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MODELING OF THE POPULATION CYCLES OF TWO RODENTS IN SENEGAL

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ABSTRACT

Models of adaptive strategy to periods of decreasing populations in two rodents in Senegal are given. Actual densities of *Mastomys erythroleucus* and *Taterillus gracilis* are compared mathematically to observed densities. Differences in various ecological parameters of the two species account for their respective adaptive success during periods of low population densities.

INTRODUCTION

The two principal species of rodents—*Mastomys erythroleucus* (Temminck) (Rodentia, Muridae) and *Taterillus gracilis* Thomas (Rodentia, Gerbillidae)—present after the population outbreak of 1975–1976 in the Bandia region of Senegal (14°37′N, 17°01′W), were studied from November 1975 to August 1977. This study particularly involved the large population decrease after the 1975–1976 outbreak. Results are given for the different habitats together—a dry deciduous woodland, some areas of it cut for charcoal production and adjacent areas under cultivation. Different soils are present in Bandia, but all the areas included in this study are on tropical lateritic soils. A further description of the area was presented by Hubert (1977).

METHODS

A large number of animals (more than 1,500 individuals) were caught in snap traps (60 traps during four nights/week in four different habitats) and in 500-m-long lines consisting of 50 livetraps of iron wire (type Manufrance) placed every 10 m. Specimens were autopsied to determine their sexual activity (particularly the number of young in the litter of the females, which varies during the breeding period increasing at first and then decreasing, Table 1). The eye lenses were taken and dried for weighing to determine the age of the individuals collected, by comparison with a diagram established from rodents in captivity (Hubert and Adam, 1975). Thus the approximate dates of birth of each generation are known.

From August 1976, an area of 600 m by 1,000 m was trapped twice each month with 160 traps in rotation and two plots of 4 ha each were trapped every 1.5 months by mark-and-release method, with a 10 m by 10 m grid of 441 live traps of iron wire (type Manufrance). The first trapping allowed determination of the density by CMR method during 10 days. The subsequent trapping (five nights every 1.5 months) allowed the monitoring of the marked population, estimation of the densities, and the distinction between migrations and mortality. Thus a monthly death rate was estimated for different periods; it varied according to the density and to possible epizootic disease being present. The death rate is calculated by the difference between the "load of living animals on the area" at one trapping period and at the following one, that is, the number of the formerly marked animals increased by the newly marked, which will be recaptured later and an average number of "residents" animals representative of the animals crossing the area during the trapping period. This loss could be interpreted as the death rate for a large enough area (where the number of entering rodents is equivalent to the departures) and when the calculation is made with the overall data for different environments taken together. A disease could have occurred from October to December 1976; in fact, a virus ("Bandia" virus, isolated from ticks and one *Mastomys* 10 years ago) was discovered again in January 1977 in four species present in Bandia, after a large population decrease. Its lethal effect has been demonstrated in the laboratory on *Mastomys erythroleucus* by the death of all the young in 10 days. Experiments are in progress for the other species.

A mathematical formula has been adjusted for modeling the population cycle of rodents in terms of the following data, that is, number of young in each litter, mean date of birth of each generation, and monthly death rate for each period. Terms for the formula are as follows: P(t), the population at time t (in days); P_o, the population at time t = o; M, the monthly death rate ($O \leq M \leq 1$); $\bar{n}i$, the average number of young for the i^{th} litter; Ti, the date (in days) of the i^{th} litter. The sex ratio is supposed to be 1.0.

For *Mastomys erythroleucus*, a Hewlett Packard HP 65 computer was employed, using the formula:

$$P(t) = P_0 10^{\frac{t}{30}\log(1\text{-}M)} + \frac{P_0 \bar{n}_1 10^{\frac{T_1}{30}\log(1\text{-}M)}}{2} \cdot 10^{\frac{t\text{-}T_1}{30}\log(1\text{-}M)}$$

$$+ \frac{P_0 \bar{n}_2 10^{\frac{T_2}{30}\log(1\text{-}M)}}{2} \cdot 10^{\frac{t\text{-}T_2}{30}\log(1\text{-}M)}$$

$$+ \frac{P_0 \bar{n}_3 10^{\frac{T_3}{30}\log(1\text{-}M)}}{2} \cdot 10^{\frac{t\text{-}T_3}{30}\log(1\text{-}M)}$$

$$+ \frac{\bar{n}_4}{2}\left[P_0 10^{\frac{T_4}{30}\log(1\text{-}M)} + \frac{P_0 \bar{n}_1 10^{\frac{T_4\text{-}T_1}{30}\log(1\text{-}M)}}{2}\right] \cdot 10^{\frac{t\text{-}T_4}{30}\log(1\text{-}M)}$$

The formula is not simplified, as it was used for the programming of the HP 65. The evolution of the different generations is given by the same program, where $\bar{n}_2 = \bar{n}_3 = \bar{n}_4 = 0$, and so on.

For *Taterillus gracilis*, it is not possible to use the same program because too many generations occur in the same year (nine from August 1975 to August 1976). In this case we used the following formula (example from May 1975 to August 1976):

$$P(t) = P_0F + \frac{\bar{n}_1}{2} P_{06}F + \frac{\bar{n}_2}{2}(P_{06} + P_{03})\,F + \frac{\bar{n}_3}{2} P_0F$$

$$+ \frac{\bar{n}_4}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right)\cdot F + \frac{\bar{n}_5}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right)\cdot F$$

$$+ \frac{\bar{n}_6}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right)\cdot F + \frac{\bar{n}_7}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right)\cdot F$$

$$+ \frac{\bar{n}_8}{2}\left[P_0 + \frac{\bar{n}_1}{2} P_{06} + \frac{\bar{n}_2}{2}(P_{06} + P_{03})\right]\cdot F$$

$$+ \frac{\bar{n}_9}{2}\left[P_0 + \frac{\bar{n}_1}{2} P + \frac{\bar{n}_2}{2}(P_{06} + P_{03}) + \frac{\bar{n}_3}{2} P_0\right]\cdot F$$

$$+ \frac{\bar{n}_{10}}{2}\left[P_0 + \frac{\bar{n}_1}{2} P_{06} + \frac{\bar{n}_2}{2}(P_{06} + P_{03})\right.$$

$$+ \frac{\bar{n}_3}{2} P_0 + \frac{\bar{n}_4}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right) + \frac{\bar{n}_5}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right)$$

$$\left. + \frac{\bar{n}_6}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right) + \frac{\bar{n}_7}{2}\left(P_0 + \frac{\bar{n}_1}{2} P_{06}\right)\right]\cdot F$$

where: $F = 10^{\frac{t}{30}\log(1\text{-}M)}$

Table 1.—*The main reproductive data for* Mastomys erythroleucus *and* Taterillus gracilis *in the Bandia area during the 1975–1976 and the 1976–1977 breeding periods.*

Species	Approximate date of each generation	Average number of young per litter	Participation of young animals in breeding
Mastomys erythroleucus	1 November 1975	8	–
	1 December 1975	13	–
	12 January 1976	13	–
	28 February 1976	10	+
	1 October 1976	8	–
	1 November 1976	10	–
	1 December 1976	13	–
Taterillus gracilis	10 May 1975	3	–
	20 August 1975	3	–
	15 September 1975	4	–
	1 November 1975	4	–
	5 December 1975	5	–
	30 December 1975	5	–
	25 January 1976	5	–
	25 February 1976	3	–
	25 March 1976	3	–
	5 May 1976	1	+
	20 August 1976	3	–
	25 September 1976	4	–
	25 October 1976	5	–
	25 November 1976	5	–
	20 December 1976	5	–
	20 January 1977	5	–
	30 March 1977	3	+

P_{06} is the number of animals older than 6 months in P_0; P_{03} is the number of animals between 3 and 6 months old in P_0. We know $P(464) = 6$; a sample of *Taterillus* caught at t = o gave the population structure (dry crystalline lens weight), so we know also $P_{06} = f(P_0)$ and $P_{03} = f(P_0)$ and now we can compute P_0; P_0 known, we can compute P(t) from t = 0 to 464 days. The observed density (by CMR method) of August 1976 is used as the basis of all the calculation for the two species.

RESULTS

The two graphs (Figs. 1 and 2) present the following data: The total fluctuations in the number of animals present per hectare at time t; the trapping population at time t, consisting of adults and recently weaned young; the appearance and growth of each litter until the disappearance of all its individuals; the ratio of each age group in the population at time t.

It is easy to see that if the actual densities of the two populations are now equivalent and close to the observed densities, they did not have the same previous development.

Mastomys erythroleucus accounted for a large portion of the population outbreak of 1975–1976, and its densities were very high during the last year. The possible occurrence of an epizootic disease (or

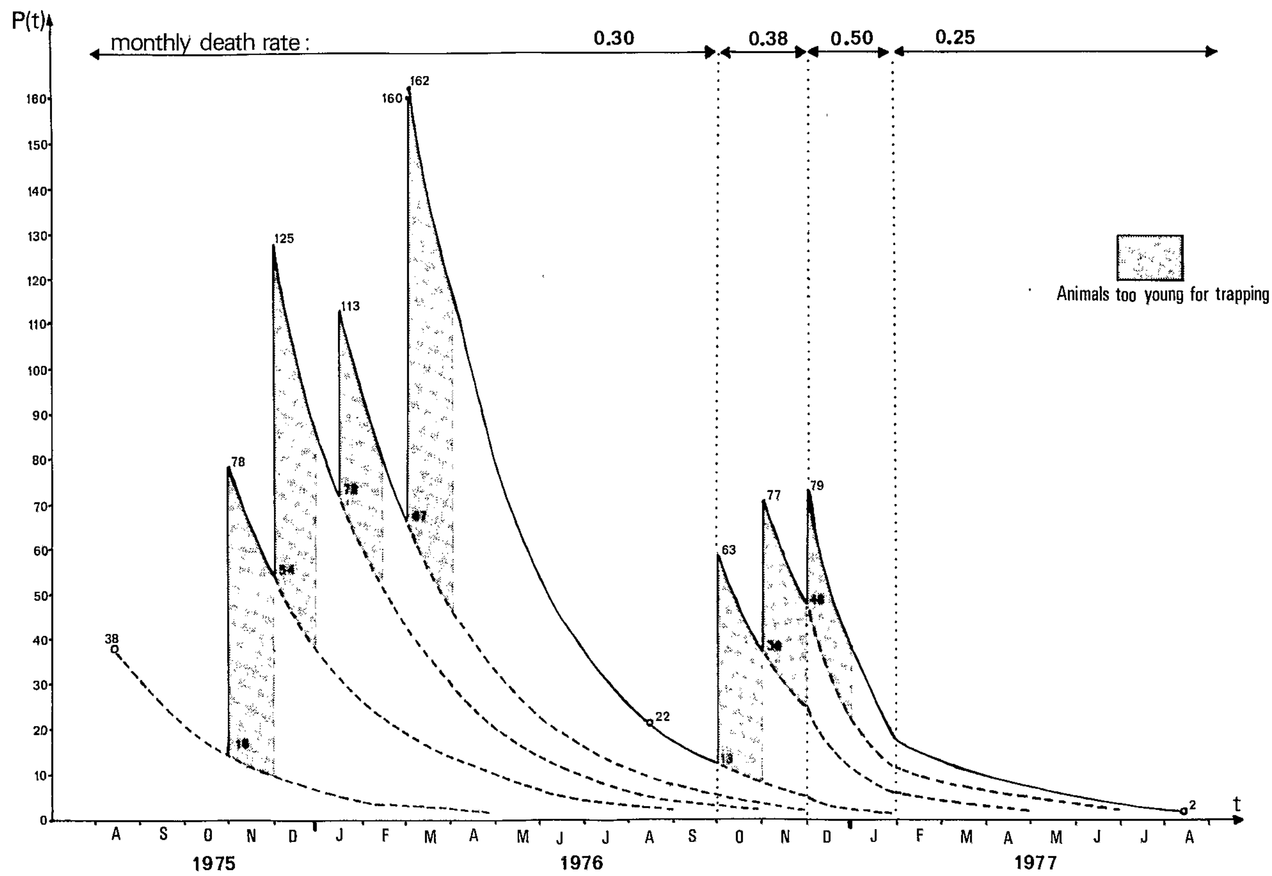

Fig. 1.—Fluctuations in the population level of *Mastomys erythroleucus* on 1 ha near Bandia, Senegal.

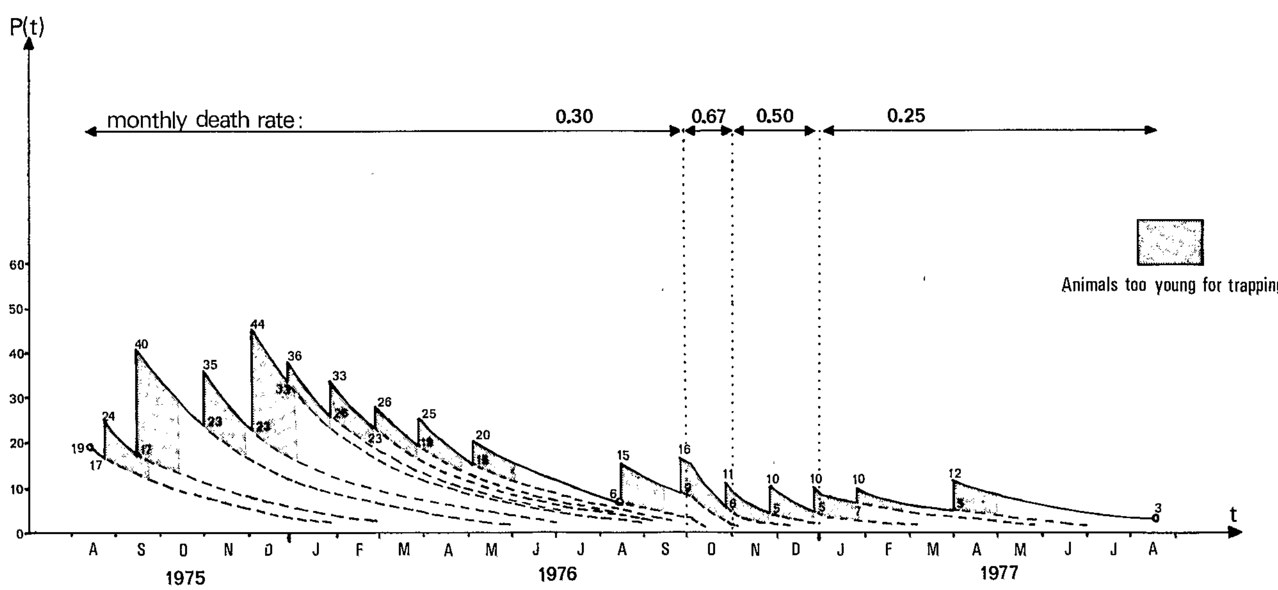

Fig. 2.—Fluctuations in the population level of *Taterillus gracilis* on 1 ha near Bandia, Senegal.

a different factor increasing the death rate) reduced the population considerably to the actual rate in spite of large reproduction. Mortality of the adults was high, and that of the young was such that the first litters, which had bred at the end of the breeding period in 1975–1976, could not do so in 1976–1977.

Although the densities of *Taterillus gracilis* were relatively high in 1975–1976, there was no population outbreak of this species. Densities were almost unchanged and less subject to variations during that year because of a longer breeding period and a higher individual survival rate. However, the *Taterillus* population was also affected by the disease, as the monthly death rate increased considerably and the population remained in the fields only because of the continuation of the breeding period late in the year.

DISCUSSION

Once more the difference of adaptative strategy appeared between *Mastomys* and *Taterillus* populations as discussed below.

Mastomys erythroleucus.—This species has a short breeding period, but with large litters (eight to 13 young per litter), allowing the population to reach a very high level. This large production of young animals permits colonization of new environments, as described by Hubert (1977). They also possess resistance to various disasters (drought, diseases) and the ability to exploit the environment when the production of young is highest, as in the beginning of the dry season. These young animals supply the parental generation for the next year.

Taterillus gracilis.—The breeding period of this species continues for a longer time; it begins earlier in the wet season and continues later into the dry season, with the largest participation of the young animals. The fertility rate is lower than in *Mastomys*; three to five young are produced per litter according to the period of the breeding season. Populations are more regularly present in the fields than those of *Mastomys* and they resisted the disease by maintaining an almost standard breeding period in 1976–1977. The individuals of this species that live more than one year are more numerous than in *Mastomys,* thereby maintaining the population in large areas.

For this computation, the death rate was supposed to be constant throughout the life of the animals, and all the females older than 6 months, or 3 months if the young females do participate to the breeding period, are supposed to be littering at each generation. These two hypotheses do not contradict the observed data. Using observed densities in August 1976 as the basis of calculation, the expected densities obtained for August 1977 are very close to the observed ones for the same period (that is, about two individuals per ha for each species).

The resemblance between observed and computed data allows us to do the same calculations on the fluctuations of the densities. This model can also be used for the calculation of productivity by estimating the complete number of rodents produced, including the juveniles too young to be trapped.

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