RYLNIKOV VALENTIN

ECOLOGICAL BASES AND APPROACHES TO MANAGING SYNANTHROPIC SPECIES OF RODENT

(Using the brown rat (*Rattus norvegicus* Berk.) as an example)

AN EXTENDED ABSTRACT OF THE STUDY

Moscow – 2012

ABSTRACT OF THE MONOGRAPHY

Rylnikov V.A. Brown rat (*Rattus norvegicus* Berk.). Ecological bases and approaches to management of
number / V.A. Rylnikov. — M.: Nonstate private scientific and educational institution “Institute of Pest Management”, 2010 — 367 p. — RUS.
The extensive material is collected, systematised and presented to monographies for the first time for many years in biology and ecology of a brown rat from the point of view of management of their number. The considerable part of the materials taken as a principle of the monography, is gathered personally by the author with many associates and colleagues. Studying of features популяционной ecology of brown rats in various natural zones, at various level of synantropy, including in the conditions of constant influence on rodents deratization means, working out of methodology of management by number of this kind was a research objective. It is used lifetime marking by chemical compounds of a dkeleton, a teeth and excrements for studyng of mobility, contact with rodenticides. The account of animals and traces of their ability to live. Methods of studying of structure of forages and age of animals. Features population dynamics (reproduction, death rate, age structure, mobility, a food, social and food behaviour) brown rats both out of, andwithin settlements of different widths of the European pert of Russia are studied. In laboratory and fieled conditions action of rodenticides, containg blood anticoagulants, poisons of sharp action is studied, ways of occurrence of adaptations at brown rats are investigated: reactions of avoiding and physiological stability to rodenticides.New means, devices and methods in the fieled of management of number of rodents are offered. Criteria of safety are entered at application of rodenticides. The new concept of continuous regular inspection and selective deratization is ecologically proved, developed and introduced in deratization practice. Some methods of mathematical modelling of the processes occurring at clearing af territories from rodents and restoration there of their number are offered.It is intended for zoologists, ecologists, specialists of pest-management and disinfectology.

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Introduction

Research relevance

The ability of living synanthropic rodents, above all the brown rat (*Rattus norvegicus* Berk.), to cause serious harm to health of the people, to production, and also agricultural livestock and crops. An infection is transferred to Russia by rodents each year, leading to disease in more than 10 thousand people. Losses to production by rodent damage are estimated to be in the millions of roubles. In response to this, actual calculations are conducted into how to improve the regulation of the numbers of synanthropic rodents. These workings out include both the study of the ecology of these kinds of rodents, and the management of their numbers.

Ecological bases for managing the numbers of synanthropic rodents are necessary for the working out and introduction of organizational forms. They should become a component of standard documents, which are obligatory for practical organizations to complete.

The period of introduction into the market economy from 1991 to 2002 (the coming into force of sanitary regulations of SP 3.5.3.1129-02) became for Russia a transitive one between the era of continuous regular deratization - the dominating concept during the Soviet period - and deratization in the conditions of the market economy. In line with legislative stages and economic conditions rodent control began to take place only in their dwelling places. Thus the volume of activity for the detection of rodents and the definition of target populations remained as before, and they have been allocated as a separate kind of work. In volume former capacity, work was also undertaken on decreasing the ability of rodents to settle or, in other words, preventative work was carried out to improve the sanitary and technical conditions of buildings.

Thus, working out the new concept of rodent management by numbers is rather new. It includes an ecological substantiation, the improvement of management methods, the creation of levers on the rodents corresponding with modern requirements; safe for people, pets and the environment, as well as the preparation of a standard, methodical base for carrying out corresponding actions.

Aims and research challenges

The research objective is the study of the features of the population ecology of brown rats in various natural zones and at various levels of synanthropy, under conditions of constant deratization methods, and the working out of a concept for management by numbers of this species, including the methodology and technology of such management, and adequate and safe levers for non-targeted species; and also the offer of organizational solutions, allowing in the implementation of the system in practice.

To fulfil these objectives, the aims are as follows:

1) To optimise and develop new methods for studying the foodstuffs, age structure of brown rat population, their mobility, contact with the materials of deratization for an estimation of population dynamics during the carrying out of exterminatory activities;

2) To study the dynamics of reproduction, death rate, age structure, mobility, and also the feeding habits and social behaviour of brown rats both in and out of settlements in order to work out the strategy and tactics for population management;

3) To analyse the causes of death and survival amongst different rodent population groups during the application of rodenticides;

4) To develop theoretical and practical foundations for the quantitative and qualitative management of the population structures of brown rats in different habitats;

5) To develop a new concept of deratization in settlements - input and output - taking into account the changing political and economic situation in the Russian Federation;

6) To offer new means (rodenticides) and devices for the extermination and catching of brown rats, as well as new methods of application in line with the modern requirements of world-standard pest control.

7) To develop and introduce new methods in testing rodenticides for the purpose of their registration and certification; to study the effect of various rodenticides in order to create models of development of the adaptation of brown rats to the materials.

Research objective

Taking into account the author's experience which was gained predominantly by studying the biology of the brown rat (*Rattus norvegicus* Berk.), and the development of methods in the struggle against it, this species has been chosen as the model for the current study though the resulting material could be, taking into account specific differences, extrapolated to other species, primarily synanthropic rodents, and above all, the *Rattus* species. To support certain positions we used information derived from research on other species of rodents (*Microtus arvalis* Pall. and *Clethrionomys rutilus* Pall.).

Subject of research

Deratization is a part of a systematic struggle against live organisms of a problematic kind which is widely know as «pest control», or « pest management » (Bibikov, 1986; Prakash, 1988; Singleton et al., 1999; Shchipanov, 2002; Rylnikov, 2005; Shilova, 2005). To speak accurately on managing the target species being studied by an individual, specific goals must be established: for example, a decrease in numbers with the aim of reducing economic or medical damage, an increase in numbers, a change the qualitative composition of the population.

Management of the targeted species of rodents is in many respects defined by the social views of the political system dominating a given country at any given stage in history. Such a belief system raises the problem of practicality and feasibility of congruent treatment, as well the establishment of a target for what is considered to be a permissible level of vermin. So, for example, raising the issue of the almost total annihilation of some species of animal is practical from the point of view of combating vermin, however it is hardly feasible in terms of covering the territory as a whole, ways of regulating the number of rodents can be subject to criticism from an ecological, bioethical perspective (Shilova, 2001; Ivanov, 2002), as well as religious, ethnic ones such as sorcery, curses, superstitions (Lapshov, Inapogy, 1992; Belmain et al, 2006), and other perspectives.

Management of the target species of rodents has a scientifically proven effect on dynamics of their population, this includes carrying out inspections (monitoring), preventive measures, extermination measures (strategy and tactics) and measures for prevention of settling of open land, including deterrents.

Methodological and theoretical basis of research

A detailed study of synanthropic rodents from the 1950s-1960s by the American scientist David Davis who made a study of brown rats in Baltimore, English scientist D.Chitty, the Russian scientists E.V.Karaseva, V.V. Kucheruk, E.V.Kotenkova and many others became major landmarks on a ways to employ ecological knowledge for deratization. The main purpose of this research was to study the ecology, behaviour, geographical spread, morphology, and the systematic and historical spread of synanthropic rodents. Deratization in these works took a modest as a practical outcome of basic research. In 50s, professor

A.P.Kuzjakin offered, for the first time, a strategy for the stage-by-stage (quarterly) clearing of rats from large cities. Conversely, in the 60s and 70s, Soviet zoologists V.G.Polezhaev, L.A.Kirin, J.V.Toshchigin, V.S.Sudejkin, G.V.Zalezhsky, supported continuous, regular deratization as the overriding concept, based on the high mobility of brown rats in a city. From the 50s to the 90s and at the beginning of the 21^{st} century, Soviet and Russian research on synanthropic rodents big city environments have occupied the works of such deratization specialists as: D.S.Ajzenshtadt, S.V.Vishnjakov, N.M.Dukelskaya, N.V.Kandybin, D.F.Trahanov, A.F.Kadirov, V.G.Zatsepin, V.A.Bykovsky, I.S.Turov, V.A.Sudejkin, V.G.Lyalin, S.A.Hamaganov, V.K.Melkova, L.N.Mazin, A.A.Jakovlev, N.V.Babich, N.V.Popov, A.N.Matrosov, M.A.Tarasov whose recommendations have made essential contributions to the development of scientifically proven methods of deratization by improving its methods and means. N.P.Naumov, S.A Shilova and N.A.Shchipanov are amongst the first in Russia to have defined an ecological basis for managing the numbers of rodents. Internationally, great contributions were made in the field of research into rodent populations and methods for managing them from 1970-2002 by Indian scientist I.Prakash, the Americans B.A.Kolvin and V.B.Jackson, the Australian G.Singleton, Chinese scientist Chauhan Zhibin, etc.

Research methods

To support the achievement of the objective and to resolve present difficulties, the current research has carried out an analysis of existing methods. Some of them were used in the way described by the literature, and some of them have been developed or improved by the author.

Markers were added into the rodenticides which helped make it possible to assess the effect of the processes and their application within the brown rat population: reaction of individuals in different intrapopulation groups to various forms of rodenticide, including avoidance reaction and resistance. In order to deliver the markers into the animal, they were added to non-poisonous foodstuffs, and into rodenticide baits, pastes and shown in the excrement and in the body tissue of the animals examined. In order to study the mobility of rodents, the same dyes were used to mark groups as were used to mark individuals which proved more comprehensive than the poor repeated catching of brown rats in mechanical traps. As a result of using some markers and their identification via analytical methods, we were able to considerably increase the opportunity to group mark the animals. The introduction of a quantitative method for analysis, has allowed us to ascertain the amount of rodenticide using a marker. Through these methods, it has been possible to study sex and age structure of the population, its temporal and spatial dynamics, mobility, and feeding habits. The method of defining a rat's age through the wear and tear on their teeth has been developed by the author, in conjunction with similar methods offered by other researchers. Methods for studying the feeding habits of the brown rat, as well as ways of calculating their reproductive capability, birth and death rates are offered.

Methods for detecting, counting and tracing the living pattern of the rats have also been developed.

Original methods for studying the effect of rodenticides in laboratory conditions were used and an evaluation of their toxicity is carried out to identify the factors influencing the efficiency and safety of rodenticides.

Mathematical modelling techniques are used to simulate the processes which occur in the rat population when affected by rodenticides in individual buildings, settlements, and on agricultural land. Without these it would have been impossible to make a comprehensive evaluation, as the dynamics clearing premises of rodents, given their constant resettling and taking into account birth rates, death rates, migratory patterns.

Scientific innovation and the theoretical relevance

1. As a result of studying the ecology of rats in various zones European Russia the area of their distribution has been divided for the first time into three ecological zones, by differing levels of synanthropy.

2. The characteristics of the population dynamics (reproduction, death rate, age hierarchy, mobility, food, social and feeding habits) for brown rats both residing within and without colonies in the different zones European Russia and the effects of rodenticides are studied.

3. Using research into the feeding habits of brown rats in laboratory and field conditions the effects of rodenticides containing anticoagulants (warfarin, difacinone, etc) in baits are studied, as well as the ways in which brown rats adapt to them are investigated: avoidance reactions and physiological resistance to rodenticide baits and coatings.

4. Methods of marking have been developed to allow for the evaluation of the frequency with which rodents come into contact with rodenticides in field conditions, and new methods for testing rodenticides in laboratory conditions for the purpose of their registration and certification have also been developed.

5. New means, devices and methods (registered patents) in the field of managing rodent numbers which lessen the risk to humans, and as well as our reliance on imported foreign technologies for pest control.

6. Safety criteria for the application of rodenticides have been outlined for the area of their application depending on their class of toxicity and formulation.

7. A new concept in continuous, regular inspection and selective destruction actions in developed areas and beyond is ecologically advanced, proven, approved and has been incorporated into the deratization process – beyond and within built-up areas and on agricultural land.

The practical relevance of research

As a result of the research conducted, the following regulatory and procedural documents, which have received federal approval and have been introduced into the activities of sanitary-prophylactic institutions and enterprises, have been developed.

The regulatory and procedural documents:

- Procedural recommendations in accordance with the efficiency, toxicity and danger of rodenticides. Moscow: Goskomsanepidnadzor of the Russian Federation, 1995;
- Testing the means of disinfection or the evaluation of its safety and efficiency. Moscow: Ministry of Health of Russia, 1998;
- Sanitary and epidemiologic regulations and standards. SP 1.2.1077–01 ”Hygienic requirements for the storage, application and transportation of pesticides and agrochemicals“. Moscow - 2002, Russian Ministry of Health.
- Sanitary and epidemiologic regulations of statute SP 3.5.3.1129-02 "Sanitary and epidemiological requirements for the carrying out of deratization.” Moscow: the Federal Centre of Gossanepidnadzor, Russian Ministry of Health, 2002.

Rodenticides, registered in Russia (all rights reserved and adapted for commercial use):

· Substances: Triphenacine (the aggregate of indandiones: diphacinone and ethylphenacine), Tetraphenacine (the aggregate of indandiones: diphacinone and isopropylphenacine).

· Premix: Gelcin (gel from 0.02 % triphenacine), Geldan (gel with tetraphenacine 0.01 %), Gelcoum (gel with 0.75 % warfarin), an Indan-fluid (vegetable oil with 0.25 % tetraphenacine), Indan-dust (dust on talc or starch with

0.25 % tetraphenacine), Vascine (paste with 0.1 % tetraphenacine), Krysid-gel (gel with 10 % α-naphtylthiourea), the Krysid-covering (paste with 10 % α-naphtylthiourea), Bromocide (gel from 0,15 % bromadiolone).

· Preprepared formulations: Zernotsin (grain with 0.015 % triphenacine), the Zernotsin-block (a paraffin block with 0.015 % triphenacine), the Indan-block (a paraffin block with 0.01 % tetraphenacine), the Krysid-bait (grain about 1 % 1-naphtiltiourea), Krysin (a soft block with 0.005 % brodifacoum).

Devices (all rights reserved and adapted for commercial use):

· Container- K (capacity for distributing rodenticide baits and pastes for the purpose of exterminating rats) (Patent RU 2104641 C1. The order no: 0442190, KL. And 01 M 25/00, 1991).

· Container - M (capacity for distributing rodenticide baits and pastes for the purpose of exterminating mice and other small rodents) (Patent RU 2104641 C1. The order no: 0442190, Kl. And 01 M 25/00, 1991).

· Universal trap for rodents, high capacity, automatic, electrically operated (the Patent of the Russian Federation №2102879, registered 27.01.98).

Ways of applying rodenticides:

· The method for exterminating small rodents (the Patent №1804293 from 09.10.92 the order №4940753, invention priority of 25.02.91).

Ways of manufacturing rodenticides:

· The method for preparing biocide gel (the Patent of the Russian Federation №2077200.-1997.-Bull. № 11.).

· Rodenticide devices (Patent RU 2144766 C1 from 09.02.1999.).

1. A review of supporting literature

A detailed presentation of the literature, based on the analysis of more than 500 sources, it will be given in the printed edition manuscript.

It has enabled the following results.

A study of the spatial distribution, dynamics of reproduction and age composition of rats in manmade structures and outside populated areas within the different geographical zones European Russia has enabled us to establish three ecological zones inhabited by brown rats: the northern zone — the area most dominated by synanthropy, with deratisation from manmade structures lasting no more than 2-3 months; the central zone — the area with partial synanthropy, where a considerable part of the brown rat population can be removed from manmade structures for 5-6 months, and separate colonies can exist outside of buildings all year round; the southern zone — the area where synanthropical rodents are capable the entire year in and outside of populated areas.

The use of N.P.Naumov's findings (1971) on the population structure of the brown rat species has allowed us to establish the hierarchical, geographical, ecological and elementary structure of the populations within the limits of aforementioned zones. Obviously, approaches to managing the numbers of ecological and elementary brown rat populations in the three geographical zones should be different. In southern latitudes, the yearly control of both ecological populations, and strategy concerning each of them should take into account temporal and spatial dynamics. In central regions, the strategy for managing the numbers of brown rats should uniformly cover the ecological population dwelling in manmade structures and in undeveloped areas. Decreasing the brown rat population in both habitats should lead to a general decrease in the overall numbers of the ecological population and, accordingly, lead to a decrease in the damage arising from their destructive activities. In northern latitudes, the problem of rats in undeveloped areas does not, as a rule, exist. In populated areas still free from rats, the primary goal is the prevention of rat infestation. In the settlements occupied by rats, the number management strategy will be similar to that in the central zone.

Studying the ecological population of brown rats, their population dynamics, spatial, age, sexual composition, and seasonal migrations is the basis for working out a strategy for managing the numbers of this kind of population both in and out of developed areas, in similar conditions.

Studying the elementary populations of brown rats and their seasonal and regional groupings, mobility, feeding habits, age, sex, phenotype and individual heterogeneity is a basis for working out tactics for managing their numbers in freestanding structures, in a building, on domestic territory, and in undeveloped areas.

The rats' resistance to harmful substances, in particular to the effect of rodenticides upon then, differs according to the season, and their "vulnerability" is increased during the winter more than during the spring and summer months.
Seasonal, age, sexual differences in the natural feeding habits of brown rats in accordance with their varying social status within a colony and their reaction to artificial non poisoned insect bait has been insufficiently explored in research on the feeding habits of brown rats, and this we can attribute to poor methods for studying their feeding habits. For example, colouring of baits with histological dyes allows us to track dye-stained food particles in excrement and, accordingly, allows us to know, from which feeding trough the bait has been eaten, however does not allow us to make a quantitative evaluation of the food eaten. The detection of antibiotics from the tetracycline group in areas where bone is growing allows us to carry out long-term marking for the purpose of studying of migrations, however the absence of methods for the identification of each tetracycline used (for example, tetracycline, tetracycline chloride, tetracycline oxide etc.). Does not allow us to pinpoint, the place where the bait with this

marker has been eaten. Defining the number of concentric markers on a slice of a rodent's incisor allows us to establish what has been consumed within a two-day period however for establishing quantity forage eaten each is impossible as there is no known technique for this. However, all these effects of food upon animals of a different level and age have are valuable in forming an idea of the effect of rodenticides upon rats. Without it, there can be no accurate strategy for the application of rodenticides.

Sex and age variability in relation to instant and cumulative acting rodenticides is reflected in the research however it is of an inconsistent nature. Nevertheless, a variety of sources show that males and young animals survive under the effect of anticoagulants more often. These sex and age groups, according to a number of authors, are carriers of richer material for selection.

From the literature that was analysed, there was no research into the mechanism driving the avoidance reaction to rodenticide baits and pastes, as well as the occurrence of physiological resistance to active ingredients in rodenticides.

An extensive amount of literature is devoted to the administering of rodenticides. Many authors only empirically come to conclusion of the necessity for the simultaneous application several kinds of rodenticide baits on a rotational basis, using rodenticide pastes in order to avoid increased resistance amongst the rodents.

Despite a number of authors offering methods for managing the birth rate as a counterpoint to managing the death rate, one can acknowledge that amongst the first methods, it is practically impossible to pick out any one method that is really effective in the practical management of rodent numbers. Conversely, the overwhelming majority of researchers came to conclusion there is no alternative for managing the death rate. Therefore, it is necessary to develop this area while simultaneously improving standards for the safe implementation methods of extermination. For the last 25 years, experts in deratization undertook attempts to standardise data on rodenticides in the form of helpful tables. The toxic properties of rodenticides needed for a Brown rat quantitatively evaluated by an average lethal dose being injected into the stomach, and the degree of danger is defined by qualitative indicators: big, average, small. The vast heterogeneity of the chemical compounds used in rodenticides has complicated comparison of the properties of various poisons. It is obvious, that there is now a growing necessity for the creation of a uniform classification of the toxicity and the dangers posed by rodenticides.

There is undoubted interest in finding alternatives to the use of rodenticides and this is demonstrated by the use natural methods for deterring, catching and exterminating rodents in conjunction with chemical means designed to rid areas of occupation by rodents. The integrated management of the number of rodents essentially raises its effectiveness along with a simultaneous decrease in danger to non-targeted animals and humans.

2. Materials and research methods

2.1. Group marking of rats.

Histological dyes.

A characteristic of brown rats is their nocturnal way of life, and the extensive study of this is not always is possible by means of visual supervision. Screening brown rats by repeatedly catching them is not an option as brown rats practically never return to live traps. As is already known, the position of moving of rats can be established by analyzing the dyes that have been added to the bait in the rodents’ excrement.

The analysis of the dyes found in the excrement has shown that fluorescent dyes (oeozine, flourosceine, and safranine) can be detected even in very small quantities. The non-fluorescent dyes offering the maximum possibilities for colouring excrement were tripane blue and diamond green. The identification of fluorescent dyes is made visible distinguishing of colour and by ultra-violet light, and on the RF scale.

The addition of in bait of dyes and subsequent detection in rodent excrement is suitable only for a qualitative evaluation of feeding habits. Quantitative analysis is impossible, as dyes are partially absorbed in the intestines.

We propose the addition of copper and zinc sulphides into the bait corresponding to those ions in rodent excrement. Copper and zinc sulphides are practically insoluble in water, weak alkalis and acids therefore it is feasible to expect that they will pass through a gastro-intestinal tract without being absorbed and be found in the excrement.

The developed by us has a number of advantages in comparison with other aforementioned methods. Firstly, it enables the comparative evaluation of the edibility of different kinds of bait in multispecific communities as excrement has a species-specific composition. Secondly, it enables us to evaluate the edibility of the bait and the species which store them. Thirdly, it allows us to evaluate the edibility of unattractive bait and its effectiveness for contact poisoning. The method of marking bait with zinc and copper sulphides devised by us, allows us to carry out quantitative evaluations of feeding habits and it is an important addition to the qualitative and quantitative marking methods developed by us for identification purposes.

Tetracycline group of antibiotics (GAT).

GAT possess yellow fluorescence in ultra-violet light. Upon entering the body of vertebrate animals, tetracyclines attach themselves to growing bones and teeth, forming complexes with ions Ca ++ which is also fluorescent. GATs enter bone tissue within the first few days, and decline within several months as a result of slow endosteal reabsorbtion.

This method has opened up enormous potential for studying the contact of rodents with rodenticide baits and coverings, by addition into their GAT compound. Setting the luminous intensity of the concentric markers on a cross-section of a rodent incisor in line with of the standards of luminosity in a microscope lens has allowed us to identify not only the contact history with the marker, but also to evaluate it quantitatively. The ability to establish the degree of a rodent's physiological resistance to poisons, along with dynamics of the consumption of the poisoned foodstuffs, has allowed us to establish links between these factors.

Using the qualitative identification of GAT in bones and excrement has enabled us to evaluate two-three food baits (with different markers) at the same time.

A no less important matter in controlling the numbers of destructive species is the identification of areas and distances covered by rodents as part of an influx of migrants increasing numbers in a certain area. Marking bait containing GAT in their original dwelling enables us to identify the migrants.

Extraction GAT from a bone tissue and chromatography. To expand on the results of using the GAT marker method, we have developed a method for extracting a mix of antibiotics of the tetracycline group (tetracycline, tetracycline chloride, tetracycline oxide and metacycline) from the bones of rodents and their subsequent identification by means of paper chromatography.

Semi-quantitative methods for identifying GAT in the incisors of brown rats: To study rodent's diet in natural conditions some researchers have proposed adding GAT to the food matter. On cross-section of the incisors (in the first quarter from the edge of the grinding) of a rodent who has consumed GAT laced foodstuffs, in beams of ultra-violet light under 30-50-X increase double microscope the concentric bands of yellow formed by the GAT gelatin complex are noticeable in the tooth's calcium under a beam of ultra-violet light with a 30-

50 fold increase under a binocular microscope. These bands are formed by daily consumption of bait with a marker and remain the brown rat's incisor has grown back to its full length. Depending on quantity of tetracycline that has entered the organism of the brown rat, these bands have luminescence varied intensity of luminosity from a weak-yellow to bright yellow tones. If a rat with a body weight of up to approximately to 150g is caught within 30 days, and an adult rat is caught within 40 days (in accordance with the growth rate of their incisors), the time that has elapsed since their marking and their capture can be established to within 2 days from the daily level of subsistence between the marker and the pulp.

If together with GAT laced bait eaten by the rat there is a known concentration of raticide added to the bait, it is easy to calculate an approximate dose of the poison entering the rat's body every day.

2.2. Studying the diet

The rat's diet has been judged mainly by the contents of their stomachs, and to a lesser degree, by the remainders left on «small tables of food».

Reference samples of the digested food have been obtained by the feeding laboratory white rats of earthworms, frogs, white mice, grape snails, fish, and also vegetative plant parts (cereals, sedge, beans) and seeds (rice, wheat, millet) to white laboratory rats. Within 2, 4 and 6 hours after eating of the food 2 rats were dissected in order to study the distinctive features of food at various stages of digestion.

At the same time, research was carried on 2 more criteria: the frequency with which a certain foodstuff appeared and its percentage.

2.3. Identifying the age of a small animal and the age structure of the population

Identifying age according to the wear on the tooth's gnawing surface using our own technique in conjunction with that of N.G.Karnouhova (1971), by dividing them into seven age groups. Studying the layered structures in the periosteal zone of the mandible is usually carried out on a cross-section taken from the beginning of the middle of last molar (M3) and finishing at the root (Clevezal, Klienenberg, 1967). The quantity of layers on the periosteal zone should reflect number of hibernations. We have discovered that the low correlation between the number of layers in the periosteal zone of the mandible should reflect number of hibernations, and an age indicator in the teeth of brown rats from the rice fields of the Krasnodar territory is the wearing down of their crowns ($r=0,6$, at $p <0,01$). The total absence of such a correlation has been shown in small animals inhabiting manmade structures in the same region ($r = -0,06$). It is possible to explain this not only by clement winters, but also the breeding of rats in buildings over the winter months.

Apart from the identification of actual age by contracting lines, we have taken advantage of the long-term analysis of the age structure of seasonally breeding populations of brown rats by establishing of speed of a transition of modal group of smaller relative age into a bigger one.

This method has its limitations and is only practically suitable for the study of brown rat populations who live outside of populated areas the whole year round. On the basis of the received data a table of age ranges has been drawn up in correspondence with actual ages.

2.4. An estimation of the numbers of brown rats and the efficiency of deratization

2.4.1. Built up areas

A report on the use of trace platforms, arc traps and Gero trap carried out in accordance with instructional guidelines on the combating of rodents in populated areas. (Moscow, 1981).

2.4.2. Undeveloped areas.

A report on the combating of brown rats in accordance with instructional guidelines developed by the author (*Rattus norvegicus* Berk.) in the natural breeding ground of icterohemorrhagic spirochetosis (Moscow, 1984).

2.5. Testing rodenticides

The testing of rodenticides for their efficiency, toxicity and safety are carried out in accordance with methodical recommendations developed by the author (Moscow: Goskomsanepidnadzor of the Russian Federation, 1995 г).

3. Population ecology of the brown rat as a basis for managing its numbers

Three zones of the former Soviet Union, with differing degrees synanthropy of the house mouse (*Mus musculus* L.), identified by N.V.Tupikova (1947), namely: a zone of constant habitation in housing, a zone with periodic evacuation to open areas in summer and a zone with year round dwelling in undeveloped areas. Using research and own data, we have identified the synanthropic zones for brown rats, which are similar to those which have been identified for the house mouse.

Without knowledge of the population hierarchy of brown rats it is difficult to effect efficient control of their numbers. For a description of brown rat's structure, we have used the classification proffered by N.P.Naumov (1971) - the coordination of geographical, ecological, elementary populations Shilova (1999) has been used.

3.1. A zone of full synanthropy

The structure of geographical population of the northern zones, apparently, represents set ecological and elementary (on N.P.Naumov, 1971) populations and, as a rule, separate colonies living in buildings predominantly in seaports. In open areas in the northern zone the problem of combating rats does not exist as a rule. In settlements still free from rats, the primary goal is preventing their incursion, and in the settlements occupied by rats the strategy for managing numbers will have elements of similarity to that used in the central zone. However, there, the rat population in settlements is more vulnerable due to exterminatory methods and the local tracking of the population and longer period of diapauses in breeding females, and as consequence of this, there is a period when the actual death rate exceeds the actual birth rate, and a negative growth rate exceeds a positive one.

3.2. A zone of partial synanthropy

3.2.1. The Rostov area (rice fields, ponds for cultivating fishes)

The absence of brown rat colonies (with the exception of vacant non-specific pockets) in open areas during the winter period (December 1984) has been established: on the banks of reservoirs and in rice fields (the most northerly in Russia) in the Salsk area, in the system of drainage channels along the river of Don near Rostov-on-Don. At the same time, in felling areas, dividing ponds for cultivating fishes in the October area around security bases, around fish food stores, around pig sties, highly populated colonies of brown rats (up to 5 entrance apertures of holes of 1 sq m) have been discovered.

Apparently, for parts of the Rostov area, seasonal migrations between open and developed areas are a characteristic of the brown rat population; with the exception the manmade ponds for cultivating fish on the northern border of the Rostov-on-Don area, where brown rats live the entire year round.

3.2.2. The Yaroslavl area (the lake Nero basin)

Research carried out by us on places in the lake Nero basin show that brown rats live outside in the summer months. From the results of animal monitoring using tetracycline, their seasonal movements have been noted: in the spring, they move from settlements in vacant territories, and return in the autumn.

3.2.3. Some patterns in the spatial distribution and numbers of brown rats in vacant and domestic areas of Moscow

Rats were found on approximately 30 % of the vacant territory surveyed in Moscow. In most cases, it is traces of the rats from buildings to vacant land (in summertime).

Three types of fixed settlement suitable for long-term monitoring have been identified and used by us for modeling purposes.

1st settlement type - " conditional-natural". Rats on the banks of ponds in parks, the closest to living in natural surroundings. Buildings are at a distance. The number of rats is low and the density of holes no more than 5 per 100 consecutive metres. The settlements are found only during the warm months.

2nd settlement type -”poly urban“. This settlement can be found on dumpsites (30 holes per 100 consecutive metres). Traces and of the rats’ movements were found under buildings surrounding a ditch, including under office buildings, apartment houses and, particularly, garages. As food waste on a dump, the same domestic waste also serves as a food source. These are all year round settlements.

3rd settlement type “urban”. The living areas are found between building blocks in the small green areas between containers and other items, as well as along the external double fence protecting the factory’s premises at which guard dogs are stationed at intervals – the rats eat their food, too. Here there are the holes with the greatest density (10 holes per 100 m) are found by these security posts, and also around places where food waste is collected like the vicinity of the factory canteen. –Here there are a smaller number of holes (5 per 100 metres) have been discovered under detritus and a combination of metal parts. The percentage of naturally occurring foodstuff is low, and the settlements are year round ones.

During the period from November to February, the reproductive activity of females living in heated buildings (the uterus is inactive) decreases; the genitalia and sperm count of the males is low. In places where brown rats spend the year outside of buildings, reproductive activity stops between September and May.

The single ecological population living in zones of partial synanthropy within settlements with adjoining open land, it is obvious the planning for managing such population including its mobile element is only possible through blanket coverage; taking measures not only in buildings, but also on open land simultaneously. In places where permanent colonies of rats reside, deratization is necessary throughout the year, and during the warm months for seasonal dwellings. Along with current measures used for combating rats, preventative barriers in the land adjoining housing should lead to a decrease in the in seasonal transit and in that way, prevent possible drift of carriers from naturally occurring areas of disease.

3.3. A zone of exoanthropy

3.3.1. Krasnodar region (rice fields)

The food supply is reflected in the diet. According to the analysis of the gut, both on frequency of occurrence and the volume showed that vegetable matter and seeds made up most of the diet over the autumn-winter period. Vegetable matter was also present during the other seasons, and consisted mainly of cereals and sedge. Animal fodder (insects, mice, amphibious) were found in smaller qualities. In the spring, vitamin-rich vegetable matter made up most of the diet. From June-July, all rice fields are filled in by water, in this instance the diet showed the prevalence of animal matter (mice, amphibians, molluscs, insects, others water invertebrates). The percentage of amphibious matter consumed was three times greater than during the period when the rice fields were not flooded. On a land by water was often possible to observe “small food tables” with the remains of pond snails, mussels, and small fish. The predominance of animal foodstuffs over vegetable matter in the rats’ diet lasted into September, prior to the start of the harvest season, the percentage of plant roots also increased a little.

During the summer period, considerable variations the diets of rats of various ages were observed. So, in the young of about two months distinctly old vegetable matter and invertebrate animals prevailed, the percentage of other kinds of foodstuffs, especially seeds and vertebrate animals, was negligible. From 3 to 6 months, the percentage of seeds increased in the maturing rat’s diet, and the percentage of vegetable matter decreased; however, the percentage of animal matter increased. Adult rats (older than 9 months) mainly ate animal matter and plant seeds. In comparison with rats of younger age groups, the elders eat the smallest percentage of vegetable matter. Similar results have been observed by us in a zone partial exoantropy, in the Yaroslavl area.

A rodent’s diet may, in many respects, define the nature of the bait used to remove them. It is evident that young rats least prefer grain-based rodenticide baits; their effectiveness will be minimal.

The monitoring we carried out using tetracycline markers in small animals in the Krasnodar region, showed that the rats living year round in open land (rice fields) do not mix with those occupying premises surrounded by rice fields.

In settlements in Kuban, reproductive activity of rats showed no appreciable decrease during the winter months.

In the rice fields of Kuban, where rats lived outside of manmade structures for the entire year, brown rats did not breed during the winter. Out of an average population, ranging from young to senior animals, sexually mature rats made up the overwhelming majority; the percentage of young was lower in comparison with other seasons of the year. In spring, all practically all females participated in reproductive activity. From May-June showed the greatest number of young. The share of sexually immature females of 2-2.5 months began reproducing and continued up to October. Breeding rises just once - during spring and summer however, the share of pregnant females during this period is essentially higher than in settlements.

In the rice fields of Kuban, due to the death of more elderly animals in the group, considerable annual changes to the population structure are a characteristic. The hibernating conditions appear more severe and a large percentage of older animals die. In settlements of Kuban, the percentage of older animals is higher practically all year which indicates that death rates can be affected by adverse environmental factors.

Dynamics of reproduction and the age structure of the rat population in rice fields and in settlements are varied, and seasonal migration between these territories does not exist and this signifies that two independent ecological populations live there. Separate strategies should be employed against each group.

4. Management of the numbers of brown rats and other rodents

4.1. Distinguishing characteristic of age and sex: avoidance reaction to rodenticide baits and physiological resistance

The survival of rodents in the conditions where intensive extermination programmes are carried out may be due to the following:

1) Developing an avoidance reaction as consequence of the lack of a lethal dose of poison at normal levels of sensitivity to poison;

2) Developing greater physiological resistance which can be related to age, and perhaps genetic resistance passed to future generations, as well as the natural tolerance level inherent a particular species.

Age variations in avoidance reaction and physiological resistance are most clearly demonstrated between sexually mature and immature animals. Finally, lethal doses of warfarin for sexually immature rats, for example, is twice that of adults. Young brown rats, especially males, eat much less bait with this poison (per kg of body weight), than adults. Some males, above all the young, appear to be pushed away from food sources by adult males occupying higher hierarchical positions, so they have less access to poisoned bait. These differences explain the higher survival amongst the young, particularly males, therefore the percentage of young and average age groups increases, and the percentage of rats of an advanced age decreases. Young rats within approximately one week after leaving their holes take bait from feeding troughs with extreme care therefore they have an additional opportunity to survive contact with a rodenticide bait. Finally, the large survival rate of males in comparison with females from exterminatory measures within their natural habitat will be characterized not so much by distinctions in levels of resistance to rodenticide substances, but by the frequency with which they encounter them.

4.2. Natural and acquired resistance to rodenticides with anticoagulants

Many brown rat populations which had no contact with rodenticides containing anticoagulants have a heterogeneous resistance to these poisons; of these there is a certain percentage that, under certain conditions, can increase their levels of resistance. This data is supported by tests undertaken by us on rats caught in the Stupino area of Moscow area, a rural area, where no deratisation programme was carried out and could not be used as a selective factor. After 6 days of feeding 25 brown rats on bait containing 0,005 % warfarin, 1 male has survived, having consumed 4,75 mg of warfarin or 27,9 mg per 1 kg of body mass, more than 4 times an average lethal cumulative dose.

The physiological resistance as defined by WHO standards (WHO, 1976), in of the brown rat population of Mytischi in the Moscow area has not been divulged. Nevertheless, they appear to be heterogeneous within the norms of reactive sensitivity to warfarin. Noticeable variations in the average arithmetic values of cumulative doses and the number of days of consumption of rodenticides baits until death are great. And among victims, there was a category of animals whose death from cumulative doses considerably exceeded those which values lie within ±3 σ (p <0,001). Such rats on the average need 6,1±2,2 % (1,6-10,6 at tst =2,0 and p <0,05). Among these small animals there were only 3 rats (2,6±1,5 %; 0-5,6 at tst=2,0 and p <0,05) which ate a rodenticide bait daily for a term more than 10 days and in doses of warfarin exceeding 1,3-1,5 mg/kg of body weight and with tetracycline of 60 mg/kg per day. It is possible, that rats with low resistance could not be killed by warfarin alone (without combining it with roughly 1 % tetracycline in the same bait).

We have identified resistance to warfarin in the locality of Moscow, in particular in a cellar under a premise housing laboratory animals for the Russian Academy of Medical Science, as a result of hybridisation of wild brown rats with the white rats, whose resistance to warfarin approximately twice as great.

4.3. Modelling the effect of bait with indirect acting anticoagulants on brown laboratory rats

In a series of experiments on three generations of two laboratory populations of brown rats, we can tentatively confirm the observance of physiological resistance to warfarin, and also a tendency to increased avoidance behaviour of bait with this anticoagulant in ensuing generations, and both of these adaptations are mutually exclusive. During screening for increased physiological resistance to warfarin and avoidance reaction to bait containing it, it became less marked. And conversely, during screening for increased avoidance reaction in relation to the bait containing 0,005 %of warfarin, a genuine increase in physiological sensitivity in three subsequent generations of to this poison was observed, which was demonstrated by the refusal of repeated contact with the poisoned bait for a second day (as is the case with fast acting poisons) and the lengthening time taken for coagulation (the increase of prothrombin time). A rather interesting fact is that the population of brown laboratory rate selected on the basis of their avoidance reaction to warfarin, had no interest in bait with diphacinone – also an anticoagulant indandione type (warfarin - 4-hydroxycoumarin type). The laboratory rats selected on the basis of their physiological resistance, on the other hand, willingly ate bait with warfarin, and did not neglect it in favour of control bait. It attests to the lack of animals poisoned by warfarin; prothrombin time remains within the norm. Thus, the marking system used in conjunction with the analysis of sex and age structures of the population and the definition of the level of physiological resistance via the WHO technique, allows us to monitor the condition of the population during the course of its extermination and to evaluate the approach taken to adaptations allowing us it to keep numbers above critical extinction levels. It opens up the prospect of artificial selection, instigated, for example, by the development of adaptations to the population level, including the mutually exclusive adaptations easily overcome by popular methods.

As we already know, house mice are less sensitive to rodenticides with anticoagulants, so for this reason the toxicity was of no less importance than the appeal of the bait. Second generation anticoagulants such as brodifacoum and bromadiolone were more effective than first generation ones such as triphenacine, ethylphenacine, chlorophacinone and diphacinone.

As the results of laboratory research have shown, with the use of bait with blood poisoning anticoagulants in the battle against brown rats, its appeal was more fundamentally important than its capability as an anticoagulant to the first or second generation.

4.4. Application of rodenticide coverings

Rodenticide coverings in the form of Vaseline paste with warfarin are tested at different temperature modes in the cellars of inhabited multi-storeyed houses. Based on the material collected in the summer of 1986, it has been established that the overwhelming majority of rat victims (males and females) had come into contact with rodenticide covering. Conversely, in winter in the refuse collection chambers and basement cellars, in both plus and minus temperatures, the extermination of the majority of rats took about two months. At minus temperatures rodents receive low concentration of poison twice as often, as at plus temperatures.

In live tests, where baits and rodenticide paste with warfarin were administered simultaneously, the efficiency rate was 82 %, and where baits with warfarin were used it was only 44 %. The contribution of the poisoned baits to the general efficiency of extermination was much lower in comparison with the effect of Vaseline paste with warfarin. As the results of the extermination of rats show. For a bait of 0.025 % warfarin on a separate area of housing estate (5 populated multi-storeyed houses) in the same timeframe, when the efficiency of a combination of Vaseline paste (of 0.5 % warfarin) was tested with the poisoned bait (of 0.025 % warfarin) on other site (5 populated multi-storeyed houses). The percentage of the surviving rats on the first site was 3 to 4 times more than on the second, to which the results of the extensive and long-term (within two months) catching of these rodents by arc traps testify.

In comparison with rodenticide baits which caused the primary destruction of adult brown rats, especially males, Vaseline paste with warfarin, on the other hand, did not have a selective effect on different ages and sexes. Therefore, rodenticide pastes can be used on a rotational basis to overcome resistance to the application of rodenticide baits.

4.5. A safety evaluation of rodenticide

On the basis of the experimental and scientific literature and scientific work of the following group (Zaeva G. N, Maltseva M. M, Rylnikov V. A, Berezovsky O. I, etc.) rodenticide, appropriate toxicity and safety classification has been developed for the evaluation of substances, concentrates and baits in all ranges of application which may be a useful methodical tool in the business of their research, improving possibilities of a meaningful study of processes and the phenomena with a view to the further increase of efficiency in deratization.

4.6. An experimental substantiation of the concept of continuous systematic inspection and selective extermination.

The evaluation of the number of rats, the area of land occupied by them and the identification of places with localized populations have enabled us to dispose of costly, outmoded strategies in the struggle and cover the greatest possible area with frequency rate of 24 times per year.

Efforts are concentrated on the basic habitats of brown rats identified during visual inspection of the KAMAZ factories (in the republic of Tatarstan) and constitutes approximately 2 % of the total area (lavatories and ventilation chambers). In the first quarter of 1991, on two sites of factory sheets with rodenticide paste were set out with grain scattered over them. On one of sites a Vaseline paste with 0.5 % warfarin was used, and on –another, a similar paste with 0.2 % ethylphenacine was used. On the site using the paste with warfarin, the rat population had been lowered between February and March by 75.8 %, and by 93.6% on a site using a paste with ethylphenacine.

In April and May, a repeat of the process using a rodenticide paste with warfarin and maintaining the same processing procedure was carried out: number of platforms, of the method of applying paste and grain, the place of their arrangement. Density of traces of rats on platforms was reduced from 58% to 5 % on one site and from 83% to 30 % - on other.

When the reporting concluded on August, 2nd, 1991 it appeared, that from 359 control devices examined traces of rats have been identified in 59 cases, i.e. the average efficiency of processing on both sites has reached 83.6 %, and the achieved effect remained till the end of the year though into the third quarter with no repeat of the exercise.

In rice fields of Krasnodar region, the optimum period for of the extermination rats is the end of winter to the start of spring (February-April) prior to the commencing of spring field work. At this time, small animals are concentrated in areas where there is a lot of straw on unploughed areas of the rice fields with lots of leftover rice seeds. It facilitates location of places for treating. Reproduction during this period is absent, and number of small animals from November till April decreases on account of the natural death rate in 3-3.5 times for the given period. Consumption of rodenticide baits at this time it is high, the majority of rats eat rodenticide bait even during periods of insufficiently security food supplies during the winter .

The threefold extermination of rats during the period from December 1981 until June 1982 on an experimental plot in an area of 175 hectares provided a practically full clearing of rodents not only on the treated site of rice fields, but also essential decrease in number of rats on the adjacent sites with a total area of 250 hectares to the findings of which are supported by the location of only one individual inhabited entrance holes (0.3 within 100m). By October birth rates for brown rats in southern zones decrease. The birth rate cannot restore the number of rats. The immigration component in replenishing the numbers of rats was, apparently, low. Rice field sites treated by rodenticides in the autumn have been carefully ploughed and all remaining seed removed. Food supplies for rats are poor and, therefore, these sites are barely attractive to immigrants. 1982 was the year of a general lowering in the numbers of brown rats in rice fields ─ one of the reasons for the low rates of restoration of numbers on this site. Thus, exterminatory processes were successfully executed during the winter, spring and summer periods, l low level of number of rats in to the autumn. The reason for this is, predominantly, the compulsory death rate over birth rate, and then prevalence of natural death rate against the natural decrease in the birth rate.

To work out a strategy for the management of the brown rat population the choice of dates and matching this to the temporal population units which are most sensitive to deratization methods is highly important. One such periods is the period when breeding decreases, for example, the late autumn, winter and early spring when percentage sexually immature animals is insignificant, the age spread, heterogeneity of phenotypic character essential to the population is substantially lower, the spatial spread of brown rats is neatly pinpointed to places with a stable food supplies and a favorable microclimate: in cities - in buildings, dumps; in the open land of the southern zone - in non-frozen reservoirs, fields with leftover crops. The consequence of this is a lower survival rate and, therefore, a smaller probability developing resistance.

On the basis of the tests conducted on the concept of continuous regular inspection and selective extermination methods have been developed. The new concept relies primarily on the obtaining the key parameters characterising the condition of the rodent population, its position, density, age and sexual structure, birth and recovery rates, the reaction of groups and individuals pest control. Development of this concept assumes use of tested ecological research by experts in deratization.

4.7. Creation of "controllable zones“ through constructing the elements of a habitat

The key elements in the registration, gathering and destruction of rodents proffered by us are: the capacity for assessing methods for the removal of rats which are continually present in building structures and attracted to auxiliary facilities allowing for undetected movement, escape from danger, rest and so on, We have designed special containers: "Container-K" and "Container-M”. The possibility of choice, along with open feeding troughs - brown rats preferred to be fed in the first, and house mice, voles and other small rodents in the second. There, where the application of pesticides is not allowed for safety reasons, lack of efficiency or any other reason, mechanical or electric traps have appeared, which in comparison with killing traps (arc, Gero trap, etc.) are effective. Live traps, especially the automatic, electromechanical have an advantage. Live traps, unlike killing ones, provided the opportunity to remove rodents from land without their destruction, decomposition, or the transition of ectoparasites on others warm blooded creatures (people and pets). The use of such technology allows for the creation of ”controllable zones” in which it is possible to limit the number of rodents for a unspecified period of time, that work in harmony with selective methods of destruction.

4.8. Mathematical modelling and an evaluation of possibility of forecasting the number of rodents after carrying out exterminatory actions

Finite-differential model of restoring numbers on a site treated by raticides,

$$(x_0(\Delta t+t) - x_0(\Delta t))/\Delta t = (r_0(x_0(t)) \times (x_0(t)) + \Delta x'/\Delta t$$

Despite its obvious primitiveness, it has allowed us to offer at least an approximate forecast. In cases when such a model has insufficient experimental material, the formula for the Bayes inference system can be used.

$$P(Д|E) = P(X|E)P(E) / P(E)P(X|E) + P(X|\bar{E})P(\bar{E})$$

Possibility of application of a logical conclusion appears higher in the conditions of stable inhabitancy of rodents in the settlement. As is already known, the stability of environmental parameters increases the accuracy of the forecast of those processes in which it has developed. Necessary parameters for the variables entering into mathematical models have been obtained by means of calculating the specific indicators of birth rate developed by us, and the death rate, immigration and emigration on the basis of the experimental data obtained by ourselves and other researchers.

Conclusions

1) The research into the ecology of brown rats carried out by us in different areas has allowed us to identify three zones in European Russia: a zone exoanthropy (located in the southern zone); a zone partial synanthropy (the central zone), a zone of full synanthropy (the northern zone).

2) Our study of the dynamics of numbers, reproduction, the age structure of the brown rat population in various zones has allowed us to establish the following: in a zone exoanthropy, the relative isolation of the populations living in settlements (reproduction all year round), from populations in undeveloped areas (seasonal breeding patterns) has been observed; in zones of partial and full synanthropy, population of settlements with adjoining open land in the central zone makes a single whole; the reproduction of rats is of a seasonal nature; population of the northern zone differs as buildings are inhabited for an entire year.

3) Efficient control of numbers taking into account characteristics of the population structures of the species and its dynamics over a year, at least, at two levels: ecological populations (in developed areas), elementary populations (in a building, or a group of structures).

4) Taking into account dynamics of sex, age structure, spatial and ethological phenotype structures of the rat population and other population parameters we have identified temporal subpopulation units - seasonally influenced according to the time of year. Temporal subpopulation units exist on a parallel with the ecological and the elementary population and possess the qualitative characteristics which guarantee their resilience during any given season. Means of managing these subpopulation units must take into account their seasonal and spatial dynamics.

5) Adaptive signs: ”avoidance reaction“ and ”physiological resistance“ are mutually exclusive in relation to the effect of anticoagulants. Heterogeneity of these signs amongst individuals of a different sex and age groups are material for selection. The subsequent selection goes either to one indicator or another. The successful management of the qualitative structure the rodent population can be carried out through a decrease in phenotype variability and the frequency of adaptive indicators within the narrow limits of variation on the average indicators which usually take place in the absence of the effects of rodenticides upon rodents.

6) Management of the quantitative and qualitative structure of an ecological population of brown rats can be carried out by an increase in the compulsory death rate in the area covering the entire ecological population of brown rats (in settlement borders) and during the whole life cycle of the population (calendar year), mainly during the period with the greatest vulnerability to harmful substances; as a result, with the greatest natural and compulsory death rate, at the greatest heterogeneity its spatial placing which are inherent in temporal subpopulation units inhabiting buildings during the autumn-winter period.

7) Management of the quantitative and qualitative structure of an elementary population of brown rats can be carried out by decreasing the level of numbers of residents and the volume of immigrants by:

· using methods and the means representing a uniform system for overcoming age, sex, individual heterogeneity of brown rats in temporal subpopulation units;

· maintenance of effective (operational and precise) feedback upon completion of a programme: effect - monitoring - result analysis - correction of management of effects.

8) Based on the study of the population structure of rodents, the temporal and spatial and temporal dynamics of the brown rat population, we have developed the concept of continuous, regular inspection and selective exterminatory activities, based on continuous inspection of structures and territory for the purpose of obtaining information on the condition of the rodent population, including its spatial structure, density, age and sexual structure, rates of reproduction, reduction and restoring of numbers in controlled areas, evaluation of the substances used on rodents. This research is the basis for the management of rodents in the territory they inhabit.

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