A stochastic model of leaf-scratching bouts in two emberizine species.—After having emphasized the need for more careful study of the two-footed leaf-scratching by emberizines (Hailman, Wilson Bull., 85:348–350, 1973), I noticed an apparent difference in scratching behavior of two species. Dark-eyed Juncos (*Junco hymelis*) of the Slate-colored form seemed to scratch only once, whereas White-throated Sparrows (*Zonotrichia albicollis*) frequently appeared to scratch twice. Therefore, I made a quantitative observational study, the results of which led to a model that may explain bouts of multiple scratching in general, as well as the nature of species-differences.

In order to accumulate sufficient data under relatively constant conditions, I baited the ground under my study window in Madison, Wisconsin. Each day during October and early November 1972, I scattered approximately one measuring cup of mixed bird seed over an area about 1 × 2 m, which is shaded by various planted bushes and trees that provide a leaf-litter over patches of bare earth and grasses. Birds visiting the feeding area are all presumed to be migrants, since neither juncos nor sparrows visited our feeding station during mid-winter. I saw as many as six juncos and as many as eight Whitethroats feeding at one time, as well as a few individuals of other emberizine species, but have no way of estimating the total numbers of individuals in the area.

I noted each scratching bout observed as being single or multiple; if multiple, I recorded the number of individual scratching motions given in succession. There is the possibility of observational bias in judging the difference between spaced single scratches and multiple scratches. If the animal noticeably paused between two movements, or made any other intervening action, the observation was recorded as two single scratches. Simultaneous judgments made on the same bird by another observer revealed complete agreement with my notes, so that bias in judgment is probably a relatively small factor in the results.

Nearly 500 single or multiple scratching bouts were recorded under these conditions: 250 from juncos and 229 from Whitethroats. Both species most frequently scratched singly: 68 percent of junco bouts and 62 percent of Whitethroat bouts. However, juncos did engage in multiple scratching, with as many as five consecutive motions, whereas multiple scratches of Whitethroats were as high as seven scratches per bout.

Since the data indicated a quantitative rather than qualitative difference between the two species, it was necessary first to understand how the number of scratches per bout was determined in either species. Biological variation is often Gaussian-like: evolution selects for an average value and there is variation around that average. In this case, however, the modal value is one scratch per bout and variation is necessarily constrained to higher values. I propose to explain this peculiar case of behavioral variation by operationally distinguishing between a "successful" scratch that is not followed by another scratch in the same bout and an "unsuccessful" scratch (failure) that is immediately followed by another scratch. After presenting the model and the data I offer a possible explanation of how "success" is determined in controlling behavior.

Suppose q is the probability that a given scratch in a series is successful, where successful means the bird halts scratching, perhaps to inspect more carefully the area at its feet or to feed. The probability of an unsuccessful scratch is therefore $p = 1 - q$, where p is the probability of performing another scratch without halting. If this probability of failure is independent of the number of scratches the bird has already performed in the bout (that is, p is constant), then a tight logical deduction can be drawn that predicts the nature of the frequency distribution of scratches/bout.

Let s stand for the number of scratches/bout, and B for the total number of bouts observed. The frequency of bouts having at least one scratch (f_1) is clearly B. The fre-

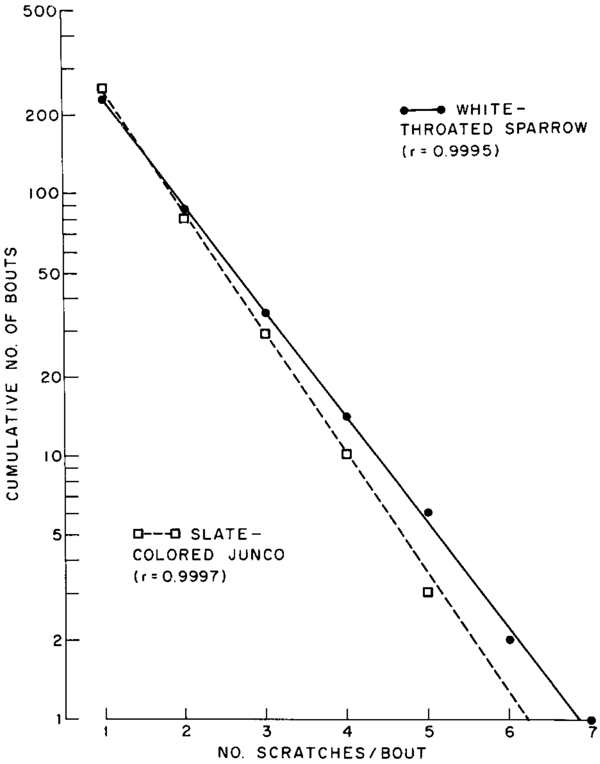

Fig. 1. "Geometric decay" curves of leaf-scratching for two species, in which the logarithm of the cumulative frequency is plotted against the number of successive scratching motions per bout. The least-squares fit of straight lines with high negative correlation coefficients (r values) indicates that the number of scratches per bout is "random" (see text). The slightly shallower slope of the Whitethroat line reflects a slightly higher probability of multiple-scratching.

quency of bouts having at least two scratches is the probability of failure on the first scratch (p) times the number of bouts having at least one scratch (B), so that $f_2 = pB$. The frequency of bouts having at least three scratches (f_3) is the product of the probability of failing on the second scratch (still the constant p) and the number of bouts having at least two scratches (pB), so that $f_3 = p(pB) = p^2B$. Clearly this sequence generalizes to

$$f_s = p^{s-1}B, \qquad (1)$$

where s is the number of scratches/bout and f_s is the frequency of bouts having at least s scratches. (In other words, f_s is a cumulative frequency, empirically arrived at by summing the frequencies beginning with the highest value of s and accumulating "backwards.") Note that when $s = 1$, $p^0 = 1$, so that $f_1 = B$. Taking the logarithm of both sides of equation (1), we obtain

$$\log f_s = (s-1) \log p + \log B, \qquad (2)$$

an exponential equation in which log f_s is linearly proportional to $s - 1$ (and hence also to s), with slope log p and intercept log B. Since the logarithm of a fraction (p) is always negative, the slope is negative. In short, if the probability of adding another scratch to a bout is constant and independent of the number of scratches already performed, then the logarithm of the frequency of bouts having at least s scratches is inversely proportional to s, the number of scratches/bout.

It may help intuitively to point out that this simple model is related to the survivorship curves of banded birds of a single year-class where mortality is constant through time, and to the decay of radioactive materials—except that scratching is a discrete variable (number of scratches per bout), whereas time is a continuous one. The model may thus be termed a "geometric decay function" in parallel with the exponential decay functions of demography and radioactive disintegration.

Figure 1 shows the graphic analysis for both species. The fit of the data to a straight line (geometric decay function) is close: negative correlation coefficients exceeding 0.999 were found for both species. The lines fitted to the data in Figure 1 are lines of least-squares regression, and it will be noted that the slope of the junco line is slightly steeper than that of the Whitethroat. Since slope expresses the probability of adding another scratching motion in a bout according to equation (2), the difference in slopes shows that Whitethroats do in fact have a slightly higher probability of multiple scratching than do juncos.

My conclusion from these results is that both species possess fundamentally the same kind of scratching behavior. The most parsimonious interpretation of the geometric decay functions is that the effectiveness of a scratch in a bout is assessed visually during scratching; the decision as to whether to scratch again before pausing to inspect for seeds is made very rapidly so that no break in the scratching motions is necessary. Indeed, birds often appeared to be looking down while scratching. Finally, the small quantitative difference between the two species might be due to several factors, such as differences in visual criterion of a "successful" scratch or differences in preferred foraging habitat.

It is my impression that the last factor may be operating, for the Whitethroats appear to pick scratching sites more heavily leaved than sites picked by juncos. Therefore, a Whitethroat scratch will have a slightly lower chance of successfully clearing the ground of leaves, and consequently performance of a successive scratch will be slightly more probable.

I thank B. Dennis Sustare and Edward H. Burtt for very helpfully criticizing the manuscript despite their sharing my bias that quantitative explanations of even "simple" behavioral patterns can yield interesting results.—Jack P. Hailman, *Department of Zoology, University of Wisconsin, Madison, Wisconsin 53706.* *Accepted 28 February 1974.*

Breeding range extensions of certain birds in New Mexico.—During field work in 1971–1973 at Tucumcari and in the Rio Grande Valley, New Mexico, I obtained the following notable extensions in the ranges of breeding birds in the state.

White-faced Ibis (*Plegadis chihi*).—On 16 June 1973, Ms. Barbara Escher and I flushed an adult White-faced Ibis from its nest at Tucumcari Lake, just east of Tucumcari, Quay County. The nest was built among cattails (*Typha* sp.) in the midst of a Black-crowned Night Heron (*Nycticorax nycticorax*) heronry. The night heron