J. Field Ornithol., 66(2):289–295

COLOR CHANGE IN HUGHES'S CELLULOID LEG BANDS

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Abstract.—Color change was recorded in 10 colors for 237 Hughes celluloid bands attached to the tarsi of 84 birds for up to 5 yr and for 45 celluloid bands exposed to natural sunlight on Mauna Kea, Hawaii. Colors of four solid-colored bands (mauve, light green, yellow and black) and two split-colored bands (orange/dark green and dark blue/white) attached to free-flying birds were still recognizable ≥3 yr. Within 2–3 yr, light blue, orange and red solid-colored bands and a red/white split-colored band had faded and could be confused with other colors. For studies ≤2 yr, most Hughes celluloid bands retained enough color to be recognized under field conditions. For long-term studies, biologists should select only those colors that can be recognized for the duration of the study or use another type of color band that is more resistant to fading or discoloration.

CAMBIO EN COLORACIÓN DE BANDAS HUGHES

Sinopsis.—Se encontró cambio en la coloración de 237 bandas plásticas Hughes de 10 colores diferentes que estuvieron colocadas por cinco años en el tarso de 84 pájaros y de 45 bandas expuestas a la luz natural en Mauna Kea, Hawaii. Bandas de cuatro colores sólidos y de dos colores mixtos pudieron ser reconocidas luego de haber estado por más de 3 años en las patas de aves silvestres. No obstante, entre 2–3 años, las bandas de colores sólidos como el azul pálido, anaranjado, rojo y bandas de colores mixtos como el rojo/blanco habían cambiado hasta el punto de poder ser confundidas con otros colores. Para estudios <2 años, las bandas Hughes retienen el suficiente color para poder ser reconocidas en trabajos de campo. No obstante, para estudios de largo alcance se recomienda el uso de colores que no cambien o el uso de otros tipos de bandas de colores que sean más resistentes al cambio en coloración causado por las inclemencias del tiempo.

The use of colored leg bands to mark and identify individual birds (Lockley and Russell 1953, Marion and Shamis 1977) is a standard method for many behavioral, population and survival studies (e.g., Hardy and Farrell 1990). Used in conjunction with numbered aluminum bands, colored bands allow rapid identification of recaptured or resighted birds.

Colored leg bands are available in celluloid, plastic, ultraviolet stable plastic, and anodized aluminum (Coulson 1963, Marion and Shamis 1977). Hill (1992) recommended using plastic hobby beads which he individually split with a safety razor to fit on the tarsi of birds. Other ornithologists make their own bands from polyvinyl cloride or vinyl plastics (Lockley and Russell 1953, Coulson 1963, Hill 1992, K. Yasukawa, pers. comm.). For our studies, we used celluloid bands because of the wide color range available in solid and split colors (top half of band one color and bottom half another color).

One problem with colored celluloid bands, however, is that colors may fade or discolor over time because of light and temperature effects (Anderson 1980). Biases in data collected from resighted birds may result if colors on bands are incorrectly identified due to fading or discoloration.

We evaluated color change in Hughes celluloid bands used to mark birds on Mauna Kea, Hawaii. The results of this evaluation have been useful in selecting colors to be used in subsequent banding studies.

METHODS

The 34-km^2 study area was located between 2000 and 3000 m elevation in a native mamane (*Sophora chrysophylla*)-naio (*Myoporum sandwicense*) woodland near Puu Laau (19°50′N, 155°35′W) on the southwest slope of Mauna Kea. Vegetation in the study area was described by Hartt and Neal (1940) and Scott et al. (1986). The prevailing climate is dry and cool; mean annual rainfall is 511 mm. Between November 1991 and October 1992, the mean monthly air temperature was 11.1 C (range 9.6–12.2 C) and the mean monthly solar radiation was 230 Wm^{-2} (range 180–288 Wm^{-2}) (Juvik et al. 1993).

We purchased celluloid bands from A. C. Hughes Ltd., 1 High St., Hampton Hill, Middlesex, England TW12 1NA. Use of trade names does not necessarily reflect an endorsement of these products.

To document color changes on bands exposed to natural light, three celluloid bands of each of eight solid colors and seven split colors were hung from branches of a mamane tree for 28 mo (June 1991–September 1993). Bands were placed to receive direct sunlight during morning hours and shade during afternoon hours. Other bands were stored indoors at room temperature and in the dark as controls.

Between 1987 and 1993, we marked birds captured in mist nets (Federal Permit Number 20279) with three celluloid and one numbered aluminum leg bands. Individual birds were given a unique color combination (see Table 1 for list of colors) with two bands placed on the tarsus of each leg.

Beginning in October 1992, colors on celluloid bands of recaptured birds were matched to color swatches (Smithe 1975) to record color changes on the bands over time. The colors were also scored as (1) unfaded, (2) faded but recognizable or (3) faded and unrecognizable or could be confused with another color following criteria of Anderson (1980). As a result of the limited number of color swatches provided in Smithe (1975), colors on bands could only be matched to the closest Smithe color swatch, which provided a close but not always perfect match.

RESULTS

Color changes in bands exposed to natural light.—The brightness and intensity of colors in bands stored indoors at room temperature and in the dark for 4 yr did not change compared to newly purchased bands. After 28 mo of exposure to natural light, three solid-colored bands (mauve, light green and black) and two split-colored bands (orange/dark green and light green/white) retained their colors adequately to be consistently identified (Table 1). After 12 mo of exposure, four colors (light blue, dark blue, red and white) in both solid and split colored bands had faded or discolored and were either not recognizable or could be con-

TABLE 1. Color change in celluloid bands (n = 3 for each color) exposed to natural light, Mauna Kea, Hawaii, 1991–1993. Colors of bands were ranked according to their likelihood of being correctly identified in the field using criteria[1] by Anderson (1980) and matched to color swatches (Smithe 1975) to document changes over time.

Color	Months			
	0	12	24	28
Black	Jet black (89)[2]	A[1]—Jet black (89)	A—Jet black (89)	B—Sepia (119)
Light green	Lime green (159)	A—Parrot green (60)	B—Peacock green (162C)	B—Peacock green (162C)
Mauve	Bluish violet (172B)	B—Deep vinaceous (4)	B—Magenta (2)	B—Magenta (2)
Yellow	Trogon yellow (153)	A—Trogon yellow (153)	B—Chamois (123D)	C—Pale horn (92)
Orange	Spectrum orange (17)	A—Spectrum orange (17)	C—Warm buff (118)	C—Buff (124)
White	White[3]	C—Straw yellow (56)	C—Cream (54)	C—Pale horn (92)
Light blue	Sky blue (66)	C—Peacock green (162C)	C—Opaine green (162D)	C—Opaline green (162D)
Red	Spectrum red (11)	C—Peach red (94)	C—Flesh (5)	C—Flesh (5)
Orange/Dark green[4]	Spectrum orange/Hooker's green (17/162)	B/A—Spectrum orange/Hooker's green (17/162)	B/B—Tawny/Indigo (38/73)	B/B—Tawny/Hooker's green (38/162)
Light green/White	Shamrock green/White (162B)	B/B[5]—Emerald green/Off-white (163)	B/B—Emerald green/Off-white (163)	B/B—Emerald green/Off-white (163)
Orange/Light blue	Spectrum orange/True blue (17/168A)	B/C—Spectrum orange/Pearl gray (17/81)	B/C—Flesh ochre/Pale horn (132D/92)	B/B—Cinnamon-rufous/Light sky blue (40/168D)
Orange/White	Spectrum orange/White (17)	B/C—Spectrum orange/Buff yellow (17/53)	B/C—Flesh ocher/Chamois (132D/123D)	B/C—Tawny/Cream (38/54)
Mauve/Yellow	Bluish violet/Sulphur yellow (172B/157)	C/B—Smoke gray/Straw yellow (45/56)	C/C—Lavender[6]/Cream (77/54)	C/C—Lavender[6]/Cream (77/54)
Dark blue/White	Ultramarine/White (270)	C/C—Medium neutral gray/Buff yellow (84/53)	C/C—Light neutral gray/Cream (85/54)	C/C—Light neutral gray/Pale horn (85/92)
Red/White	Geranium/White (12)	C/C—Orange-rufous/Cream (132C/54)	C/C—Vinaceous/Cream (3/54)	C/C—Vinaceous/Cream (3/54)

[1] A = color unfaded, B = color faded, but recognizable, C = color faded and unrecognizable or confusable with another color.

[2] Number in parentheses refers to Smithe (1975) color number.

[3] White color swathe not included in Smithe (1975).

[4] Split color celluloid band.

[5] White on one band tended toward a cream color.

[6] Lavender color very faint.

fused with another color. The solid light blue bands had faded to pale green and the dark blue in split-colored bands had faded to a pale bluish-gray. Red had faded to a peach or flesh color and white discolored to an offwhite, cream or yellow. Interestingly, although the solid mauve bands retained their color, the mauve in the mauve/yellow split band had faded to a smoke gray within 12 mo. After 28 mo of exposure, the yellow, orange and white solid-colored bands were not distinguishable from each other.

Color changes in bands attached to free-flying birds.—We recaptured 60 Common Amakihi (*Hemignathus virens*), 16 Palila (*Loxioides bailleui*), three Akiapolaau (*Hemignathus munroi*), three Elepaio (*Chasiempis sandwichensis*), one Iiwi (*Vestiaria coccinea*) and one Red-billed Leiothrix (*Leiothrix lutea*) that had previously been marked with colored bands. Assessment of color change, at different ages, of these bands was subjective, with the bands being ranked according to the likelihood of being correctly identified by observers in the field. Color change in 237 celluloid bands from recaptured birds (Table 2) tended to follow the same pattern of fading exhibited in the 45 bands exposed to natural light, except that the colors changed at a slower rate over time. Four solid colors (mauve, light green, black and yellow) and two split-colored bands (orange/dark green and dark blue/white) were still recognizable ≥3 yr. Within 1–2 yr, red color bands could be confused with orange color bands. Within 2–3 yr, light blue and orange solid-colored bands, and red/white split-colored bands faded and were not recognizable under field conditions.

DISCUSSION

Loss of color in celluloid bands may vary depending upon the total solar radiation received in the study area, the behavior of birds toward exposing the bands to sunlight (Anderson 1980), and the quality of manufacturing (Hill 1992). Our results indicate that light green, mauve and black solid-colored bands and orange/dark green and light green/white split-colored bands were the most color-fast and, therefore, most appropriate for long-term use. In contrast red, orange and light blue solid-colored bands, and red/white and mauve/yellow split-colored bands were the least color-fast and may lead to misidentification of banded birds. Anderson (1980), in a study of color-banded Northern Fulmars (*Fulmarus g. glacialis*) found that black and dark blue bands were the most color-fast, whereas pink, dark green and light blue were the least color-fast. Although Coulson (1963) and Anderson (1980) reported that light green bands faded to yellow, we found that light green bands placed on free-flying birds could be identified under field conditions for at least 5 yr.

Dye lots used to color celluloid bands apparently are not always prepared to the same specifications and field life of colors can be drastically different. For example, in bands exposed to natural light, the mauve solid-colored band was color-fast for at least 28 mo, whereas the mauve in the mauve/yellow split-colored band faded to a smoke gray within 12 mo. Park (1981) reported that mauve, light blue and pink bands faded with

TABLE 2. Change in color, over time, for 237 celluloid bands attached to the tarsi of 84 free-flying birds on Mauna Kea, Hawaii.

Color	Years						Comments
	<1	1–2	2–3	3–4	4–5	>5	
Black	—	—	—	—	A (1)[1]	A (1)	Retained color. Difficult to see black band on bird's leg in shady foliage.
	—	—	—	—	B (1)	—	
Light green	A (2)	—	B (5)	B (7)	A (1)	B (2)	Retained color.
	—	—	—	—	B (1)	—	
Mauve	A (2)	A (6)	A (4)	A (3)	A (1)	—	Retained color.
	—	B (6)	B (9)	B (1)	B (2)	—	
Yellow	A (1)	A (1)	A (5)	B (3)	—	—	Retained color, but became lighter with age, tending toward buff yellow (53)[2] or chamois (123D).
	—	B (3)	B (4)	—	—	—	
White	—	A (1)	A (3)	—	—	—	Color changed to offwhite or dingy white. White bands exposed to natural light became unrecognizable after 12 mo, and could be confused with yellow.
	—	B (1)	B (1)	—	—	—	
Orange	B (1)	A (1)	A (1)	A (1)	B (2)	—	Color changed from chrome orange (16) to salmon (106) to flesh ochre (132D). Could be confused with red.
	—	B (2)	B (4)	B (2)	C (2)	—	
	—	—	C (1)	—	—	—	
Light blue	A (1)	—	A (1)	A (1)	B (2)	C (1)	Color changed from sky blue (66) to Robin egg blue (93) to opaline green (162D). Could be confused with green.
	—	—	B (6)	B (4)	C (5)	—	
	—	—	C (1)	—	—	—	
Red	A (1)	C (1)	B (2)	B (5)	B (3)	—	Color changed from spectrum red (11) to geranium pink (13) or peach red (94). Could be confused with orange.
	—	B (1)	C (2)	C (1)	C (1)	—	
Orange/Dark green	—	B (5)	A (4)	A (1)	—	—	Orange changed from spectrum orange (17) to burnt orange (116) after 3 yr. Dark green retained color.
	—	—	B (4)	B (1)	—	—	
Light green/White	—	B (1)	B (6)	—	—	—	Retained colors.
Dark blue/White	A (2)	A (1)	A (2)	B (5)	A (2)	—	Retained blue/white colors. Differed from dark blue bands exposed to natural light in that the blue in these bands faded to gray within 1 yr.
	—	B (5)	B (6)	—	B (6)	—	

TABLE 2. Continued.

Color	Years <1	1–2	2–3	3–4	4–5	>5	Comments
Red/White	A (2)	B (10)	A (2)	B (7)	A (2)	B (1)	Red changed from ruby (10) to peach red (94) to flesh ochre (132D). White discolored to offwhite, dingy white or cream.
	—	—	B (11)	C (2)	—	—	
	—	—	C (1)	—	—	—	
Mauve/Yellow	A (1)	—	A (1)	—	—	—	Mauve change to lilac (76) and yellow to cream (54) after 2 yr. Mauve in bands exposed to natural light became unrecognizable within 12 mo.
Orange/Light blue	A (1)	—	—	—	—	—	

[1] A = color unfaded, B = color faded, but recognizable, C = color faded and unrecognizable or confusable with another color. Number in parentheses is number of bands observed.
[2] Name of color and color number from Smithe (1975).

age in his study of Welcome Swallows (*Hirundo neoxena*) despite the fact that the swallows seldom exposed their legs to sunlight. Coulson (1963) reported that one batch of green bands faded to yellow before he could use them, though he did not state how long or under what conditions these bands were held in storage.

Although some colors fade or discolor with age, Hughes celluloid bands remain an acceptable method to individually mark birds if band colors are carefully selected. The number of colors available for use depends upon the length of the study and the environmental conditions in the study area. For example, some of the color changes that we noted may be less drastic in habitats with less intense solar radiation than our study area. Certain colors, such as black, can also be difficult to see on birds with dark legs (Coulson 1963) or on birds that tend to remain inside foliage or in shady areas. In short-term ($\leq$2 yr) studies, most Hughes celluloid bands will retain enough of their color to be recognized under field conditions. For long-term studies, biologists should select only those colors that can be recognized for the duration of the study or use another type of color band that is more resistant to fading or discoloration.

ACKNOWLEDGMENTS

We thank numerous research interns recruited through the Student Conservation Association program for their assistance with the capture and marking of birds in this study. We especially thank National Biological Service staff members Donna Ball, Jennifer Crummer, Calvin Harada, Alfred Parent, Jr., Michelle Reynolds, Tanya Rubenstein and Kelly Stapp for field assistance. Danny R. Bystrak, Charles P. Stone, Thane K. Pratt, Paul M. Cavanagh and James Jacobi provided valuable comments on this manuscript.

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Received 11 Jul. 1994; accepted 26 Sep. 1994.