THE STATISTICAL TRENDS OF BANDING

By O. L. AUSTIN, JR., and J. M. DALLAVALLE

THE purpose and value of banding are not in putting bands on the greatest possible number of birds or of species; nor are the pleasure and glory of banding in marking the bird that flies the farthest or lives the longest. While these are of vital interest and consideration to the bander, the ultimate goal lies in the stimulation of our forces of reasoning and the advancement of knowledge. Ever since the official beginning of organized bird-banding on this continent in 1920, we have been amassing data concerning the movements of birds, but as yet comparatively few attempts have been made to utilize these data and to extract from them the full degree of their value. It is not so much the purpose of this paper to show how these results may be interpreted—the necessary technique may be found in any standard work on the theory of statistics—as it is to show some of the probable developments in banding in the near future as indicated by the data at hand.

One of the first things that becomes evident after data have been accumulated over a period of years is "trend." Though organized banding has now continued in North America for nine years, the number of data is not so great as would be expected; and though the data now have statistical significance, the element of chance still enters to some degree. Were the data more numerous, our results would be more accurate, but we must content ourselves with what we have on hand. Statistics, as such, are dependent on the number, quality, and interpretation of data. Number adds greater weight to probabilities and removes fluctuations. By quality we mean the degree of selectivity of choice offered by the data, whereby they lend themselves to association and correlation. Interpretation is the judgment of the attributes concerned, and, given the data, it is the most important consideration by far, for on it hinges the entire worth of the figures. The bander must know his bird, and in the final estimate interpretation is neither less nor more than ordinary common sense.

We have enough data at hand at present to allow us to make certain predictions concerning future banding. Let us take, for example, the data showing the total numbers of juvenal Common and Roseate Terns banded yearly at Tern Island, Chatham, Mass., for the past eight years, and see what we can deduce from them, using statistical methods. These data were furnished by Charles B. Floyd, who did by far the greater part of the banding, and Mrs. Alice B. Harrington, who obtained the figures on birds banded by others on the island from the files of the Northeastern Bird-Banding Association. The most satisfactory method of showing data of any kind is by means of a histogram, which consists simply of pillars drawn to scale according to the data. The advantage of this method over a tabular structure is that it gives at a glance the whole history of the case, and allows one to form a mental picture of it. Not only does it show a trend effect at once, if there is one, but it also gives a relative comparison of one year to another. It is a highly efficient way of presenting data and can be relied upon to give far more effect in most instances than ordinary tables. (See Fig. 1.)

We note at once from this figure that the numbers banded in 1922 and 1923 were small and haphazard, and that they increase in a regular sigmoid or S-shaped curve up to 1928, to drop again slightly in 1929. We may interpret the curve in the light of our experience to understand the causes. In the earlier days of this banding it was an unorganized, hit-or-miss procedure. No plans were made ahead of time, and no one person, armed with sufficient bands and a knowledge of when

FIGURE 1

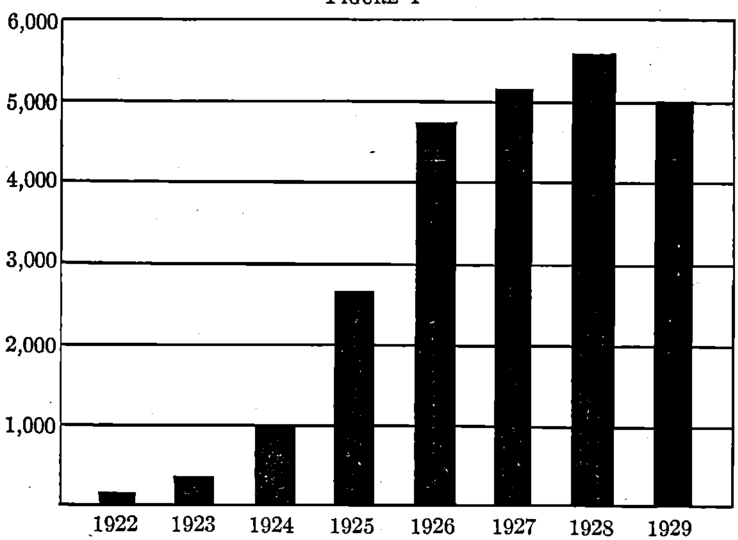

FIGURE 1 shows the total numbers of juvenal Common and Roseate Terns banded yearly at Tern Island. Chatham, Mass., during the past eight seasons.

most of the young would be ready to band, made it his business to see that the work was carried on. Then in 1924 Charles B. Floyd took a hand and organized it, with noteworthy results. It became a matter of knowing when to visit the island to band the maximum of young birds during the limited number of days the operators could spend at the rookery, and the numbers banded logically increased as those in charge became more experienced. But a limit has to be reached in all things, and it stands to reason in this case that we cannot band more young birds than grow to maturity on the island. We can do that only if we reach absolute perfection, which is highly improbable on a stretch of land the size of Tern Island and offering so much cover to so many birds. What we shall do is reach a stage where we band by our perfected methods a certain high percentage, which we may safely estimate here at about 75 per cent of the birds available, and we may call this number the saturation point. We are assuming, of course, that the number of young terns raised yearly on the island remains constant, which it does not exactly, but enough to be eliminated from our considerations. Of far more importance as variables are the number of banders who can lend a hand with the work each year and the amount of time they can spend on the island. From the histogram we see that a peak was reached in 1928, and that the banding in 1929 fell considerably below that number. There was considerably less time spent on the island by the banders in 1929 than during either 1927 or 1928, and the banding was started a trifle late, when many of the young were already on the wing. Thus we can estimate from the curve shown in the histogram, coupling it with our experience, that we may be able in future years, employing the same banding methods, to band slightly more birds than the highest peak yet reached. We may also arrive at this by a somewhat more roundabout method of reasoning. We have estimated that there are about 12,000 eggs laid on the island,[1] and that there is a mortality rate on the island from the time the eggs are laid until the young are able to fly of roughly 30 per cent. Hence, theoretically, about 8400 young birds comprise the yearly crop. If we reach our estimated efficiency of 75 per cent, we should band about 6300 juvenal birds yearly, which appears to be very logical.

In order to clarify the figures and to show this more definitely, we may plot the data on what is known as the logistic

[1] See Austin, O. L., Jr., "Contributions to the Knowledge of the Cape Cod *Sterninæ*," *Bull. N. E. B. B. A.*, Vol. V, 1929, pages 123–140.

FIGURE 2

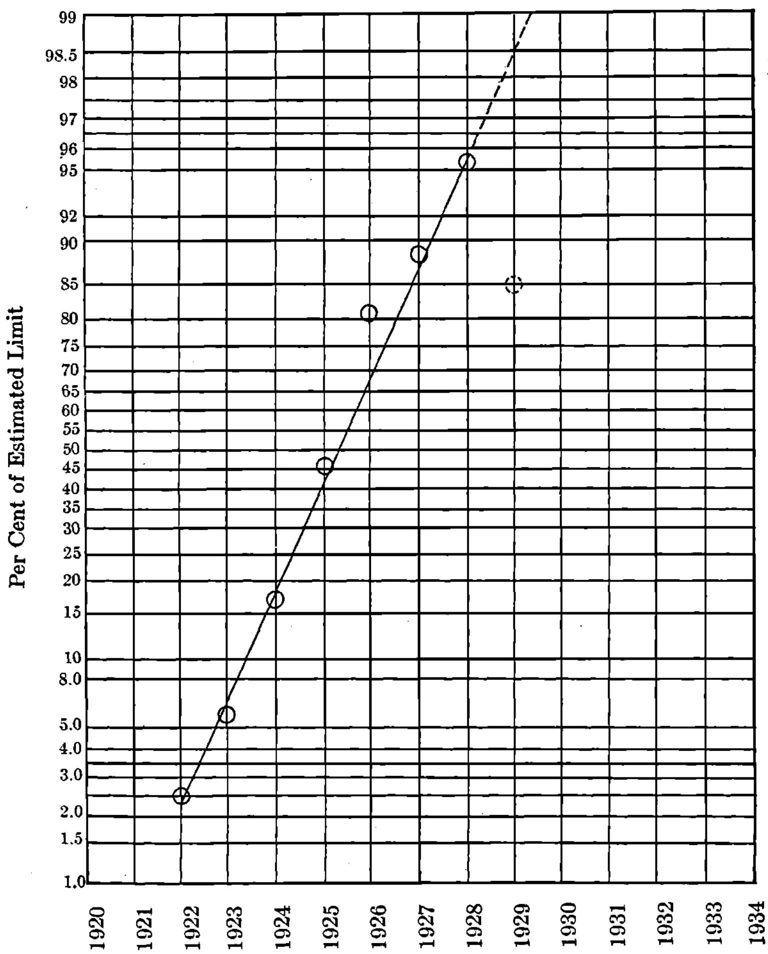

FIGURE 2 shows the data of Figure 1 plotted on logistic grid. The vertical scale is in per cent of an estimated limit, in this case 5900.

grid. This is merely a coördinate paper which turns an S-shaped curve into a straight line. It is a convenient and accurate method of estimating certain types of trends, for a straight line may be continued indefinitely into the future, where a curve may not be plotted with surety beyond the limits of the data at hand. We will not attempt to discuss the mathematics of this grid paper except to explain a few of its properties.[2] It is convenient mathematically to obtain the parameters of the equation, $y = \frac{L}{1 + e^{-n(t-t_0)}}$ where y is the number banded per year, L is the saturation point, t is the year, e is the base of the Napierian system of logarithms and is equal to 2.718 . . . , and n and t_0 are the parameters of the equation which represents our sigmoid curve. This curve occurs most frequently in chemistry, where it is especially concerned with the rate of certain reactions. It has also been used recently by Yule and Pearl in their population studies. Wilson (*loc. cit.*) used the grid to predict the growth of scarlet fever and the ultimate saturation point of the population of the area fed by the Boston Metropolitan Water Supply. It must be understood, however, that the logistic grid will not rectify every curve of a sigmoid character, but only those for which the general equation will apply, as it does to the case in point.

The method of testing for a fit on this type of grid has been shown by Wilson (*loc. cit.*) and is very simple. From the alignment of the previous data, a saturation value is estimated. Each datum is then divided by this estimated number and plotted as a per cent saturation on the ordinate against the year on the abscissa. The estimate is repeated and retried until as nearly a perfect fit as possible is obtained on the grid. In the case of the data for Tern Island (see Fig. 2) 5900 birds yearly seems to be the ultimate saturation level. It may also be noted from the grid how far the figure for 1929 falls below the estimate. We see that the saturation point should have been reached within about 3 per cent in 1929, instead of 15 per cent as actually happened. Had the banders reached the island several days sooner, and been able to spend as much time there as during the previous two years, there is no doubt in the minds of any of us who worked on the island that at least 800 more juvenile birds might have been banded. It is a safe prediction that if all goes well in 1930, and an efficiency of

[2] For full discussion see Wilson, E. B., "The Logistic or Autocatalytic Grid," *Proc. Nat. Acad. Sci.*, Vol. II, No. 8, pages 451–456.

banding of 75 per cent is reached, about 5841 young birds will be banded. This checks very nicely with our estimate from the histogram and the mortality figures, for there is a discrepancy between the two of only 459 birds, certainly a very small percentage for a study such as this where the variables cannot be controlled as under laboratory conditions. It is possible, of course, that a higher percentage of efficiency may be reached, which will raise the banding figures to over 6000, but at any rate, we may be sure that it is impossible to band on the island over 8400 young birds, and to band even 75 per cent of these will be an accomplishment to be proud of.

It can be seen readily that the element of chance still exists. Suppose, for example, that a tidal wave overwhelms Tern Island during the nesting-season, or that the whole colony of terns is demolished by rats or summer boarders before any human assistance can be rendered. Suppose the banders are unable to reach the island, what then of the figures? The answer is that the figures make no claim for the future. They

FIGURE 3

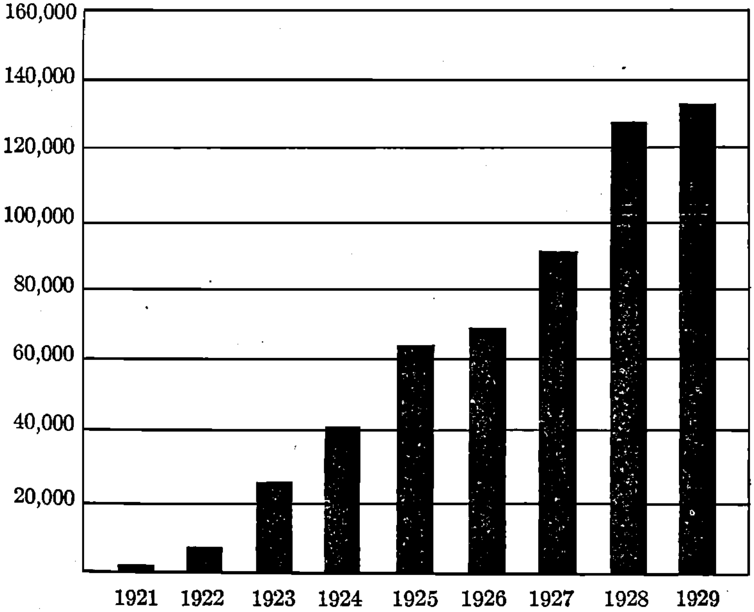

FIGURE 3 shows the total number of birds banded yearly in North America since 1921.

point out the experience of the past and as much as possible of the present. Future banding on Tern Island, when the element of chance is considered, is no more predictable than the population of this earth we live on a hundred years hence. But there is nothing to prevent us from making our estimate, and so long as we make one which is plausible and which is based on the experience of the past, we are quite within our bounds as prophets of the future.

The Biological Survey has furnished us the data for the histogram (see Fig. 3) showing the growth of banding in North America since its official start in 1920. Let us attempt to predict from these data the growth of banding here for the next few years, using the logistic grid method. The value of being able to make such a prediction with but a small percentage of error is obvious, for the better we can plan for the work of the future, the better will our future results be. From the histogram we see at once that though the curve is slightly irregular and has not assumed definite parameters, the number of birds banded yearly is still on the increase. That the curve will eventually be of sigmoid character is evident, but at present there are influencing it too many variable factors which have not yet straightened themselves out.

The yearly increase in the number of birds banded depends on three principal factors: the total bird population of the country, the increase of interest in banding, and the increase in banding efficiency. The ultimate limit of our banding will be when we are banding the maximum possible percentage of the total bird population of the continent. Of course, we cannot as yet estimate that total population, though we may be able to do so when we are able to figure our percentage of banding efficiency more or less accurately. At any rate, whatever our percentage of efficiency is, the fluctuations of the bird population will affect our data, for the number of birds banded must vary with them. We do not know definitely whether this population is increasing or decreasing, much less how much either way, as the case may be, and the best we can do for our present purpose is to assume that the population will be approximately constant now and henceforth. The increase of interest in banding seems to be fairly stable at present, and is not likely to take any sudden large jumps or drops. The most probable manner in which added interest in the subject will increase the growth-rate immediately will be in the more thorough handling, following the example set by Floyd at Tern Island, of the many large colonies of sea-birds hitherto not covered. The factor in which the greatest amount of uncer-

FIGURE 4

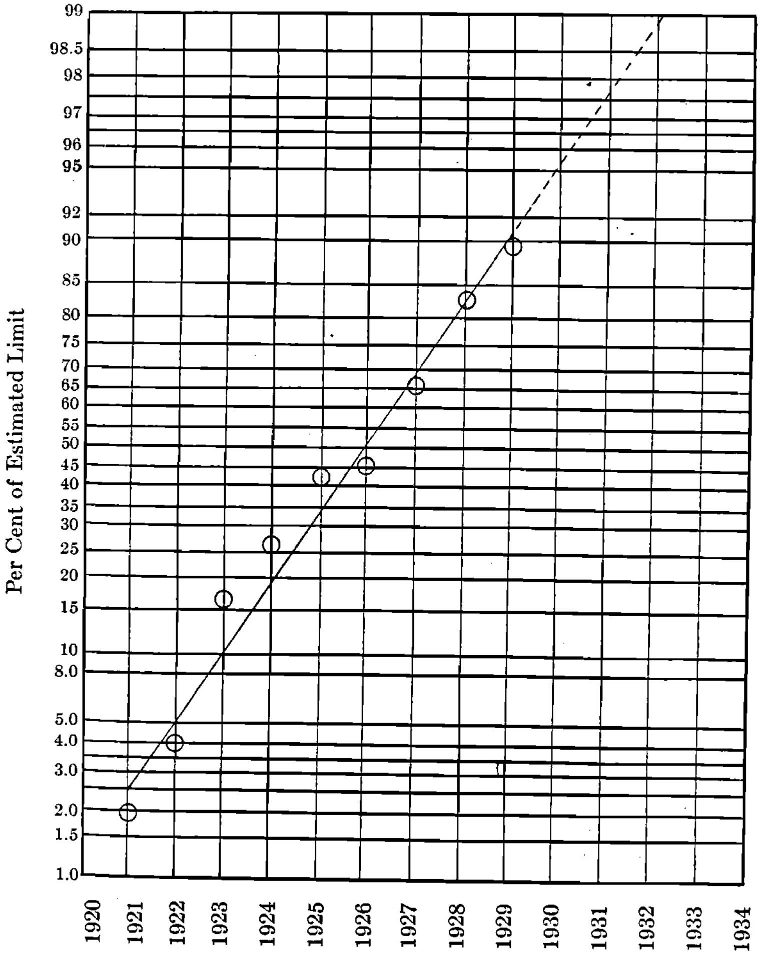

FIGURE 4 shows the data of Figure 3 plotted on logistic grid. The vertical scale is in per cent of an estimated limit, in this case 150,000.

tainty lies is the increase of banding efficiency. We are hampered in our efforts more by the crudity and obsoleteness of our methods of trapping birds than by any other single factor. Banders everywhere are working, either consciously or unconsciously, to improve our technique, and it is very likely that radical changes in the methods now in use may soon appear. This must happen before we can start to band any appreciable percentage of the total bird population.

We have data for only nine years—a pitiful amount when we want to prophesy for thirty years hence. With it we cannot make long-range predictions with any degree of certainty. solely because the true parameters of the curve are not yet evident, though we may estimate for short ranges with an average expected error of not more than ± 4 per cent. In fitting these data to the logistic grid (see Fig. 4) the best fit seems to be made when the maximum banding per year is estimated at 150,000. The grid also shows us that we shall probably reach within 1 per cent of this maximum by 1932, which is as far ahead as we can predict with the data at hand. We should band in 1930 about 142,500 birds, in 1931 about 146,400, and in 1932 about 148,500. This does not seem to be a great increase—only 17,000 in three years—but the fit is within 4 per cent, and there is a possible error of only 6000 birds either way. When this possible error is eliminated from the estimates of 1930 and 1931 by actual fact, and we can add the new figures to the curve, we shall have still less error in our prediction for 1932, and we should be able to predict very safely for 1933, 1934, and 1935. depending on how well the sigmoid character of our curve has asserted itself by then.

It is reasonable to suppose for the present that the growth will be along the trend we have just furnished, and that we shall be banding within 5 per cent of our estimated saturation point by 1932. Whatever it will be, it will be interesting to watch the manner of growth, and by constantly altering our curve on the grid to fit the new data, to improve the accuracy of our predictions. When once the curve is well established along its natural trend, we shall be able not only to predict the total bird population of the country for any future time with considerable accuracy, but we shall be able to show its fluctuations, together with their causes and effects. It will be then, and not until then, that we shall be able to confront our legislatures and other governmental bodies with hard, cold facts, backed by incontrovertible figures, which will permit them to rule properly concerning avian matters.

Orleans, Cape Cod, Mass.