BIRD WEIGHTS AS AN AID IN TAXONOMY[1]

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IN recent years several ornithologists have pointed out that bird weights are a valuable aid in many problems. Among general papers on this subject may be mentioned those by Mrs. Nice (1937, Chap. 3; and 1938); Baldwin and Kendeigh (1938); and Zedlitz (1926). All of these, as well as most other writers that have dealt with this subject, have been interested primarily in physiological problems, such as daily, monthly, and seasonal weight rhythms; weight changes during growth; and weight as related to various aspects of metabolism. Referring to such studies, Baldwin and Kendeigh (1938: 458) write: "A surprisingly large number of records of the weight of birds is required before reliable interpretations can be made." Unfortunately such statements have led to a general belief that in taxonomic work, where it would indeed be unusual to have a large series of weights available for each of the forms included in any given study, weights are too variable to be useful. A few taxonomists have published weights of birds, but usually only as an incidental part of their studies. The present paper summarizes and compares the various methods in common use for measuring general size,[2] and attempts to evaluate weight as an index of general size, and as a standard for use in comparing the relative dimensions of parts, organs, and appendages. The importance in taxonomy of such an index and standard may be summarized as follows:

1. *For direct comparison of variations in general size.* A kind of variation in birds very frequently used by taxonomists to distinguish geographical forms is a difference in general size (measured in various ways). A number of subspecies are based solely on this difference, and a still larger number are based on this difference plus other distinctions such as color. Of 27 subspecies of non-passerine birds which I have discussed in recent papers, 6 are based solely upon differences in general size (as reflected in measurements of appendages); 8 upon size and color; 11 upon color alone; and 2 upon differences in proportions. Subspecies of passerine birds are less often based on size variation, but this may be due to the greater difficulty in detecting such variation in small birds. Very frequently a species shows geographical size variation even though it is too slight, too gradual (altitudinal or latitudinal clines—"Bergmann's Rule"), or too irregular in distribution to justify the naming of subspecies. Mayr (1942:37) lists several instances of such variation.

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[1] I am greatly indebted to Ernst Mayr for his careful revisions of the manuscript.

[2] Alternative but less commonly employed terms are "total size" and "basic size".

2. *As a standard of comparison for measurements of parts and appendages.* The usual "taxonomic" measurements of birds—lengths of wing, tail, culmen and tarsus—are all taken from appendages. Observed variation in such dimensions may indicate variation in general size, independent variation in the appendages themselves, or a combination of the two. For example, two subspecies, A and B, might have the following measurements:

	Tail	Wing	Tail/Wing Ratio
A	50	75	2/3
B	50	100	1/2

If A and B are the same in general size, the variation in wing length and in tail/wing ratios is entirely due to B's having a longer wing. Knowing this, a biological explanation may be sought; perhaps B is more migratory or lives at higher altitudes. But if B, in general size, is larger than A by one-third, then wing length is correlated with general size, and an explanation for the variation in relative tail length may be sought. It thus becomes apparent that we usually cannot fully evaluate the biological significance of geographical variation in measurements of appendages without first relating these measurements to general size.

Linear Indices of General Size

The following linear indices of general size have been used or proposed by taxonomists working with birds:

1. *Total length.* This would be a very useful index of general size except that in birds it cannot usually be taken with reasonable accuracy, because: (a) birds' necks are relatively long and curved, and the longitudinal axis of the head meets that of the neck at an angle. The success with which this curvature is eliminated in measuring total length is affected, both by the technique of the observer and by the condition of the specimen, to such an extent as to make this measurement extremely variable; (b) as usually defined, total length includes tail length, and the tail often varies in size independently of other measurements; (c) the length of the neck and head (especially the bill portion) not infrequently varies independently of other measurements, very noticeably in such long-billed genera as *Hemignathus* of the Drepaniidae. A "body length," obtained by subtracting tail length from total length (and in long-billed genera, by subtracting also the bill length) would provide a more reliable index than total length.

When taken from museum skins, total length is even more subject to error, since such specimens are little more than tubes of skin whose length varies with the amount of stuffing put in and the amount of stretching which occurs in skinning. However, when the size differences to be measured are comparatively large, total length taken from selected skins may prove useful. Chapman (1940:422, 426) used it with worthwhile results in his study of *Zonotrichia,* by "selecting when possible, series prepared by the same collector," and even concluded that total length when taken from such selected skins is more reliable than when taken, by various collectors, from birds in the flesh.

2. *Body length.* To provide a standard measurement that can be taken more accurately than total length, Chapin (1929:8) proposed 'length of body', defined as: "the distance in a straight line from the anterior surface of the shoulder to the vent, or, if the bird is already skinned, to the tip of the small bone (pubis) which extends down in the belly wall close to the vent." I know of only one collector who has recorded this measurement for any considerable number of specimens, and apparently no one has used it in a published study. Though it may well prove to be useful in restricted problems, 'length of body' is not a generally acceptable index of general size. The feathers interfere with the taking of this measurement, especially in birds with long, dense plumage. It cannot be taken from skins, and would be rather difficult to take from live birds. Collectors would probably prefer to take it from the skinned bodies of birds, but then comparison of measurements taken from skinned birds with those taken from unskinned birds would introduce a further element of error. Finally, there are many birds so large that this measurement could not be taken with any dividers of a size usually available.

3. *Measurements of appendages.* Lack of a good index of general size has obliged some ornithologists to use one appendage as a standard of comparison for another. Such a practice is in general unsatisfactory because, though one appendage is often correlated with another—for example wing and tail lengths frequently increase or decrease proportional amounts—each appendage often varies independently of other measurements. Though it cannot be assumed that in any given case the size of an appendage is correlated with general size, however defined, the usual measurements, especially wing and tail lengths, seem, more often than not, to be at least partially correlated with it. When it is stated that one subspecies is larger than another, usually only measurements of appendages are given as evidence of the difference. As a rule the taxonomist has noted that specimens of one race appear to be or are obviously larger in "general size," but has made no actual measurement of the general size. Sometimes it is evident that one appendage is more closely correlated with "general size" than another. Thus in comparing races of *Zonotrichia capensis,* Chapman (1940: 424–427) found a pronounced increase in wing length without a proportionate increase in tail length, which he found to be more or less correlated with general size (defined as total length). He was, then, able to use tail length as a rough measure of the relative increase in wing length. But obviously the use of a consistently reliable index of general size as a basis of comparison would be preferable to the

use of measurements of appendages, whose apparent correlation with general size or with each other is sometimes deceptive.

4. *Measurements of hind-limb.* Although the femur, the tibia, and the tarsus are segments of an appendage, there is evidence that their measurements are frequently correlated with "general size." Linsdale (1928:311) has shown graphically that in the Mariposa Fox Sparrow (*Passerella iliaca mariposae*), variation in length of tibia roughly parallels variation in weight. Since he found length of femur and tarsus to be closely correlated with that of tibia, their variation also would, in this subspecies, parallel variation in weight. Hence he used length of tibia as an index of general size and expressed all other measurements in terms of it (p. 357). Miller (1941:358) found inter-racial correlation of tarsus and weight in the genus *Junco*. These findings suggest that the hind-limb segments of birds sometimes follow Wolf's Rule (bones tend to increase in size in proportion to increases in the weight they support). Yet length of hind-limb is obviously affected by other factors, such as habits of the species; and related species of about the same general size, as shown by weight, differ noticeably in length of hind-limb. The tarsus is the only longer hind-limb segment that can be measured in museum skins. It is often rather difficult to measure accurately, especially in species in which the tarsus is short or feathered. Consequently, length of hind-limb segments is usually not a satisfactory index of general size.

5. *Measurements of skeleton.* Several measurements which give a reliable index of general size can be taken from the trunk skeleton of birds. Engels (1940:367 ff.) used two such measurements in his study of the thrashers (*Toxostoma*). He emphasized the difficulties and fallacies which usually attend studies of variation in the proportions of appendages when differences in general size are ignored (p. 368). But relative scarcity of bird skeletons in collections will often preclude the use of measurements taken from them in avian systematics.

Thus we see that all the usual measurements employed by bird taxonomists are linear measurements, either too variable to be reliable indicators of general size, or unobtainable in large series. When they are *apparently* correlated with general size, it is impossible to determine how close the correlation is without recourse to some direct measurement of general size. When an estimate of general size must be based on linear measurements, body length (defined as total length minus tail length, and in special cases, minus bill length) is usually the most reliable, unless series of skeletons of the forms to be compared are available.

Weight as an Index of General Size

Precision of weight as an index. Since birds are three-dimensional objects, mass or volume as an index of general size would seem more logical than linear measurements. In such irregularly shaped, featherclad objects, volume cannot be directly measured, but weight is easily recorded. It is an index of the mass of a bird and an indirect index of its volume, since closely related birds, such as are usually compared in taxonomic studies, may be assumed to have the same specific gravities. But even in the comparison of distantly related groups, weight is the best available index of general size. In comparing diverse avian types as, for example, herons with quail or songbirds, or with members of other classes, to use a linear dimension would obviously not yield valid results. But the comparative size of organs such as the brain, heart, or pituitary, can be determined by using ratios derived from the weight of the organ as compared with the total weight of the bird.

Differences in general size of solids will always be reflected more accurately by an index such as weight, which is proportional to the mass or volume of the object, than by any single linear measurement (as a simple example: in two cubes with edges respectively 2 and 3 units, the difference in volume is 19 times as great as the difference in edges). Table 1, which gives the absolute and relative differences in wing length, body length, and weight for subspecies of *Nycticorax caledonicus, Chen hyperborea* and *Pinicola enucleator,* for species of *Cacomantis,* and for male and female of *Accipiter fasciatus vigilax,* shows that the same is true for weights of birds as compared with their linear

TABLE 1

Comparisons of Absolute and Relative Differences in Wing Length, Body Length, and Weight

	Wing Length (mm.)	*Body Length* (mm.)	*Weight* (gm.)
Nycticorax	Diff: 7.6 %		Diff: 17.9%
caledonicus caledonicus	2♂ 291,304 (298)		1♂: 884 (884)
caledonicus mandibularis	10♂: 267–290 (277)		3♂: 700–800 (750)
Chen	Diff: 4.7%	Diff: 8.9%	Diff: 49.5%
hyperborea atlantica	20♂: 430–485 (450)	13♂: (675)	13♂: 3175–4735 (3626)
hyperborea hyperborea	45♂: 395–460 (430)	12♂: (620)	17♂: 1815–2835 (2425)
Accipiter	Diff: 13.9%	Diff: 15.5%	Diff: 77.3%
fasciatus vigilax	5♀: 273–287 (278)	5♀: (231)	5♀: 459–502 (477)
fasciatus vigilax	10♂: 237–253 (244)	8♂: (200)	10♂: 240–309 (269)
Cacomantis	Diff: 16.4%	Diff: 10.6%	Diff: 26.5%
p. pyrrophanus	9♂: 139–145 (142)	7♂: (115)	7♂: 43.5–55.8 (48.2)
variolosus addendus	17♂: 116–126 (122)	12♂: (104)	8♂: 34.0–42.0 (38.1)
Pinicola	Diff: 9.9%		Diff: 35.4%
enucleator leucura	♂*: 116–128 (?)		5♂: 70–83 (?)
enucleator eschatosus	37♂: 106–115 (111)		9♂: 52–61 (?)

Percentages are amounts by which the larger member of each pair exceeds the smaller in each measurement. (Since the mean was not given for some of the measurements of *Pinicola,* the percentages for this species were calculated from the averages.) Figures in parentheses are the means of the measurements.

* Number of specimens not stated.

measurements. The measurements given in the table are from the following sources: *Nycticorax* (Amadon 1942*a*:4–5); *Chen* (Kennard 1927:88–89); *Accipiter* (specimens in Amer. Mus. Nat. Hist.); *Cacomantis* (specimens in Amer. Mus. Nat. Hist., in part recorded by Amadon 1942*b*:16, 20); *Pinicola* (wing lengths from Griscom 1934:7; weights from Van Tyne 1934:530). The body length was found by subtracting tail length from total length; this measurement was taken from skins in the case of *Accipiter* and *Cacomantis;* from birds in the flesh (by Kennard) in *Chen.* In the three genera for which body lengths are given, the difference between forms as compared in this measurement is, as was to be expected, markedly less than the difference in their weights. The same is true here of wing length as compared with weight, but since wing length may vary independently, subspecies may differ in mean length of wing though not (or to a less significant extent) in weight. When wing length is correlated with general size (however defined), forms will often be more sharply differentiated by weight, despite its somewhat greater variability (see below) than by wing length. The two races of *Pinicola* compared in the table seem to be an example of this; Van Tyne (1934:530) has commented on the marked difference in the weights of these two races.

Since differences in general size seem to be reflected more accurately and sensitively by weight than by linear dimensions, it should be possible by a comparison of weights to detect differences in general size which are too slight to produce a measurable difference in linear dimensions. Data to test this probability are scarce, but Mayr (1931:668–669) has published weights and linear measurements of *Melanocharis* (Dicaeidae) which are suggestive. In *Melanocharis versterii maculiceps,* females are significantly larger than males in both wing length and weight; in *Melanocharis longicauda captata,* the wing lengths of the sexes do not differ appreciably, but the females are significantly heavier. The measurements of the two forms are shown in the accompanying table. To determine whether the differences in weight in *M. l. captata* and in both weight and wing length in *M. v.*

	M. v. maculiceps		*M. l. captata*	
Wing (mm.):	6 ♂ 59.0-64.0 (61.8)	5 ♀ 66.0-71 (69.0)	7 ♂ 64-67 (65.9)	10 ♀ 64-67 (65.5)
Weight (gm.):	5 ♂ 12.5-15.5 (14.0)	5 ♀ 16.5-20 (18.5)	6 ♂ 13-15 (13.9)	6 ♀ 14-16 (15.4)

maculiceps are statistically significant in view of the rather small size of the samples involved, the "*t* test" was used (Simpson and Roe 1939:207 ff.). In all three cases this test indicated that the observed differences are almost certainly significant (less than one chance in a hundred that they are not, in each case). The slight difference in the wing lengths of males and females of *M. l. captata* is, of course, not significant.

Blanchard (1941:10–11), in her study of *Zonotrichia leucophrys,* found no significant difference in the lengths of wing, tail, or other appendages in the two races *pugetensis* and *nuttalli*. Yet she found *nuttalli* to be significantly heavier; for males the difference was 2.59 grams or about 10 per cent of the total weight. Blanchard interpreted this to mean that the lengths of the appendages are not correlated with general size in these subspecies, but it seems equally possible that even if such correlation exists, the difference in general size is too slight to be detected in the appendicular measurements.

An example of the opposite type of variation in which two subspecies differ in the lengths of appendages but not in weight was published by Grinnell (1926:406–408). In comparing two races, *Sitta carolinensis aculeata* and *S. c. alexandrae*, of the White-breasted Nuthatch, he found that although *S. c. alexandrae* weighs no more than *S. c. aculeata*, all of its appendages—wing, tail, culmen, tarsus and hind toe—are, on the average, significantly longer.

Variability of weight. Although weight is in many respects the most logical and sensitive index of general size available, it is affected by several factors such as variation in the amount of fat present, and the contents of the alimentary system. Hence many have assumed that weights are too variable to be useful in taxonomic work, but the few taxonomists who have actually used weights in their studies have not found this true. Miller (1941:255) writes, "Despite the numerous factors which affect the weights of birds..., the moderate variability of this measurement, compared with that of mammals, makes it fairly reliable." For the weights of 100 males of *Junco oreganus montanus*, collected during the breeding season, he found that: "The coefficient of variability was 5.2 per cent, which is about twice that of wing length but equal to that of some of the toe and bill measurements." Linsdale (1928:312), after discussing the factors other than geographical variation which affect weights of the Fox Sparrow, concluded: "The exact amount of the effect of each of these factors has not yet been determined, but it is thought that they have little effect on the means of large series." Regarding geographical variation in weight he said (p. 315): "It is easily seen that the average body-weight of these samples is a useful characteristic, to be used along with others for making racial distinctions."

The relative variability of weights is best determined by computing the coefficient of variability *V* (Simpson and Roe, 1939:122). Results for a number of bird forms are given in Table 2.

The species represented in the table are a mere handful, and all of them are passerines. Since the variability of linear dimensions seems to be much the same for all groups of birds, it is very likely that the variability of weights will also prove to be fairly constant. Some of the extraneous factors influencing weights may, however, be more marked in some groups than in others. Van Tyne has pointed out to me that seasonal fluctuation in the amount of fat present is greater in some species and groups than in others. Y. Hagen (1942) in an extensive paper on bird weights, which became available after the present one was in press, gives considerable information on this question. Since he was working with a local collection, his discussion of weights as related to taxonomy is little more than suggestive.

TABLE 2

SAMPLE VALUES OF THE COEFFICIENT OF VARIABILITY (V) FOR BIRD WEIGHTS

Species	Number	V	Authority
Junco oreganus montanus	100 breeding ♂	5.2	1
Zonotrichia leucophrys nuttalli	17 breeding ♂	6.54	2
Zonotrichia leucophrys nuttalli	28 wintering adult ♂	8.55	2
Zonotrichia leucophrys nuttalli	19 wintering immature ♂	4.28	2
Zonotrichia leucophrys nuttalli	21 wintering immature ♀	7.25	2
Zonotrichia leucophrys pugetensis	43 wintering adult ♂	8.75	2
Passerella iliaca brevicauda	30 ♂	6.21±0.54	3
Passerella iliaca brevicauda	18 ♀	8.41±0.95	3
Passerella iliaca mariposae	38 ♂	5.60±0.45	3
Passerella iliaca canescens	16 ♂	5.33±0.64	3
Pachycephala schlegelii obscurior	13 adult ♂	5.07	4
Pachycephala soror klossi	11 adult ♂	4.16	4
Ptiloprora g. guisei	18 ♂	6.41	4

Authorities: (1) Miller, 1941:255; (2) Blanchard, 1941:120, 121; (3) Linsdale, 1928:313; (4) Mayr, 1931:665, 672 (raw data, calculation mine).

The variability of volumes or weights will, to some extent, represent the cumulative variabilities of the linear dimensions of the object, and will inevitably have a larger value than that of any one linear dimension. It is usually advisable to use the cube roots of weights rather than the weights themselves as a standard of comparison for linear measurements (see below). Extracting the cube roots has the effect of reducing the variability to a value comparable with that of linear dimensions. For example, available weights of *Pachycephala soror klossi* have a V of 4.16; for the cube roots of the same weights V is only 1.38; V for the wing lengths of the same sample is 1.55.

USES OF WEIGHTS IN ANALYZING MEASUREMENTS

The measurements usually used by the avian taxonomist are all of appendages. Since the independent variation of appendages is often masked by variation in general size, the general size factor must somehow be eliminated. The simplest method of doing this is to express the appendicular measurements in terms of (that is, as a ratio or percentage of) general size, thus transforming the general size in the forms to be compared to the common base 100. The transformed measurements may then be compared with the assurance that the differences observed are independent of general size.

When weight is used as the index of general size, as is advocated here, it is not valid to compare ratios derived from linear measurements divided by weights. As noted above, weights vary in proportion to the cube of the linear dimensions, and this distorts the value of the ratios. The distortion could be corrected either by cubing the linear measurements or by taking the cube root of the weights. Since the object is to compare linear dimensions, the first alternative is not acceptable. Furthermore, the approximation to volumes (or weights) by cubing linear dimensions has inherent difficulties, the most important one being that the error of the measurements is thereby increased (cubed). The opposite is true when cube roots are extracted. This was illustrated above for weights of *Pachycephala soror.* The cube root of weight may be considered to be of the same magnitude as a linear index of general size,[3] but more reliable and usually less variable, since it is a generalized quantity (like weight itself), which is independent of variation in body form or proportions. For example, in a comparison of the relative length of intestine in a pelican and a quail to show correlation of length of intestine with food habits, ratios derived by taking length of intestine over weight (or cube root of weight) would constitute a basis for significant comparison, whereas use of any linear measurement, such as body length, in species of such different body form, would give misleading results.

The method of calculating the ratio of any given linear measurement to cube root of weight will vary according to the completeness of the data available. The simplest method is to take the ratio of the measurement (e. g., wing length) over the cube root of weight for each specimen; the mean of the series is then taken. When working with published data, however, such detailed individual measurements and weights will rarely be available. It is then necessary to base the ratio upon available means or averages of the measurements. If the weights and linear measurements are taken from different individuals, and especially if different localities are involved, the specifications for the samples should be fully stated as well as the reasons for considering them to belong to a population homogeneous as to size. Sumner (1920), who was working with abundant, laboratory-raised material of *Peromyscus,* illustrates several satisfactory methods of dealing with statistical material, of which the most precise is that involving the use of regression coefficients.

[3] Although Teissier (1931) used cube root of weight in a study of relative growth in the mealworm, the only use of this quantity in the analysis of linear measurements of vertebrates up to the present time, so far as I know, is that of Romer and Price (1941:7 ff.) in their monograph on the Pelycosaurs. For these fossil reptiles, no actual weights, of course, were available. An estimated relative weight factor or weight index was ingeniously obtained by assuming that the average area of the vertebral centrae in a given species, since the vertebrae supported the animal's weight, would be proportional to its weight (Wolf's rule). The cube roots of these weight indices were then taken and used as a standard of comparison for measurements of the skull, and various bones of the body and limbs, with valuable results.

After the mean ratio (linear dimension over cube root of weight) for each population included in the study has been secured by any acceptable statistical method, the ratios for the various populations may be directly compared. Comparison is facilitated if all the ratios are multiplied by the factor necessary to increase the largest to 100. The relative magnitude of the dimension in the various populations can then be read off directly as percentages.

The following examples are given to illustrate the use of cube root of weight in analyzing measurements of birds:

1. *Wing/tail proportions in the Fox Sparrow.* The Fox Sparrow is of interest because in the northeastern subspecies, which breeds from Newfoundland to Alaska, the wing is considerably longer than the tail, while the reverse is true in several races of the California and Great Basin mountains. Subspecies of the intervening areas of the west are more or less intermediate. A considerable variation in general size (as shown by weight) occurs among these races, and it has not yet been demonstrated whether the difference in tail/wing ratio is the result of increase in relative tail length or decrease in relative wing length in the southern races. To determine this, the general size factor was eliminated by expressing the measurements as ratios of

TABLE 3

Comparison of Absolute and Relative Wing and Tail Lengths in Eight Subspecies of the Fox Sparrow (*Passerella iliaca*)

	Wing	Tail	Weight	Wing Ratio	Tail Ratio
P. i. iliaca	88.5 mm.	71.7 mm.	40.7 gm.	97.9	77.3
P. i. altivagans	81.2	76.1	30.9	98.5	89.9
P. i. sinuosa	81.0	73.1	32.5	96.6	84.9
P. i. schistacea	80.4	80.6	28.9	99.7	97.3
P. i. fulva	80.8	82.2	30.1	98.8	97.9
P. i. brevicauda	83.4	84.3	34.4	97.6	96.1
P. i. monoensis	82.8	85.0	31.3	100.0	100.0
P. i. stephensi	83.4	85.2	34.5	97.5	97.0

The ratios were derived by taking: wing × 8.198 over cube root of weight; tail × 7.985 over cube root of weight (the numerical factor given for the numerator being the one necessary to increase the largest included ratio to 100).

cube root of weight. In Table 3, these ratios are given for eight subspecies, together with the absolute measurements. The weights are from Linsdale (1926:314) and Wetherbee (1934:60). Other measurements are from Swarth (1920:182). All data are for males. Because available weights of *P. i. iliaca* included both sexes, I have corrected them on the basis of Linsdale's statement that males of this species average 2 per cent heavier than females. Since the present objective is primarily to illustrate a method, it has not seemed necessary to repeat here the specifications of the samples upon which Table 3 is based. The weights of *P. i. iliaca* are from specimens trapped in New England (Wetherbee); the wing and tail lengths of this subspecies are from four Alaskan specimens, but since they agree quite closely with measurements taken from eastern specimens, as published by Wetherbee and others, it seemed acceptable to use a ratio based on samples from even such widely separated localities, the geographical variation involved, if any, being negligible in comparison with the inter-racial variation to be analyzed. For a number of races Swarth gave measurements taken from several series collected at separate localities; in such cases I used the largest sample in the table.

Comparison of the relative wing and tail lengths given in Table 3 immediately reveals certain things which the absolute measurements do not. The eastern race, *P. i. iliaca,* is seen to have a longer wing only because its general size, as shown in weight, is larger; relatively, its wing is no longer than that of the other races. In fact, wing length is closely correlated with general size, as shown in weight, in all eight races. The tail of *P. i. iliaca* is much shorter, and that of *P. i. altivagans* and *P. i. sinuosa* considerably shorter, relative to weight, than the tails of the other five races. Swarth believed *P. i. iliaca* to be more closely related to *P. i. altivagans* than to *P. i. sinuosa,* and it is interesting that the relative tail length does not agree exactly with this division. The other five races were placed by Swarth in a "*schistacea* group" because of resemblances in color and in other characters, and this grouping receives additional support from the fact that relative tail length is almost the same in these five races. Though *P. i. monoensis* exceeds all the other races in relative length of both appendages, the difference, as compared with other members of the *schistacea* group, is so slight that we may assume that it is not significant. The general conclusion is that the geographical variation observed in tail/wing proportions of the Fox Sparrow is to be ascribed to variation in the relative length of tail. Clearly it is necessary to know this before attempting to find a biological explanation of the change in proportions.

2. *The cuckoos of the genus Cacomantis.* Out of eight subspecies of two closely related species of this genus, seven were found (Amadon, 1942*b*:17–20)[4] to have a wing/tail ratio of about .96, but in the eighth (*C. variolosus addendus* of the Solomon Islands) the ratio was only .88. Weights, which were available for *C. v. addendus* and for one of the other forms (*C. p. pyrrophanus* of New Caledonia), made possible an analysis of this difference in wing/tail proportions:

	Wing	Tail	Wing Ratio	Tail Ratio
C. v. addendus	121.8 mm.	138.8 mm.	92.78	100.00
C. p. pyrrophanus	142.2	148.3	100.00	98.62

The ratios were derived by taking: wing × 2.56 over cube root of weight; Tail × 2.42 over cube root of weight.

[4] This reference may be consulted for the size of samples, weights and other detailed data used here. The methods used in that study needed improvement by transforming the ratios to the base 100; it would also have been better to use mean ratios derived from linear measurements and weights taken from a series of individuals, and to exclude the specimens for which weights were not available.

It is evident that relative tail length is essentially the same in the two, and that the difference in wing/tail proportions has been produced by a change in relative wing length. Since it is *C. v. addendus* that differs from all the related forms studied, we may assume that it, and not *C. p. pyrrophanus,* has changed, but there are no life history data available to suggest whether the relative shortening of the wing in *C. v. addendus* is correlated with habits.

3. *Relative weights of Snow Geese.* In his study of the Snow Geese, Kennard (1927) stated that the Greater Snow Goose is "a much stockier and more heavily built bird" than the Lesser Snow Goose, and published weights and measurements to illustrate this difference, which he considered an important part of the evidence supporting his contention that the two are distinct species. However, Kennard failed to point out that a difference in weights greater than the difference in linear dimensions is to be expected, even when the body forms of two birds to be compared are alike. If the cube roots of the weights are used, a valid comparison designed to test Kennard's conclusion can be made. Analysis of his data for adult males shows that the Greater Snow Goose exceeds the Lesser by 10.5 per cent in wing length, 8.9 per cent in body length and 14.3 per cent in cube root of weight. The greater difference in the cube root of the weights does indicate that the Greater Snow Goose is a "stockier" bird than the Lesser, but the disparity is seen by this method to be too slight to be necessarily considered a specific character, for subspecies may differ in body proportions just as they do in other morphological characters.

In the examples given here, the significance of the difference in ratios is apparent; when necessary, the significance of such difference can be determined by various statistical tests similar to those recently elaborated by Reeve (1940) for studies of allometric variation in proportions.

Recording of Weights

The greatest difficulty in the use of weights in systematic work is the fact that they cannot be taken from study skins. Recording of weights on specimen labels should be made a routine part of museum collecting. This has long been done at the Museum of Vertebrate Zoology under the progressive leadership of the late Joseph Grinnell and at a few other institutions such as the University of Michigan Museum of Zoology. Weights should also be recorded during banding work. In order to increase the value of weights for taxonomic studies and for the still more stringent requirements of physiological studies, information recorded for each bird weighed should include locality, date, time of day, sex, status of species (migrant or resident) and (if the specimen is collected) the contents of the alimentary system, size of gonads, and amount of fat present.

In publications on the taxonomy of birds, weights should be given whenever available, preferably in a way which will permit them to be individually correlated with measurements of appendages. Perhaps the only paper in which this has been done for large numbers of specimens is Mayr's report (1931) on the birds of the Saruwaged and Herzog Mountains of New Guinea. Weights should be recorded in grams, but when the cube root of weight is used, the relative values sought are unaffected by the unit or system of measurement employed, provided it is the same in all the forms to be compared.

Summary

A reliable measurement or index of general size is needed in avian taxonomy both as a direct measure of differences in general size and as a standard of comparison for measurements of appendages.

Linear indices of general size are usually either too variable to be reliable, or are not available in sufficiently large series to be of general use. Weight has moderate variability and reflects differences in general size more sensitively than do linear measurements.

When used as a standard of comparison for linear measurements, the cube root of weights should ordinarily be used.

The use of weights in taxonomic studies is demonstrated.

Weights of birds should be recorded whenever possible, to aid in taxonomic and other problems.

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