[ED.], Avian energetics. Publ. Nuttall Ornithol. Club No. 15, Cambridge, MA.

CLARK, C. W., AND J. EKMAN. 1995. Dominant and subordinate fattening strategies: a dynamic game. Oikos 72:205–212.

EKMAN, J. B., AND M. K. HAKE. 1990. Monitoring starvation risk: adjustments of body reserves in Greenfinches (*Carduelis chloris* L.) during periods of unpredictable foraging success. Behav. Ecol. 1:62–67.

EKMAN, J. B., AND K. LILLIENDAHL. 1993. Using priority to food access: fattening strategies in dominance-structured Willow Tit (*Parus montanus*) flocks. Behav. Ecol. 4:232–238.

GOSLER, A. G. 1996. Environmental and social determinants of winter fat storage in the Great Tit *Parus major*. J. Anim. Ecol. 65:1–17.

HAFTORN, S. 1992. The diurnal body weight cycle in titmice *Parus* spp. Ornis Scand. 23:435–443.

HAKE, M. 1996. Fattening strategies in dominance-structured Greenfinch (*Carduelis chloris*) flocks in winter. Behav. Ecol. Sociobiol. 39:71–76.

HOGSTAD, O. 1987. Social rank in winter flocks of Willow Tits *Parus montanus*. Ibis 129:1–9.

KNOPS, J. M. H., W. D. KOENIG, AND T. H. NASH III. 1997. On the relationship between nutrient use efficiency and fertility in forest ecosystems. Oecologia 110:550–556.

KOIVULA, K., AND M. ORELL. 1988. Social rank and winter survival in the Willow Tit *Parus montanus*. Ornis Fenn. 65:114–120.

KOIVULA, K., K. LAHTI, M. ORELL, AND S. RYTKONEN. 1993. Prior residency as a key determinant of social dominance in the Willow Tit (*Parus montanus*). Behav. Ecol. Sociobiol. 33:283–287.

KOIVULA, K., M. ORELL, S. RYTKONEN, AND K. LAHTI. 1995. Fatness, sex and dominance: seasonal and daily body mass changes in Willow Tits. J. Avian Biol. 26:209–216.

LAHTI, K., K. KOIVULA, S. RYTKONEN, T. MUSTONEN, P. WELLING, V. V. PRAVOSUDOV, AND M. ORELL. 1998. Social influences on food caching in willow tits: a field experiment. Behav. Ecol. 9:122–129.

LIMA, S, L. 1986. Predation risk and unpredictable feeding conditions: determinants of body mass in birds. Ecology 67:377–3–85.

MCNAMARA, J. M., AND A. I. HOUSTON. 1990. The value of fat reserves and the trade-off between starvation and predation. Acta Biotheor. 38:37–61.

PRAVOSUDOV, V. V., AND T. C. GRUBB JR. 1997. Energy management in passerine birds during the non-breeding season. A review. Current Ornithol. 14: 189–234.

PRAVOSUDOV, V. V. AND T. C. GRUBB JR. 1999. Effects of dominance on vigilance in avian social groups. Auk 116:241–246.

RICE, W. R., AND S. D. GAINES. 1994. Extending non-directional heterogeneity tests to evaluate simply ordered alternative hypotheses. Proc. Natl. Acad. Sci. 91:225–226.

VERHULST, S., AND O. HOGSTAD. 1996. Social dominance and energy reserves in flocks of Willow Tits. J. Avian Biol. 27:203–208.

WAITE, T. A. 1987. Vigilance in the White-breasted Nuthatch: effect of dominance and sociality. Auk 104:429–434.

WITTER, M. S., AND I. C. CUTHILL. 1993. The ecological costs of avian fat storage. Phil. Trans. R. Soc. Lond. B 340:93–125.

WITTER, M. S., AND J. P. SWADDLE. 1995. Dominance, competition, and energetic reserves in the European Starling, *Sturnus vulgaris*. Behav. Ecol. 6: 343–348.

The Condor 101:884–886

PLASTIC COLOR BANDS HAVE NO DETECTABLE SHORT-TERM EFFECTS ON WHITE-BREASTED NUTHATCH BEHAVIOR[1]

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Abstract. We examined whether plastic leg bands had short-term effects on foraging behavior in White-breasted Nuthatches (*Sitta carolinensis*), a species which, because of their very short legs and unusual habit of hanging upside-down on bark, may be particularly susceptible to deleterious effects of plastic bands. Ten nuthatches were outfitted with varying numbers of colored plastic bands and observed foraging in an aviary after two days of habituation. Wearing up to five plastic bands caused no detectable change in any of the variables measured: number of flights, body position, choice of foraging substrate, seed caching, seed hammering, and seed retrieval.

Key words: color bands, leg bands, Sitta carolinensis, *White-breasted Nuthatches.*

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Ornithologists have been using colored plastic bands to distinguish individual research subjects for nearly 50 years (Poulding 1951). The most commonly used type of color band, butt-end, has not been widely suspected of causing detrimental effects on birds. However, nearly 10% of a population of Willow Flycatchers (*Empidonax traillii*) wearing this kind of band suffered long-term leg injuries (Sedgwick and Klus 1997). Perhaps most surprisingly, the rate of injury for legs with only color bands was much higher than that for legs with only U.S. Fish and Wildlife Service (USFWS) metal bands. Our objective was to test the hypothesis that plastic color bands also have short-term deleterious effects on bird behavior.

We chose to study nuthatches because they seemed especially likely to experience problems with color bands due to their short tarsi and unusual method of foraging upside-down while clinging to the trunks of trees. All permits issued by the Bird Banding Laboratory for color banding of nuthatches contain the following warning, "Use caution on nuthatches; ensure that multiple bands do not impede movement of legs." We outfitted White-breasted Nuthatches (*Sitta carolinensis*) with varying numbers of plastic bands, allowed them to habituate to a large aviary, and then recorded the frequency and duration of important foraging behaviors.

METHODS

We captured 10 nuthatches in mist nets or treadle traps between 11 November 1997 and 19 March 1998. Birds were banded with one USFWS aluminum band (size 1B) on the right leg and placed in a large outdoor holding cage (3.1 × 2.4 × 2.1 m) for 1–7 days before further banding. Length of the right tarsus was measured on eight subjects using digital calipers.

We outfitted birds with 0–5 colored plastic bands (Redbird Products, Sacramento, California, yellow, size 35C). Six banding regimes were used: no color bands, one on the left leg, one on each leg, two on the left leg and one on the right, two on each leg, three on the left leg and two on the right. Because all birds wore a single USFWS band on the right leg below the color bands, the six regimes were collapsed into three treatment groups based on total number of bands worn: low (1–2 bands), medium (3–4 bands), and high (5–6 bands). We tested each subject with all three of the treatments in random order.

Immediately after application of color bands, birds were moved from the holding cage into a test cage of unfamiliar layout, but identical size, for two days of habituation. The test cage contained a 1.4 × 0.2 m strip of pine bark, a 3-m tree trunk (0.1–0.2 m circumference) with 20 smaller branches (0.02–0.06 m circumference), 5 smaller perches made from branches, and a traditional cedar birdfeeder, all hanging from the wire of the cage sides or roof. Water and additional seed were available ad libitum from dishes on the ground. All birds were tested singly in this same cage.

During habituation, and while in the holding cage, birds were fed ad libitum black-oil sunflower seeds, sunflower hearts, cracked corn, peanut bits, and millet. After 48 hr of habituation to the bands and the new cage, birds were tested. On the evening prior to testing, all food except previously cached seeds was removed from the test cage. During testing, black-oil sunflower seeds were available in a hanging feeder.

The following five classes of foraging behaviors were observed: number of flights, proportion of time spent hanging from a vertical substrate in head-up vs. head-down posture, proportion of time spent on trunk vs. branches, number of instances of hammering on a seed with the beak, number of seeds retrieved. A single observer in a blind recorded the occurrence and/or duration of a focal behavior in 5-min bouts. Only one behavior was observed at a time to ensure that no occurrences were missed. The observer switched focal behaviors according to a predetermined order every 5 min until each behavior had been the focus of 4, 5-min bouts. Thus, each class of behavior was recorded for 20 min over a 2-hr period beginning 30 min after sunrise. Whether a bird pecked at its bands and the amount of time spent storing seeds were recorded throughout the observation bouts.

After observing foraging behaviors, birds were rebanded with a different color band regime and returned to the test cage for two days of habituation followed by further testing as described above. Rebanding, habituation, and testing were then repeated for a third color-band regime. Birds were thus held for 1–7 days in a holding cage and 6 days in a habituation/testing cage before being released at sites of capture.

The effect of color band treatment on each of the six classes of foraging behavior was tested using repeated-measures 2-way ANOVA (individual bird; low, medium or high band category). Because the individual bird effects were not relevant to the question of whether number of color bands affected behavior, we report only the whole model result, unless this was significant, in which case we also report the band regime effect. Data were transformed (log or square root) when appropriate to eliminate heterogeneity of variance and to reduce non-normality. The power of each nonsignificant test was calculated using a hypothesized effect size (Δ) of 25% of the low treatment's mean value. To determine whether individuals with shorter tarsi experienced greater band effects, we used linear regression to test for a relationship between tarsus length and the difference in each bird's performance in the high and low treatments.

RESULTS

Color band regime had no effect on number of flights ($F_{11,18} = 3.3$, $P = 0.01$; band regime $F_{2,18} = 1.7$, $P = 0.21$, power = 0.99), proportion of time spent in head-up vs. head-down posture ($F_{11,18} = 1.5$, $P = 0.23$; power = 0.97), proportion of time spent on trunk vs. branches ($F_{11,18} = 4.7$, $P = 0.002$; band regime $F_{2,18} = 1.5$, $P = 0.25$, power = 0.65), mean time taken to hide seeds ($F_{11,18} = 0.95$, $P = 0.52$; power = 0.88), number of instances of hammering a seed with the beak ($F_{11,18} = 1.8$, $P = 0.13$; power = 0.58), or number of seeds retrieved ($F_{11,18} = 1.13$, $P = 0.40$; power = 0.83). Only 2 of the 10 birds were ever observed to peck their bands, and these pecked only one or two times. For the eight birds on which tarsus length was measured, there was no significant relationship between tarsus length and the difference in their performance of any

of the six behaviors measured (all $r^2 < 0.17$, all $F_{1,6} < 0.38$, all $P > 0.56$).

DISCUSSION

Recognition that the color of leg bands can sometimes influence behaviors such as mate choice, territory defense, and mate guarding has allowed researchers to improve research design and to avoid confounding effects (Burley et al. 1982, Holder and Montgomerie 1993, Johnsen et al. 1997). However, little attention has been paid to the potential for color bands to have effects beyond those produced by color per se (Sedgwick and Klus 1997).

We observed six characteristic foraging behaviors of recently captured White-breasted Nuthatches wearing 0–5 plastic color bands in addition to a metal band. Multiple color bands produced no detectable short-term effects on any of these important foraging behaviors, as evident from the lack of significant whole model or band regime effects in the comparisons between low, medium, and high band treatments. For the two behaviors where there was a significant whole-model effect, this was the result of variability between birds rather than between band regimes. This negative finding is somewhat surprising because nuthatches have relatively short tarsi which are frequently in contact with tree trunks. Thus, nuthatches would seem particularly likely to suffer deleterious effects of multiple color bands, either through abrasion or reduced mobility of the legs. We found no short-term effects but this does not preclude the possibility of serious long-term injury such as that reported for other species (Nisbet 1991, Sedgwick and Klus 1997).

Although we observed each subject for only 100 min within each of the three treatments, and recorded only six behaviors, we feel that because (1) observations were made under carefully controlled conditions in a naturalistic outdoor aviary, (2) the behaviors observed constituted virtually the entire nuthatch foraging repertoire, and (3) our high band treatment was the maximum number of bands that could possibly fit on the leg of a nuthatch, we had a high probability of detecting even subtle short-term behavioral effects of color bands. Furthermore, our statistical power was reasonably high for all nonsignificant tests (range: 58–99%), so our negative results are informative. We effectively eliminated the possibility that color band effects did occur, but only under the most extreme circumstances, by demonstrating that the difference in each individual's performance under low and high band treatments bore no relationship to the length of that individual's tarsus. In other words, individuals with short tarsi did not tend to suffer greater relative disruption from the high band treatment than larger birds.

Nuthatches cache food, use tools, and breed cooperatively—all of which require individual identification of birds for thorough study and are topics that will undoubtedly attract future research. Responsible use of plastic color bands requires a clear understanding of this technique's short- and long-term effects on behavior, questions that have been noticeably absent from the literature. We suggest that controlled aviary studies of short-term effects be performed before researchers embark on large-scale studies involving plastic color bands.

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LITERATURE CITED

BURLEY, N., G. KRANTZBERG, AND P. RADMAN. 1982. Influence of colour-banding on the conspecific preferences of Zebra Finches. Anim. Behav. 30: 444–455.

HOLDER, K., AND R. MONTGOMERIE. 1993. Red colour bands do not improve the mating success of male Rock Ptarmigan. Ornis Scand. 24:53–58.

JOHNSEN, A., J. T. LIFJELD, AND P. A. ROHDE. 1997. Coloured leg bands affect male mate-guarding behaviour in the Bluethroat. Anim. Behav. 54:121–130.

NISBET, I. C. T. 1991. Problems with Darvic colorbands on Common Terns: band losses and foot injuries. N. Am. Bird Bander 16:61–63.

POULDING, R. H. 1951. The use of extruded plastic for color marking. Brit. Birds 44:126–127.

SEDGWICK, J. A., AND R. J. KLUS. 1997. Injury due to leg bands in Willow Flycatchers. J. Field Ornithol. 68:622–629.