SEASONAL VARIATION IN THE GENUS *LEUCOSTICTE* IN NORTH AMERICA

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Many characters used in taxonomic studies of birds vary seasonally and this variation may be greater than that between populations. Therefore seasonal variation must be understood before a proper evaluation of geographic patterns can be attempted. The primary purposes of this study are to examine variation during the breeding season in several characters of rosy finches (*Leucosticte*) in North America and to discuss the importance of these variables to studies of geographic variation. Several new methods of analysis of certain characters also will be discussed. Variables selected for study include several bill traits, body weight, feather wear, bill color and plumage color.

For purposes of orientation to the discussions that follow, salient features of the eight taxa recognized in the A.O.U. Check-list (1957) are summarized in table 1. Nomenclature follows that of Johnson (1972). Characters most important at the species level include body color and pattern of gray on the head, while those varying at the subspecific level include, in addition, body size and bill shape. Members of all taxa breed in alpine habitat in the mountains of western North America except the two large forms (*L. g. griseonucha* and *umbrina*) which occur on the maritime tundra of the Aleutian Islands and the islands of the Bering Sea.

As a matter of convenience the subspecies of *L. griseonucha* and of *L. tephrocotis* will be designated by their respective racial names and the two monotypic species will be referred to simply as *atrata* and *australis*. Except when indicated to the contrary, samples cover the entire range of each taxon.

MATERIALS AND METHODS

A total of 2590 museum specimens of adult birds was examined during the study. Of these 1574 were considered breeding birds (collection dates between 15 May and 15 September) and these form the basis for most of the critical remarks in this report.

MENSURAL CHARACTERS. Measurements used during the study were defined as follows: bill length—the distance between the anterior margin of the nostril and the tip of the upper mandible; bill depth—the distance (chord) from the culmen to the lower edge of the ramus of the mandible at the anterior margin of the nostril; bill shape—the ratio of bill depth to bill length; wing length—the chord of the unflattened wing when closed; tail length—the distance from the point where the inner pair of rectrices emerge to the tip of the longest rectrix.

COLORIMETRIC ANALYSIS. Plumage color of the breast below the black of the chin and throat was measured by reflectance colorimetry using a Bausch and Lomb 505 recording spectrophotometer equipped with a reflectance attachment. The Bausch and Lomb trichromatic coefficient computing chart for illuminant C (selected ordinate method) was used for recording and for computation of the trichromatic coefficients (x, y and z). The three components of color (dominant wavelength, excitation purity and brightness) were computed from these coefficients. Dominant wavelength was determined to the nearest 0.1mμ by interpolation using table six in Judd (1933). Purity (in percent) was computed using the formula:

$$p = 100\ (x - x_w) / (x_1 - x_w)$$

where x is the abscissa of the sample point plotted on a chromaticity diagram (i.e., the trichromatic coefficient x), x_w is the abscissa of the white point (I.C.I. Illuminant C) and x_1 is the abscissa of the point of intersection of the spectrum locus with an extension of a line connecting x and x_w. Brightness equals 100Y. For additional treatment of colorimetric procedures see Hardy (1936), Johnson and Brush (1972) and Sears and Zemansky (1960).

STATISTICAL METHODS. The levels of significance between sample means were determined by the two-tailed *t* test. Regression lines were computed by the least squares method using an Olivetti Underwood Programma 101 desk computer and programs 2.14 and 2.15.

SEASONAL VARIATION

BILL CHARACTERS

Many species which are primarily granivorous in winter and insectivorous in summer have been shown to have shorter bills in winter, presumably due to greater wear associated with a diet of seeds and the concomitant grit (Clancey 1948, Davis 1954, 1961, Packard 1967, Selander 1958, Selander and Johnston 1967). Moreover, the seasonal differences in some of these species are as great as nine or ten percent, clearly too large to ignore in studies of geographic variation.

Rosy finches are granivores most of the year but consume significant numbers of insects during at least a portion of the summer (French 1959, Johnson 1965, Leffingwell and Leffingwell 1931, Swarth 1922, Twining 1938a, 1940). Therefore it seemed advisable to examine bill length for possible variation through the summer months.

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TABLE 1. Characteristics of the North American members of the genus *Leucosticte*.

Taxon	Gray on head	Body color	Body size	Bill
L. griseonucha umbrina	cap and cheek	very dark brown	large	slender
L. griseonucha griseonucha	cap and cheek	dark brown	large	slender
L. griseonucha littoralis	cap and cheek	brown	small	stout
L. tephrocotis tephrocotis	cap	brown	small	stout
L. tephrocotis wallowa	cap	dark brown	small	stout
L. tephrocotis dawsoni	cap	brown	small	slender
L. atrata	cap	black	small	stout
L. australis	none	brown	small	stout

Mean monthly bill length of samples representing each taxon except *wallowa* is given in table 2. The sexes have been combined in order to obtain as large a sample as possible for each month. A few samples of *dawsoni* and *atrata* are sexually dimorphic and were excluded. There are clines in bill length in *griseonucha, littoralis* and *tephrocotis* and in each case the portion of the cline with the largest sample was used.

In every taxon sampled the bills are shortest in June. Subsequently there are two basic patterns: (1) bills reach their greatest length in July and then become shorter, and (2) they continue to increase in length until August or September. The data for the large island races (*umbrina* and *griseonucha*) follow the first pattern with the July bills being significantly longer than those from most other months. The closely-related mainland form, *littoralis,* follows the same pattern but the monthly differences are smaller and not significant. All other forms follow the second pattern. In each of these except *atrata,* the bills in August or September are significantly longer than those in many of the preceding months.

These data are in only limited agreement with the theory, mentioned above, regarding bill length, wear and diet. For example, observations of the feeding behavior of *dawsoni* (Twining 1938a, 1940, Johnson, unpubl. data) suggest that insects are important in their diet starting at least as early as the beginning of May, reach a peak in mid-July and then decline. To correspond with the theory, bill length should be greatest in July but my data show that it continues to increase through September when seeds form most of the diet and the shortest bills would be expected. Moreover, the direction of change in bill length agrees with the theory only during one (June to July) of the four monthly intervals examined. Likewise, feeding observations on *tephrocotis* (Johnson 1965) and crop analyses of *atrata* (French 1954, 1959) indicate that insects decline in the diet of these taxa from July to August, yet bill length shows a noticeable, though not significant, increase over this period. Again the only portion of the data in agreement with the theory for either taxon is the interval from June to July. The probable explanation for these discrepancies is that the theory as stated considers only one factor contributing to wear, whereas bill length is the net result of all wear factors plus growth.

Growth and wear also might be expected to affect bill depth. This possibility has rarely been examined for any species. It seemed important to do so in the present study since

TABLE 2. Variation in bill length during summer months (sexes combined).

Taxon	May $\bar{x} \pm$ S.E. (N)	June $\bar{x} \pm$ S.E. (N)	July $\bar{x} \pm$ S.E. (N)	August $\bar{x} \pm$ S.E. (N)
umbrina		10.99 ± 0.05(50)[a]	**11.19** ± 0.06(30)	11.01 ± 0.08(14)[a]
griseonucha[d]	10.75 ± 0.05(37)[a]	10.66 ± 0.05(38)[b]	**10.91** ± 0.06(32)	10.75 ± 0.08(14)
littoralis[e]	8.86 ± 0.07(8)	8.76 ± 0.06(38)	8.86 ± 0.06(43)	8.78 ± 0.06(15)
tephrocotis[f]	8.84 ± 0.10(8)	8.62 ± 0.08(8)[b]	8.88 ± 0.04(72)	**8.96** ± 0.05(25)
dawsoni[g]	8.83 ± 0.07(21)[a]	8.72 ± 0.04(55)[c]	8.82 ± 0.03(84)[b]	8.82 ± 0.06(36)[a]
atrata[h]		8.69 ± 0.07(16)	8.72 ± 0.03(94)	8.81 ± 0.06(28)
australis	8.74 ± 0.13(8)	8.73 ± 0.06(22)[a]	8.75 ± 0.03(115)[b]	**8.95** ± 0.06(23)

[a] $P < 0.05$ for difference with mean in boldface (usually largest mean for race).

[b] $P < 0.01$, as above.

[c] $P < 0.001$, as above.

[d] Fox group of the Aleutian Islands, Alaska.

[e] Oregon north to 56° north latitude in central British Columbia.

[f] Populations along the Continental Divide from Jasper National Park, Alberta to Glacier National Park, Montana, plus the Mission Mtns, Montana.

[g] Sierra Nevada only. Comparisons are with September bills (9.07 ± 0.08(15)).

[h] Montana and Wyoming only.

TABLE 3. Variation in bill depth during summer months (sexes combined).

Taxon	May $\bar{x}$ ± S.E. (N)	June $\bar{x}$ ± S.E. (N)	July $\bar{x}$ ± S.E. (N)	August $\bar{x}$ ± S.E. (N)
umbrina		8.23 ± 0.03(37)[a]	8.25 ± 0.05(19)	**8.38** ± 0.05(9)
griseonucha[d]	8.04 ± 0.05(27)	8.04 ± 0.06(17)	7.99 ± 0.04(18)	8.24 ± 0.12(12)
littoralis[e]		6.87 ± 0.05(27)[a]	**7.06** ± 0.06(36)	6.93 ± 0.06(9)
tephrocotis[f]			6.98 ± 0.03(45)	7.09 ± 0.06(14)
dawsoni[g]	6.52 ± 0.07(13)	6.43 ± 0.02(45)[c]	6.51 ± 0.02(66)[a]	6.64 ± 0.07(16)
atrata[h]		6.86 ± 0.09(8)	6.91 ± 0.03(53)	6.91 ± 0.05(20)
australis		6.98 ± 0.08(15)[a]	7.03 ± 0.02(89)[b]	**7.18** ± 0.05(13)

[g] Sierra Nevada only. Comparisons are with September bills (6.63 ± 0.05 [11]).
For other symbols see table 2.

bill depth figures prominently in the discussion of geographic variation in this group. Data for seasonal variation in bill depth (table 3) show that there is nearly as much seasonal variation in depth as there is in length. For the island races the bills are deepest one month later than they are longest. In the remaining taxa the bills are deepest and longest in the same month, though in two cases equally deep bills occur in the preceding month.

These data suggest that wear at the tip and along the tomia of the bill are not always in the same proportions. For example, the island birds apparently have the least wear at the tip in July and the least wear on the tomia in August. Such differences probably reflect differences in foraging techniques as well as in the type of food items consumed. Increased probing, especially in abrasive substrates, or increased consumption of abrasive food items would probably differentially wear the tip whereas hard food items might cause more wear on the tomia.

These differences result in seasonal changes in bill shape (table 4). The forms with stout bills (*littoralis, tephrocotis, atrata,* and *australis*) show little seasonal variation. In each case the bills are stoutest in July but in no instance do they differ significantly from bills from other months. The races with slender bills (*umbrina, griseonucha* and *dawsoni*) show much greater variation in bill shape and many of the differences between monthly means are significant. In each case here the bills are stoutest in August. It should not be concluded from this that *dawsoni* has the same feeding habits as the two island forms. The alpine habitat of *dawsoni* differs greatly from the maritime tundra and beach habitat of the island taxa. There are probably also differences in the food items and in their seasonal availability. Perhaps this is reflected in the changes in bill shape prior to August. The island forms have noticeably thinner bills in July than in the preceding months (for *griseonucha* the differences are significant at the 0.05 level) whereas *dawsoni* does not. Limited data from late fall indicate further differences. The bills of *griseonucha* are as stout in November ($\bar{x} = 0.782$, $n = 5$) as they were in August whereas those of *dawsoni* become more slender by September ($\bar{x} = 0.735$, $n = 11$) and may retain this shape into winter (November, $\bar{x} = 0.748$, $n = 15$).

Seasonal changes in the bill characters of rosy finches are too large to ignore in studies of geographic variation but the causes underlying these changes are not yet fully understood. Detailed studies of the feeding habits of all taxa would be useful in interpreting the

TABLE 4. Variation in bill shape during summer months (sexes combined).

Taxon	May $\bar{x}$ ± S.E. (N)	June $\bar{x}$ ± S.E. (N)	July $\bar{x}$ ± S.E. (N)	August $\bar{x}$ ± S.E. (N)
umbrina		0.750 ± 0.004(37)	0.739 ± 0.006(19)[a]	**0.760** ± 0.007(9)
griseonucha[d]	0.749 ± 0.006(24)	0.749 ± 0.007(17)	0.728 ± 0.007(12)[b]	**0.780** ± 0.016(9)
littoralis[e]		0.790 ± 0.006(27)	0.794 ± 0.007(36)	0.792 ± 0.012(9)
tephrocotis[f]			0.789 ± 0.004(44)	0.788 ± 0.009(13)
dawsoni[g]	0.740 ± 0.010(13)	0.740 ± 0.004(45)[a]	0.739 ± 0.004(72)[a]	**0.760** ± 0.009(19)
atrata[h]		0.784 ± 0.011(8)	0.798 ± 0.005(53)	0.784 ± 0.009(20)
australis		0.799 ± 0.007(15)	0.807 ± 0.003(89)	0.802 ± 0.007(13)

[g] Sierra Nevada only.
For other symbols see table 2.

TABLE 5. Seasonal variation in body weight.

		May	June		July		August	
		16–31	1–15	16–30	1–15	16–31	1–15	16–31
dawsoni								
	n	7	6	16	5	16	8	3
M	Mean	23.59	23.37[b]	24.55[a]	23.86[a]	24.43[a]	**25.72**	25.80
	S.E.	1.02	.42	.26	.68	.29	.43	.23
	n	7	7	7	4	13	20	
F	Mean	22.03[c]	23.90[a]	**26.67**	25.18	24.88	24.13[a]	
	S.E.	.53	.46	.93	.35	.36	.31	
atrata[d]								
	n		3	2	22	18	6	2
M	Mean		26.40	24.70	25.00	25.18	25.33	27.05
	S.E.		.23		.19	.35	.69	
	n		3	3	8	13	8	4
F	Mean		25.77	**27.47**	26.06	25.74	24.15[b]	23.98
	S.E.		1.47	.55	.73	.60	.55	1.38
australis								
	n	2		2	35	6	12	
M	Mean	24.45		25.05	26.86	26.45	26.92	
	S.E.				.25	.81	.40	
	n			4	13	7	6	
F	Mean			29.20	**27.77**	26.70	26.30[a]	
	S.E.			2.09	.45	.52	.45	

[d] Wyoming, Montana and Utah.
For other symbols see table 2.

differing patterns of variation for the several forms; I have such studies underway.

BODY WEIGHT

Changes in body weight of rosy finches are known to occur in late winter and early spring associated with the onset of spring migration (King and Wales 1965). Additional changes might be expected during the summer related to the breeding effort; such changes should be considered when analyzing geographic variation. For most taxa, weights are available for only a small proportion of the specimens, making analysis of seasonal variation impossible. However, there is some evidence for a general pattern of weight change, at least in mainland forms, since the three taxa with the largest samples (*dawsoni, atrata* and *australis*) exhibit similar patterns of change (table 5). In each case, females are heaviest in late June, and in each case males gain weight throughout the summer. Moreover, many of the differences between monthly means are significant.

The maximum weight for females is probably related to egg laying since it occurs at a time that agrees closely with the many published nest records for *dawsoni* and *atrata* (Dawson 1922, 1923, Dixon 1936, French 1959, Johnson 1965, Miller 1925, Ray 1910, Rowley 1939, Sharsmith 1937a, b, Taylor 1923, Twining 1938a, Wheeler 1940). However, the few records for *australis* suggest that it may breed as much as two weeks later than the others (Bailey and Niedrach 1965, Davis 1960, Lincoln 1916). The lowest weights for males are probably associated with the peak of courtship activities in late spring and early summer when fighting between males is intense and occupies a large portion of their time (Leffingwell and Leffingwell 1931, Twining 1938a, b).

FEATHER WEAR

All birds taken during the summer months show some feather wear. Nearly all the visually perceptible wear occurs during the breeding season and almost none during the longer period from the fall molt until spring. In order to document the changes in wear through the summer and to help develop a method for dealing with wear in studies of geographic variation, I scored all birds as to amount of wear on both wings and tail. A scale of increasing wear, from one to ten, was devised for wings based upon wear on the outer three primaries. For tails, I based a similar scale upon wear at the margins of the inner pair of rectrices and wear at the tips of the outer four. On either scale, birds with imperceptible wear were placed in the first category and those with broken or badly abraded feathers were placed in the tenth

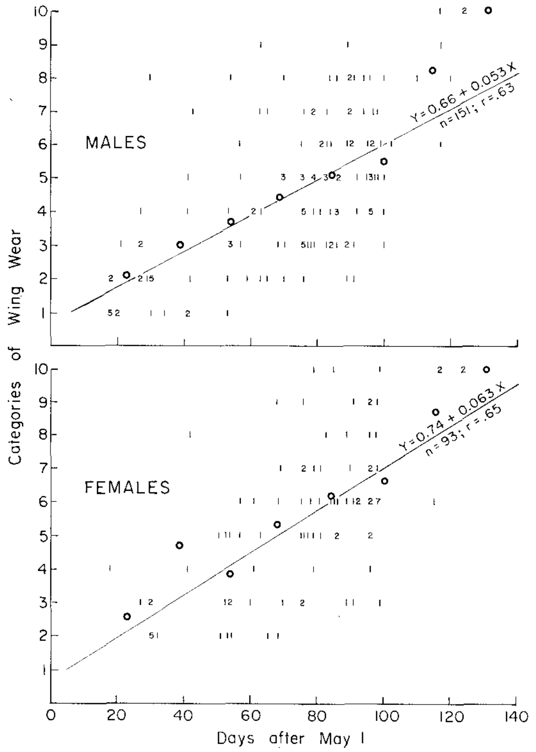

FIGURE 1. Relationship between wing wear and collection date for *L. t. dawsoni*. Categories of wing wear are described in the text. Numbers represent sample size for each date and wear category. Open circles represent mean wear for each two-week interval. The regression line for the entire sample of each sex is plotted and the regression equation, sample size and correlation coefficient are given.

category. In order to reduce any bias in the scoring process, all birds of all taxa and both sexes were intermixed in one large array and then chosen at random to be scored. This was done twice, once for wings and once for tails. Although the categories were somewhat subjective and loosely defined in order to encompass the wide range of conditions encountered, I found on repeated tests of the procedure that 90% of all specimens were scored the same when examined on another day and none of the scores differed by more than one category.

Typical results for wing wear plotted against date are shown in figure 1. Similar graphs were obtained for all taxa and sexes where specimens spanning more than 30 days were available. In each case wear increased markedly through the breeding season and was greatest in the female samples. These relationships are made especially evident using regression lines. In several taxa the difference in y-intercept between the sexes is much greater than that illustrated for *dawsoni* in figure 1 (e.g., in *umbrina, atrata,* and *australis* the difference exceeds 2.00) and strongly suggests that wear may begin earlier for females than for males. For most taxa large numbers of winter (December to February) specimens are available but there are few from spring (March to May). Of the winter specimens 95% of each sex are in wear category one. Larger samples from spring will be needed to determine exactly when the increased rate of wear begins and whether it begins first in females.

In *dawsoni* (fig. 1) and certain other taxa the slope of the regression line is steeper for females than for males, suggesting that the rate of wear is also greater in females. A tempting explanation is that females have a similar average body weight but shorter wings than males and, thus, probably incur greater wear through a faster wing beat. However, caution is suggested since the differences in slope are usually small and occasionally reversed.

Graphs of tail wear against time resemble those discussed above in that all slopes are positive and rather uniform and in that females have a higher y-intercept than males. One striking difference, however, is that the sexual dimorphism in wear is much greater for tails than it is for wings. It seems likely that this wear is more a result of direct abrasion on hard surfaces than of wear through flight and that the increased sexual dimorphism may relate to differing behavior at the nest site. Nests are usually placed in small cracks and crannies such that the incubating bird must rub its tail on the rough walls of the cavity as it turns. Since only the female incubates (Bailey and Niedrach 1965, Dixon 1936, Elliott 1875, French 1959, Hanna 1922, Lincoln 1916, Miller 1925, Rowley 1939, Shaw 1936, Twining 1938a,b, Wheeler 1940), she would incur greater wear.

The use of regression lines as above is strictly correct only if the wear categories are chosen so that each step of increasing wear has an equal decrement of wing length. While this is difficult to prove, there is strong evidence that it is generally true for both wing and tail wear categories. I computed mean wing (and tail) length for each wear category for every taxa. When these data are plotted (e.g., fig. 2) it is evident that as sample size increases the lines connecting means assume the same slope. When surveying the graphs for all taxa it is clear that this principle applies to each step in wear and not just to those illustrated by the male curve for *atrata* presented here. As a further test, I increased

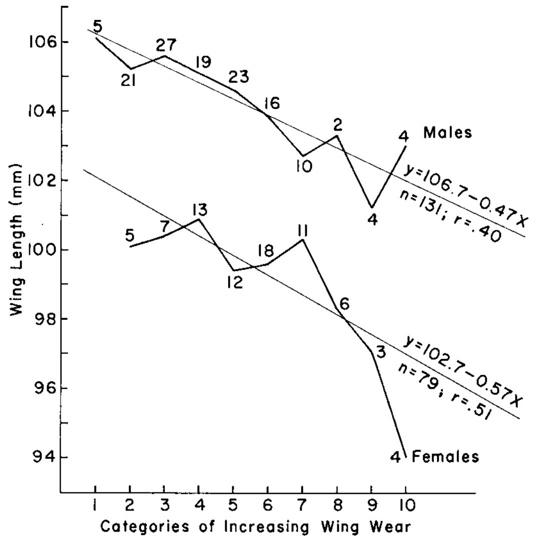

FIGURE 2. The relationship between wing length and feather wear in *Leucosticte atrata.* Categories of wear are described in the text. Numbers represent sample sizes. Mean wing length and sample size for each wear category are plotted along with the regression line and equation, sample size and correlation coefficient for the entire population.

sample sizes by combining data for samples of four taxa (*wallowa, dawsoni, atrata* and samples of *tephrocotis* south of the 54th parallel) which differ only slightly in wing length. The resulting graphs for wings and for tails are nearly straight lines.

A distorted picture of geographic variation and of sexual dimorphism may result if differential wear between samples is not considered. Most workers correct for the possible effects of wear by excluding those birds with badly worn feathers. One difficulty with this approach is that even though birds with the most worn wings have been eliminated from all samples, differential wear among the remaining birds may still occur and distort the patterns of variation under study (Calhoun 1947). Another problem is that reduction in the influence of wear is accomplished only at the expense of sample size.

Some workers also increase each measurement beyond the observed length in proportion to the amount of wear that is judged to have occurred. In other words, the measurement is of a subjectively restored wing or tail instead of the actual abraded one. This approach makes two assumptions: that the amount of feather that is missing can be accurately estimated on the basis of that which is present, and that any preconceived ideas by the observer regarding each sample have no effect on his subjective evaluation of wear. This second assumption is important because wear must be evaluated at the same time that the measurement is taken rather than independently of that measurement. Under these circumstances there would be a tendency to overcompensate for the wear of a bird from a long-winged race whose wing was shorter than expected and to undercompensate for one from a short-winged race whose wing was longer than expected.

The weaknesses of this second procedure can be overcome by using the method described earlier by which the lengths of the feathers and the degree of wear are measured independently. The shortcomings of the first procedure are eliminated by either of the methods described below. The first of these is to plot regression lines as shown in figure 2. This procedure is useful when samples are quite large and are spread over the entire range of wear categories. It is used here to demonstrate the differences in the sexes and also could be used to compare taxa. However, it could not be used to compare the samples of which *atrata* is composed since these are often small and taken during only one part of the season with the result that a limited range of wear classes is represented.

An entirely different approach is to compute the mean difference corrected for wear between two samples. In this procedure birds of each wear category of one sample are compared only to those of like category of the second and from these comparisons (actually arithmetic differences) a mean difference between the two samples is calculated. In this computation more weight is given to differences between large than small samples. The exact procedure is as follows: (1) determine the mean wing (or tail) length in each wear category for each sample, (2) subtract the means for one sample from the corresponding means of the other, (3) multiply each difference by the weighting $n_1n_2/n_1 + n_2$, where n_1 and n_2 equal the number of birds in a particular wear category for samples one and two, respectively (Cockran 1965), (4) sum the products and divide by the sum of the weightings. This procedure can be expected to give a more accurate estimate of the difference in wing (or tail) length between samples than can be obtained by the standard methods in current usage discussed above. However, it does not provide actual values for mean wing length of the samples but only the difference between them with no way to test the significance of this difference.

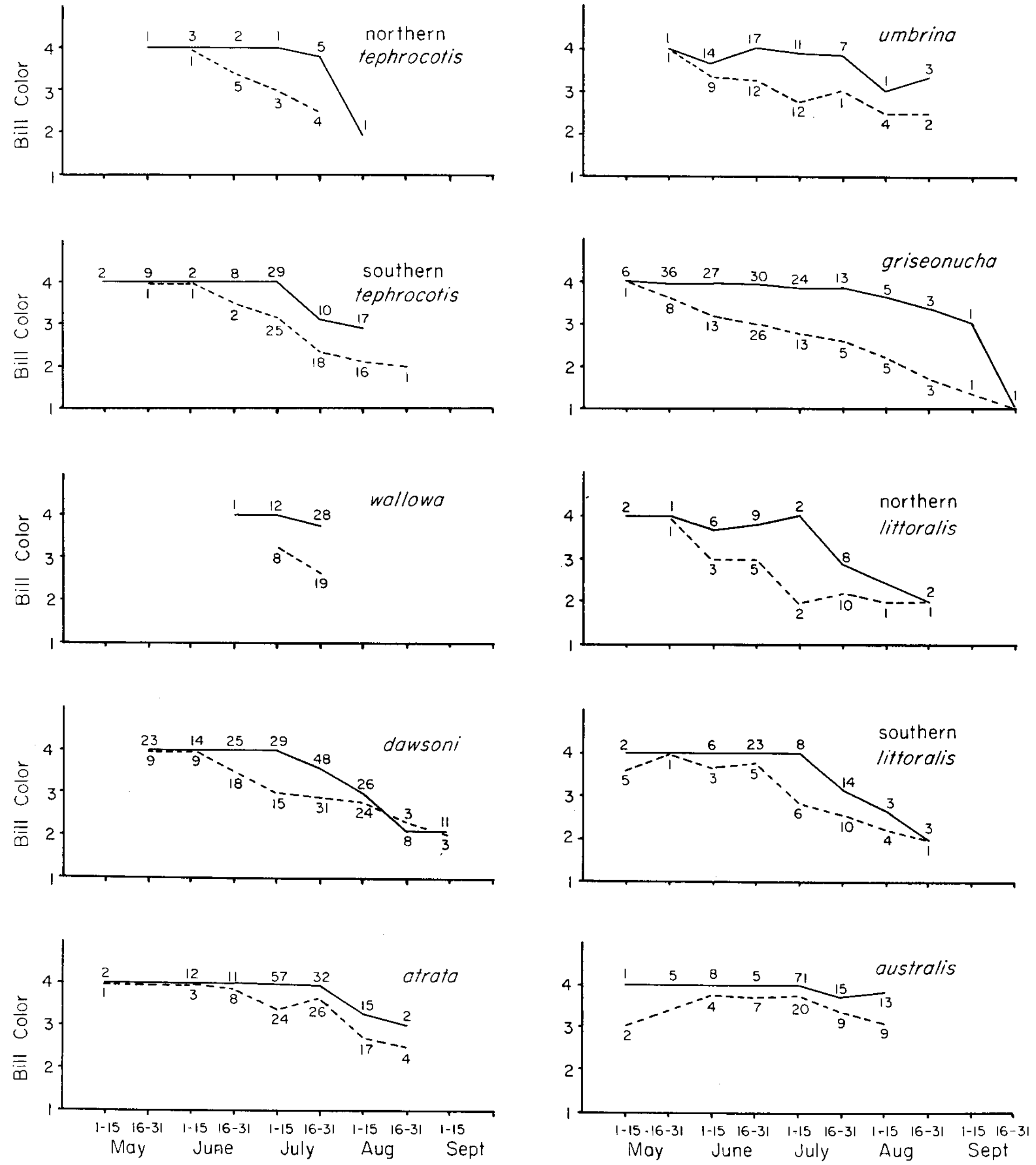

FIGURE 3. Seasonal changes in bill color from May through September. Bill color scale is from yellow (1) to black (4). Solid line, males; dashed line, females. Numbers along lines give sample size. Northern and southern *littoralis* are all populations north and south, respectively, of the 51st parallel. Northern *tephrocotis* includes Alaska and the Yukon Territory. Southern *tephrocotis* encompasses all populations south of the 54th parallel.

It might appear, therefore, that the procedure is of little or no value. However, it can be useful as an adjunct to current methods. If by current methods two samples are significantly different in wing length but a difference in wear is suspected, this method provides a way to determine if average wear is an appreciable component of that difference.

This procedure is especially useful when examining geographic variation in tail length. Often a high percentage of all birds are too worn to be used when the usual methods are employed, resulting in the omission of this character in studies of some species. When examining *griseonucha* I found a size cline in many mensural characters. There appeared to be a cline in tail length as well. However, one-third of the localities and nearly one-half of all birds had to be excluded because of excessive wear. When I applied the pres-

TABLE 6. Seasonal change in dominant wavelength of breast feathers.

	Males				Females		
	May	June	July	August	June	July	August
griseonucha[d]							
n	23	23	24				
Mean	**586.32**	585.94[a]	585.79[b]				
S.E.	.11	.13	.11				
tephrocotis							
n	11	13	44	13			
Mean	**585.37**	585.04[a]	584.86[c]	584.93			
S.E.	.10	.10	.07	.19			
dawsoni							
n	20	37	78	23	26	46	26
Mean	**585.40**	584.95[b]	584.75[c]	584.69[c]	583.22	583.17	583.15
S.E.	.11	.09	.06	.12	.14	.09	.10
atrata							
n		17	81	13	13	39	11
Mean		**584.71**	584.32	583.94[b]	**583.05**	582.68[a]	582.50[b]
S.E.		.21	.09	.15	.15	.10	.12

[a] $P < 0.05$ for difference with mean in boldface.
[b] $P < 0.01$, as above.
[c] $P < 0.001$, as above.
[d] Fox group of Aleutian Islands, Alaska.

ent method, the full sample was used, all localities were represented, the scatter about the trend line was reduced and the existence of the cline was substantiated.

A special application of this method can be made when two samples differ so much in wear that there is no overlap in the wear categories represented. In such a case both samples can be compared to a third which includes birds with wear extending over the range of the other two. A good example is given by the White and Inyo mountain samples of *dawsoni*. The difference of 1.68 mm between means of these samples was significant at the 0.05 level. However, when both samples were compared to the larger Sierra Nevada sample I found that they differed from each other by only 0.27 mm or 16% of the original difference. The remaining difference was due to wear. This illustrates how large a difference can result from differential wear between samples even when badly worn specimens already have been excluded.

BILL COLOR

The bills of rosy finches are black during the early part of the breeding season and yellow during the winter. French (1959) described the pigment changes which occur during the periods of transition; French (1959) and King and Wales (1965) documented the timing of these changes in late winter and spring. These authors found that repigmentation (increase of black) in *atrata* was about two weeks ahead of that in *littoralis* and *tephrocotis* and that in all three taxa repigmentation in females lagged behind that in males.

In the present study the timing of depigmentation in late summer and fall is described for each form of rosy finch (fig. 3). Museum specimens were scored on a scale from one (yellow) to four (black). A greater number of color categories, such as King and Wales (1965) used for live birds, seemed undesirable for museum specimens where progress of individuals could not be followed and some deviation from normal pigmentation was evident.

Depigmentation begins about four weeks earlier in females than in males in the races of *L. tephrocotis* and in *L. atrata*. The difference is somewhat greater in *L. griseonucha* though larger samples may show southern populations of *littoralis* to be close to four weeks. In *australis* the sexes do not appear to differ in timing. It also appears that not all females of this form assume the intense black color characteristic of male *australis* (and of both sexes of all other taxa) during early summer. However, larger samples of all taxa from early summer will be needed to determine if this apparent difference is real.

Curves for depigmentation in the races of *L. tephrocotis* are very similar. The color change begins between 1 and 15 July for males and between 1 and 15 June for females. Depigmentation begins about two weeks later

TABLE 7. Seasonal change in color purity of breast feathers.

	Males				Females		
	May	June	July	August	June	July	August
griseonucha[d]							
n	23	23	24				
Mean	30.14	29.48	29.41				
S.E.	.40	.44	.34				
tephrocotis							
n	11	13	44	13			
Mean	35.74	36.18	35.76	35.00			
S.E.	.79	.66	.47	1.23			
dawsoni							
n	20	37	78	23	26	46	26
Mean	31.72[c]	**34.01**	32.76[a]	31.77[b]	29.55	29.07	28.84
S.E.	.34	.56	.27	.57	.61	.49	.53
atrata							
n		17	81	13	13	39	11
Mean		14.74	14.33	14.38	17.49	17.30	16.53
S.E.		.44	.21	.44	.62	.30	.43

For explanation of symbols see table 6.

in *atrata*. In *L. griseonucha* the process appears to begin earliest in the race *griseonucha* and progressively later in forms to the south and north. More data are needed for both samples of *littoralis* and for *umbrina* but it appears that the timing of *umbrina* is closest to that of southern populations of *littoralis*.

PLUMAGE COLOR

Plumage fade is a well-known phenomenon but it is seldom studied. Rosy finches undergo an annual molt in the fall and the new feathers are invariably much darker than the old worn plumage. Visual observations suggest that most of the color change occurs before summer. However, any significant amount of change during the summer months could be important in studies of geographic variation based on breeding specimens. Therefore, in the present study seasonal trends in each of the three components of color were examined for each taxon. All data discussed here pertain to the upper breast, an area largely devoid during the summer months of the rosy trim which typifies the plumage over much of the rest of the body.

TABLE 8. Seasonal change in color brightness of breast feathers.

	Males				Females		
	May	June	July	August	June	July	August
griseonucha[d]							
n	23	23	24				
Mean	5.35	5.34	5.32				
S.E.	.09	.12	.10				
tephrocotis							
n	11	13	44	13			
Mean	**6.88**	7.63[b]	7.72[c]	7.89[b]			
S.E.	.12	.23	.13	.25			
dawsoni							
n	20	37	78	23	26	46	26
Mean	**6.70**	7.09[a]	7.57[c]	7.44[c]	9.84[a]	**10.60**	9.64[c]
S.E.	.13	.12	.09	.14	.25	.17	.18
atrata							
n		17	81	13	13	39	11
Mean		**4.56**	5.12[b]	5.69[b]	**7.33**	8.17[a]	8.25
S.E.		.16	.10	.29	.37	.19	.47

For explanation of symbols see table 6.

Because variation in the color characters is very large, seasonal trends can be seen only in the larger samples and the ensuing discussion is based upon these. Data are presented in tables 6, 7 and 8 for each taxon and sex where sample size exceeds ten for three or more consecutive months.

The most conspicuous trend occurs in dominant wavelength, which becomes shorter in all six sets of data (table 6). Many of the differences in monthly means are significant. The same trend is present in the smaller samples of *littoralis* and *australis*.

The presence of a seasonal trend in purity is less certain (table 7). In each of the samples purity tends to decrease over a three month period but few of the monthly differences are significant. Males of *tephrocotis* and *dawsoni* from May disagree with this trend and in *dawsoni* the difference between means for May and June is significant at the 0.001 level.

Brightness tends to increase through the summer for both sexes of *atrata* and for males of *tephrocotis* and *dawsoni* and many of these seasonal differences are significant (table 8). Female *dawsoni* from June and July also follow this trend, but those from August do not. Three-fourths of these August birds are from the White Mountains and birds from these mountains have a much lower brightness than birds from the other localities. For August the mean for the White Mountain sample differs from that of the Sierra Nevada at the 0.001 level and the coefficient of difference is 0.84. If these birds are excluded the August mean is larger (10.51) and more in line with the other data presented. There is no apparent seasonal change in brightness in males of *griseonucha*. This may result from greatly reduced solar radiation because of constant fog on the Aleutian Islands.

SUMMARY

Variation in several mensural and color characters was examined through the breeding season for the eight recognized taxa of rosy finches (*Leucosticte*) in North America. Bill length in each taxon was shortest in June but thereafter two patterns emerge. In the three gray-cheeked forms length was greatest in July and declined thereafter whereas in the remaining five taxa length increased through August or September. Bill depth also showed monthly variation, with the bills being thickest either in the same month or the month after the greatest length was attained. Bill shape (ratio of depth to length) showed greatest monthly variation in the three slender-billed forms (*umbrina*, *griseonucha* and *dawsoni*). Body weight increased throughout the summer in males and was greatest in late June in females. Wear of flight feathers was small in winter but increased rapidly during the summer months with greatest wear occurring in females. The change in bill color from black to yellow following breeding occurred four weeks earlier in females than in males in most taxa and six or more weeks earlier in the gray-cheeked forms. There was no apparent difference in timing of the sexes in *L. australis*. Fade of plumage color, as examined by reflectance colorimetry, was accompanied by a shift to a shorter dominant wavelength, an increase in brightness and possibly a decrease in purity.

Differences in monthly sample means for most of the characters examined were significant during at least parts of the breeding season and are too large to be ignored when examining geographic variation in the genus. The effect of wear on feather length is especially important and a new method for dealing with this problem is discussed.

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