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Color dichromatism in female American Redstarts.—Male American Redstarts (*Setophaga ruticilla*) are easily categorized by plumage into yearlings (subadults) and adults. Here we relate differences in plumage and color of females of the species to their age and to the age of their mates. Differences of color in patches of yellow or orange on parts of the body and the tail feathers of female American Redstart have been attributed to age (Chapman 1907, Ficken 1964). As there is a significant difference in the external measurements and weights between first-year and older birds in many species (Crawford and Hohman 1978, Koenig 1980, Norman 1983, Roskraft and Jarvi 1983, Alatalo et al. 1984 and references cited therein), we examined morphological measures as possible indicators of female age. Further support for this approach comes from significant differences between subadult and adult male American Redstarts in wing chord and culmen and tarsus length (Lemon, unpubl. data). Some of our data come from females captured in more than one year, thereby allowing us to assess differences in these individuals over time.

Materials and methods.—We caught females in mist nets, and then banded them during the breeding seasons of 1981–1985. Birds were captured in mixed deciduous-coniferous forests on or near properties of the Huntsman Marine Laboratory, St. Andrews, New Brunswick. The male in the vicinity of the nest or area where a female was captured was assumed to be her mate. No mate could be assigned for 5 females. We made morphological measurements and removed the sixth right rectrix on each bird.

We classified the colors of the yellowish portions of the ventral surface of the wider vane of the sixth right rectrix of 83 females, using the Munsell Book of Color (Anonymous 1976), and following standard techniques of usage (American Society for Testing and Materials 1968). The Munsell system of color notation specifies a given color in terms of three characteristics: hue, value, and chroma. Hue denotes the redness, blueness, etc., of the color; value specifies the greyness; and chroma indicates the intensity. The feathers were placed against the white background supplied with the charts, and were viewed from an angle perpendicular to the specimen. Natural light from a north facing window illuminated the specimen and color plates from an incident angle of 45°. Feathers were assigned to the Munsell color chip to which they were most similar. No attempt was made to interpolate between color chips. The classification of the first author was compared to that made by the last two authors. The results showed only minor discrepancies.

External measurements, including wing chord and culmen and tarsus length, were determined using vernier calipers. We also weighed each bird on a Pesola spring scale. The entire length of the sixth right rectrix, as well as the length of the brown tip of the rectrix, was measured using calipers. The ratio of the length of the brown tip to the total length of the rectrix was calculated to examine the relative extent of the two contrasting colors on a single feather.

A one-way analysis of variance was performed on the morphological data to examine the possibility of any between-year variability due to differences in field technique and personnel. Rather than perform the analyses separately by year, with a consequent reduction in sample size, we used correction factors to permit the combination of data from 1982, 1984, and 1985. The variances of the measurements were not significantly different for these years (Bartlett-Box F-test, $P > 0.10$); therefore, the differences in the means of the two variables significantly different between 1982 and 1984 were used to adjust the 1982 data. For all observations made in 1982, we added 0.1108 to the tarsus length and subtracted 0.0839 from the culmen length.

Principal component analysis was carried out using the PRINCOMP program of the Statistical Analysis System) (Sarle 1982). Discriminant analyses were done using the DISCRIMINANT program of Klecka (1975).

Results.—All feathers appeared pale yellow to the observers. All had a Munsell value of 9, so value was of no use as a discriminator. The feathers were grouped into either of two hues, 5Y which we designate as "yellow," and 2.5Y which we designate as "orange." Feathers were then ranked on individual chromas within each hue (Table 1), with a neutral chroma 1 between the two hues. The frequency distribution so obtained is bimodal, and it is in this sense that we refer to the colors as "dichromatic."

We used three methods to relate these differences in feather color to possible differences in ages of the subjects and to ages of mates. First, we examined morphological differences that we sometimes associated with age. If we hypothesize that the females with the more orange feathers are older than those with more yellow feathers, just as adult males are more orange than subadult males, then we predict that the orange-feathered females should be larger than yellow-feathered females with respect to certain morphological features. In fact, of all measures made, only tarsus length showed a significant mean difference between the two groups (mean tarsus length: orange females, $\bar{x} = 1.93 \pm 0.060$ cm [SD], N = 21; yellow females, $\bar{x} = 1.87 \pm 0.095$ cm, N = 41; $F = 2.5$, df = 1,48, $P < 0.05$). The results of a

TABLE 1

NUMBER OF FEMALE AMERICAN REDSTARTS SORTED BY HUE AND CHROMA ASSIGNED TO THE YELLOWISH PORTION OF THE RIGHT RECTRIX

	Hue					
	"Orange"				"Yellow"	
Chroma[a]	8	6	4	Neutral	4	6
Number	9	11	6		15	42
Totals		26			57	

[a] 4 = low intensity, 6 = moderate intensity, 8 = high intensity.

principal component analysis of the combined morphological data from 1982 and 1984 showed no obvious separation between females with orange or yellow rectrices. Similarly, stepwise discriminant function analysis did not separate the two groups. In conclusion, morphological evidence that orange females are larger, and, therefore, assumed to be older, is limited to differences in tarsus length.

A second basis for examining feather color and age comes from demography. In our study, about 65% of the breeding male American Redstarts are adults. Assuming the proportions are the same for age of females, as is the case in the Prairie Warbler (*Dendroica discolor*) (Nolan 1978), there should be more "orange" than "yellow" females. In fact, the proportions observed were opposite to those predicted (Table 1).

Adult males arrive on breeding grounds about 7 to 10 days earlier than yearling males (Procter-Gray and Holmes 1981). These older males acquire mates before the younger males. Therefore, if older females arrive earlier than do younger females, as they do in White Wagtails (*Motacilla alba*) (Leinonen 1973), then more often older females should pair with adult males than with subadult males. As predicted, a disproportionate number of orange females mated with adult males: of 25 orange females, 23 had adult mates, while of 53 yellow females, 35 had adult mates ($\chi^2 = 6.01$, df = 1, $P < 0.02$).

The third approach of assessing the relationship between color and age is to examine year-to-year color changes of banded females (Table 2). The number of such recaptured individuals was small. Two of 6 females first recorded as yellow changed to orange in a later year; but both then changed from orange back to yellow in a subsequent year. Three individuals remained yellow over two years, and one remained orange. Obviously, color is not strictly related to age.

Discussion.—The use of morphological structures of the females as an indicator of age may be useful in some species, but this is not always the case (Knapton 1978). Furthermore, even measurements with significantly different means may overlap considerably between groups, and consequently may be poor discriminators (Alatalo et al. 1984).

Although Nolan (1978) noted no tendency for either sex to pair preferentially with an age class of the other sex in Prairie Warblers, the distribution of female American Redstarts observed in this study seems to indicate some form of selective mating. In studies of Meadow Buntings (*Emberiza cioides*) (Yamagishi 1981) and Great Tits (*Parus major*) (Greenwood et al. 1979), the smallest percentages of breeding pairs were composed of older females mated

TABLE 2

MUNSELL COLORS ASSIGNED TO THE YELLOWISH PORTIONS OF RECTRICES OF FEMALES RECAPTURED IN DIFFERENT YEARS AND THE AGES OF THEIR MATES

Female	Year	Hue	Chroma[a]	Age of mate[b]
249	1982	Yellow	4	ASY
	1984	Yellow	4	ASY
291	1982	Yellow	6	SY
	1983	Yellow	6	SY
330	1983	Yellow	6	?
	1984	Orange	8	ASY
	1985	Yellow	4	ASY
976	1981	Yellow	6	ASY
	1982	Yellow	6	ASY
478	1984	Orange	4	ASY
	1985	Orange	4	ASY
980	1981	Yellow	6	ASY
	1983	Orange	4	ASY
	1985	Yellow	6	ASY

[a] 4 = low intensity, 6 = moderate intensity, 8 = high intensity.
[b] SY = subadult; ASY = adult; ? = age unknown.

to younger males (2.6% in the former study, 16% in the latter). Pigmentation may also be related to diet and condition. Chemical analysis of feathers of wild finches revealed that the difference between orange and yellow birds was an apparent buildup of dietary carotenoid (Brush and Power 1976). Since all our banded females did not change color from year to year in a manner consistent with age, it is possible that differences in female color are partly a reflection of diet, as well as age, and that females with certain feeding backgrounds arrive earlier.

Dwight (1900) and Wood (1969) stated that the main molts of American Redstarts occur in July and August for juveniles of the year, followed in each succeeding year by a molt in March and April, chiefly on the head and throat, and a complete postbreeding molt in July and August. Problems in color analysis may arise if feathers are taken at different times during the season. The plumage color of House Finches (*Carpodacus mexicanus*) changes without a molt, due to abrasion and wear in a single feather generation (Michener and Michener 1931, as cited by Brush and Power 1976). Although this should not affect the assessment of Munsell hue, it may increase the Munsell chroma as greyish feather edges are worn away (Brush and Power 1976), and it should be considered if chroma is to be included in an aging technique.

Summary.—We attempted to determine whether color or morphological characters of female American Redstarts could be used as indicators of age. Tail feather patches fell into two categories of orange or yellow. Orange females had longer tarsi and mated disproportionately with older males; however, orange females were proportionately less frequent in the population than expected if all two-year-old or more females were "orange." Tracking histories of females showed that they do not consistently change from yellow to orange with age, and that some change from orange to yellow.

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