AN AMATEUR ATTEMPTS DATA ANALYSIS: Tree Sparrow Repeats and Returns, Counts and Proportions

Hannah Bonsey Suthers

ABSTRACT

An analysis of repeat and Return data from the simplest look to sophisticated proof-techniques, shows the backyard bander where the pitfalls lie in gathering data, and how far analysis itself can be carried before breaking down. A significant relation is found between repeating and Returning.

HANNAH BONSEY SUTHERS
53 East Broad Street
Hopewell, N.J. 08525

Received 4 September 1973
Revised January 1974

The purpose of this paper is to show, step by step, how to gather usable data, how to arrange data meaningfully, and how to test a theory about the data. Tree Sparrow (*Spizella arborea* [Wilson]) repeat and Return data is used for this demonstration. (Repeating here means that the bird is captured and released alive at the same station and within the same wintering-over season in which it was originally banded. Returning is used in the extended sense of recapture after a round-trip migration to the breeding ground and back to the wintering grounds.) Since only a beginner in statistics can appreciate the pitfalls and mental blocks of another novice, this paper will point out how to avoid common and annoying pitfalls, how to get enough of the right kind of data, and how to recognize data that is inadequate for analysis. Another purpose of this paper is to give the results of the Tree Sparrow study: that repeating augments Returning.

Help for the bird bander in analyzing data is available in several papers from other banders (Berger, Blake, Clench, Farner, Robbins, Strecker, Wiseman). By necessity this help has followed the increasing pressure on volunteer banders to gather adequate data that can be used in population studies, and to analyze and publish, even though statistical analysis is completely foreign to the volunteer.

Robbins (1966) in the Project Guide gives step by step procedures for summarizing data by calculating the mean, and a measure of the individual differences from the mean, the standard deviation that measures the spread of the individuals on both sides of the mean, and confidence limits or confidence intervals that give the probable limits within which the true mean may lie.

These summary calculations are for measurement data, called continuous variates, with a bell-shaped curve on a graph. Some analyses appropriate to such data (also called normal data) are: the *t*-test which

indicates whether or not the mean of one sample is different from the mean of another sample; the F test which tells whether or not one sample varies more than another; the correlation coefficient which tells the strength of a relationship or the accuracy with which the value of one variable may be predicted if the value of the other variable is known; regression which tells how much a change in one variable can be expected from a unit change in the other variable; and the analysis of variance which can look for differences in a whole series of samples.

This paper is concerned with the analysis of a different kind of data, counts, rather than measurements. Repeats and Returns of banded Tree Sparrows are counted and analyzed. The counts of repeats and Returns, and the proportions of Returns/repeats in this paper are called discontinuous variates, or discrete data, and must be handled differently. The counts are discontinuous in that they are definite whole numbers that cannot be split into inbetween values. Measurement and weight data are continuous; there is an infinite series of measurements possible between two given measurements. There is no such thing as half a living bird, but there is half a millimeter between a 70 and 71mm wing measurement. The term proportions is used between Returns and repeats because the word ratio in a text commonly means the ratio of continuous variates, such as Simon's wing measurement/tail measurement for separating Black capped from Carolina Chickadees. These ratios are themselves continuous variates. Formulas used for distinguishing the species of the Empidonax flycatchers, for example Formula B, the difference between the longest primary and the 5th from the outside (Phillips, Howe, and Lanyon), are also continuous variates. Discontinuous variates make discontinuous proportions that must also be handled differently.

Counts are called frequency data (not to be confused in a textbook with the section on the "frequency distribution of a normal population"), attribute data, classified data, one-way classification of frequencies, two-way classification of frequencies. Counts are hard to look up in the contents or index of a text! Counts of haves and have-nots, male or female, or some other pair of attributes that divide a population, are called binomial data and may have a binomial distribution curve. Binomial data can be described with confidence intervals of binomial proportions, which tell whether or not the observed haves or have-nots are representative of some hypothetical population. The Chi-square comparison of proportions test tells whether or not two observed proportions are different from each other. Counts can be tested with various forms of the Chi-square test. The form depends on the question to be answered from the data, such as: goodness of fit which determines if the frequency distribution of the counts resembles some hypothetical distribution; or the similarity of the distributions of two or more populations; or whether or not there is some association between two or more attributes. The last use of the Chi-square will be shown in this paper.

A pitfall awaits the novice who is not aware of the different kinds of data and the respective kinds of analyses appropriate to them. The methods given for analyzing measurement data, continuous variates, break down for counts data, discontinuous variates. The bulk of a text concerns analysis of continuous variates only, and the distinction between the methods is often only implied or mentioned in scattered portions of the text, or at best handled in a closing chapter dealing with counts. Counts require special techniques. The novice, unaware of this, and eager to apply each step through the text, can spend considerable time and effort applying the wrong kinds of methods to the data on hand. This blind spot of the inexperienced must be recognized and dealt with: the difficulty in distinguishing whether the data is like a chameleon in another color phase, or

whether the data is not a chameleon at all, but a newt! An amateur, responding conscientiously to the pressure to publish, has also the responsibility of checking his work with someone who knows data analysis. Preferably this check should be made before working the data so that one can be guided to the right path. To ask is not to admit incompetence. In the world of pure science one asks the experienced to comment on a new project, to point out what is already known, what the problems may be, and what literature to see.

POINTERS AND PITFALLS IN GATHERING DATA

Experimental Conditions: Looking back, I see the first frustrating and baffling pitfall to the novice to be the banding of as many of a species as possible over a period of years, taking all the measurements possible, and expecting some increased understanding to reveal itself out of the accumulation. Each problem requires its own conditions for gathering data, so the study problem has to be chosen first. The problem of determining the sex of the Tree Sparrow by wing measurement requires some other way of determining sex. This could be done during the breeding season only, by brood patch or cloacal protruberance. If a winter population is being studied, data should be gathered between the fall and spring migration dates - unless migration data are to be used as a control. If the wintering-over group is being studied from season to season, the same amount of banding or trapping hours with the same trapping or netting arrangement must be observed during the same calendar dates to avoid the bias of getting more birds one season because they had more chance to be caught.

Furthermore, because counts and measurements take different forms of statistical analysis, data gathering has to be done to give the right kind of information. The analysis to be used below on repeats and Returns, counts data, requires that the total number of birds repeating or not repeating be known, and that the number of repeats per bird be known. That requires a lot of record keeping. Tests on measurement data, such as the *t* test mentioned earlier, require that the data be chosen randomly from a population. This is hard to do with field studies but not impossible. Supposing, in the fall migration, wing measurements of the adult *vs.* hatching year Tree Sparrow were being studied, age determined by skulling. Get two paper bags and popsickle sticks, or round metal-rimmed tags. Put the numbers of the adult birds on the tags in one bag, the numbers of the immatures on the tags in the other bag. Shake the bag and draw out a tag. Shake again and draw out the next tag, etc., until your desired sample size is needed. Repeat for the other bag. This hilarious procedure helps provide random selection of field data by avoiding the possible bias of larger, dominant birds being captured first.

Literature Search: A literature search done first will help avoid pitfalls by showing what others have done on the problem, and by giving ideas on how to set up the study. This requires access to a library with Biological Abstracts and ornithological journals. Lacking access to these, one can ask a professional in the subject what the most recent papers and reviews are, then to request copies of these from the authors. One can look at the literature cited in these papers and try to get copies of the references.

Adequate Sample Size: Then there are pitfalls of field studies, the uncontrollable variables of weather, and other changes of environment such as farms being sold for housing. A sample of a population must have enough individuals to make statistical testing of the results possible. The statistical tests for biological data will handle samples as small as 2 in each of the experimental and control groups, though 5 to 20 is recommended as a manageable size.

Here is a catch: If the problem being studied depends on Returns, then death rates and Return rates have to be predicted and a large enough number have to be banded in the first place to yield an adequate sample of Returns. These rates may have to be predicted on the basis of the first year's results while the project is still in progress. There is a general rule for the sample size needed to show a difference between two groups: the smaller the real differences, the larger and more uniform the groups need to be, for the difference to show at statistically significant levels. Robbins has a useful paper prepared for the 1971 Annual Conference of the Inland Bird Banding Association: "Sample size; how do you know when you have enough data?" (*i.e.* of measurement data). Later in this paper a method is shown for calculating when you have enough counts data.

Expand the Question: Before beginning the study, stating and restating the problem to be explored, and expanding its implications, will help to show what kind of information is needed, and how to get it. The problem in this paper is to prove or disprove a relationship between repeating and Returning. Is this Returning a sign of intelligence, or lack of it? Are Tree Sparrows smart enough to wander with food supply, or are they fixed on a locality? If Returning can be taught the birds by frequent repeating, then baited traps are a good idea to provide the motivation to repeat. Also letting the birds feed in the traps without capture can promote repeating. Learned behavior, *i.e.* memory of where to find food, can promote survival during future wintering over seasons. But, if Returning is a species characteristic, that is, if Tree Sparrows are fixed on a locality, then we must see to it that their wintering grounds are not destroyed by housing expansion or other disturbances of their ecological niche.

With the question and experimental conditions established, consider some practical questions. Is there enough time (days, sequential years) to gather adequate data? Is the expense and effort justified? What other problems would the data clarify?

Materials and Methods: Now let's get to the methods by which these data were gathered. The data, first published in entirety in Suthers 1965, were gathered near Lansing, Michigan, the northern part of the Tree Sparrows' winter range. A government sparrow trap and an all-purpose ground trap were used. The traps were placed on the edge of a cultivated field, near trees. A 10 foot square chicken wire fence kept animals out. Traps and fence were set up after the fall harvest, and taken down before the April plowing. When the traps were not in operation, they were left open for feeding. The birds in this study were banded from December through March, in 1955-56, 1956-57, 1961-62, and 1962-63. Each of these four years had heavy snow and cold temperatures, and similar total trapping hours, so the data can be compared, and the results of the individual seasons pooled into larger sample groups. The inbetween years were mild and open, and new bandings sparse, though the Returns came in from the first two banding years. The closing banding date of this project gave enough time for birds of the later two banding years to Return at least three times. Complete repeat records allowed for an experimental group and a control group, namely the Returns that repeated first, *vs.* the Returns that did not repeat first, or the repeats that Returned *vs.* the repeats that didn't Return. The Returns from each banding season started from the same base line, *i.e.* the next wintering over season from banding, at least 9 months from banding. For a discussion of these basic premises, see Chapter 12, Birdbanding in the Study of Population Dynamics, by D.S. Farner, in Wolfson, ed., 1955.

POINTERS AND PITFALLS IN HANDLING THE DATA

Handling the Raw Data: Individual records are kept of each bird's Banding, repeat, and Return histories. These are assembled in Table 1. Look over Table 1 for a pattern. Of 19 birds that repeated during the banding season, 18 Returned during the consecutive wintering over season. Only one failed to Return the consecutive season, but Returned later. In contrast, of 15 non-repeating birds, 11 Returned the consecutive season, and 4 failed to Return the consecutive season, but Returned later. Is 18:19 different from 11:15? Percentages will tell: 18 out of 19 represents 94.7% repeats that Returned consecutively; 11 out of 15 represents 73.3% non-repeats that Returned consecutively. The non-consecutive Returns will be left out of further analysis because a Return 2 to 5 years later is too long an interval to think that repeating has affected the Returns.

A quick look at the histories, that requires no math, is provided by a tally, also called a frequency distribution, of the repeats that Returned, and repeats that did not Return (Fig.1,p.36). A more useful variation of the cross-hatch tally, this is called a stem-and-leaf display (Tukey). The stem represents the number of times a bird repeated. The leaves are the numerals representing the individual birds that have Returned (or not Returned) and their respective repeats. The leaves are always entered outward from the stem. The conventional hatch tally looks like this:

# times a bird repeats	repeaters Returning	# times a bird repeats	repeaters not return'g
one repeat	/	one repeat	𝍸 𝍸 𝍸 ////
two repeats	////	two repeats	𝍸 𝍸 /

The stem-and-leaf display (Fig.1) is the same idea:

#times a bird repeats	repeaters Returning
1	1
2	2222
etc.	

#times a bird repeats	repeaters not Returning
1	1111111111111111111
2	22222222222
etc.	

This kind of display can be put back to back by flopping the repeat-not-Returning tally over to the left, so that the leaves are on the left side of the stem which both tallies now have in common. Again, the leaves branch outward from the stem.

repeaters not Returning	#times a bird repeats	repeaters Returning
1111111111111111111	1	1
22222222222	2	2222
	etc.	

This display is especially handy if you want to pool groups, say, 1 with 2 repeats, and 3 with 4 repeats, etc.

repeat no Return	#repeats	repeat Return
222222222221111111111111111111	1 - 2	12222
4433333	3 - 4	3344
655555	5 - 6	555566

The tally is thus compressed so as to accomodate a lot of data, yet the information on the number of repeats of each individual bird is retained. The display shapes itself into a rough kind of graph handy for visual comparison. It is useful for various comparisons such as the number of birds (stem) captured in two different traps or net sizes (leaves); or for comparing wing lengths (stem) of males *vs.* females (leaves). For a fuller discussion of this technique and its possibilities, see Tukey, 1970.

Figure 1 shows that there are more repeaters that did not Return, than repeaters that Returned (53 *vs.* 19). This is understandable considering the low Return rate, 15.79%, not including the non-consecutive 1st Returns, compared to the non-Return rate of 84.21%. The Group A (repeat no-Return birds) shows more individuals with fewer individual repeats, and more birds with the "trap habit", than Group B (repeat Return birds). Group B birds tend to repeat more often than the birds that did not Return: the middle ranking B bird has 5 repeats, whereas the middle ranking A bird has only 2 repeats. The number of repeats of the middle-positioned (median) birds are compared instead of the average (mean) number of repeats, because there are atypical or wild numbers in group A that distort the average value so much that the true picture of what happens in the group is buried. The middle or median value does not show this distortion: the median shows the typical behavior of the group even though there are extremes. In this way, the birds with the trap habit are neither ignored nor allowed to distort the data because of the wild repeat values they give. These atypical values must be kept if later statistical tests are to be valid, that is, data should not be trimmed to exclude straggling values at one end or wild values at the other end. Something can be learned from them. The biological approach considers not only the bare data, but the living organism and the things that can go right or wrong with it and its environment. One of the two high repeaters had a drooping wing, the other had a head injury.

This look at the stem-and-leaf display indicates that there could be a relation between repeating and Returning in Group B. How to make it show? Figure 2 is a stem-and-leaf display showing multiple Returns, from 1st to 5th as the stem, and the number of repeats of each individual Returning as the leaves. There were more repeat Returns with more multiple Returns, than non repeat Returns. This is worth looking into, in depth.

Another picture: The raw data on Table 1 is worked into a percentage analysis of consecutive repeats and Returns, in Table 2. As seen earlier, percentages sharpen differences between proportions being compared. (The non-consecutive Returns are left out of Table 2 because a Return 2 to 5 years after banding is too long an interval to suppose that previous repeating or non-repeating had any effect.) The percentage of repeat 1st Returns is nearly three times that of non-repeat 1st Returns, 26.39% *vs.* 9.32%. There are 31.25% repeat 2nd Returns and no non-repeat 2nd Returns.

This percentage analysis makes a striking picture on a graph, Figure 3. (See Strecker, 1971, on how to make bar graphs.) In Figure 3, the incidences of repeat Returns accelerates to the 3rd Return, then drops off, probably because of mortality. The 4th and 5th Returns are by one persistent bird who also repeated after each of these Returns. However the data at the 4th and 5th Returns become untrustworthy, precisely because there are too few birds to base conclusions on, a minimum number for statistical analysis being 5 to 20.

The surprise non-repeat Returns at the 3rd Return could be a signal that a second thing is happening, namely that Returns reinforce Returning. Robbins (1969) suggests that a Return is more likely to be captured again, having Returned, than a non Return would be. Again, after the 3rd Return the sample sizes become too small to be trustworthy, and here an important and tempting pitfall of basing conclusions on small samples is clearly demonstrated. This is why reliable investigators always state sample sizes with their data. A trend is there on the graph, and perhaps could be verified if more than 190 birds were banded in the first place, hopefully yielding more individuals with multiple Returns. If projected percentages could be calculated from the

first year's results while the study was still in progress, this pitfall of too few individuals could be forseen and perhaps avoided.

First Statistical Analysis: To look and find nothing is better than not to look at all. An attempt shall be made to pin down the validity of the data through the third year. At this point of serious analysis, another pitfall is avoided: that of including data in categories where all subjects did not have equal time to act by chance, the 4th and 5th Returns. The study ended before birds from the last two banding years could Return more than three times.

Two hypotheses suggest themselves from the data displays: 1) that repeating augments Returning; and 2) that Returning reinforces multiple Returns. The question on hand is what statistical tests to use. This question should be considered before a study starts, so that the data required by the tests will not be overlooked.

If Returning can be considered an attribute reinforced by the treatment of baited repeating, then two tests can be applied based on these assumptions. First the attribute of Returning can be tested by the "Confidence Interval for Binomial Distribution." Confidence Intervals are easy to look up, and by their overlapping or non-overlapping are a quick way of telling whether or not the Return rate by repeaters is different from that of non-repeaters. Second, the comparison of proportions by Chi-square test can indicate if the difference between the observed values is random, that is, by chance, and whether or not the treatment, in this case repeating, has made the difference between the two populations, repeaters and non-repeaters. A Chi-square of simple proportions can indicate if the multiple Return rates are the same as the 1st Return rate, or significantly different.

The Confidence Intervals (C.I.) also called Confidence Limits (C.L.) can be looked up on a table in statistics books. The book Statistical Methods (Snedecor and Cochran, 1969) has such a table on pages 6-7. The Chemical Rubber Co. Handbook of Tables for Probability and Statistics, 2nd Ed., also has these tables, called Confidence Limits for Proportions, on pp. 219-237. The reference section of the public library may have this book. The Tables V-IX in Mainland, Herrera, and Sutcliffe, 1956, show one step at a time the confidence intervals for small observed numbers in small sample sizes. The use of all these tables is explained with them, including an example. The observed number from a population can be any of the numbers in the range between the low and high limits, and still represent the population 95% or 99% of the times the test is repeated.

Table 3 is a formal presentation of the data scratched down in the stem-and-leaf display, now put down in table form for convenience in determining the confidence intervals. The first column, the frequency class (f), is the same as the stem of the display. Column 2, sample size of repeaters, is the total (n) of repeaters from that class, the no-Return leaves plus the Return leaves. Column 3, observed no. (f) with attribute, is the number of Returns for that class. The relative frequency, f/n, is the proportion having the attribute in the sample. The relative frequency is converted to percent (%) in the next column, for convenience in graphing. The confidence intervals are of f observed Returns in the sample size of n repeaters. The C.I.'s of the individual frequency classes turn out to be too wide to mean anything. Such is the case when the number of observations, f, is small. When all classes are pooled, the C.I.'s for repeat Returns become narrower, 16.41 and 37.64. The lower interval does not touch the upper interval of non-repeat Returns, 15.81, and the non-overlapping suggests a possible difference between the groups.

The higher proportion of non-repeat Returns than one-repeat Returns cannot be explained except by the possibility of sampling variation. The confidence intervals of the former are contained in the latter, and this indicates that there is no real difference between them.

Simpson, Roe, and Lewontin (1960), on pp 353-4 give the following general rules for the cases where confidence intervals can indicate significant differences:

1. If the confidence interval for one sample includes the observed mean for another sample, the two means are certainly not significantly different.

2. If the confidence intervals for two samples are nearly equal in length and these intervals are clearly nonoverlapping, the difference between the samples is significant.

3. As a corollary of (2), if both means are arbitrarily assigned confidence intervals equal in length to the larger of the two intervals, and if there is no overlap of these intervals, then the means are significantly different.

In any other situation, the overlap or lack of overlap of the graphed intervals is not a reliable measure of significance.

With typical zeal of the novice, I spent many hours learning how to interpolate Confidence Intervals for observed values and sample sizes between the values on the tables. A biologist later commented that, except for the sake of flexing mathematical ability, these hours were unnecessary, since statistical analysis of the data was going to be done, anyway.

Now back to Table 3 for further comments. There appears to be a cut-off point after frequency class 7 repeats. There was no data for frequency class 9 repeats. Frequency classes 10 and higher have only one Return, from class 11. These classes are pooled into two classes as the number of birds is sparse. Freeloading seems to begin at class 10. Are these birds old, and therefore do they prefer to freeload than forage? The answer could be determined if there were a known way of aging Tree Sparrows beyond the first fall, or if a large number of hatching year birds could be banded and the Returns watched over successive years. Two birds in frequency class 16-Hi were injured: one had a drooping wing, the other a bald, bloody crown. These did not Return, possibly because they may not have survived the roundtrip migrations.

The increasing relative frequencies of the classes 2 to 7 indicate a strong relation that shows when graphed, Fig. 4. As the frequency class of repeats increases in value, the probability of Returning, Returns/repeats in percent, also increases. Using Linear Regression procedures, a straight line is calculated through the sloping pattern of dots. The dots are close to the ideal line, meaning that the test is significant, that there is a positive relationship between repeating and Returning. The formula for calculating the line is shown on the Figure. The "how-to" for linear regression is beyond the scope of this paper. We shall go on to a simpler test that will demonstrate whether or not the Returns increase by chance, or because of repeating.

A Simple Test: The Chi-square test, calculable by hand or slide rule, will tell if there are significant differences between groups.

This test, like all other statistical tests, is based on the presupposition that the data to be tested has been randomly selected. This test is good

for counts, scores, ratios, as opposed to measurements which require a different technique. The actual size of the sample, and the actual number of individuals having, and not having the attribute, must be known; proportions alone are not enough information for calculating Chi-square. Chi-square tests the significance of:

1. the way in which the individuals distribute themselves according to certain characteristics, whether the observed ratio is different than the expected ratio, for example male *vs.* female, hatching year *vs.* after hatching year, first Returns *vs.* second Returns;

2. the way the arrangement of individuals is determined whether by chance or by some other significant relationship, for example repeat Returns *vs.* non-repeat Returns.

This test is based on the null hypothesis which states that there is no difference between the groups, and that if we had a large number of samples, or samples of the total population, the true difference between them would be zero. In short, the null hypothesis states that a measurement of differences in a total hypothetical population is really zero. A high calculated Chi-square value means that the null hypothesis may not be true in the particular case and is traditionally rejected. This indicates a real difference between the groups. The high Chi-square value is called "significant".If the Chi-square value is 3.841 or more, the null hypothesis is rejected by a test of significance at the 5% probability level, 0.05 on a Chi-square table under one degree of freedom. This jargon means that the difference between the two groups is accepted as "significant" only if that difference can occur by chance no more than 5% of the time, or in 5 out of 100 repeated trials. A Chi-square value of 6.635 or more is significant at the 1% probability level

(0.01), and a difference between the two groups by chance will be tolerated only in 1 out of 100 trials. To be reasonably certain that this chance occurrence hasn't happened at the first trial, the sampling must be repeated more than once.

The Chi-square test is more sensitive to small differences of rates or proportions between the two groups if the two groups are about the same size. For example to test the difference of Return rates between repeaters and non-repeaters, these groups should be the same size if possible. Groups of unequal sizes may be tested, but the test will be weaker. Another weakness of the test is that if the number of expected attributes in a group is under 5, the test gives only a poor approximation of differences between the groups. The groups have to be large for a small difference to show significantly. This weakness can be overcome by repeating the experiment more than once and summing the Chi-squares of the respective trials, and reading the probability off a Chi-square table under the appropriate "degrees of freedom" (equals the number of experiments pooled). This accentuates either the homogeneity of the groups (high probability level), or a trend toward differences between them (low probability level).

Now let's get down to work. The formula for the Chi-square test follows, with some of its variations.

1) $$\chi^2 = \underset{\text{(the sum of)}}{\Sigma} \frac{(\text{Observed value} - \text{Expected value})^2}{\text{Expected value}}$$

abbreviated as: $\chi^2 = \Sigma \frac{(O-E)^2}{E}$

To work the formula:

Subtract the expected number from the observed number. Square the difference, that is, multiply the

number by itself. Divide by the expected number. Repeat for each of the other classes in the population. Add the quotients from all the classes.

2) $$\chi^2 = \frac{(\text{Obs 2nd Return} - \text{Expected 2nd Return})^2}{\text{Expected 2nd Return}} + \frac{(\text{Obs non 2nd Return} - \text{Exp non 2nd Return})^2}{\text{Exp. non 2nd Return}}$$

3) $$\chi^2 = \frac{(\text{Obs \# repeats Returned} - \text{Exp \# repeats Ret})^2}{\text{Exp \# of repeats Returned}} + \frac{(\text{Obs \# non-rep Returned} - \text{Exp \# non-rep Ret})^2}{\text{Exp \# of non-repeats Returned}}$$

$$+ \frac{(\text{Obs.\# rep non-Ret} - \text{Exp \#rep non-Ret})^2}{\text{Exp \# of repeats non-Returned}} + \frac{(\text{Obs \# non-rep non-Ret} - \text{Exp\#nonrep nonRet})^2}{\text{Exp \# of non-repeats non-Returned}}$$

4) a shortcut formula:

$$\chi^2 = \frac{N\ (ad-bc)^2}{(a+b)(c+d)(a+c)(b+d)}$$

where N is the grand total on the 2x2 table, and a to d represent the values in the respective cells.

Because one amateur's difficulty may well be another's, and mine is difficulty with plugging data from tables into a formula, the formulas are written out and demonstrated with data. The idea is to compare the expected amount with the observed amount of members in a group having an attribute, and to compare the expected amount with the observed amount of members without the attribute. The catch is to give the expected amount a rational basis of expectation. There were some false runs before arriving at a rational basis, and this is in itself a learning experience. The Chi-square, using formula (1) is non significant with a 50:50 expectation of repeat Returns and non-repeat Returns. It is also non-significant with the expected ratio derived from the data itself, the repeat Returns over the total banded, to the non-repeat Returns over the total banded.

The catch is that we are dealing not only with an attribute that the samples have or have not; we are dealing with the having and not having an attribute, and its effect upon behaving or not behaving in a certain way. There are four variables going here, not only two. These are repeating and non-repeating, and their effect on Returning and non-Returning. These four variables make up four classes of birds: repeats Returned, non-repeats Returned, repeats non-Returned, and non-repeats non-Returned. The confusion is cleared by making what is called a "2x2 contingency table" of the action. The actual total of the samples is used, as are the actual numbers in the classes. Chi-square cannot be calculated when only the percentages or proportions in the classes are known. All four classes should be summed in the Chi-square test, using formula (3). This form of the test is called the Comparisons of Proportions by Chi-square. It is explained in Snedecor & Cochran, p.215, but is easier to follow in Finney (1955), p.18. The 2x2 table for repeating and 1st Returns follows, with the Chi-square test step by step. Because the Return figures are small when arranged by banding year, and because the data are homogeneous over the years used, they are pooled according to 1st Returns, 2nd Returns, and 3rd Returns. The observed values are taken from Table 2. The expected values are calculated. See Table 4a and 4b for the 2x2 tables of observed and expected 1st Returns.

The rule for finding the expected entry for any cell, (a) to (d), of the table is to multiply the corresponding observed column total with the observed row total, and divide the product by the observed

grand total. Expected entry (a) is thus the observed values of:

$$\frac{(a+c)(a+b)}{N}$$

The expected number is thereby in the same proportion as the observed totals, though the value may be higher or lower. The other cells are then found by subtraction. A good internal check of whether or not the entries in both Tables 4a and b are correct is this: the row totals when summed must equal the Grand Total, and the column totals when summed must equal the Grand Total.

The next step is to calculate the differences, also called deviations, of the expected values from the observed values. These are:

(a) 19 - 11.37 = 7.63 (b) 53 - 60.63 = -7.63

(c) 11 - 18.63 =-7.63 (c)107 - 99.37 = 7.63

The deviations above when squared, each become 58.22. The data plugged into formula (3) looks like this:

$$x^2=\frac{58.22}{11.37}+\frac{58.22}{60.63}+\frac{58.22}{18.63}+\frac{58.22}{99.37} = 5.12+0.96+3.12+0.59$$

= 9.79, significant at less than the 0.05 level.

The correction for continuity, presented in texts as a routine step in the Chi-square test, is controversial. It is considered unnecessary when using Chi-square for null hypothesis testing, so it is not used in this paper.

A difference in Return behavior between Tree Sparrows that repeat and those that don't repeat, indicated from the first scratch-down and preliminary look-see graphing, has now been statistically demonstrated. Some terms can be coined to describe the behavior: 190 Tree Sparrows showing 37.89% repeats and 15.79% Returns could be called Trap Inducible. During the same 4 years 134 Juncos showed 33.6% repeats and 1.5% Returns could be called Trap Neutral. Another species showing both low repeats and Returns could be called Trap Inhibitable.

A point becomes obvious in the method of capture that must be used for the different groups. Using baited traps to study topophilia (love of locality) in birds that are also Trap Inducible, then becomes nonsense. Netting these birds would give more trustworthy results. Migration studies and ecology studies are best done by nets; you want to know what is there, not what you can lure with bated traps. However, studies on ageing by plumage changes, or sexing by acquisition of adult plumage can be done to an advantage by using traps for Trap Inducible birds to reassure repeats and Returns, but by nets for Trap Inhibitable birds to reassure repeats and Returns. Banders would be wise to learn both trapping and netting methods. Other banders will share knowledge, so one should not hesitate to contact others, or the regional stations in the Atlantic Flyway Review Project (Annual reports are in EBBA NEWS).

Another implication of this study, mentioned earlier as a possibility, is that since the birds do come back to where they remember food, we must be careful to spare from "progress" at least their favorite feeding grounds in their winter range. We may consider the possibility that these birds are not adapted to wander freely with food supply.

The Problem of Sample Size: A study requiring Returns has the inherent problem of sample size, or starting with enough birds to give adequate Returns through consecutive years. If my sample sizes were larger, the 2nd Returns could be used to compare with the 1st Returns.But there are only 5 2nd Returns, all of which repeated first. The Chi-square test

gives them an expected value of only 3, and gives the non-repeat 2nd Returns an expected value of 2. As mentioned earlier, the Chi-square test gives a poorer evaluation of the difference between groups as the expected numbers in the cells diminish, 5 being the traditional cutting off point. The 2nd Returns give a Chi-square of 5.24, significant at the 2.5% level. But because two of the cells have expected values below 5, the test cannot be considered firm. See table 4c and 4d for the 2x2 tables of observed and expected 2nd Returns.

Another rather laborious test, the Fisher's Exact Test, can be used instead if the smallest cell is less than 5, and the grand total under 250. This test transforms the numbers into factorials and requires the common logarithms of factorials. Step by step procedures are demonstrated in Sokel and Rohlf (1969) Box 16.7, pages 595-598, and require the use of the Statistical Tables by Rohlf and Sokel (1969), Table D. Or the probability of less likely results can be looked up directly on a Table of Hypergeometric Distribution such as found in the Chemical Rubber Co., Handbook of Tables for Probability and Statistics. According to the Fisher's Exact Test, the probability of obtaining the results of the 2nd Returns, and less likely results, by chance, is 6%. The traditional cutting off point between non-significance and significance is arbitrarily set at 5%. Since the data gives results in the desired direction, we can ask our readers to be willing to believe these results though they may be repeatable only 94 out of 100 times, and let the readers decide for themselves. The results may well be significant at the 5% level if the sample size were larger. Chi-square characteristically increases as the sample size increases. Here is the right kind of data, but there isn't enough of it.

There is a trick, based on Chi-square, for calculating how big a sample size must be to give a

Chi-square on comparison of proportions a value at the desired probability level. However, like Chi-square, this trick does not work if, in the 2x2 table, a+b or c+d are small originally. It indeed does backfire with the above 2nd Returns, calling for a sample size smaller than the one at hand! Unfortunately the problem of borderline significance cannot be neatly wrapped up by bringing out the magic formula. But the trick remains so useful in general that it will be demonstrated.

Supposing it were important to know if there were enough data from only the first two of the 4 years used here. The data on Table 2 for only two years of 1st Returns gives a Chi-square of 8.9. This sounds highly significant, but the firmness of the results can be questioned because the expected value in cell a) is small, 3.60. How much larger must the sample be to keep expected values above 5 and give significance at the 1% level? Now the trick is useful. Some preliminary calculations have to be made from the 2x2 table of observed values.

	Return	non-Return	Total	
repeat	a) 8	b) 26	a+b) 34= n_1	$\hat{p}_1$=0.235
non-repeat	c) 3	d) 67	c+d) 70= n_2	$\hat{p}_2$=0.043
Total	a+c) 11	b+d) 93	N = 104	

The letter n_1 represents the first row total, and n_2 represents the second row total. The letters $\hat{p}_1$ and $\hat{p}_2$ ("p hat sub one and p hat sub two") represent the estimated probability of the cell a) value in the first row total, and of the cell c) value in the second row total respectively. Calculate them:

$$\hat{p}_1 = \frac{a}{a+b} \quad \text{and} \quad \hat{p}_2 = \frac{c}{c+d} .$$

The Greek lower-case letter η, eta, represents the size that n_1 should be at least, and that n_2 should be at least. They may be larger, and they do not have to equal each other.

The Chi-square value, to be significant at the 1% probability level, has to be 6.635, rounded up to 7 for convenience in the formula. Then:

$$\chi^2 = \frac{2\eta(p_1 - p_2)^2}{(\hat{p}_1+\hat{p}_2)(2-(\hat{p}_1+\hat{p}_2))}$$

Solved algebraically for eta, the formula becomes:

$$\eta = \frac{\chi^2 (\hat{p}_1+\hat{p}_2)(2-(\hat{p}_1+\hat{p}_2))}{2(\hat{p}_1-\hat{p}_2)^2}$$

The Chi-square value, and the values from the preliminary calculations are plugged in, and the formula looks like this:

$$\eta = \frac{7\ (.235+.043)(2-(.235+.043))}{2(.235-.043)^2}$$

Do the additions and subtractions within the brackets first, then the multiplications, and finally the divisions, to get:

$$\eta = \frac{3.3510}{0.07373} = 45.4496, \text{ or 45 minimum row total.}$$

So the banding project continues for at least one more season. The data for 3 years has row totals of 52 and 100 respectively (data from Table 2). The smaller value is above the required row total of 45 for a Chi-square significant at the 1% value. The expected values all calculate out above 5. The Chi-square for three-year's results is 7.36, firmly significant at the 1% level. For extra practice, calculate the value eta for the 1st Returns of all 4 years. It calculates out to be 70.5636, and the smallest row total is indeed 72 (Table 4a).

Getting enough Multiple Returns: Finally, how many birds have to be banded to get more multiple Returns? Both the survival rate and the Return rate have to be considered. Both these rates were unknown at the beginning of the study, so the total number of banded birds needed could not be calculated at the outset. Data from multiple Returns were needed for this. Now the Robbins (1969) paper, "Suggestions on gathering and summarizing return data", is used for calculating the Tree Sparrow survival rates by age groups from banding year, and for calculating the chart of the number of birds expected to survive by year after banding, according to the overall survival rate. The raw data is on Table 1, and the results are on Tables 5 and 6. Table 7 gives the number of survivors expected to Return by year after banding. Table 7 also shows estimates of how many birds have to be banded to give adequate sample sizes of multiple Returns. Not very encouraging with a winter flock of only 50 to 75 birds!

The consecutive Return rate of 15.79%, tested by the sample Chi-square formula 2) for any changes, shows no more 2nd Returns than could be expected. Though the 3rd Returns give a Chi-square significant at the 1% level, this test is not firm because the sample size and hence expected values are too small. There is not enough data to test the 4th and 5th Returns for changes in rate because they involve only one bird.

Some choices left to the bander, then, from simplest to most complicated are:

Accept the hypothesis that repeating reinforces Returning to traps by firm statistical evidence from only 1st Returns;

Test consecutive multiple Returns with Fisher's Exact Test;

Organize a cooperative study in the same 10' block, done according to the same specifications so that data can be pooled into large samples.

The encouragement of "how to" papers from among our own has been substantial. Hopefully, this paper will help supplement them with suggestions on handling counts data. Hopefully this will be another encouragement to banders to get out records and work on the data. The editors of our bird banding journals urge us to stop sitting on our data and publish. In all fairness the following phrase should be added to an editor's admonition: don't be discouraged that preparing a paper may take an unexpected amount of time and work, that your personal worth is not at stake if your antiquated algebra eludes you; such is the name of the game. Every school district has an algebra teacher. May I add that the mental flexibility and mathematical confidence gained from laboring through a paper will make easier the tackling of the next paper. Shall we run a Chi-square test on that statement?

Acknowledgements

Many thanks to Dr. Gary Simon for help with the statistics, to Dr. Stephen Fretwell for his thoughtful comments, and to Kit Price and Walt Protzman for reading for clarity and commenting on the manuscript.

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TABLE 1. Raw data: Banded (B), repeats (r), Returned (R).

Given wintering-over season, November - March

Band Number	1955 1956	1956 1957	1957 1958	1958 1959	1959 1960	1960 1961	1961 1962	1962 1963	1963 1964
53-52031	B 5r	R 6r	R 21r	R 13r					
39	B 5r	R 21r	R 35r	-					
41	B 8r	R 1r	-						
44	B 5r	R 1r	-						
46	B 11r	R 35r	R 39r	R 4r	-				
47	B -	R -	-						
70	B 1r	R 47r	-						
97		B -			R 1r				
53-52100		B -	R 2r	R -	R 2r	R 2r	R 2r		
54-21402		B -	R -						
10		B 3r	R -						
23		B 7r	R 1r					R -	
39		B -						R -	

TABLE 1. Continued

Band Number	1961 1962	1962 1963	1963 1964	1964 1965
54-21497	B -	R 2r	-	
54-21501	B 3r	R 13r	-	
03	B 6r	R 2r	-	
04	B 4r	R 6r	-	
13	B -	R -		
20	B 2r	R 6r	R -	R 2r
21	B -	R -		
23	B 2r	R -		
24	B -	R -		
27	B -	R -		
29	B -	R 2r	-	
32	B 2r	R 3r	-	
36	B -	R -		
43		B -	- -	R -
44		B 7r	R -	
47		B 2r	- -	R 1r
48		B 5r	R -	
49		B 4r	R 1r	
57		B 6r	R -	
59		B -	R -	
64		B -	- -	R -
65		B 2r	R -	

TABLE 2. Relation between repeating and Returning, consecutive winter seasons.

	1956	1957	1962	1963	Total
Number Banded	51	53	48	38	190
repeated, banding season	22	12	18	20	72
% repeat/banded	43.14%	22.64%	37.50%	55.26%	37.89%
non-repeated, banding season	29	41	30	18	118
% non repeat/banded	56.86%	77.36%	62.50%	44.74%	62.11%
1st Return, consecutive winter	7	4	13	6	30
% Return/banded, 30/190					15.79%
repeat Return	6	2	6	5	19
% repeat Return/repeats, 19/72					26.39%
repeat non-Return	18	8	12	15	53
% repeat non-Return/repeats, 53/72					73.61%
non-repeat Return	1	2	7	1	11
% non-repeat Return/non-repeats, 11/118					9.32%
non-repeat non-Return	26	41	23	17	107
% non-repeat non-Return/non-repeat, 107/118					90.68%
2nd Return, 2nd consecutive winter	3	1	1	0	5
% of 1st Return, 5/30					16.67%
repeat Return	3	1	1	0	5
% repeat Return/repeat after 1st Return, 5/16					31.25%
repeat non-Return	3	1	6	1	11
% repeat non-Return/repeat, 11/16					68.75%
non-repeat Return	0	0	0	0	0
non-repeat non-Return	1	2	6	5	14
% non-repeat non-Return/non-repeats, 14/14					100%
3rd Return, 3rd consecutive winter	2	1	1	0	4
% 2nd Return, 4/5					80.00%
repeat Return	2	0	0	0	2
% repeat Return/repeat after 2nd Return, 2/3					66.67%
repeat non-Return	1	0	0	0	1
% repeat non-Return/repeats, 1/3					33.33%
non-repeat Return	0	1	1	0	2
% non-repeat Return/non-repeat, 2/2					100.00%
non-repeat non-Return	0	0	0	0	0
4th & 5th consecutive Returns	0	1	0	0	1
% 3rd Return, 1/4, 25% of 3rd Returns; 1/1, 100% of 4th Returns					
repeat Return, 1/4, 25%	0	1	0	0	1
repeat non-Return, 3/4, 75%	2	0	1	0	3
Non-consecutive Returns	0	3	0	3	6
		3yr 3mo after B 5yr after 1st R 5yr 9mo after B		2yr after B 2 yr after B 1 yr 11mo after B	
repeat		1		1	
non-repeat		2		2	

TABLE 3. Number of repeats as related to Returns.

Frequency class, no. of repeats.	Sample size (n) no. of repeaters	Observed attribute, no. of Returns (f)	Relative frequency of repeats that Returned (f/n)	in %	95% Confidence Intervals of f Returns in n repeats Lower Limit	Upper limit
0	118	11	.0932	9.32	4.66	15.81
1	20	1	.05	5.00	0.13	24.85
2	15	4	.2667	26.67	7.80	55.14
3	7	2	.2857	28.57	3.67	71.00
4	4	2	.5000	50.00	6.75	93.25
5	9	4	.4444	44.44	13.76	78.84
6	3	2	.6667	66.67	9.43	99.16
7	3	2	.6667	66.67	9.43	99.16
8	2	1	.5000	50.00	1.26	98.74
9	-	-	-	-		
10-12	4	1	.2500	25.00	0.63	80.60
16-Hi	5	0	0	0	0	0
repeat Return	72	19	.2639	26.39	16.41	37.64
All classes	190	30	.1579	15.79	11.11	21.99

TABLE 4a. 2x2 contingency table of 1st Returns, observed values.

Treatment after banding	Observed 1st Return	Observed 1st non-Return	Row Total	
repeating	(a) 19	(b) 53	(a+b) 72	
non-repeating	(c) 11	(d) 107	(c+d) 118	
Column Total	(a+c) 30	(b+d) 160	Grand Total	N 190

TABLE 4b. 1st Returns, expected values.

Treatment after banding	Expected 1st Return	Expected 1st non-Return	Row Total	
repeating	(a) 11.37	(b) 60.63	(a+b) 72	
non-repeating	(c) 18.63	(d) 99.37	(c+d) 118	
Column Total	(a+c) 30	(b+d) 160	Grand Total	N 190

How entries in the expected cells are derived:

(a) 30/190 of 72 = .1579 x 72 = 11.37
(b) 72 - 11.37 = 60.63
(c) 30 - 11.37 = 18.63
(d) 160 - 60.63 = 99.37

TABLE 4c. 2x2 contingency table of 2nd Returns, observed values.

Treatment after banding	Observed 2nd Return	Observed non-Return	Row Total
repeating	(a) 5	(b) 11	(a+b) 16
non-repeating	(c) 0	(d) 14	(c+d) 14
Column Total	(a+c) 5	(b+d) 25	Grand Total N 30

TABLE 4d. 2nd Returns, expected values.

Treatment after banding	Expected 2nd Return	Expected 2nd non-Return	Row Total
repeating	(a) 2.67	(b) 13.33	(a+b) 16
non-repeating	(c) 2.33	(d) 11.67	(c+d) 14
Column Total	(a+c) 5	(b+d) 25	Grand Total N 30

TABLE 5. Survival rates from Returns.

Number of birds Returning, given wintering-over season after banding.

Banding season & No.		Winter after: 1st	2nd	3rd	4th	5th	6th
1955-56	51	7	3	2	0	0	0
1956-57	53	4	1	2	1	1	2
1961-62	48	13	1	1	-	-	-
1962-63	38	6	3	-	-	-	-
Total	190	30	8	5	1	1	2
Adjusted		30	5	4	1	1	2

Survival rates by age group:

Yr 1 to Yr 2	8/30	27%
Yr 2 to Yr 3	5/5	100%
Yr 3 to Yr 4	1/4	25%
Yr 4 to Yr 5	1/1	100%
Yr 5 to Yr 6	2/1	200%
Weighted mean	17/41	41%

TABLE 6. Number of birds expected to survive by year after banding at 41% rate.

Number banded:	Year after banded: 1st	2nd	3rd	4th	5th	6th	7th	8th	9th
50	20	8	3	1	-				
100	41	17	7	3	1	-			
200	82	34	14	6	2	-			
500	205	84	34	14	6	2	-		
1000	410	168	69	28	11	5	2	-	
2000	820	336	138	57	23	9	4	2	-
3000	1230	504	207	85	35	14	6	2	-
4000	1640	672	276	113	46	19	8	3	1

TABLE 7. Probability of surviving and Returning consecutive seasons.

$$P(S \cap R) = P(S)\,P(R) = .41 \times .16 = .07$$

Number Banded	Year after banded: 1st	2nd	3rd	4th
100	7	-		
200	14	1	-	
500	35	2	-	
1000	70	5	-	
2000	140	10	1	-
3000	210	15	1	-
4000	280	20	1	-
5000	350	24	2	-
6000	420	29	2	-

FIGURE 1. Stem-&-Leaf display comparing repeats that did not Return, with repeats that Returned, 1st consecutive season.

Unit: 1 bird per number

	Group A repeat, no Return	no. of repeats DIGIT	Group B repeat, Return	
	1111111111111111111	1	1	
	222(2)2222222	2	2222	
	33333	3	33	
	44	4	44	
	55555	5	(5)555	
	6	6	66	
	7	7	77	
	8	8	8	
		9		
Median = 2 repeats,	10	10		Median = 5 repeats,
value of 53/2 bird		11	11	value of 19/2 bird
or 27th bird from	1212	12		or 10th bird from
each end, (),		13		each end, ().
averaged.		14		
Count top to bottom		15		Count bottom to top
from inside, out.	1616	16		from outside, in.
		17		
		18		
	19	19		
	63	High		
	102	High		
370 repeats, birds	53	Total	19 birds, 88 repeats	

FIGURE 2. Stem-&-Leaf display comparing repeats that Returned with non-repeats that Returned.

Group B repeat-Return birds, each entry as an individual's no. of repeats before the respective Return	no. of Returns	Group C no-repeat-Return birds, one zero per bird
11,877665555443322221	1st	00000000000
35,21,662	2nd	-
39,21	3rd	00
2	4th	
2	5th	
28	Total Returns	13

Total individuals

19	1st R	11
5	2nd R	0
2	3rd R	1
1	4th R	-
1	5th R	-

FIGURE 3. Repeating and non-repeating as related to Returning, consecutive winter seasons.

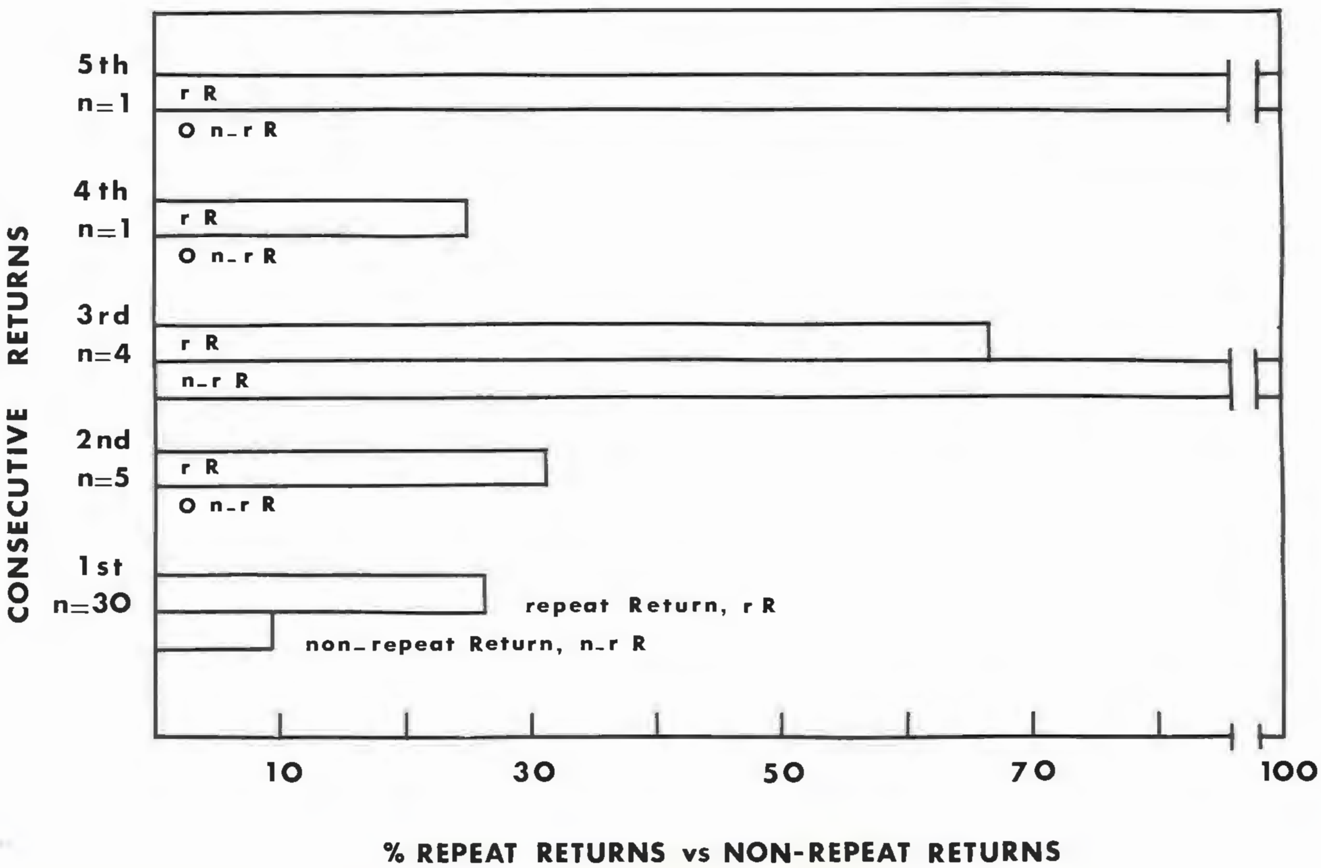

FIGURE 4. Number of repeats as related to Returning. The open dot represents non-repeats that Returned. The calculated Linear Regression Line and its formula are shown.