Bull. Org. mond. Santé }
Bull. Wld Hlth Org. } 1963, **29**, Suppl., pp. 25-29

Rodents in Relation to Problems of Arthropod-Borne Diseases

V. V. KUČERUK [1]

Because rodents are numerically predominant in most terrestrial biotopes, exhibit a high degree of ecological plasticity and live in close contact with both man and a number of blood-sucking arthropods, they have become the main reservoirs of many human diseases occurring in natural foci, including some that spread without the intervention of a vector. The author describes the unique ecological characteristics of rodents, analyses their role in the maintenance of infection in natural foci, and examines the conditions under which epizootics among rodents may give rise to epidemics in man. In the light of such knowledge, it is possible to forecast the epizootic and epidemiological situation several months in advance and to improve the efficacy of control measures based on rodent eradication.

BIOLOGICAL AND ECOLOGICAL CHARACTERISTICS

The order of rodents has reached the peak of its evolutionary development in modern times. The world fauna contains about 2500 species belonging to the order, or roughly a third of all existing mammalian species.

There are rodents in every continent. Among warm-blooded animals they are the main consumers of vegetable matter and make the fullest use of it (Shantz, 1956). As a result, rodents are numerically predominant in most terrestrial biotopes and form the bulk of warm-blooded animals. Representatives of the order are characterized by the multitude of their adaptations to different types of living conditions. The order contains semi-aquatic freshwater and swamp dwellers, tree-dwellers, some of which have acquired a capacity for gliding flight, dwellers in arid spaces with a swift, bounding run, terrestrial burrowing forms, animals living in cliffs and boulder-strewn areas, etc.

Rodents and man

Human agricultural activities have been favourable to a considerable number of rodent species. Wide areas sown to single crops quite often prove to be ideal habitats, where the rodent population density reaches its highest peak (Naumov, 1948; Karaseva, 1960). During the initial phases of harvesting, crops are often left stacked in the fields. Stacks of unthreshed cereals and straw, and primitive open-air stores of vegetable and grain are particularly attractive to rodents. The animals congregate in such habitats from extensive neighbouring areas, finding there optimum conditions for existence (Kulik, 1951; Kučeruk & Rubina, 1953; Rowe, 1958). With the colder weather in the autumn or the onset of the rainy season, the rodents migrate into human dwellings. This migration is intensified by the large numbers of rodents brought into centres of population together with agricultural products, fodder and fuel. This seasonal migration of rodents is most clearly marked in small settlements of the village type but it also occurs in large concentrations of population, including the outskirts of modern cities. The extensive creation of parks, sports grounds, etc. has led to a still greater penetration of non-commensal species into urban areas.

Of wild mammals only rodents have become constant commensals of man and live in his dwellings. They make their homes not only in primitive structures but even in modern multi-storeyed buildings. Man has involuntarily spread all over the world some of the rodent species best adapted to a synanthropic mode of life (*Rattus norvegicus, Rattus rattus, Mus musculus*).

[1] Head, Laboratory of Medical Zoology, N. F. Gamaleja Institute, Moscow, USSR.

Fertility and mortality

The representatives of this order are of small, or more rarely, medium size. This is bound up with high rates of fertility and mortality, and abundant population, and a high population density. Many rodents, such as voles, gerbils and mice, reach sexual maturity at the age of 6-8 weeks, have a gestation period of about 20 days, and mate again on the same day as they give birth. The death rate is also high. Among many voles the mean duration of life amounts to only 4-6 months and the population changes completely every 12-18 months. During some periods, the density of a rodent population may reach colossal proportions—several hundred animals per hectare. From season to season there may be as much as a tenfold variation in the numbers of small rodents and over a longer period of time as much as a hundredfold variation. It is their numerical superiority over other mammals that makes rodents the main harbourers of the larvae and nymphs of the majority of *Ixodes* tick species and of the larval instars of trombiculid mites. Rodents do not play an important role as harbourers of blood-sucking winged insects but nevertheless they are the main source of nourishment for desert *Phlebotomus* and some species of Tabanidae and Culicidae.

Habitats

Because of their small size and inadequate heat regulation, rodents are forced to make wide use of shelters for protection against the attacks of predators and against the unfavourable effects of abiotic environmental factors. In most cases the rodents construct their own shelters, building nests in trees or among the grass or digging underground burrows. Burrowing is particularly common in open treeless landscapes. The rodents use their burrows not only to rear their young and for long periods of rest, but also, at their feeding places, as temporary shelters from danger or from the unfavourable effects of abiotic factors. For that reason the rodent will usually have in use at any one time a group of burrows, ranging from a few units to 20 or 30 (Kučeruk, 1960). The construction of burrows is a complex process requiring a large expenditure of energy. In uncultivated areas many generations of rodents will use the same burrow, constantly repairing and transforming it. Burrows that have lost their owners are soon repopulated by new animals of the same or a different species. Even if the entrances to the burrows are filled in, the underground system of runways is maintained for a long period. When their numbers increase, the rodents do not dig new burrows but merely re-open the entrances to an existing system of underground runways. Measurements of the mounds of soil thrown out of the burrows by susliks and marmots have established that many burrows are centuries old (Varšavskij, 1962; Dubrovskij, 1962).

Rodent burrows are used not only by their builders but also by a large number of " lodgers ", representing the most varied groups of animals. Some of them use the burrows as shelters at unfavourable times of the day or live in them during the bad seasons. A considerable number of blood-sucking arthropod species (ticks, fleas and sand-flies) use rodent burrows as their main or only habitat, passing their most important biological cycles or even their whole lives in these quarters.

RODENTS AS RESERVOIRS OF DISEASE

Because of the characteristics mentioned above, rodents have become the main reservoirs of a large number of human diseases occurring in natural foci. These include both communicable diseases (tick-borne encephalitis, a number of rickettsial diseases, tick-borne spirochaetosis, tularaemia, plague and cutaneous leishmaniasis) and those that spread without the intervention of a vector (leptospiroses, erysipeloid, listeriasis, toxoplasmosis, etc.).

Even those pathogens that are transmitted transovarially in arthropods must pass through an epizootic phase—mass multiplication in the organism of a warm-blooded host—to ensure normal circulation in a natural focus.

Natural plague foci

In natural foci of the majority of the diseases listed above, a considerable number of species of warm-blooded animals have been shown to acquire these diseases by natural infection. However, by no means all these species play roles of equal importance in the maintenance of the natural focus. It was in regard to natural foci of plague that it was first proposed to divide rodents into primary and secondary carriers of infection (Fenjuk, 1948). The primary carriers are those species that ensure the continuity of circulation of the pathogenic agent, both in time and in space. The secondary carriers comprise those species that may participate in epizootics occurring among the primary carriers although not capable by themselves of ensuring the

circulation of the pathogen for any length of time. Rodents are the primary carriers of infection in natural foci of plague and show the following combination of characteristics:

(a) They are the predominant mammalian forms in the biocoenoses of the natural foci, and their numbers are high and relatively stable.

(*b*) They spread themselves over considerable areas of land, forming either continuous settlements extending over great distances or colonizing narrow strips in a criss-cross pattern.

(*c*) In the natural foci of plague they are the main builders and occupants of a complex system of burrows, maintained over a great many years and widely used as shelters by other animal species. Among these the chief role is played by burrow fleas, vectors of the causative agent of plague.

(*d*) As the primary carriers of plague, rodents exhibit a relative resistance to the plague pathogen, which may be either permanent or show seasonal variations. The infective process is invariably marked by a phase of bacteraemia, which either develops into septic bacterial infection or ends in recovery.

Other natural foci

In the natural foci of other diseases, where rodents are the primary carriers of infection, the ecological characteristics and forms of interrelationship between causal agent and rodent may be of an entirely different nature (Naumov, 1959). However, a feature of every natural focus is the presence of a restricted number of species—sometimes only a single species—of the primary carrier. If these species can be eliminated from the chain of circulation of the causal agent, the focus can be cleared.

The probability of human infection with diseases occurring in natural foci depends upon changes in the loemopotential in the foci concerned.[1] Numerous observations have shown that the loemopotential reaches an epidemiologically dangerous level only when an epizootic attains great severity over a considerable area of land. In years when epizootics are mild and localized, human infection occurs rarely, if at all, and is sporadic. Mass epizootics spreading over large areas and accompanied by heavy infection of blood-sucking arthropods usually occur in periods when the rodent numbers are high or when the conditions of their existence have suddenly worsened, leading to a considerable increase in their mobility. The seasonal aggravation of epizootics follows a constant pattern, determined both by the properties of the causal agent and by the ecological features of the rodents among which the epizootic is taking place (Kučeruk, 1955, 1960).

Pathways of transmission

The pathways by which the causal agent of infection is transmitted to man are numerous and varied and depend on the species of rodent attacked by the epizootic and on the ecological and epizootiological features of the natural foci. In plague epizootics among rats, human beings are infected by direct transmission. In the case of plague among marmots man is infected only as a result of contact, either when skinning the animal or when eating marmot meat. During epizootics of tularaemia in hares, people are infected through the alimentary tract. During vole epizootics they are infected through the respiratory tract and in epizootics among water-rats mainly by direct transmission. The water-rat is the species responsible for maintaining the circulation of the causative agent of tularaemia in natural foci of two types: swamps in river flood plains and streams in foot-hills. In the swamp foci, human infection is acquired mainly by direct transmission and in the foci in foot-hill streams through water (Olsuf'ev & Dunaeva, 1960; Kajskij, 1960).

In a number of cases, the primary carriers of infection in natural foci do not play any noteworthy epidemiological role. The danger of human infection arises only when other species of rodent in close contact with man enter the chain of circulation. These species, which have no importance in the maintenance of natural foci, carry the infection from the foci into human dwellings. This situation has been described on numerous occasions in relation to natural foci of plague and tularaemia (Heisch et al., 1953; Fedorov et al., 1955; Kamnev, 1957; Majskij, 1960).

Forecasting and prevention of epidemics

A knowledge of the laws governing the course of epizootics in different types of natural foci of each infection makes it possible to forecast the epizootic and epidemic situation well in advance. The most

[1] Moškovskij (1961) defined loemopotential as the intensity of transmission of an infection in a given focus at a given time; it determines the proportion of persons present in that focus into whose organism the causative agent will penetrate in a form and dose adequate to produce clinical infection in a susceptible individual.

readily discernible indicators of the probable exacerbation of an epizootic are changes in the numbers and mode of life of the rodents and their arthropod parasites. Where a special service exists which keeps these phenomena under observation and carries out laboratory investigations to determine the degree of infection of the rodents and arthropods, sufficiently accurate data may be available for a number of infections to make possible annual and six-monthly forecasts of the epizootic and epidemic situation. On the basis of these forecasts, the local medical authorities can be given sufficiently early warning to enable them to prepare in advance the most essential prophylactic measures.

In cases where rodents are the primary or only hosts of the vectors (e.g., fleas) or where rodent burrows are the main habitat of the vectors (e.g., desert sandflies), rodent eradication will be the simplest and most effective method of ensuring freedom from the danger of epidemics. A reduction in the numbers of rodents in a circumscribed area may serve as a quick means of interrupting the epizootic process. If the number of primary carriers over a large area is kept at a low level for a long time, the complete eradication of the natural focus becomes possible.

Control measures will ensure the maintenance of low rodent numbers over a long period only if certain conditions are fulfilled. Eradication must be carried out simultaneously over vast areas populated by continuous settlements of rodents. This is possible if the area is inhabited by a single population of rodents, relatively well isolated by ecological or physical barriers from neighbouring populations. From the epidemiological point of view, three types of rodent eradication can be distinguished (Fenjuk, 1959):

(1) Emergency or short-term preventive measures. Rodent eradication is carried out in order to suppress an epizootic that has already begun and to prevent or at least reduce to a minimum the possibility of human infection and illness.

(2) Advance or long-term prophylaxis. The aim of rodent eradication is to eliminate, for a certain period of time, all possibility of the development of an epizootic in economically important areas and centres of population, and to prevent the extension into such areas of epizootics from outside.

(3) Rodent eradication as a method of completely eliminating natural foci. Reduction in the number of rodents acting as the primary carriers of infection over a large area during a long period breaks the normal epizootic cycle and leads to the disappearance of the causal agent from the biocoenoses in the foci. Control measures based on this principle have already been used successfully in the USSR, eliminating a number of natural foci of plague (Donskoj, 1959; Fenjuk, 1960). If rodent-control measures are confined to periods when the number of rodents is low and are concentrated on habitats actually in use in " elementary " foci, good results can be obtained at relatively low cost.

RÉSUMÉ

Les rongeurs représentent à eux seuls un tiers de tous les mammifères, on les rencontre sur tous les continents, ils s'adaptent très facilement aux conditions de la géographie physique et de la géographie humaine, ils sont en contact étroit avec l'homme d'une part, avec de très nombreux arthropodes piqueurs d'autre part. Tout cela en fait des vecteurs de nombreuses maladies humaines soit par l'intermédiaire d'un arthropode (encéphalite à tiques, nombre de rickettsioses, spirochètose à tiques, tularémie, peste, leishmaniose cutanée) soit directement (leptospirose, listériose, toxoplasmose, etc.). L'auteur passe en revue les caractères écologiques, à vrai dire bien particuliers, des rongeurs, analyse leur rôle dans le maintien de l'infection dans des foyers naturels, examine enfin les conditions dans lesquelles les épizooties sévissant chez les rongeurs peuvent entraîner l'apparition d'épidémies chez l'homme. A la lumière de ces données, il est possible de prévoir l'apparition d'épizooties et l'évolution de la situation épidémiologique plusieurs mois à l'avance. L'on peut ainsi rendre plus efficace la lutte basée sur l'éradication des rongeurs.

REFERENCES

Donskoj, N. A. (1959) [*Some experiences in sanitation at the Transbaikalian plague focus*]. In: [*Natural foci and epidemiology of highly infectious diseases*], Saratov

Dubrovskij, Ú. A. (1962) [*The size of earth mounds from burrows of steppe marmots as an indicator of the age of their settlements*]. In: [*Explorations on the geography of natural resources of the animal and vegetable world*], Moscow

Fedorov, V. N., Rogozin, I. I. & Fenjuk, B. K. (1955) [*Plague prophylaxis*], 2nd ed., Moscow, Medgiz

Fenjuk, B. K. (1948) [*Ecological factors in relation to natural foci and the epizootiology of rodent plague*]. In: [*Proceedings of the Conference called to celebrate the Twenty-fifth Anniversary of the " Microbe " Institute, August 1944*], Saratov

Fenjuk, B. K. (1959) [*Main problems in tactics, methods and organization of anti-epidemic rodent control in natural plague foci*]. In: [*Natural foci and epidemiology of the highly infectious diseases*], Saratov

Fenjuk, B. K. (1960) *Bull. Wld Hlth Org.*, **23**, 263

Heisch, R. B., Grainger, W. E. & d'Zouza, I. St. A. M. (1953) *Trans. roy. Soc. trop. Med. Hyg.*, **47**, 503

Kamnev, P. I. (1957) [*Concerning the problem of natural plague foci in the south-west of North-East China in districts of intensive agriculture*]. In: [*Proceedings of the Irkutsk Antiplague Institute of Siberia and Far East*], vol. 15

Karaseva, E. V. (1960) [*Peculiarities in the distribution of* Microtus arvalis *and the significance of various stages in its life span in the central districts of the USSR*]. In: [*Fauna and ecology of the rodents*], No. 6, Moscow

Kučeruk, V. V. (1955) [*Epizootics in relation to the regulation of rodent numbers*]. In: [*Problems of regional, general and experimental parasitology and medical zoology*], Moscow, vol. 9

Kučeruk, V. V. (1960) *Med. Parasit. (Mosk.)*, **29**, No. 6, 5

Kučeruk, V. V. (1960) [*Burrows as a means of protection against the unfavourable effect of abiotic environmental factors*]. In: [*Fauna and ecology of the rodents*], No. 6, Moscow

Kučeruk, V. V. & Rubina, M. A. (1953) *Zool. Zh.*, **32**, 495

Kulik, I. L. (1951) [*Rodents of various grain stacks*]. In: [*Problems of regional, general and experimental parasitology and medical zoology*], Moscow, vol. 7

Maiskij, I. N. (1960) [*The epidemiology of tularaemia*]. In: [*Tularaemia*], Moscow, Medgiz

Moškovski, Š. D. (1961) *J. Hyg. Epid. (Praha)*, **5**, 125

Naumov, N. P. (1948) [*Essays on the comparative ecology of mouselike rodents*], Moscow & Leningrad

Naumov, N. P. (1959) *Zool. Zh.*, **38**, 320

Olsuf'ev, N. G. & Dunajeva, T. N. (1960) [*The epizootiology (natural foci) of tularaemia*]. In: [*Tularaemia*], Moscow, Medgiz

Rowe, F. P. (1958) *Proc. zool. Soc. (London)*, **131**, 320

Shantz (1956) *History and problems of cultivating arid lands*. In: *The future of arid lands*, Washington

Varšavskij, S. N. (1962) [*Age types of settlements and history of a small souslik distribution*]. In: [*Explorations on the geography of natural resources of the animal and vegetable world*], Moscow