THE MIGRANT LOONS OF WESTERN PENNSYLVANIA

BY F. W. PRESTON

BENT (1919: 48) says of the Common Loon (*Gavia immer*), "The loons are apparently paired when they arrive on their breeding grounds, and I believe they mate for life." The implication would seem to be that they migrate as mated pairs.

Todd (1940: 32) says, "The loon is a rather solitary bird in our region (Western Pennsylvania), and a number together have a common interest rather than a sociable disposition. In the spring, however, presumably mated pairs may sometimes be encountered and on one occasion (May 1, 1932) Professor Seiple saw as many as twelve together on Conneaut Lake." This might be interpreted to mean that Todd construed Seiple's dozen as comprising six mated pairs, though I do not think Todd so intended it.

However, in conversation, Dr. Parkes of Carnegie Museum expressed the opinion that a considerable proportion of migrant loons may be moving in mated pairs, along with a lesser number of unmated birds. My own observations seemed to lend no support to this view, and on the contrary, tended to the opposite view, that all loons migrate as independent voyageurs, though sometimes assembling into fortuitous flocks of various sizes. It seemed advisable to submit the full evidence to such mathematical treatment as might be helpful on this point.

Material.—Western Pennsylvania from the West Virginia border north for a hundred miles or more, including the Pittsburgh area, contains few bodies of water attractive to loons: it is an upland country, much of it wooded, ranging in elevation from roughly 1,000 to 2,000 feet. None the less, the loons pass over it in some numbers, but they fly high, fast, and apparently silently, and are not often observed. I have seen one or two, traveling singly at a great height. The best opportunity to observe them is when they have alighted on some body of water, which happens frequently enough to give some idea of their behavior. The materials used in the present analysis are five years' observations at Oneida Dam, Butler County, in the years 1949 to 1953, inclusive. Most of the observations are my own, but some are by Mrs. Preston and others.

An account of the water birds of Oneida Dam, including all migrant species, for the first four of these years has been given elsewhere (Preston, in press), and a map of the area is there included. It is shown that in the four years in question, the peak of the loon migration came at April 22, the standard deviation (of the timing) was 11.6 days,

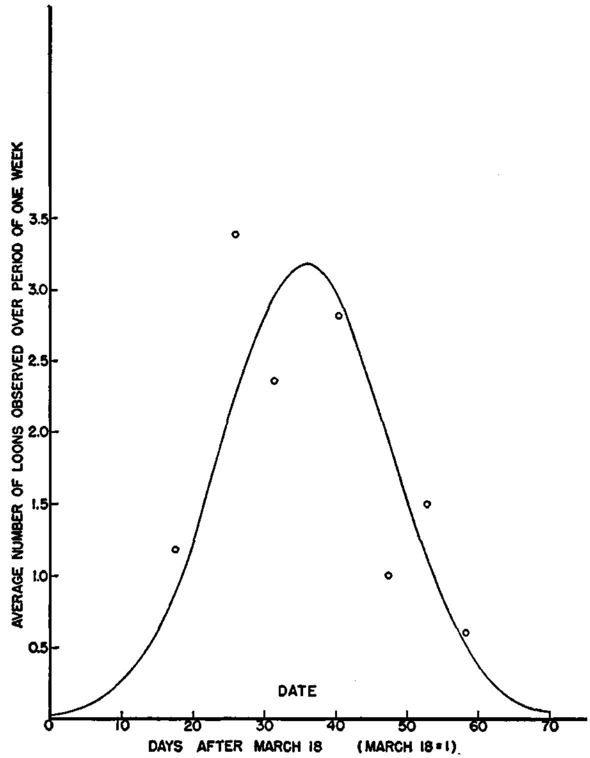


FIGURE 1. Gaussian curve fitted to the loon observations for 1949 through 1952. Vertex is at April 22; standard deviation, 11.6 days.

and the "effective" migration season extends from about April 1 to May 12, a period of six weeks. Figure 1, taken from that paper, shows the nature of the migration as a function of time, i.e., of the "season."

In 1953 a more meticulous watch was kept on the Dam, very few days being missed, and in Table I we report the number of loons seen on each day when a visit was made in the springtime of each of the five years. The 1953 observations add considerably to the total number of visits, and even more to the total number of loons; they also throw some light on the conditions producing good "loon days." But partly because the four years were treated separately in the previous paper and partly because lumping the 1953 observations with the rest might sometimes give undue weight to the behavior found in a single year (1953), a partial separation of the figures will be retained in the present paper.

TABLE I

LOONS SEEN AT ONEIDA DAM BY DATES

		1949	*1950*	*1951*	*1952*	*1953*			*1949*	*1950*	*1951*	*1952*	*1953*
March	18	0				0	April	22					1
	19	0	0		1	0		23		5			1
	20	0			0	0		24					1
	21	0	0	0	0	0		25					1
	22	0		0		0		26				2	
	23				0	0		27	6	1		0	
	24	0	0	0		0		28	3				
	25	0	0	0	0	0		29					0
	26		0	0		0		30					0
	27	0			0	0	May	1	1	0			2
	28	0				1		2					0
	29	0	0		0	1		3			3		1
	30		0	0	0	1		4	0		3		0
	31				0	2		5		0	0		0
April	1	2	1	1		6		6		0	2		0
	2	2			0	9		7					0
	3	3				1		8					0
	4	2				3		9					0
	5	2				1		10					
	6				0	53		11				3	
	7			0	0	0		12			1		
	8					1		13		0	1	0	1
	9	7				2		14			1		
	10	7		0		2		15					
	11		2	0		0		16					
	12		8			1		17					
	13	3	0	0	5	1		18			1		
	14	5	3	4		1		19					
	15		1	2	1	1							
	16	5				0							
	17		2	4		24							
	18			2		12							
	19			3		3							
	20	4	2		0	2							
	21					2							

The question to be decided is, primarily, do the loons migrate over western Pennsylvania in mated pairs? More broadly the question is, do the loons travel independently or in flocks? Here a pair can be considered a special or minimum size of flock. But it should be noted that a "pair" is not necessarily a "mated pair." The birds may not even be of opposite sexes, and since there seems to be nothing in plumage, size, or behavior to distinguish the sexes as we see the birds at Oneida, we have to be prepared for the possibility that two birds seen together may simply be a "random assemblage" of two.

The Odd/Even Ratio.—In the first four years, loons were seen on 41 occasions. On 25 occasions there was an odd number, and on

16 occasions an even number. In 1953, odd numbers were observed on 19 days, even numbers on 9. Now if *all* the birds were traveling in mated pairs, we should always see even numbers of birds. If they were all traveling independently, we ought to see odd numbers and even numbers about equally often. Since odd numbers predominate, we might draw the conclusion that the birds must all be traveling independently. There are, however, two hurdles to be crossed before this conclusion could safely be drawn. The first is an objection raised by Dr. Parkes in conversation. He said, "Let us suppose a reasonable number of birds are traveling independently. Then they ought to show up equally often in odd and in even numbers. Now add as many mated pairs as you like, and it will not change the ratio of odd to even occasions." This would be true if mated pairs never traveled on days when unmated ones didn't. It is not likely that this condition obtains, and if they do sometimes travel without unmated friends, then there will be a tendency for days of even numbers to predominate. Observations on this point can be made only at places where relatively few loons are assembled, places where "blank" days occur in the height of the season, for it is only at such places that adequate opportunities exist for mated pairs to put in an appearance in the complete absence of independently-traveling birds. Oneida meets the requirement, however, and lends no support to the argument.

The next hurdle is different. When a visit is made, in "loon season," and no loons whatever are seen, is the record to be ignored, as being neither odd nor even, or is the observation to be interpreted as showing an even number? For zero is certainly not an odd number, and in some cases is to be construed as even. This question permits us to raise the problem in a more precise form.

If the loons are all traveling independently, and all days are equally "attractive" during the migration season, then they should be distributed among these days in accordance with the terms of a Poisson Series. The probability of seeing none, one, two, three . . . loons will be given by the terms of the series

$$e^{-p}\left(1 + p + \frac{p^2}{2!} + \frac{p^3}{3!} + \text{etc.}\right) \qquad (1)$$

where p is the "average expectation" or "mean," and $p = Q/N$, Q being the total number of loons and N the total number of days "available" to them. Q may be taken as the total number of loons *observed* if we take N to be the total number of days that the observer was present and that were "available" or satisfactory to the loons.

Since the observer may be present at times before and after the main season, and since days very near the beginning and very near the end of the season must necessarily be less attractive or satisfactory to the loons than days near the height of the season, some uncertainty exists as to what is the proper estimate of N. It may even be contended that there is no proper estimate, but we shall for the present assume that there is a "fictive" value of N that can be found by not-too-arbitrary methods, and that it will serve our purpose. The evidence will be given later.

Equation (1) may now be dissected. The probability of our getting an odd number of birds is the sum of the terms

$$e^{-p}\left(p + \frac{p^3}{3!} + \frac{p^5}{5!} + \text{etc.}\right) = e^{-p}\sinh p \qquad (2)$$

while the probability of our getting none, two, four, six . . . birds is

$$e^{-p}\left(1 + \frac{p^2}{2!} + \frac{p^4}{4!} + \text{etc.}\right) = e^{-p}\cosh p \qquad (3)$$

The ratio of odd to even days is under these conditions

$$e^{-p}\sinh p / e^{-p}\cosh p = \tanh p \qquad (4)$$

This assumes we count a "blank" day as an "even" day. If we do not feel sure how many days we ought to treat as blank, on the grounds above outlined, but are sure of the days when at least one loon was observed, then the ratio of odd to even days is

$$\sinh p / (\cosh p - 1) \qquad (5)$$

In the above equations

$\sinh p$ is the "hyperbolic sine" of p, $= (e^p - e^{-p})/2$
$\cosh p$ is the "hyperbolic cosine" of p, $= (e^p + e^{-p})/2$
$\tanh p$ is the "hyperbolic tangent" of p, $= (e^p - e^{-p})/(e^p + e^{-p})$

The numerical values of expressions (4) and (5) are given below for several values of p. They are also graphed in Figure 2.

p (average expectation)	0.5	1.0	1.5	2.0	2.5	3.0
$\tanh p$	0.462	0.762	0.905	0.964	0.987	0.995
$\sinh p / (\cosh p - 1)$	4.1	2.16	1.57	1.31	1.18	1.11

In the first four years, 117 loons were observed on 41 days; that is, at least one loon was present on each of 41 days. The value of p, therefore, cannot exceed 117/41 or 2.85, and will be somewhat less according to the number of blank days we admit, p being defined as

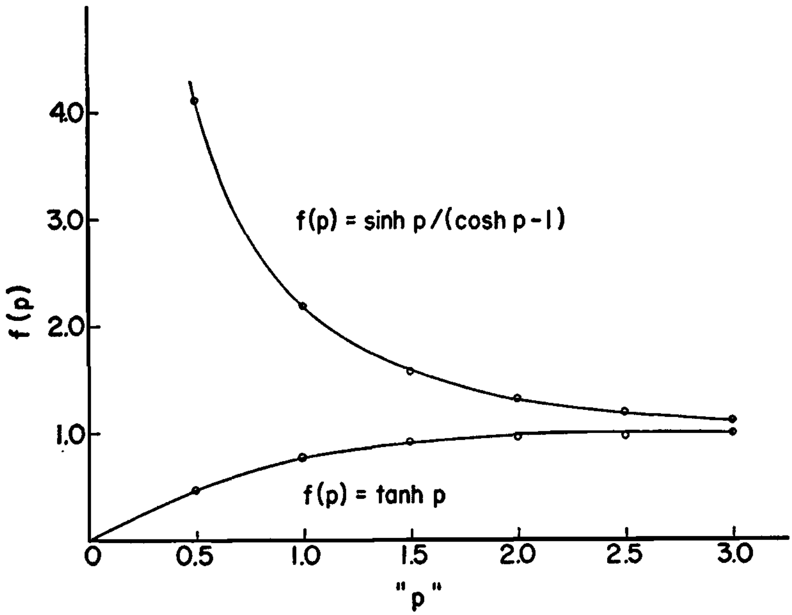


FIGURE 2. The Odd/Even Ratio. Functions tanh p and sinh $p/(\cosh p - 1)$.

117/(41 + number of available but blank days). The ratio of odd to even days was 25/16 = 1.57, which corresponds to a p value of 1.5 loons per day. This means that we could allow many blank days and still be consistent with the hypothesis that all birds are traveling independently.

For the year 1953 the same general picture applies.

"Contagious" Distributions.—If loons fly in pairs, the departure, or arrival, of one loon entails the departure or arrival of another, its mate. This is the mildest form of "contagion." The term is familiar to plant ecologists in dealing with the number of individual plants that occur in a "quadrat." With many species, the individuals are "clumped," so that some quadrats have far more individuals than would be expected by random distribution. On the other hand, many plots are blank or nearly so.

If we assume that the pairs are the real units and that the behavior of a pair does not appreciably affect that of another pair, so that the pairs travel independently, then, subject to the conditions above specified with respect to the available days being intrinsically equal in attractiveness, we shall get a Poisson Distribution if we take the pairs as units. But if the units are really the pairs and we make the mistake of assuming that the individuals are the units, we shall get a different sort of series.

It is frequently stated, and easily proved, that in a Poisson Series "the Variance is equal to the Mean," but in a contagious distribution the Variance exceeds the Mean. ("Mean" is the same thing as "Average Expectation.") By the same procedure it is easily shown that if the true unit is the pair and we mistakenly suppose it is the individual, we shall compute a Variance that is twice the Mean. In fact, more generally, if the true unit is a flock of m individuals and we make the mistake of taking the individual as a unit, we shall compute a Variance that is m times the Mean. (See, for instance, Arley and Buch, 1950.)

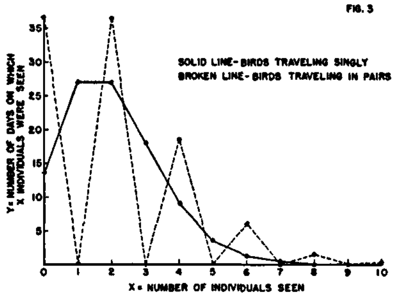
It may therefore be assumed that if we compute the Variance for our actual observations and divide it by the Mean, we shall get an estimate of the average number of birds in a flock. Once more, this depends on our being able to assign a satisfactory "fictive" number of available days in the four-year period, when the observer was, and the loons might perfectly well have been, present. If we take this figure as 45 days, the average expectation or Mean is 2.6, and the Variance is 3.77; so we might make a first estimate that the average size of the flock that acted as a unit was 3.77/2.6 or 1.45. The ratio is not very sensitive to the "fictive" value, and if we take the latter as 55 days (almost certainly a substantial over-estimate) the ratio rises only to 1.57.

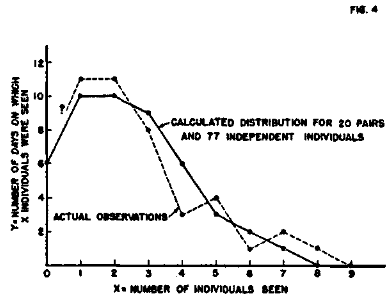
Since this figure is substantially less than 2, it follows that a large proportion of the birds must be flying singly. We know that some are, because we have quite a number of days when a single loon is seen on the Dam. But the computation implies that even when we see more than one, they are often independent events.

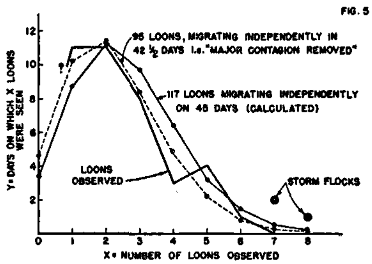
We may now test this assumption. Suppose a substantial number of the birds are traveling in mated pairs, but another substantial proportion are traveling singly or in random aggregates, can the observations at Oneida be fitted to the assumption?

The prospect is not promising, for the assumption that *all* the birds are traveling in pairs would result in a series of peaks on the distribution curve (Figure 3) at the even numbers and a series of zeros on the odd numbers, and any combination of this with a normal Poisson Series (arising from the random distribution of birds that travel as independent individuals) would give a curve with humps at the even values and hollows at the odd ones. However, we may examine briefly the consequences.

Mixtures of Individuals and Pairs.—Let us assume that there are







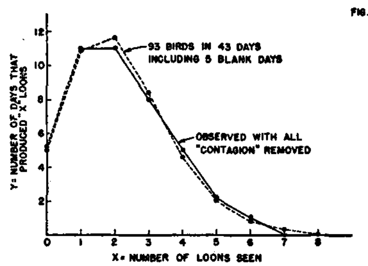


FIGURE 3. Distribution to be expected if 100 birds are traveling singly or in pairs. FIGURE 4. Distribution to be expected if some loons are traveling in pairs and some singly. FIGURE 5. Distribution to be expected if all loons are migrating independently, major contagion removed or not removed. (See text.) FIGURE 6. Distribution to be expected if all loons are migrating independently, both major and minor contagion removed.

m birds per day traveling as independent individuals and n pairs of birds per day, making a total of $m + 2n$ individuals per day. If "contagion" is limited to the existence of mated pairs, the probability of our having 0, 1, 2, 3 . . . individuals contributed by the first group (those traveling as individuals) is given by the terms of the Poisson Series

$$e^{-m}\left(1 + m + \frac{m^2}{2!} + \frac{m^3}{3!} + \text{etc.}\right) \tag{6}$$

Call these terms $M_0\ M_1\ M_2\ M_3$ etc.

The probability of our having 0, 2, 4, 6 . . . individuals contributed by the second group (those traveling in pairs) is given by the terms of the Series

$$e^{-n}\left(1 + n + \frac{n^2}{2!} + \frac{n^3}{3!} + \text{etc.}\right) \tag{7}$$

Call these terms $N_0\ N_1\ N_2\ N_3$ etc.

Now the total number of birds observed is known: call it T. Then $\frac{mT}{m + 2n}$ is the number of birds traveling solitarily and $\frac{nT}{m + 2n}$ is the number of pairs traveling "contagiously." Call these figures T_1 and T_2 respectively. $(T = T_1 + 2T_2)$

Assume that the number of available days is Q, which figure we have to calculate from what follows. Then $m = T_1/Q$ and $n = T_2/Q$.

Then the *probability* of completely blank days is

$$M_0N_0 = e^{-(m + n)} = e^{-(T_1 + T_2)/Q} \tag{8}$$

and the *number* of such days is

$$Q \cdot e^{-(T_1 + T_2)/Q} \tag{9}$$

so that the number of non-blank days is

$$Q\,(1 - e^{-(T_1 + T_2)/Q}) \tag{10}$$

But this number of days is known experimentally: it is simply the number of days on which one or more loons were actually observed. In order to limit ourselves as strictly as possible in the matter of arbitrary constants, let us suppose that the theoretical value must be identical with the observed value.

Then since T, the total number of birds accounted for theoretically must also equal the experimental (observed) total, the transcendental equation (10) can be solved for Q once we assign a value to T_1, the total number of birds traveling solitarily. This simultaneously assigns a value to T_2, and to m and n, though the values of the last two cannot be written down explicitly until Q has been found. Having solved for Q, we obtain m and n, and so obtain all the values M_0, M_1, M_2, M_3 . . . N_0, N_1, N_2, N_3 . . . in equations (6) and (7).

Now if we find, let us say, six birds present on a given day, these six may be (a) six individual birds and no pairs, or (b) four individuals and one pair, or (c) two individual birds and two pairs, or (d) no individual birds and three pairs. The combined probability of all these combinations is obviously

$$M_6N_0 + M_4N_1 + M_2N_2 + M_0N_3 \tag{11}$$

and similarly for any other number of loons we may encounter. The full tabulation is as follows:

Probability of a complete blank (zero birds) is	M_0N_0
Probability of a single bird	M_1N_0
Probability of two birds	$M_2N_0 + M_0N_1$
Probability of three birds	$M_3N_0 + M_1N_1$

Probability of four birds	$M_4N_0 + M_2N_1 + M_0N_2$
Probability of five birds	$M_5N_0 + M_3N_1 + M_1N_2$
Probability of six birds	$M_6N_0 + M_4N_1 + M_2N_2 + M_0N_3$
Probability of seven birds	$M_7N_0 + M_5N_1 + M_3N_2 + M_1N_3$

and so on. The total of all these probabilities, of course, adds up to unity, and if we multiply each probability by Q, the computed number of available days, we get the number of days on which we should theoretically have seen no birds, one, two, three, and so on.

The computations were made, for our four years, with several assumptions as to how the birds might be divided into individuals and pairs. For instance, if we assume that out of our 117 birds, 40 were in pairs and 77 flying individually, $T_1 = 77$, $T_2 = 20$, and $T_1 + T_2 = 97$, while the number of non-blank days was 41, so that our transcendental equation is

$$41 = Q\,(1 - e^{-97/Q}) \tag{12}$$

which we find by trial is satisfied when

$$Q = 47, \tag{13}$$

thus calling for six blank days.

Then

$$\left.\begin{aligned} m &= 77/47 = 1.64 \\ \text{while} \quad n &= 20/47 = 0.426 \end{aligned}\right\} \tag{14}$$

Average Expectation $= m + 2n = 2.49 = 117/47$.

We can now formulate our two Poisson Series (6) and (7) in numerical terms, and find the values of the M's and N's, and from these in turn by the tabulation above, we can calculate all our probabilities and the number of days on which we ought to see none, one, two, three . . . birds. A rough slide-rule calculation comes out as follows, the values being given to the nearest whole day:

Number of loons	0	1	2	3	4	5	6	7	8	Total days
Number of days on which this number should be seen (calc.)	6	10	10	9	6	3	2	1	0	47
Observed number of such days	?	11	11	8	3	4	1	2	1	41 + ?

The agreement is fairly good, slightly better than on the assumption that all birds travel independently, but probably not significantly so. The results are graphed in Figure 4. It is quite obvious, from this and other computations not herein reported, that no assumption we can make as to the proportion of birds that might be traveling in pairs will produce any really great improvement over the assumption that they are all traveling independently. There is *some "contagion,"* but the contagion is not that which arises from traveling in pairs.

The True Nature of the "Contagion."—From the calculations it became clear that the contagion arose almost entirely at the tail end of the distribution; there was one flock of seven birds that stayed for two consecutive days and hence was counted twice, and there was one flock of eight birds that stayed only one day. Removing these birds from the list reduces the total number of loons by 22, from 117 to 95, and the total number of non-blank days by 3, from 41 to 38. Solving for Q in the equation $Q(1 - e^{-95/Q}) = 38$ gives $Q = 42\frac{1}{2}$ days, and a comparison of the expected and observed results now reads:

Number of loons	0	1	2	3	4	5	6	7	8	Total days
Number of days on which this number should be seen (calc.)	4.6	10.2	11.4	8.4	4.7	2.1	0.8	0.3	0.1	38+4.6
Observed number of such days	?	11	11	8	3	4	1	0	0	38+ ?

The fit is now becoming very good. We have removed the *major* source of the contagion. See Figure 5.

Let us now make one other minor change: let us suppose that on two days when I saw five loons I ought to have seen only four. Then we have reduced the total number of loons to 93, and the number of non-blank days stays at 38. Proceeding as before we find $Q = 43$ days and our results are as follows:

Number of loons	0	1	2	3	4	5	6	7	8
Number of days on which this number should be seen (calc.)	4.96	10.71	11.59	8.35	4.51	1.95	0.70	0.22	0.06
Observed number of such days	?	11	11	8	5	2	1	0	0

The agreement is now virtually perfect. We have removed the *minor* source of the contagion. Figure 6 shows the comparison graphically.

The Variance and Mean of the Amended Observations.—With only the major contagions removed, the Variance is 2.32 as against a Mean of 2.23. With both major and minor contagions removed the Variance is 2.16 and the Mean also is 2.16, so that the amended observed series is in this respect a perfect Poisson Series to three significant figures.

The Odd/Even Ratio.—The expected odd to even ratio from the formula $\sinh 2.16/(\cosh 2.16 - 1)$ is approximately 1.26. The observed ratio for the amended series (both contagions removed) is 1.24.

Biological Conclusion.—Of the loons seen in the four years 1949–1952 inclusive, none were in pairs, approximately 80 per cent were in random assemblages, and 20 per cent in organized flocks.

Caveat.—The one point that would appear to be inadequately established in the foregoing is that it is legitimate to establish a "fictive" number of available days. If the loon season began sharply on a definite date (say April 1) and finished equally sharply on another date (say May 12), and all intermediate days were equally attractive or suitable for loon migration, then the Poisson Series ought to hold exactly, and the number of days (Q) is known without computation. It is simply the number of days on which visits were made. In the absence of any proof as to how legitimate the fictive method really is, we must assume that at best it can be only approximate, and that its almost exact fit is partly accidental. None the less, no modification that I can foresee is likely to increase the probability that the loons at Oneida Dam are in mated pairs on spring migration.

The Spring Migration of 1953.—The conclusions reached in respect of the four years 1949 to 1952 receive some confirmation from the figures for 1953, which were obtained after the analysis of that four-year period was largely completed, and hence are not included with them. In 1953 we visited Oneida every day from March 13 to May 9, except April 26, 27, and 28. No loons were seen before March 28, and none were seen after May 3, except that on one visit beyond the season, viz. May 13, one belated loon was seen. There were accordingly 40 days on which visits were made in what may roughly be called the loon season, which in previous years had covered essentially the same period. If we arbitrarily decide that the season terminated on May 4 this year, the number of visits "in season" was 35. In this period 117 loon-days were accumulated, the distribution of them among the various days being as follows:

Number of loons seen	0	1	2	3	4	5	6	7	8	9	12	24	53
Number of days on which this number was seen	12	15	6	2	0	0	1	0	0	1	1	1	1

The observations fall naturally into two groups: those days on which small numbers of loons were seen (0 to 4 or 5 loons) and those on which larger numbers were seen. In the first group there are 33 loons spread over 35 days. These loons behaved as if moving independently. However, there were also a few loons acting independently on days when larger numbers showed up. Thus there were really more than 33 "independent" loons and slightly more than 35 days on which they were observed (counting blank days).

Field notes report, as regards the assembly of 53: "27 in one flock, 20 in another, 3 in a third, and 3 separated individuals," and as regards the assembly of 24: "one flock of 11, one of 9, one of 2, and two singletons." As regards the flock of 6, the field notes say simply, "They were not in pairs," but do not specify whether there was any apparent "clumping."

It is not practicable to deal at all rigorously with this information, but a first approximation may be made by assuming that on days when more than five birds were seen, *all* these birds were in flocks, and subject to "contagion," while the rest, 33 birds in all, were free from it. Assuming further that the 35 days on which these 33 birds were observed was a fair, but rough, estimate of the available "equivalent" days for them to be seen, the "average expectation" is 33/35 = 0.945. The Poisson Series is then as follows:

Birds seen	0	1	2	3	4	5	Total days
Days (calculated)	13.6	12.8	6.1	1.9	0.4	0.1	34.9
Days (observed)	12	15	6	2	0	0	35

The agreement is sufficiently good and would probably be even a little better if certain individual birds had not stayed around for more than one day. It seems probable that, in general, a single bird may stay more than one day, but if there are several birds and one gets the notion it would like to resume its journey, the contagion spreads to all the rest, so that sizeable flocks have little chance of remaining as long as twenty-four hours. Trautman (1940: 100) has in fact described exactly how the excitement is spread from a single bird to a whole flock. He says that a single bird rises from the water and flies at a low altitude, calling persistently, and one after another of the remaining birds join it and circle until an altitude of more than two hundred feet is reached, after which they resume migration. In his description there is no evidence of the birds acting in pairs, but his observations refer to the fall migration.

The "Storm Flocks."—The big flocks, or aggregates of flocks, at Oneida comprising 53 and 24 birds were forced down by bad weather; the flock of 12 probably was. The group of 6 was, and the group of 9 may have been. "Bad weather" here means heavy rain and mist, or a thunderstorm front coming in.

In no case is there any evidence that the birds are traveling in pairs. They seem to be traveling either singly or in flocks of some size. Mated pairs may, of course, be present in such flocks, but there is no evidence for it.

Few people, apparently, have seen 53 loons at once, and to see so many on such a small lake as Oneida Dam (approximately one mile long and a quarter mile wide) must be a still rarer event. It is clear that loons sometimes fly over us in considerable numbers but do not normally stop off. They go straight through unless forced down by weather. The same thing has been observed to be true at Oneida Dam with many other species: wild swans, Horned Grebes, Ruddy Ducks, Old Squaws, and so on, which are seen only in very small numbers and very rarely, except when a storm forces them down, whereon they may be seen in dozens or even hundreds.

Trautman (1940: 100) observed essentially the same phenomenon at Buckeye Lake, Ohio. "More than half the transients observed were noted when cloudy and stormy conditions prevailed. The largest flock, of apparently one hundred and fifty birds, were observed to approach and light upon the lake during a severe wind and rainstorm . . . Nov. 2, 1927."

It is tolerably clear, therefore, that our loons may properly be divided into two categories: those that arrive in any sort of weather, more or less normal weather as a rule, and those that alight to avoid flying through severe fog and rain. The former are flying as individuals or strictly random assemblages and appear on the Dam only in very modest numbers, up to about half a dozen at any one time. The latter, the storm birds, may appear in large numbers, and their arrivals must be treated as freak or exceptional events. Such events will not fit into any mathematical pattern until a very large number of such events has been observed, and this would require perhaps a century of watching. They are legitimately removed from consideration while we investigate the pattern of the normal events.

The Control Chart Technique.—In industry there has developed in the last decade or two, a widespread use of the "Control Chart," which was introduced by Shewart (1931). It depends on the same basic statistical concepts but is operated in a routine fashion which is superficially quite different from the methods commonly used by biologists. Accordingly, I reported to one of my associates, Dr. L. G. Ghering, who has much experience in working with these charts, that over a period of some weeks, a number of "defects" had occurred in an industrial operation, and would he set up a control chart and see what had been going on? The "defects" were actually the number of loons per day at Oneida Dam, but he did not know that, and the sequence of figures was compiled by taking the data from March 28 to May 12, inclusive, for all five years combined. Thus a sequence might be April 1, 1949; April 1, 1950; April 1, 1951; April 1, 1953; April 2, 1949; April 2, 1952; April 2, 1953; and so on. The date was not provided, only the sequence of observations. Zeros (blanks) were reported in their proper position in the sequence, but nothing was reported about days on which no visit was made.

When the control chart was prepared, it rejected as abnormal all observations of more than 7 individuals, that is, those days on which 9, 53, 8, 24, and 12 loons were observed, a total of five observations out of ninety-seven. Days with seven individuals were borderline cases. In industrial practice such events are due to "assignable causes": if you go into the factory, you will find that something has "gone wrong," and you will be able to find what it is. In our case we go into the field, and find what it is, viz., a storm. The other observations are regarded, in industrial operation, as the "normal" day-to-day variations, due to many causes, which are not worth tracking down or incapable of being tracked down.

Thus, the Control Chart Technique agrees with our own investigations.

The Validity of the "Fictive" Number of Available Days.—There are some days, those outside the loon season, for instance, when it is quite unlikely that we shall see a loon at all, and there may be days within the loon season which for some meteorological reason are unlikely to produce a loon, just as there are occasional days that produce an unreasonably large number of loons. However, during the height of the season we might expect that most days are suitable, perhaps roughly equally suitable. The crest of the Gaussian Curve, the height of migration, is (for the first four years) at April 22. Let us assume that this is true enough for the whole five-year period, and accordingly let us take the week ahead of April 22 and the week that follows it, as the period in which all days might be expected to be equally suitable for migration. In the five-year period twenty-six visits were made to Oneida Dam in these two weeks (the period from April 15 to April 28, inclusive), and a total of 55 loons was seen, excluding those that appeared in numbers exceeding seven on one day. The average expectation is accordingly 55/26 = 2.12, and we can compute their apportioning among the twenty-six days on the assumption that it was random.

Number of loons seen	0	1	2	3	4	5	>5
Calculated number of days	3.1	6.6	7.0	4.9	2.6	1.1	0.7
Observed number of days	3	8	7	3	2	2	1*

* Observed number of loons was 6.

Clearly the agreement is good (the variance is about 2.5 instead of the exact value 2.12), and we are justified in assuming that "normal" loons, those that arrive in the absence of storms, are random assemblages.

Note that in this calculation we have not allowed ourselves any leeway whatever in the way of adjusting the "blank" days. Our computation is based on the actual number of visits, including the unproductive ones, and the actual count of loons. We may, therefore, feel some confidence that we reached the right conclusion in the more general case, the whole of the loon season, in spite of the fact that we had to estimate the number of genuinely blank days. This "estimate" was made, it will be recalled, not arbitrarily, but by a rigorous mathematical treatment of the days that were *not* blank, and it appears that we were not far wrong.

In conversation, Dr. Parkes commented that the question whether loons are paired on migration is a biological rather than a mathematical matter, and that it ought to be capable of being decided on that basis. From the field evidence as we see it at Oneida Dam, it would not have occurred to me to suppose that any of them were in mated pairs. It is only the comments in the literature, by Bent, Todd, and others, that raise the question. Trautman, in his work on the birds of Buckeye Lake, gives no indication of suspecting that the loons there were mated pairs, and in a private communication (1954) he writes as follows:

"I have no recollection of having seen Loons obviously paired during actual migration, in either fall or spring. On the whole, loons did more calling in spring than in fall at Buckeye Lake but they never conspicuously associated in pairs. This was likewise true for southern Michigan immediately south of their normal breeding grounds. When the loons arrived on their breeding grounds in Michigan, they did much calling and flying from one lake to another. I have always believed that the calling birds were looking for mates and that when a lake and mate were chosen the birds thereafter occurred in pairs. . . . It is my belief that if Loons do pair during migration the pair are not attentive to each other as are such species as the Black Duck, and that pairing as such is infrequent or sporadic until the birds reach the breeding grounds."

Dr. Gudmundsson of Reykjavik, Iceland, tells me that no lake, even quite a large one, contains more than one pair of breeding loons: each pair demands a lake to itself, and other observers have told me the same thing. On this basis, loons ought to run short of lakes long before they run short of food. Dr. Parkes comments that there may be an abnormally large pool of non-breeding birds in this species, and that the presence of great numbers of loons on a single lake in Manitoba in the breeding season seems to confirm this. (Rand, 1948).

I should like to acknowledge my indebtedness to Dr. R. C. F. Bartels of the University of Michigan for looking over this paper and for supplying the reference to Arley and Buch (1950). His help has

permitted a substantial condensation of the mathematical treatment of the subject.

Conclusion.—There is no evidence that the loons we normally see in central western Pennsylvania ever travel in mated pairs on spring migration. If mated pairs fly over us, they either never stop off, or their identity is lost in the large flocks that we see only very occasionally. There is not enough evidence to disprove their existence entirely, but there is at present no evidence whatever of their existence in our region.

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