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Another Assessment of Gape Color in the Purple Finch

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Observations on the use of gape color to determine sexual identity of Purple Finches *(Carpodacus purpureus)* have been reported previously (Blake 1954, Magee 1924 and 1927, and Whittle 1928). These results suggest that reddening of the gape occurs in males. However, in some cases the results are not totally consistent (Whittle 1928 compared to Blake 1954 and Magee 1927), nor always quantified (Magee 1924 and 1927, and Whittle 1928), nor sufficient in number during the breeding season (Blake 1954) to explain fully the role of gape color in identifying the sex of brown-plumaged birds. This study of nearly 9000 observations over a ten-year period on an Adirondack summer resident population is offered to aid in that understanding.

METHODS

Purple Finches were captured by mist net at a feeding station located at Jenny Lake near Corinth in northern Saratoga County, New York, during the period 1980-1989. At the time of capture, the color of the gape was noted visually using ratings of pale-yellow (PY), yellow (Y), yellow-orange (YO), orange (O), orange-red (OR), and red (R) as recorded by Blake (1954). These observations were made within 15-30 cm of a 20-watt, circular, "cool white" fluorescent lamp.

Early in this study, I attempted to relate these color variations to the Naturalist's Color Guide (Smithe 1975) and Munsell Soil Color Charts (Munsell Color Division 1971) and found both less than satisfactory. The Munsell colors were least applicable. While certain of Smithe's colors approximated the observed gape colors, the Smithe color patches were far more intense or brighter than the observed gape colors. The gape colors referred to here are approximated by the following Smithe colors represented by color number and name in parentheses: red, 12 (geranium); red-orange, between 14 (scarlet) and 15 (flame scarlet); orange, 16 (chrome orange); yellow-orange, between 17 (spectrum orange) and 18 (orange yellow); yellow, between 18 (orange yellow) and 55 (spectrum yellow); and pale-yellow similar to 54 (cream color). However, in my judgement, there was variability in how closely these patches matched the observed gape colors; and, therefore, I relied on my visual recognition of gape color differences rather than matching of those colors to standard color patches.

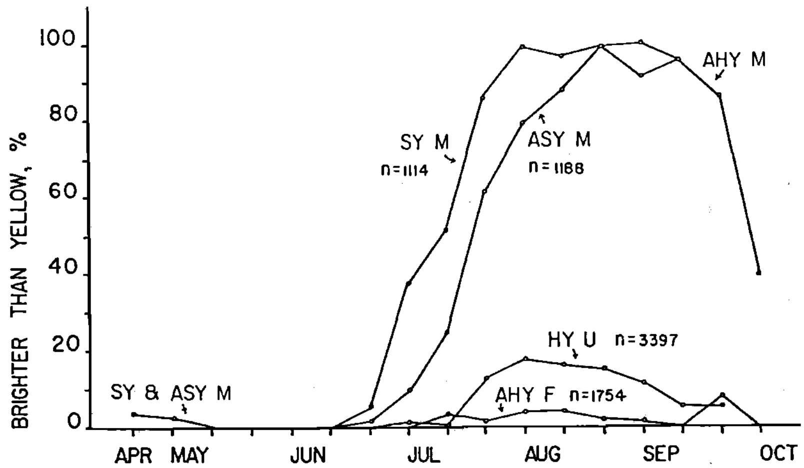
Age and sex were determined using methods previously described (Yunick 1983).

Data on new bandings were grouped for analysis by monthly thirds between 1 May and 30 September. Early arrivals in April were relatively few in number and were grouped into one class, as were the few birds that lingered in October. During all other months of the years of the study, the species was essentially absent from the feeders. Data on recaptures (returns and repeats) were combined with those on new bandings with the restriction that only one observation was included on any individual bird in any particular monthly third, regardless of how many times in that monthly third the bird was captured. In case there were differences in gape color on a bird caught more than once within a particular monthly third, the redder or brighter of the ratings was used for analysis. In this regard, the term "brighter" will be used throughout to be synonymous with "redder." Thus, pale-yellow was assumed to be a base color, and yellow was brighter or redder than pale-yellow, and orange was brighter or redder than yellow-orange, etc.

Data were grouped and analyzed in several ways to test whether the development of redder gapes is restricted to males and, if so, whether this criterion could be used to determine the sex of immature birds, for which no sexing method is known.

RESULTS

Gape colors were recorded on 4632 new bandings and over 4000 recaptures; however, only 2831 of the latter met the previously described restriction to give a combined data base for analysis of 7463 gape color observations covering the period mid-April to mid-October. The temporal distribution of four age-sex classes of birds with gapes brighter than yellow is plotted by monthly thirds in Figure 1. The occurrence of gape colors among brown-plumaged birds beyond hatching-year (HY) is given in Table 1. This group includes second-year males (SY M) and mixed-age



ASY M	n=	73	80	49	92	44	106	80	77	69	78	92	104	86	46	48	42	22
SY M	n=	28	44	64	121	84	195	75	99	72	98	68	91	59	11	3	2	-
AHY F	n=	3	25	47	106	45	143	114	138	130	238	210	207	160	74	53	61	10
HY U	n=	-	-	-	-	-	-	7	61	106	307	481	732	749	493	256	145	-

Figure 1. Temporal distribution of gape color change for four age-sex classes of Purple Finch from April to October. Except for April and October data, which are monthly composites, all other time periods are monthly thirds. Sample sizes for each time period are indicated at the bottom where AHY = after-hatching-year, ASY = after-second-year, F = female, HY = hatching-year, M = male, SY = second-year, and U = unknown age. The plotted percentages represent for each age-sex class the percentage of each class' members having a gape color brighter than yellow in that particular time period.

females (after-hatching-year or AHY F). This grouping is limited to the time period 21 June through 30 September, corresponding to the time of development and recession of gape colors brighter than yellow.

Table 2 shows the percentage distribution of gape colors for the four age-sex classes during the peak molt period of 1 August - 10 September. Table 3 contains information on HY birds of all gape colors whose sexual identity was confirmed on recapture during a subsequent breeding season. Table 4 shows the earliest capture dates of the first individual in each age-sex class for each gape color brighter than yellow over the ten-year period.

On several occasion I noticed that my ranking of gape color in daylight changed when the same bird was viewed under fluorescent light. I did not make a formal study of this effect of light source to determine whether it affected all color rankings, or just those of redder ranking; but I did notice that on some birds the color declined by one rank; i.e., red-orange in daylight was orange under fluorescent light. This was believed due to the relatively yellower daylight and bluer fluorescent wavelengths. For consistency, only rankings under fluorescent light were used.

DISCUSSION

The results portrayed in Figure 1 are consistent with some, but not all, conclusions of Magee (1924 and 1927), Whittle (1928), and Blake (1954) regarding the timing of the appearance and decline of gape reddening, its occurrence at the time of molt, its relation primarily to males, and to certain age-related criteria. Since these prior authors lacked use of some of the age-sex criteria available today (Yunick 1983) such as use of brood patch and cloacal protuberance, they were not able to sort out fully the age-sex classes among brown-plumaged birds. The results presented here allow a greater, but still not complete, sorting of these birds, thereby allowing additional conclusions about appearance of gape reddening and its use as a sex-determining criterion.

Figure 1 shows that reddening is most prevalent in males and that its appearance and disappearance coincide with the occurrence of prebasic molt. Magee (1924) observed that gapes of crimson males (ASY M) in spring were yellowish to deep-yellow with molt beginning about 1 July when the gape color progressively reddened, followed by fading in fall to orange or orange-yellow. Blake's (1954) results corroborate these findings and give a quantitative assessment of them. Magee (1927) went on to add that some "dull-colored" birds (=SY M, HY U, and/or AHY F) develop orange and orange-red gapes, as Blake (1954) also noted, and concluded: "I have yet to trap one of these birds after molting that was not a male." Blake (1954) was more reserved in commenting: "It is still not certain that orange and red-orange gapes seen in a few brown birds in postjuvenal (=first prebasic) molt indicate male birds." Whittle (1928), on the other hand, in five years of banding, stated he never saw a "known bird of the year"(= HY) that exhibited gape reddening. Figure 1 and Table 2 indicate the extent to which I found this phenomenon to occur in HY's.

Figure 1 also shows that among 1382 gape observations of the three age-sex classes analyzed up to 20 June, 1367

Table 1. A comparison of gape colors and sexual identity of adult brown-plumaged Purple Finches during the period of gape reddening, 21 June - 30 September.

Gape Color	Age-Sex Distribution Within Each Gape Color Class					
	SY M, n	AHY F, n	Total, n	M, %	F, %	Total, %
Pale-yellow and Yellow (PY, Y)	178	1265	1443	12.3	87.7	100.0
Yellow-orange (YO)	39	18	57	68.4	31.6	100.0
Orange (O)	188	9	197	85.4	4.6	100.0
Orange-red (OR)	74	1	75	98.7	1.3	100.0
Red (R)	66	1	67	98.5	1.5	100.0
Total All Colors, n	545	1294	1839	-	-	-

Gape Color Class	Cumulative Change of Gape Color by Age-Sex Class	
	SY M, cum. %*	AHY F, cum %*
R only	12.1	0.08
R and RO	25.7	0.15
R, RO and O	60.2	0.85
R, RO, O and YO	67.3	2.2
R, RO, YO, Y, PY	100.0	100.0

* Cumulative percentages for SY M are based on n=545 and AHY F n=1294, given above, and represent the percentages of birds in each of the combined gape color classes.

Table 2. Distribution of gape colors within each age-sex class during peak molt period, 1 August - 10 September.

Gape Color Class	Cumulative Gape Color Distribution by Age-Sex Class, cum. %*			
	ASY M	SY M	AHY F	HY U
R only	21.0	27.1	0.2	2.9
R and RO	35.1	54.1	0.3	4.3
R, RO and O	82.6	89.5	1.2	8.4
R, RO, O and YO	88.4	97.8	2.8	15.1
R, RO, O, YO, Y and PY	100.0	100.0	100.0	100.0
Sample size n, for each age-sex class	328	229	651	2515

* These cumulative percentages are based on the sample sizes at the bottom of the table and indicate the percentages of birds in each of the combined gape color classes.

or 98.9% were yellow or lighter. The exceptions were six yellow-orange SY M's, and two yellow-orange, six orange, and one orange-red ASY M's. Beginning 21-30 June, males began to display increased reddening of the gape, and SY M's developed this trait more rapidly than did ASY M's. It was not until the 21-30 August period that these two age classes showed nearly comparable degrees of reddening. Shortly after, as molt entered its last stages, it became difficult to differentiate SY M's from ASY M's and all data on them were combined and represented as AHY M's. During the various monthly thirds in the peak molt period of 1 August - 10 September, 80 to nearly 100% of all of these males had gapes brighter than yellow. Table 2 shows the gape color percentages by age-sex class during that period.

Just as the appearance of gape reddening coincided with the timing of prebasic molt, the timing difference in gape color development among SY M's and ASY M's related also to a difference in molt timing between these two age classes. I examined 18 years of my molt data (1972-1989) at this same site and found that the average dates of first capture of a bird in molt were 10 July for SY M's, 19 July for ASY M's, and 17 July for AHY F's. In some cases, these first capture dates involved birds that had truly just begun molting as evidenced by a missing first primary (P1). In other cases, the first capture represented a bird that had half grown or fully grown P1, or more, indicating that molt had begun some number of days earlier. Based on a review of these molt results, I feel that the true average date of first molt is up to 10-14 days earlier than the average first capture dates, placing the beginning of molt in the same monthly third (21-30 June) as the first significant appearance of reddening gapes. Nevertheless, even though the first capture dates referred to above lack precision in defining the exact initiation of molt, they serve well as a comparison of initiation among the three age-sex classes and suggest that SY M's begin nine days before ASY M's, while ASY M's and AHY F's show similar timing.

Table 4 presents some additional information on the timing of color development. The data for ASY M's show no particular trend or pattern other than erratic distribution of dates. However, each of the remaining age-sex classes show time-related trends of color development, with color brightening as the season progressed. SY M's showed earliest development, followed by HY U's lagging always by two time periods. Females showed latest color development.

Blake (1954) conjectured that gape redness was associated with carotenoid pigment development during molt, and then offered the comment: "It may well prove that redness is related to age, least in juvenal birds and greatest in old males and females." He appears to have been partially correct. Figure 1 shows that juveniles show only modest development of color; however, females less frequently develop color, an observation borne out also in Tables 1 and 2. In males, color development is age related, as Blake (1954) suggested, with much more occurrence of color in SY and ASY M's than in HY M's. This

Table 3. Sexual identity of HY Purple Finches grouped by gape color.

Gape Color When Banded as HY U	Confirmed Sexual Identity on Recapture in a Subsequent Breeding Season					
	Male, n	Female, n	Total, n	M, %	F, %	Total, %
Pale-yellow (PY)	10	12	22	45.5	54.5	100.0
Yellow (Y)	72	39	111	64.9	35.1	100.0
Yellow-orange (YO)	5	1	6	83.8	16.2	100.0
Orange (O)	3	1	4	75.0	25.0	100.0
Orange-red (OR)	3	0	3	100.0	0.0	100.0
Red (R)	2	0	2	100.0	0.0	100.0
Total, n	95	53	148	-	-	-

Gape Color Class	Cumulative Gape Color Change by Sex Class, cum. %*	
	Male	Female
R only	2.1	0.0
R and RO	5.3	0.0
R, RO and O	8.4	1.9
R, RO, O and YO	13.7	3.8
R, RO, O, YO and Y	89.5	77.4
R, RO, O, YO, Yand PY	100.0	100.0

* Cumulative percentages for males are based on n=95 and females n=53, as given above, and represent the percentages of birds in each of the gape color classes.

Table 4. Earliest recorded appearance dates of gape colors brighter than yellow.

Age-Sex Class	Gape Color: Yellow-Orange	Orange	Orange-Red	Red
ASY M	1-10 July	21-30 June	11-20 July	1-10 July
SY M	11-20 June	21-30 June	1-10 July	1-10 July
AHY F	11-20 July	11-20 July	11-20 Aug.	1-10 Sept.
HY U	1-10 July	11-20 July	21-31 July	21-31 July

is demonstrated using the color criterion of orange or brighter in Table 2. About 85% of the combined SY M and ASY M sample met this criterion, while only 8.4% of the HY U sample did. If one assumes that the HY U group is 50:50, male:female, and the hypothesis that only males in the HY group are orange or brighter, than the estimated ratio of the combined SY/ASY M sample to HY M sample becomes about 85:17, or 5:1.

However, it is not the old males that show greatest color as Blake (1954) conjectured. For all gape color categories in Table 2, SY M percentages exceed ASY M percentages. It is these brown males acquiring their first rose-colored plumage that develop the brightest gape color and in greater number than do the older males. In addition, they accomplish the process ahead of the older males, as shown in Figure 1.

While there is strong relation of gape reddening occurring in males, it is only infrequently found in females. During the period of molt and color development of 1 August - 10 September, only 2.8% of the females in Table 2 were brighter than yellow. Over the entire color period of 21 June - 30 September presented in Table 1, only 2.2% of the 1294 females were redder than yellow; and at brighter colors of orange and redder, the percentages decline significantly. I reviewed in detail the capture history of the 11 females that were orange or brighter. Five of the nine birds with orange gapes were typically in brownish plumage overall, while the other four had some rose in their plumage. It occurred as pale rose edging to newly molted lesser coverts, and leading edges of primaries and secondaries; or as a rosy cast to the rump; or slight rose all over the body and head. The female with the orange-red gape was brownish, lacking rose; and the bird with the red gape had a rosy cast all over, except for a gold rump. Thus, five of the 11 of these females had faint male-like rosiness in their plumage and six did not.

One of these females showed that the orange gape color did not develop until well into her molt. When first captured on 23 August with a yellow gape, she had already renewed P1-4, P5-6 were in process, and the lesser and greater coverts were new. The body and much of the head were new on the surface with sheaths underneath. When recaptured on 28 September, P1-6 were new, P7-9 in process, and S1-4 in process; and at this time, the gape was orange.

In order to test the reliability of this reddening criterion as a means of identifying males within the brown-plumaged population, two comparisons were made. In Table 1, I compared only brown-plumaged birds of known sex and found among the 396 birds in that sample that a gape color of yellow-orange and brighter was not sufficiently reliable in identifying a male (68.2% were male). However, at colors of orange and brighter, the reliability was 96.8%, meeting the Bird Banding Laboratory's criterion that an age- and sex-determining method should be at least 95% reliable. This assessment quantitatively verifies some of the conclusions of the earlier authors.

My second comparison relied on the recapture data in Table 3. At the beginning of this study, I had hoped that I could gather sufficient HY recapture data on birds of later-known sex to directly assess

the use of gape color in determining the sex of HY birds, rather than rely on inferential data from the other age-sex classes. After ten years of study, HY recapture data have proved relatively scarce, and like Blake (1954) who lamented a lack of fully adequate data and who chose to put forth his results for examination, I, too, finally chose this route. The reasons for few usable return data are twofold. Only about 15% of the HY's developed gape color brighter than yellow, and only about 9-10% of all HY's were recaptured during a subsequent breeding season to confirm sexual identity. Despite the thousands of bandings, a combined return rate of only about 1.5% created a small data base. Table 3 shows the 148 observations that were available. Males far outnumbered females, most likely due to one or some combination of the following: differences in survivability, site fidelity, and/or capturability.

The results show that HY M's appeared in all color classes from pale-yellow to red. Females tended to be distributed predominately toward yellow and lighter. Only 3.8% of the females were yellow-orange or brighter, and 1.9% orange or brighter. Repeating the analysis made above for Table 1, a gape color of orange or brighter was 88.9% reliable in recognizing an HY M. While this reliability does not meet the 95% requirement of the Bird Banding Laboratory, I feel that this is the result of an unfortunately small sample (n=9) wherein only one bird made the difference between 100% reliability and that which is noted. Based on the combination of this evidence with the strength of the other evidence, I feel that HY M's can be recognized reliably by a gape color of orange or brighter, but the number that can be so recognized represents only about 17-18% of the HY M population.

Combining this gape color criterion with prior age- and sex-determining information that apply during the breeding season (Yunick 1983), the following key applies to brown-plumaged Purple Finches from late June through early October. The color abbreviations used here are as presented earlier.

1A. Brown plumage *worn,* no symmetrical flight feather molt
  1. Gape color O, OR or R . . . . . .SY M
  2. Gape color PY, Y or YO. . . . . .See 2

1B. Brown plumage *worn,* symmetrical flight feather molt with or without body-covert molt in progress
  1. Gape color PY, Y, YO, O, OR or R and molt progressing from brown to rose plumage (gape usually YO, O, OR, R). . .SY M
  2. Gape color PY, Y, YO or O and molt progressing from brown to new brown plumage (gape usually PY, Y or YO). AHY F

2A. Brood patch (BP) present. . . . . AHY F

2B. Cloacal protuberance present or missing, but *no* BP present . . . . SY M

3A. Brown plumage *unworn* (juvenal), no symmetrcal flight feather or body molt, skull not completely pneumatized
  1. Gape color O, OR or R.. . . . . . . .HY M
  2. Gape color PY, Y or YO. . . . . . . .HY U

3B. Brown plumage *unworn* (juvenal) and undergoing body and covert molt but no symmetrical flight feather molt, skull not completely pneumatized
  1. Gape color O, OR or R. . . . . HY M
  2. Gape color PY, Y or YO. . . . . . . .HY U

Combining these data with those of Blake (1954) may allow gape color to be used into December to identify HY M's. Some of the birds he observed continued to have orange gapes into December.

DEDICATION - ACKNOWLEDGMENT

This paper is dedicated to the memory of Charlie Blake whose previous results inspired this study, and whose memorable presence at EBBA meetings long ago always enlivened a meeting and enlightened a beginner like me. I acknowledge with thanks the comments of two referees who improved the quality of this presentation.

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