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ULTRAVIOLET REFLECTANCE OF COLORED PLASTIC LEG BANDS

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Abstract.—The bright coloration of plastic leg bands used in avian research has been shown to affect the social interactions of birds by augmenting the ornamentation that traditionally mediates intersexual mate choice and/or intrasexual competition for mates. With ultraviolet (UV) vision and plumage reflectance playing a role in the mating decisions of some species, it would seem important to examine the UV reflectance properties of colored bands, as these bands may be providing strong and meaningful UV color signals that are invisible to the human eye and are potentially unaccounted for in most avian behavioral studies. In this study, we used a fiber optic spectrometer and a UV/visible light source to collect spectral reflectance data for the commonly used types and colors of bands and showed that none exhibit peak reflectance values throughout the range of UV wavelengths that is visible to birds. Instead, UV reflectance of colored bands at these wavelengths is comparable to levels of background reflectance found elsewhere in the avian visible spectrum. Consequently, colored bands lack discrete UV color signals and can safely be used in studies of wild birds with a minimal risk of influencing intraspecific signaling that is based on ultraviolet ornamentation. However, caution must be exercised when using these bands under experimental conditions, as certain treatments (e.g., indoor lighting, one-way glass, sunscreens) may mask the background levels of UV reflectance that still contribute to the overall band color, effectively inducing a color change in the bands that could provide unnatural visual cues to the birds and unintentionally influence their social interactions.

REFLECTANCIA ULTRAVIOLETA DE LAS BANDAS PLÁSTICAS DE COLORES PARA LAS PATAS.

Sinopsis—Se ha demostrado que la coloración brillante de las bandas plásticas para las patas usadas en investigaciónes de aves afectan las interacciones sociales de estas al aumentar la ornamentación que tradicionalmente media la selección intersexual de parejas y/o la competencia intrasexual por parejas. Como la visión de luz ultravioleta (UV) y la reflectancia del plumaje juegan un rol en las decisiones de apareamiento de ciertas especies, parecería importante examinar la reflectancia en UV de las bandas de colores, ya que podrían producir señales fuertes y significativas en color UV que son invisibles al oho humano y que no son consideradas en la mayoría de los estudios etológicos. En este estudio usamos un espectrómetro de fibra óptica y una fuente de luz visible/UV para obtener datos de reflectancia espectral para los colores y tipos de bandas comunmente usadas y mostramos que ninguna exhibe valores de reflectancia mayores a través de los largos de onda UV que son visible a las aves. Por el contrario, la reflectancia de las bandas de colores en estos largos de onda son similares a los niveles de reflectancia del fondo hallados a través del espectro visible de las aves. Consecuentemente, las bandas de colores carecen de señales de color UV discreto y se pueden usar de forma segura en estudios de aves silvestres con un mínimo de riesgo de influenciar las señales intraspecificas basandose en ornamentación ultravioleta. Sin embargo, se debe tener cuidado cuando se usen estas bandas bajo condiciones experimentales ya que ciertos tratamientos (e.g., luces interiores, espejos de visibilidad de un lado, cremas protectoras de piel) pueden enmascarar los niveles de reflectancia de UV del fondo que todavía

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contribuye al color general de la banda, induciendo efectivamente un cambio en color en las bandas que podían producir señas visuales nonaturales a las aves e influenciar no intencionalmente sus interacciones sociales.

The classic means by which individual birds are identified in both field and captive studies is through the application of colored plastic leg bands (Spencer 1978). This technique assumes that colored bands do not significantly alter any aspect of avian social behavior. In some cases, it has been demonstrated that colored bands do not affect the interactions of birds (Watt 1982, Beletsky and Orians 1989, Belthoff and Gauthreaux 1991, Weatherhead et al. 1991, Cristol et al. 1992, Hannon and Eason 1995). In other studies, however, colored leg bands have been shown to influence a variety of bird behaviors, including mate choice (Burley et al. 1982, Burley 1986a,b; Johnson et al. 1993, Swaddle and Cuthill 1994, Bennett et al. 1996, Fiske and Amundsen 1997), mate guarding (Johnsen et al. 1997), and intrasexual competition (Metz and Weatherhead 1991). Thus, indiscriminant use of these bands could undermine many of the behavioral studies in this field. In fact, some researchers avoid using leg colors that are similar to the ornamental coloration of the bird under study. These concerns warrant further, careful consideration of the signaling properties of colored leg bands.

To address this issue fully, we must consider not only colors in the visible spectrum (400–700 nm), but also those in the ultraviolet (UV) (290–400 nm). Given our inability to see UV wavelengths of light (Wald 1952), reflectance in the ultraviolet has rarely been considered. However, several avian species are known to possess specialized UV-sensitive retinal cones (Chen et al. 1984, Chen and Goldsmith 1986) and associated oil droplets (Goldsmith et al. 1984) that extend their vision into the short-wavelength portion of the spectrum (Parrish et al. 1984). Peak visual sensitivity in this range appears to be between 350 and 380 nm (Emmerton and Delius 1980, Chen et al. 1984, Maier and Bowmaker 1993), with a lower limit of around 325 nm (Govardovskii and Zueva 1977). Additionally, the plumage of a number of species has been shown to reflect UV light (Burkhardt 1989, Burkhardt and Finger 1991, Maier 1993, Bleiweiss 1994, Andersson 1996, Bennett et al. 1996, 1997, Andersson and Amundsen 1997, Johnsen et al. 1997, Andersson et al. 1998, Keyser and Hill 1999), and ultraviolet vision and plumage reflectance can play a role in mate choice (Maier 1993, Bennett et al. 1996, 1997, Andersson and Amundsen 1997, Andersson et al. 1998, Hunt et al. 1998).

Hence, it appears both valuable and necessary to characterize the degree of ultraviolet light reflectance for the colors and types of plastic leg bands used in avian research, as the bands may provide meaningful UV color signals to the birds that are invisible to humans and have subsequently gone unaccounted for in both field and captive studies. This issue has been partially addressed by Johnsen et al. (1997), who used spectroradiometry to quantify the UV reflectance of colored bands used in their study of wild Bluethroats (*Luscinia svecica*) and found low to moderate reflectance levels in four colors of hobby beads. However, as of yet no one has investigated the UV signaling capacity of all of the bands used by field ornithologists. Here we used a fiber optic spectrometer and a UV/visible light source to provide spectral reflectance data for the colors and brands of plastic leg bands that are commonly used in avian studies.

METHODS

In search of color signals, we work under Andersson's (1996) assumption that "colourfulness . . . is related to deviations from uniform reflectance." The absence of color is typical of the two shades, black (no light reflectance) and white (near-perfect reflectance), that both show uniform reflectance. In contrast, colors are characterized by the presence of peaks at certain wavelengths; for example, an object is perceived to be blue when it exhibits peak reflectance at a wavelength between 425 and 475 nm. In this study, we looked for discrete reflectance peaks within the range of UV wavelengths known to be visible to birds (325–400 nm) and above typical background readings throughout the rest of the spectrum.

The three most commonly used types of colored leg bands are hobby beads, split-ring bands, and wrap-around bands. Although hobby beads are manufactured by a number of companies, Perler Beads® (Novacon Corp., Santa Rosa, California) are often used in avian research. These beads come in solid, translucent, fluorescent and glittery styles (Hill 1992) and fit most passerines and other species with similar sized tarsi. Wrap-around bands from the National Band and Tag Company (Newport, Kentucky) and split-ring bands from A. C. Hughes (Hampton Hill, Middlesex, UK) have also been traditionally used. In our spectrometric analyses of the three band types, we have only included the most commonly used solid colors.

We collected reflectance data with an Ocean Optics, Inc. S2000 fiber optic spectrometer (Dunedin, Florida). The unit is fitted with a grating that acts as a prism and divides light reflected from the surface into its spectral components from 250–880 nm. However, we only present data from 300–700 nm, which spans the range of UV and visible light wavelengths. The colored bands were illuminated simultaneously by a visible (tungsten-halogen) light source and an ultraviolet (deuterium) light source (Analytical Instrument Systems, Inc., Flemington, New Jersey). Readings were made with a reflectance probe that was held at a 90° angle to and 5 mm from the reading surface for all samples. A metal sheath mounted on the probe excluded all external light. Colored band readings were taken from an area 1.75 mm in diameter. Data integration time was set at 55 ms and optical pixel resolution was obtained using data smoothing level 10. Reflectance was measured as the percent of light reflected

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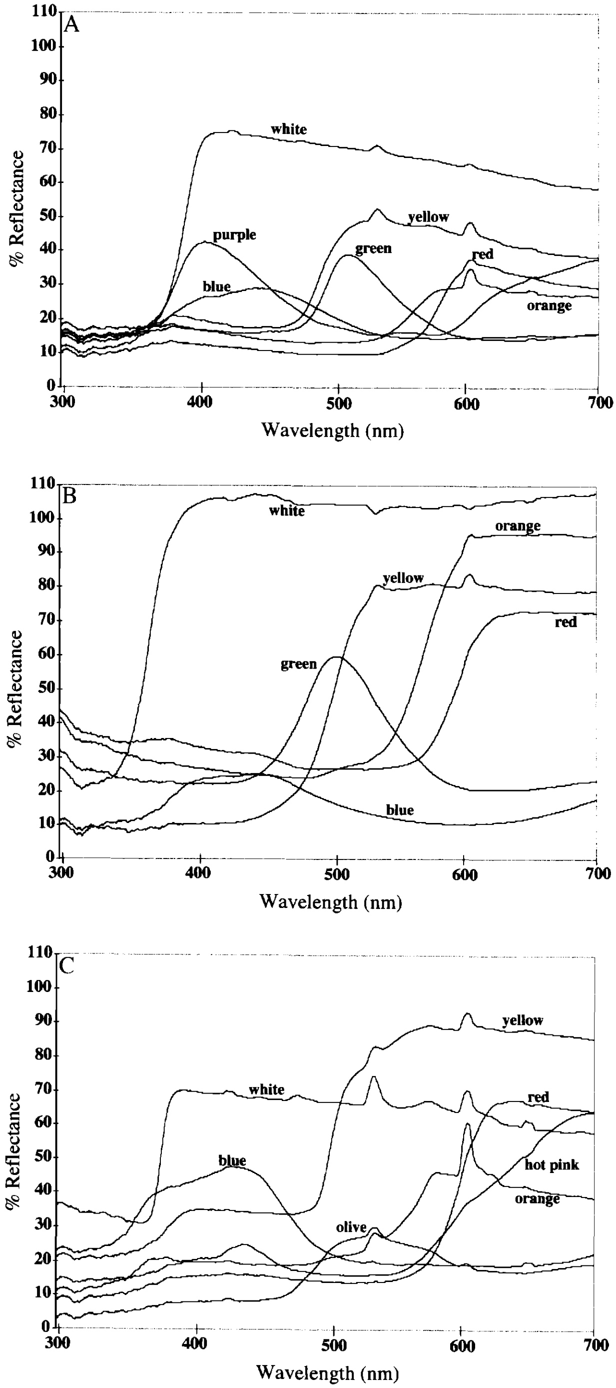
FIGURE 1. Reflectance spectra for the commonly-used colors of: a) hobby beads, b) wrap-around bands, and c) split-ring bands. Each curve represents the average of 20 spectra.


A
% Reflectance
Wavelength (nm)
white
yellow
purple
green
red
blue
orange
B
% Reflectance
Wavelength (nm)
white
orange
yellow
red
green
blue
C
% Reflectance
Wavelength (nm)
yellow
white
red
blue
hot pink
orange
olive

from the surface of the band relative to a 99% Spectralon white reflectance standard. For each band, 20 spectra were measured and then averaged without lifting the probe tip from the band surface.

RESULTS AND DISCUSSION

Reflectance spectra from the most commonly used colors and types of leg bands show that none of the bands exhibit discrete reflectance peaks in the ultraviolet portion of the spectrum (Fig. 1); thus, these bands lack hidden UV color signals. Instead, reflectance peaks are confined to the portion of the spectrum that is visible to humans. Interestingly enough, all colors and types of bands reflect some amount of UV light. This reflectance is often less than or equal to the baseline intensity at which light is reflected throughout the rest of the spectrum, and this passive reflectance at shorter wavelengths contributes to the overall, full-spectrum color that is exhibited by each band. These results are in agreement with those of Johnsen et al. (1997), who found a wider range of UV reflectance intensities among four colors of hobby beads, but also failed to detect substantial UV color peaks in the beads used in their study.

Comparing the relative reflectance intensities of the band types, wraparound bands reflect more intensely than do split-ring bands, which in turn are more reflective than hobby beads (Fig. 1). Across all band types, light-colored bands (e.g., white, yellow) seem to exhibit more intense reflective peaks than darker colors (e.g., blue, green) (Fig. 1). The glossy plastic surfaces of certain bands are largely responsible for the generally-high reflectance values across the entire spectrum, and the differences in shininess among the three types are noticeable to the human observer (pers. obs.). Abrading the surfaces of the bands with sandpaper significantly reduces reflectance intensities across the entire spectrum, but does not change the overall shapes of the curves (pers. obs.).

Colored bands differ both in the wavelengths of peak reflectance (the true color) and in the heights of the peaks (the reflectance intensity), and avian biologists can use the data presented here to weigh the benefits and risks associated with using bands of different color and manufacturer and select those bands that least influence the social system being studied, while maximizing band detectibility. Others may be interested in actually testing the influence of leg bands in a controlled situation, where matching plumage color with band color might be important. In this case, spectral data from feather patches can be compared to the colored band spectra we present here.

Given the absence of UV reflectance peaks among the types and colors of plastic leg bands analyzed here, we now know that the use of these bands in avian studies of behavior in the wild should not disrupt intraspecific signaling systems based on ultraviolet ornamentation. However, it is imperative that we not ignore the UV reflectance that is in fact present in all of the colored bands examined. Although merely at background levels, the ultraviolet wavelengths of light reflected by the bands are an integral part of the overall color that is perceived by birds. Eliminating such reflectance would create a deviation in uniform reflectance, effectively inducing a color change that could influence the visual communication system under study.

Conditions like these that mask background levels of UV reflectance are common in the experimental settings under which UV signaling in birds is currently investigated. In their studies of zebra finches, Bennett et al. (1996) used UV light filters to prevent the UV reflectance of plumage and colored bands from being transmitted to the signal receivers. Andersson and Amundsen (1997) have used human sunblock to prevent UV light from being reflected from body regions of male bluethroats, consequently preventing females from seeing areas that may reflect in the UV and from being able to use such plumage cues when selecting a mate.

While these studies have employed such manipulations to explore the function of UV vision and plumage reflectance, any haphazard use of these techniques or others, in conjunction with colored bands, could unknowingly provide unnatural cues to the birds and influence the observed social interactions in an unintended fashion. In fact, Hunt et al. (1997) have emphasized the differences in the colored band preferences of zebra finches with respect to changing UV light conditions. Implicated in this scenario have been the use of one-way glass and mirrors that often absorb UV light (Swaddle and Cuthill 1994), as well as the weak emissions of UV light wavelengths by standard indoor lighting (Wysecki and Stiles 1967).

This example highlights the need to carefully consider the experimental conditions to which study individuals are subjected when exploring the role of UV reflectance in social situations. As researchers become increasingly interested in the function of UV plumage ornamentation, the apparent challenge is to design controlled experiments that adequately manipulate UV signals that we cannot see. While our study demonstrates that biologists can continue to use colored bands, albeit more carefully, in avian research, we hope that it concurrently emphasizes the importance of UV vision in the behavioral interactions of birds.

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