding contradicts the field guide description that females are “duller” than males. It is possible that the field guide classification represents a bias towards

traditional thinking about female ornamentation (see introduction). The preconception that females exhibit reduced plumage may have made bird watchers and ornithologists more inclined to view female plumage as duller, even though this has not been shown to be the case.

Chipping sparrows also do not exhibit sexual dichromatism in the UV range. There may, however, be a trend towards sexual dichromatism in UV hue ($p = 0.059$). Our study was limited to a relatively small sample size of dead specimens (males, N=19; females, N=16), and it is possible that a larger sample size could have shown a stronger degree of dichromatism in the UV spectrum. Sexual dichromatism in the UV spectrum is an increasingly common finding in bird species as more studies are being performed that take UV reflectance into consideration. According to Bennett and Cuthill (1994), the nature of avian color perception is vastly different from that of humans. Human vision is trichromatic, which means that all hues can be produced by mixing red, green and blue light, while avian vision is tetrachromatic (and sometimes pentachromatic), which can result in six (or eight) primary hues. Mixing of these primary hues allows birds to see many more classes of hue than humans. Bird plumage is thus even more colorful than we as humans could ever perceive. The scope of our study did not extend into an investigation of assortative mating and crown color. Further research to see if females and males preferentially mate with brighter or more UV chromatic partners might help clarify the role of sexual selection in crown color.

Morphology and crown color

UV hue appears to be an important aspect of crown color because in addition to the trend towards dichromatism in UV hue, we also found a significant positive correlation between UV hue and wing length in dead males (see Figure 1). This correlation suggests that UV hue may communicate information to other individuals. The most likely scenario is that the UV hue of the crown is a part of signaling in mate choice because such small differences in crown color could not be seen over large distances and would thus not be an effective signal in territoriality or male–male interactions (Pruett-Jones pers comm). No significant correlations between morphological traits and crown color were found in live males. This could be due to the fact that the live male sample size (N=9) was smaller than the dead male sample size (N=19). Further investigations of the relationship between crown color and other aspects of morphology are needed to determine whether or not chipping sparrow crown color is an honest signal of the quality of an individual.

A significant difference was found in wing length of males and females, with males having longer wings (see Figure 2). Considering this sexual dimorphism, the correlation between UV hue and wing length in males further supports the trend in sexual dichromatism.

Extra-pair fertilizations and dichromatism:

Although chipping sparrows have traditionally been considered a monogamous species, a study of a chipping sparrow population in Ontario found chipping sparrows to be opportunistically promiscuous and polygynous (Middleton 1988). A large-scale study by Dunn et al. (2001) found an association between sperm competition (i.e. extra-pair fertilizations) and dimorphism in wing length in socially monogamous species. These

studies are consistent with our findings of sexual dimorphism in wing length and support, though do not prove, the finding that chipping sparrows participate in extra pair copulation. Extra-pair fertilizations may increase sexual dimorphism due to the increased intensity of sexual selection on male morphological traits (Dunn et al 2001). Additionally, a study by Moller and Birkhead (1994) found plumage dimorphism to be positively related to extra-pair paternity rather than traditional mating systems. Thus the occurrence of extra-pair fertilization in chipping sparrows lends further support to the trend in sexual dichromatism that we found.

Conclusion

In summary, although we found no statistically significant dichromatism, we found a trend towards sexual dichromatism in UV hue in chipping sparrows. This trend is supported by several of our own observations as well as findings from previous studies. It is supported by the significant sexual dimorphism in wing length and the corresponding correlation between wing length and UV hue in males. Further support comes from the correlation between extra-pair fertilizations and sexual dichromatism.

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FIGURE LEGEND

Figure 1: Crown coloration of live and dead male chipping sparrows. Live and dead mean estimates with significance values given by one-way ANOVA test.

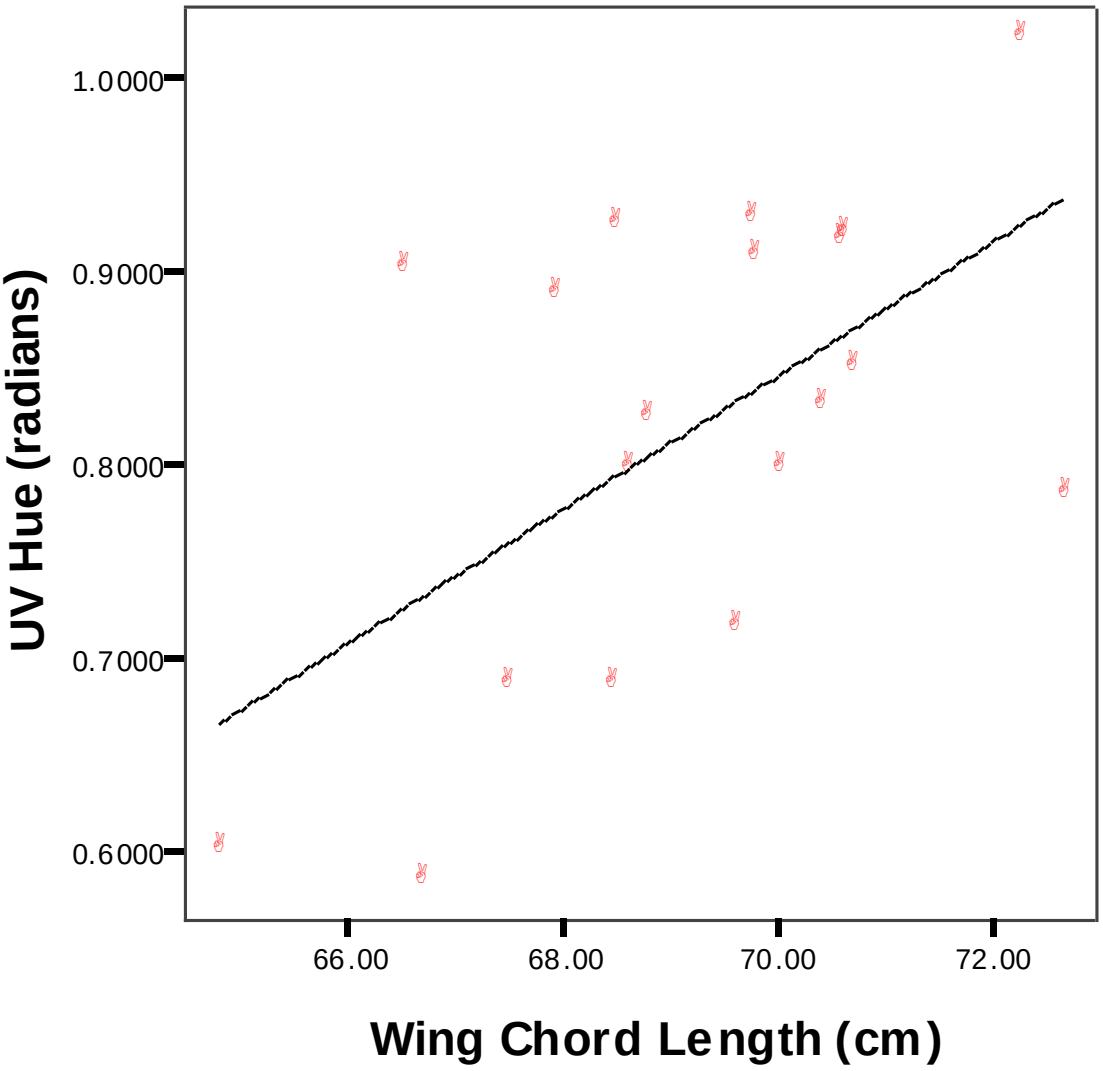
Figure 2: Crown coloration of male and female dead chipping sparrows. Males and female mean estimates with significance values given by one-way ANOVA test.

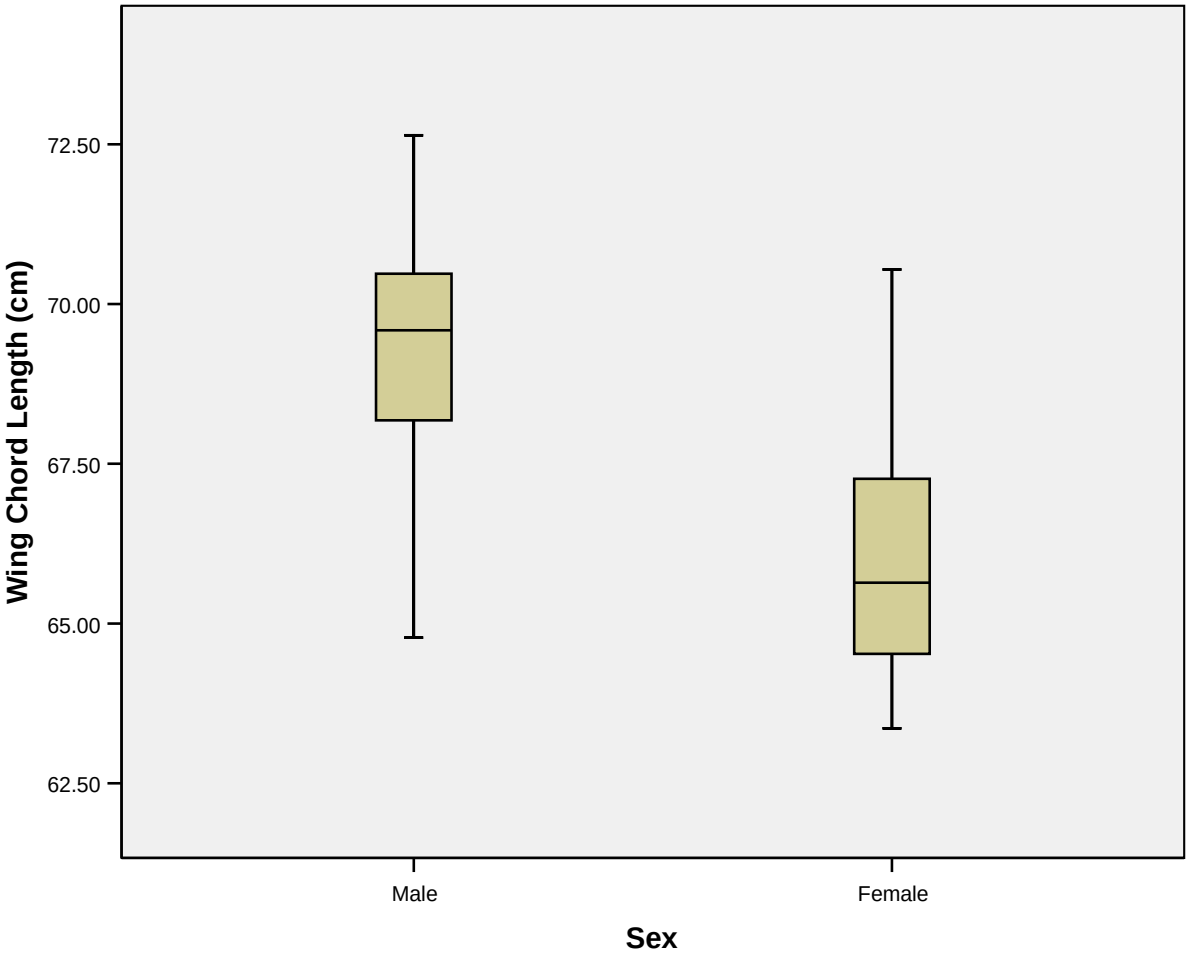
Graph 1. UV hue (in radians) plotted against wing length (in cm) of 19 dead males showing positive correlation between UV hue and wing length ($R=0.570$, $p=0.011$)

Graph 2. Sexual dimorphism in wing lenth of chipping sparrows given in cm. Box plots are shown as means with 25%, 50% and 75% percentiles. Males $N=19$, females $N=16$.

			One-way ANOVA	
	Live males (n=9) mean ± s.d.	Dead males (n=19) mean ± s.d.	F	*p*
Hue				
UV	0.583 ± 0.285	0.818 ± 0.119	9.69	0.004
Visible	0.463 ± 0.036	0.490 ± 0.026	5.39	0.028
Chroma				
UV	0.038 ± 0.020	0.111 ± 0.151	1.99	0.169
Visible	0.404 ± 0.018	0.354 ± 0.027	24.3	0.000
Brightness				
UV	0.025 ± 0.004	0.311 ± 0.008	3.63	0.068
Visible	0.087 ± 0.016	0.097 ± 0.012	3.81	0.062

			One Way ANOVA	
	Males (n=19) Mean ± st dev	Females (n=16) Mean ± st dev	F	P-value
Hue				
UV	.818 ± .12	.642 ± .37	3.839	.059
Visible	.491 ± .03	.508 ± .03	2.906	.098
Chroma				
UV	.111 ± .15	.040 ± .02	3.473	.071
Visible	.354 ± .03	.347 ± .03	.468	.499
Brightness				
UV	.031 ± .01	.034 ± .01	.996	.352
Visible	.097 ± .01	.097 ± .01	.000	.999


1.0000
0.9000
0.8000
0.7000
0.6000
UV Hue (radians)
66.00
68.00
70.00
72.00
Wing Chord Length (cm)


Wing Chord Length (cm)
72.50
70.00
67.50
65.00
62.50
Male
Female
Sex