The Moonlight Effect on Rat Breeding

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THE OBJECT of this note is to correct an error which appeared in an earlier paper *Breeding rhythms of Selangor Rodents* (Harrison 1952).

In that paper the variation in pregnancy rate of forest species was discussed. A pronounced bimonthly rhythm was observed, which seemed to fit in a little too closely with the lunar month to be explained wholly by the effect of gestation and delayed fertilisation or implantation of embryos. To explain this correspondence a moonlight effect was postulated, namely a tendency for conceptions to be more frequent at some parts of the lunar month than at others. In order to test this, records of pregnancies of trapped rats were examined to see if young or old embryos were more frequent at one part of the month than at another. As a simple criterion of age, litters were classed as "young" or "old" according to whether the average weight of the embryos was less than or greater than the median weight of all embryos of that species.

An inspection of Table 4 (p. 120) of that paper shows that "young" litters were in fact more frequent in the early parts of the lunar months and that "old" litters were more frequent in the later parts, considering those species for which enough records were available. Since the gestation period of these rats is of the order of 20 days this is what would be expected if there were a greater probability of conception during the early part of the lunar month: that there should be an excess of young litters during the early part of the month and a corresponding excess of old litters some 10 days later. The question which arose was whether the observed difference was due to the supposed moonlight effect or due to chance fluctuations in numbers.

The test used was, quite legitimately, a chi-squared test, but the result obtained, 16·37, was misinterpreted, since the table of values was entered with 5 degrees of freedom, giving a probability of such a value of less than 0·01, instead of with 11 degrees of which gives a probability of only 0·13. I am indebted to Dr. W. van der Bijl of the Royal Netherlands Meteorological Institute, for pointing out the error, and also for suggesting the more sensitive test used below.

The chi-squared test does not, in fact, give a significant result. That does not prove that the suggested relationship is not true. It shows merely that, with the particular test used, the effect is indistinguishable from a chance variation of numbers. A more sensitive test is needed, such as is used below.

Before using the more sensitive test, however, the opportunity has been taken of bringing the information up-to-date by including pregnancies observed up to the end of 1952 (Table 1). Since 1952 the collecting method has been changed, and it was thought advisable to treat the figures obtained before and after the change separately. The condition that no longer applies is that collections shall be equally likely from all parts of the lunar month.

TABLE 1

Numbers of "young" and "old" litters consolidated for each five-day period of the lunar months (New Moon = day 1) during the years 1948–1952 for rats of the following species from forest areas in Selangor.

Day of lunar month ..	1–5	6–10	11–15	16–20	21–25	26–30
Rattus mülleri						
Old	3	1	3	0	4	3
Young	3	0	2	4	1	4
Rattus sabanus						
Old	3	4	3	2	7·5	7
Young	4	8	3	6	1·5	4
Rattus rattus jalorensis						
Old	4	1	1	3·5	5	4
Young	3	0	7	1·5	5	2
Rattus whiteheadi						
Old	1·9	5·7	4	4	4	8·9
Young	5·1	6·3	7	3	2	5·1
Rattus rajah						
Old	1·5	3	2	1	4	2
Young	1·5	1	4	2	2	3
Total all species						
Old	13·4	14·7	13	10·5	24·5	24·9
Young	16·6	15·3	23	16·5	11·5	18·1
All ages	30	30	36	27	36	43

The hypothesis to be tested is that there is a tendency for there to be an excess of "young" litters in one part of the lunar months, with a corresponding excess of "old" litters some ten days later, and that the same rhythm should appear in each species. If this is so, then the numbers of "young" litters for each species should be correlated with the numbers of "old" litters ten days later for the same species and all other species. That this is true is shown in Table 2 where the twenty-five correlation coefficients obtained are set out. If there were no such correlation, then the values obtained should be distributed at random about zero. Their mean value, however, is 0·222, and the test of significance is to decide the probability that such a value could occur in a random population.

TABLE 2

Correlation coefficients between the numbers of "young" litters by five-day periods (Table 1) and the numbers of "old" litters for periods ten days later for each species and between each pair of species.

Species	*mülleri*	*sabanus*	*Rattus jalorensis*	*whiteheadi*	*rajah*
R. mülleri ..	0·271	0·559	–0·449	0·716	0·452
R. sabanus ..	–0·658	–0·176	–0·037	0·487	–0·433
R. r. jalorensis ..	0·803	0·521	0·418	–0·500	0·646
R. whiteheadi ..	–0·215	0·100	–0·039	–0·093	0·643
R. rajah ..	0·491	0·813	0·260	0·045	0·948

Mean value = 0·222.

If the values of the correlation coefficient (r) are transformed into values of z according to the relation.

$$z = \tfrac{1}{2} \log (1+r) - \log (1-r)$$

then z is distributed normally with variance $1/(n-1)$ (where n = degrees of freedom). This relationship is tabulated by Fisher and Yates (1943) and using their table we obtain

$z = 0{\cdot}291$, standard deviation = 0·116.

The probability of obtaining such a deviation from zero by chance is 0·012, and the probability of getting such a *positive* correlation is 0·006. Clearly there is a significant correlation between the numbers of "young" litters and the numbers of "old" litters ten days later of each species.

By our definition of "young" and "old", however, any variation in the number of young litters should be accompanied by a similar variation in the number of old ones some ten days later, and thus fluctuations in numbers which were not related to the lunar month would contribute to a positive correlation. The effect of such fluctuations is partly eliminated by the consolidation of results over a period of

about sixty lunar months, but it is important to show that variations do occur in all species at the same time. This has been done already to a certain extent, since twenty of the twenty-five coefficients are correlations between different species. If we consider only these correlations between different species we obtain average correlation of 0·209, with a probability of 0·026; a value still significant. As a confirmation, however, we may take the correlations between the numbers of young litters in different species for corresponding periods, as set out in Table 3, and similarly those between numbers of old litters for corresponding periods (Table 4).

TABLE 3

Correlation coefficients between the numbers of "young" litters for different species at corresponding periods.

	Rattus			
	rajah	*whiteheadi*	*jalorensis*	*sabanus*
R. mülleri ..	0·339	−0·179	−0·056	−0·152
R. sabanus ..	−0·534	0·334	−0·834	—
R. r. jalorensis ..	0·717	0·046	—	—
R. whiteheadi ..	0·302	—	—	—

Mean value = −0·0017.

TABLE 4

Correlation coefficients between the numbers of "old" litters for different species at corresponding periods.

	Rattus			
	rajah	*whiteheadi*	*jalorensis*	*sabanus*
R. mülleri ..	0·490	−0·023	0·381	0·734
R. sabanus ..	0·813	0·628	0·577	—
R. r. jalorensis ..	0·096	−0·049	—	—
R. whiteheadi ..	0·127	—	—	—

Mean value = 0·378.

In fact the average correlation coefficient for the "young" litters is very close to zero, and offers no evidence of moonlight effect. The average coefficient for the "old" litters, however, is 0·378, with a probability only 0·006 that it could have occurred by chance.

The question immediately arises whether the lack of correlation for the young litters disproves the moonlight effect. A further scrutiny reveals that almost the whole of the negative element in the table is caused by the single item of 8 "young" litters of *Rattus sabanus* during the second five-day period. If this figure has been say zero then the correlation would have been significant. Furthermore if the two Tables 3 and 4 are treated as a single calculation, the average coefficient

between litters of the same age in corresponding periods is 0·190 with a probability of 0·046, which is within the conventional level of significance.

Summary

This paper corrects an error in an earlier paper: "Breeding rhythms of Selangor Rodents". In that paper a moonlight effect was postulated to explain certain rhythms. It was suggested that conceptions are more frequent at some part of the lunar month than at others, and figures were quoted in evidence of that.

The test of significance of those figures was, however, incorrectly applied, and did not in fact prove the case. Here the figures are brought up-to-date and a different test of significance applied. The result is good evidence for the existence of such a "moonlight effect."

References

FISHER, R. A. & YATES, F., 1943. *Statistical tables for Biological Agricultural and Medical Research*, London. Oliver & Boyd.

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