WHY ARE BIRDS' WINGS AS LONG AS THEY ARE?

Stephen Fretwell, William Pursley, Grover Icenogle, and Robert Tuelings

Measurements on birds' wings are easy to obtain from birds in the process of being banded. But we must ask--why bother to record them? There are several reasons. Some people simply find the variation in birds' wings to be interesting. They note that some small birds (like Goldfinches) have long wings while some larger ones (Song Sparrows or Carolina Wrens) have short wings. They might note that the wings of some species (like Field Sparrows) very over a wide range of sizes, while other species (Purple Finches) have wings almost all the same size. Finding something interesting is justification enough to do it, even if we do not know why we are interested. We must not forget that our sub-conscious minds know a great deal more than our conscious minds are aware of. If our sub-conscious minds tell us something is worth doing (by making it interesting), then we should trust ourselves and go ahead.

However, in the case of wing lengths, we have a conscious purpose in making the measurements. For a bird's wings tell us a great deal about where and how that bird lives. Migratory birds must have different wings from resident ones. Birds that catch their food on the wing must have different wings from ground-feeding, or even tree-feeding, birds. Wing length is probably different in young and old or male and female birds. And if wing length variation reflects these differences in ecology, we can look closely at the wings of the birds we catch to band and can perhaps unravel some of the details of their life history. Maybe, when we catch some wintering chickadees, we can identify them as migrants or residents based on their wing lengths. Or we might be able to use wing length data to age the birds we catch.

Our purpose in this paper is to begin to unravel the meaning of wing length. The first step is to do the obvious: to try to quantify or to be precise about the common sense idea that bigger birds will have bigger wings. What we now ask is: How much bigger are the wings of birds that weigh more? How does a gram increase in average species body weight increase the average species wing length?

We could approach this problem aerodynamically and compute areas, angles of attack, wing loading, and all that sort of thing. But we won't; instead we will start by testing the simple assumption that the overall shape of birds does not change with size. We will theoretically relate the average wing length of a bird species to the average weight, under this assumption of constant shape. Then we will look at some typical data to test the consequences of this assumption.

The Model. The volume of a bird is proportional to its weight, so that birds with more volume weigh more. If the density of the birds stays the same, a big bird has just as much volume per gram of weight as a small one, and so doubling the volume will double the weight. The volume of a bird cannot be computed very easily, but imagine the bird laying in a box just big enough to achieve a snug fit. The bird in this box touches all the sides, the top and the bottom. The volume of the box is found by multiplying the length, the width and the height. The volume of the bird is somewhat less than the volume of the box, but let's assume for that we can find boxes that fit every bird equally snugly. Then each bird takes up the same fraction of the total volume in the box. Further assume that the length of each box is exactly equal to the length of each bird's wing, so that the poor bird is really in quite an awkward position. Now, because we are assuming that all sized birds have equal shapes, it is reasonable to suppose that all the boxes will have equal shapes. Thus, the height and width of each box is some constant fraction of the length. To find the volume of the box, you would multiply the length times the width times the height. But if the width and the height are equal to the length multiplied by some fractions, then the volume of the box can be computed by simply multiplying the length times itself three times, and then multiplying this number times the fractions; for example, if the length of the box is 50 mm, the width is $\frac{1}{4}$ the length or $(\frac{1}{4} \times 50)$, and the height is also $\frac{1}{4}$ the length $(\frac{1}{4} \times 50)$, then the volume $V = lwh = 50 \times (\frac{1}{4} \times 50) \times (\frac{1}{4} \times 50) = (\frac{1}{4})(\frac{1}{4})\ (50 \times 50 \times 50)$. In short the volume of the box is directly proportional to the length cubed.

Now, the bird is taking up some other constant fraction of the box's volume. So the bird's volume is proportional to the box's volume. Thus, the bird's volume will be equal to

some constant times the length of the box (also the length of the bird's wing) multiplied times itself three times. Written as a formula, this says:

(1) Volume of bird = constant x (wing length of bird)^3

The constant is the fraction the volume of bird is of the volume in the box, times the fraction the box's width is of the length, times the fraction the box's height is of the length.

Now, the volume of the bird is directly related to the weight of the bird, so we can tie wing length and weight together with a new constant:

(2) Weight of bird = constant x (wing length of bird)^3.

The new constant is the old constant multiplied by the number of grams per cubic millimeter of bird, when the bird is squashed up in the box.

There are two ways to test this model. Suppose you have conducted an operation recovery station and have wing lengths and weights for a number of birds of different species. You can take the wing lengths, multiply them times themselves three times, and then plot weight versus wing length cubed on a graph. You should get a straight line, that when extrapolated back will go through zero weight and zero wing length. The slope will be the constant in equation 2.

Or, you can transform your data to logarithms, and again plot your data. You should again get a straight line, which has a slope of 3 (or 1/3) depending on whether you plot log weight versus log wing length, or log wing length versus log weight. The intercept will be the logarithm of the constant in equation 2.

We have worked up some data for an example. The data was collected by Liz and Bob Tuelings on the outer banks of North Carolina in Operation Recovery, September - October, 1966. We tried both methods, and you can see for yourself that on the average, the model fits. In figure 1, we plotted the cube of the wing length against the volumetric measurement, eight. In figure 1 each point is a different individual. The species are grouped and circled. In figure 2, the mean wing length and body weight have been computed and then transformed into logarithms. The slope of the regression line is .32, very close to .33, the predicted value. The intercept is 1.48 while the log of the slope of the cubic equation (Figure 1, after correcting for the 10^5 transformation) is 1.46, again as predicted. Figure 3 is included to show the natural relationship of wing length to weight. Happily, in all graphs, the points are quite scattered. We say happily because as we observed in the beginning, we hope to use variation in birds' wings to explain the birds' ecology. This analysis leaves us with much species to species variation to use in this way. We now must explain why some of the birds fall above the straight lines in Figures 1 and 2, and some below. We will report on our findings as soon as they are available.

Acknowledgments

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--Stephen Fretwell, Bird Populations Institute, Kansas State University, Manhattan, Kansas 66506

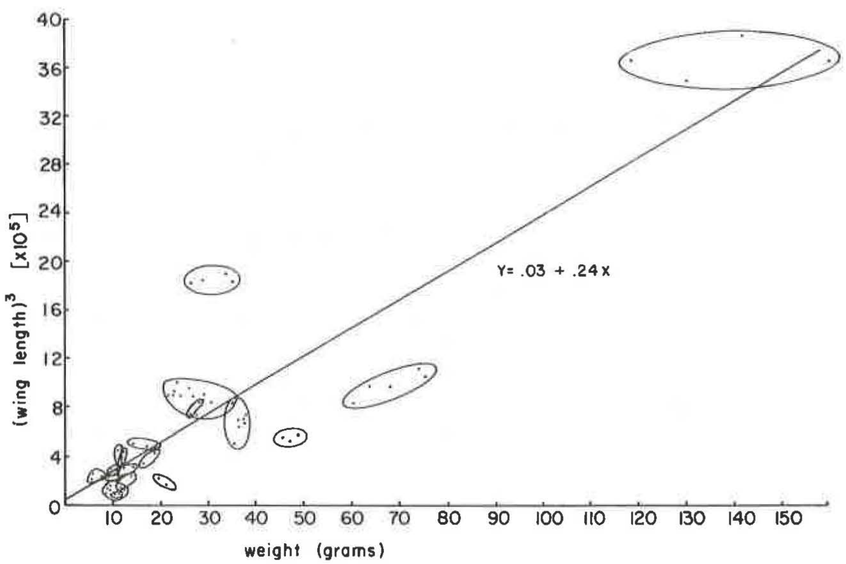

FIG. 1

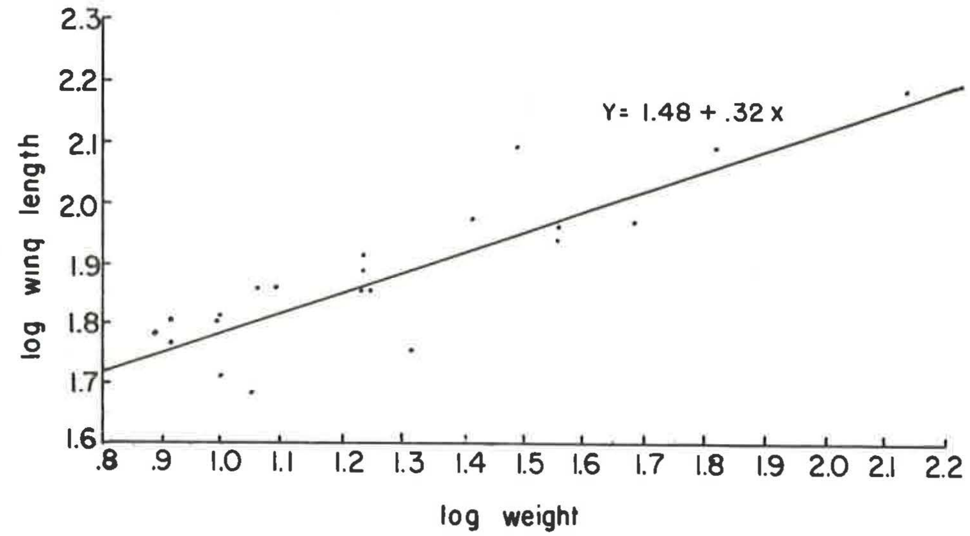

FIG. 2

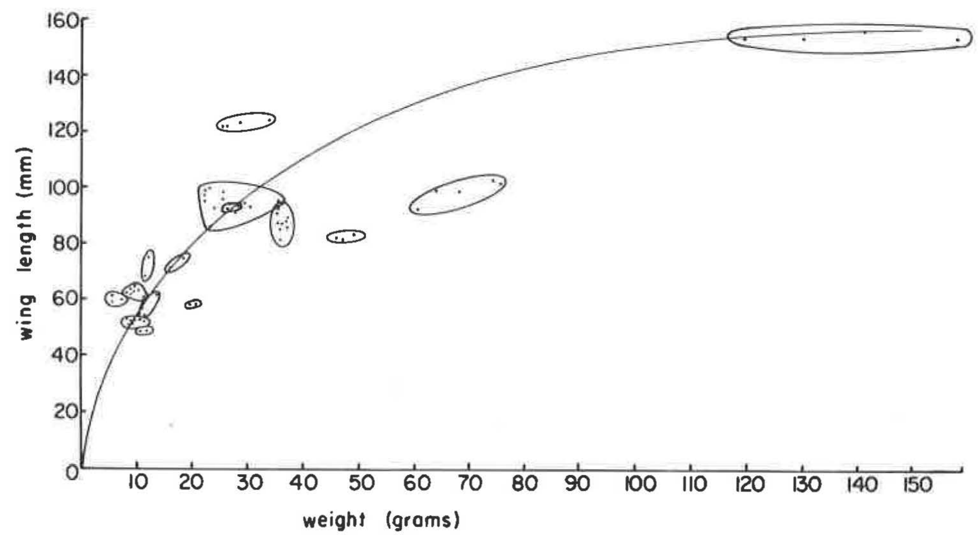

FIG. 3