COLORIMETRIC METHODS IN ORNITHOLOGY

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The quantitative description and analysis of variation of color is a chronic problem facing ornithologists engaged in a variety of systematic, ecological, and physiological studies. It is the purpose of this paper to call attention to two instruments that will assist ornithologists in the study of color variation.

A useful review of methods of designating color has been provided by Bowers (Syst. Zool., 5, 1956: 147–160, 182). Visual methods include disc colorimetry and the comparison of samples (specimens) with color chips in some standard color system such as the Munsell Color Atlas. Bowers (*op. cit.*) has also described a spectrophotometric method, employing a General Electric-Hardy recording spectrophotometer (colorimeter) that provides spectral curves of reflectance. However, in his own work on color in the Wrentit (*Chamaea fasciata*), Bowers (Condor, 62, 1960: 91–120) used a series of reference specimens that were assigned scores to permit a quantitative analysis of individual and geographic variation. This technique, which in recent years has been employed by a number of systematists (for example, Selander and Giller, Bull. Amer. Mus. Nat. Hist., 124, 1963: 213-274), has several disadvantages and limitations, including the following: (1) There is a strong subjective element in the matching of specimens to the reference series. (2) Assignment of specimens to reference categories varies with the observer, the light source employed, and the color used to frame the specimens. (3) Use of the method is severely limited when variation involves changes in more than one of the aspects of color, namely hue (dominant wavelength), value (brightness), and chroma (purity). (4) Intervals between colors of the reference specimens in a series are likely to be uneven. (5) Because the reference specimens are subject to post-mortem fading and other changes in color over a period of years, the results of a study cannot be duplicated in later years.

Ornithologists seeking a precise, objective, and reproducible method of color analysis can use modern photometric colorimeters. Of the several available instruments which can be adapted for ornithological work, the least expensive is the Bausch and Lomb Spectronic 20 Colorimeter equipped with a Color Analyzer Reflectance Attachment, which is designed to measure reflectance from a surface as a function of wavelength. In the standard model of the reflectance attachment, a rectangular 2 x 8 mm. spot of monochromatic light (with a wavelength band pass of 20 mμ) is projected against the sample, and the reflected light is gathered by an integrating sphere and measured by a photomultiplier tube. By taking readings at a number of wavelengths, one obtains for any sample a spectral curve showing percentage reflectance as compared with the reflectance from a block of magnesium carbonate. For routine analysis we have used 10 wavelengths ranging from 415 mμ to 685mμ. In the Spectronic 20, a built-in porcelain "working standard" eliminates the necessity of repeated reference to the magnesium carbonate standard once the porcelain surface has been calibrated. Approximately six minutes are required to take single readings at 10 different wavelengths; and, since most of this time is spent in adjusting the instrument from one wavelength to another, it takes relatively little more time to obtain readings from a small series of specimens than from a single specimen.

For measuring reflectance from heterogeneous surfaces or from patterned areas, the manufacturer recommends use of a special model of the reflectance attachment that utilizes a monochromatic spot of light having an area approximately 12 x 12 mm.

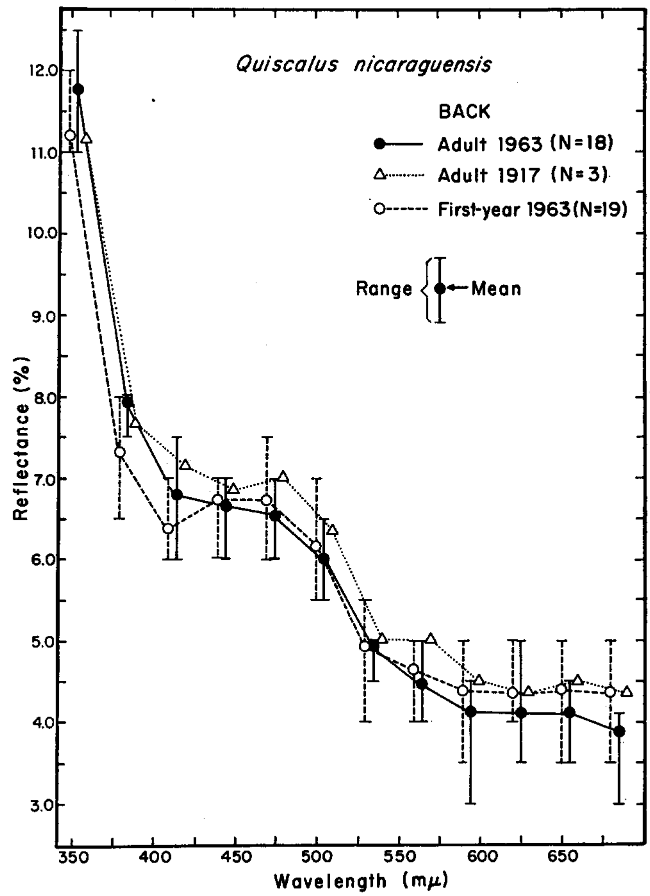

FIG. 1. Spectral reflectance curves for back of male specimens of Nicaraguan Grackle.

Current cost of the Spectronic 20 with the reflectance attachment is $675.00. Reflectance attachments are also available for a number of other brands of spectrophotometers and colorimeters, including recording models in which spectral curves are plotted automatically.

In our own work with the Spectronic 20 Colorimeter, we have found it useful to insert a glass disc (optical glass ground to a thickness of 2 to 3 mm.) in the circular opening of the integrating sphere over which the sample is placed. The glass prevents dust and fragments of feathers from falling into the sphere and, more importantly, insures that the feathers of the specimens being measured remain at a constant distance from the light source and the photomultiplier tube. Use of the glass disc does not in any way affect color determination. We have also found it convenient to reduce the size of the opening of the integrating sphere by inserting a thin metal disk with a central aperture 5 mm. in diameter.

Instructions for use of the Spectronic 20 Colorimeter are provided by the manufacturer, and references to the literature on color designation are provided by Bowers (Syst. Zool., 5, 1956: 160). Therefore, further discussion is unnecessary, and we shall here limit ourselves to providing a few examples of the application of the colorimeter to ornithological studies.

Figure 1 shows spectral reflectance curves of the center of the back of males of the Nicaraguan Grackle (*Quiscalus nicaraguensis*), as obtained by use of the Spectronic 20 (small-spot model). For each specimen 12 determinations of reflectance were made at wavelength intervals of 30 mμ. The wavelength span covers the visible spectrum. The graph shows the mean and range of reflectance for 18 adult and 19 first-year specimens taken in March, 1963. By employing Dice-Leraas graphic techniques, it would be possible to indicate in addition the standard deviation and standard error of the mean for each age group at each wavelength measured. Note that first-year males differ on the average from adults in showing greater reflectance in the red range (600–685 mμ)

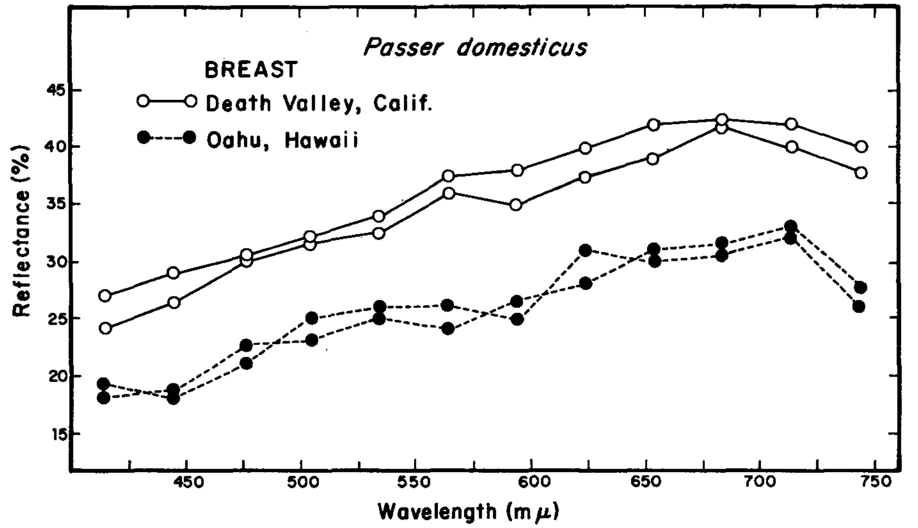

FIG. 2. Spectral reflectance curves for breast of adult female House Sparrows.

and lesser reflectance in the violet range (350–450 mμ). Also note that the first-year sample tends to be more variable individually than that of the adults. Finally, attention is called to the mean reflectance curve of three adult males taken in 1917. Compared with adult specimens taken in 1963, these skins show increased reflectance at all wavelengths except 355 mμ. This difference, which results from post-mortem changes, gives the birds a more reddish purple appearance.

Two of us are currently using a colorimeter in a study of rapid evolution of morphological characters in the introduced House Sparrow (*Passer domesticus*) in North America (Selander and Johnston, Proc. XVI Internat. Congr. Zool., 1: 173; Johnston and Selander, Science, 144, 1964: 548–550). Figure 2 shows spectral reflectance curves for two adult females from Death Valley, California, and two adult females from Honolulu, Oahu. Note that the curves for specimens from the two localities are more or less parallel, indicating that the color difference involves mainly chroma and value rather than hue.

Use of the actual spectral curves is only one of several methods of presenting colorimetric data. The reflectance values can be converted to Munsell Color System equivalents or used to calculate Tristimulus Values (X, Y, Z) and Trichromatic Coefficients

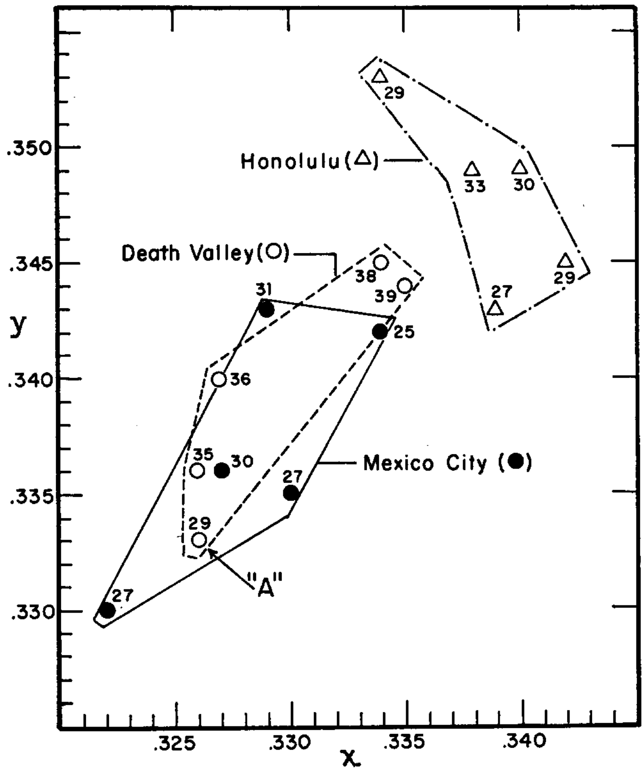

Fig. 3. Chromaticity diagram showing x and y Trichromatic Coefficients and Y (brightness) for color of breast of five female House Sparrows from each of three localities. Note that specimens from Death Valley and Mexico City are generally similar in their position on the diagram (indicating similarity in hue and purity) but differ in brightness (brightness values, in per cent, indicated by numbers adjacent to points). Specimen "A" from Death Valley is unusually dark for that locality and cannot be distinguished from birds from Mexico City on the basis of breast color.

Table 1

Trichromatic Coefficients and Brightness

	Number of specimens	Trichromatic coefficients x Mean	x Range	y Mean	y Range	Brightness (per cent) Y Mean	Y Range
Quiscalus nicaraguensis							
Male back							
Adult: 1963	18	.2700	.252–.282	.2835	.270–.292	4.83	4.5–5.3
Adult: 1917	3	.2747	.273–.277	.2867	.283–.291	5.17	5.1–5.2
First-year: 1963	19	.2745	.267–.283	.2859	.278–.294	4.97	4.2–5.4
Passer domesticus							
Female breast							
Death Valley	5	.3296	.326–.335	.3396	.333–.345	35.57	28.7–39.3
Honolulu	5	.3385	.334–.342	.3476	.343–.353	29.67	27.3–32.9
Mexico City	5	.3285	.322–.334	.3372	.330–.343	28.00	25.5-31.0

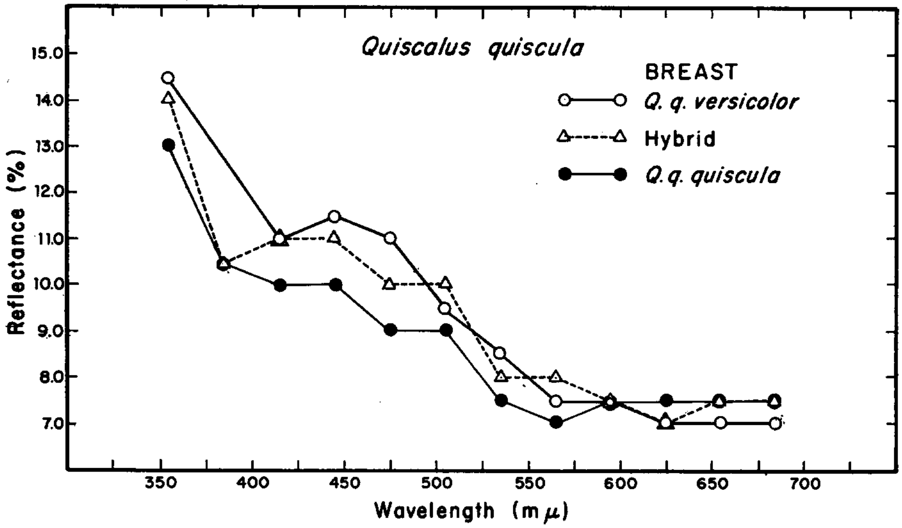

FIG. 4. Spectral reflectance curves for upper breast area of male specimens of Common Grackle.

(x, y, z), and the data can be plotted on chromaticity diagrams (fig. 3) or presented in tabular form (table 1); see Bowers (Syst. Zool., 5, 1956) for explanation.

Colorimetric equipment has been of special value in a study of hybridization of races of the Common Grackle (*Quiscalus quiscula*) in Louisiana, in which the parental forms differ markedly in color and the hybrids present a great variety of intermediate conditions. Figure 4 shows spectral reflectance curves for the upper breast area of three adult males, a purple type (*Q. q. quiscula*), a bronze type (*Q. q. versicolor*) and a hybrid.

A second instrument that is useful in ornithological studies involving color comparisons of specimens is the Macbeth Super Color Matching Skylight (Model BX-848A), which provides constant illumination of 200 footcandles over a viewing surface of 44 x 33 inches. The light has a color temperature of 7500° Kelvin, which closely approximates that of north sky daylight; and the interior of the viewing booth is painted neutral gray. The merits of the instrument will be readily apparent to anyone who has attempted critical color matching under the constantly varying conditions of sunlight. The Macbeth Super Skylight is manufactured and distributed by the Macbeth Daylighting Corporation, Newburgh, New York.

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