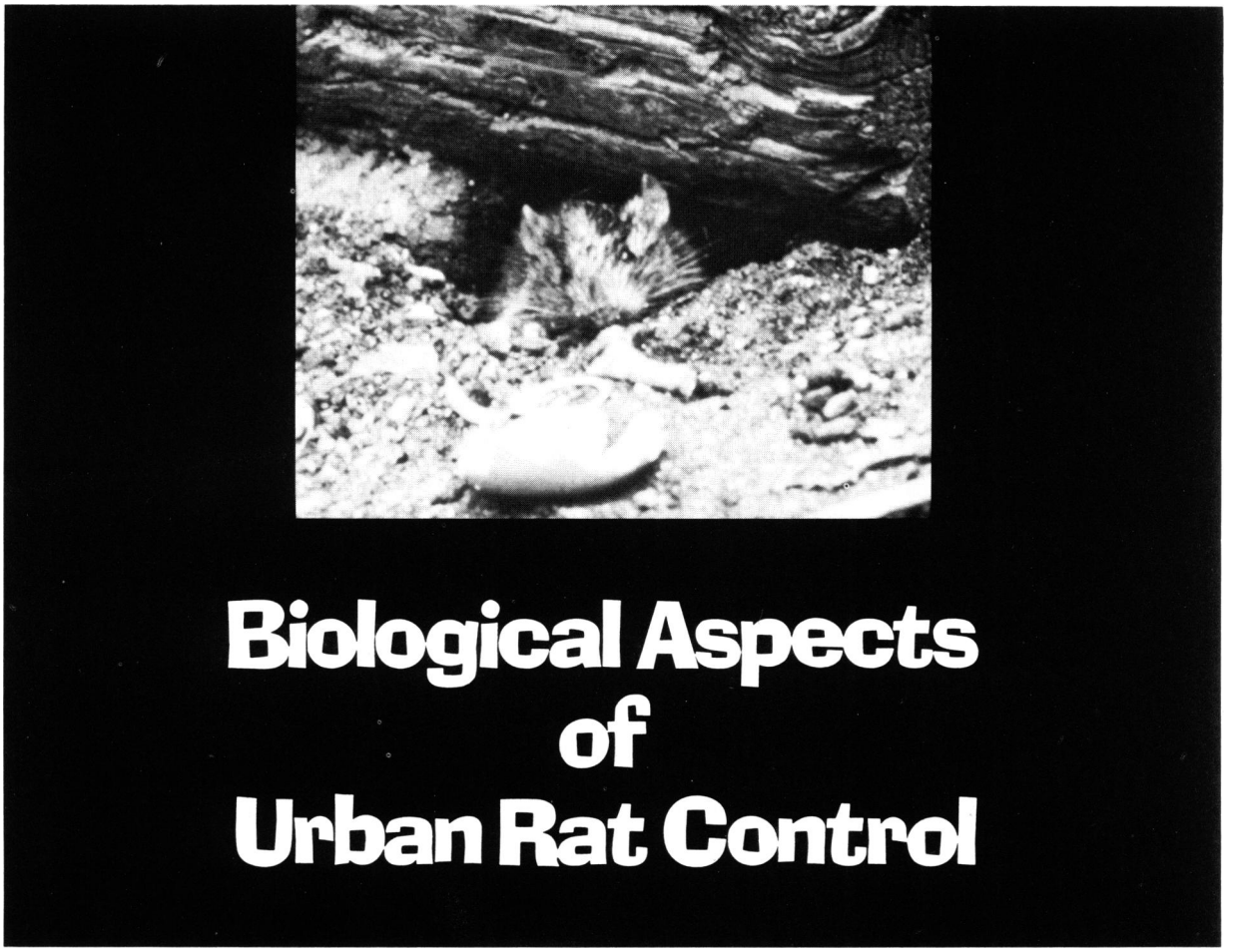

Biological Aspects of Urban Rat Control

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The frequently cited figures of economic damage caused by rats and annual reports of rat bites indicate only a portion of the cost of rat infestations. In the past, primitive traps and poisons were the main weapons against rats. Recently, more sophisticated traps and poisons, lethal gases, and chemosterilants have been developed. But,

despite these new extermination methods, rat populations continue to thrive and to endanger human health.

In 1967, under the Partnership for Health Act, section 314 (e), Federal funds were allocated for rat control programs in the inner cities. Additionally, several States, such as New York and Connecticut, have funded their own rat control projects. All these programs vary tremendously. Not only do they differ in size and function, but also in the methods they use. Too often these methods have only a temporary effect.

In this paper we discuss the limitations of the new techniques currently being used and analyze one method of rat control—environmental improvement—which is the most promising. We also highlight some characteristics of the Norway rat (*Rattus norvegicus*), the species commonly found in cities and responsible for most rat bites (*1*). Current information about rat control is dispersed widely in specialized publications which deal with only one or two aspects of the subject. We have gathered pertinent information into this article so that a greater understanding of the problem can be gained and more successful programs carried out.

Natural Forces

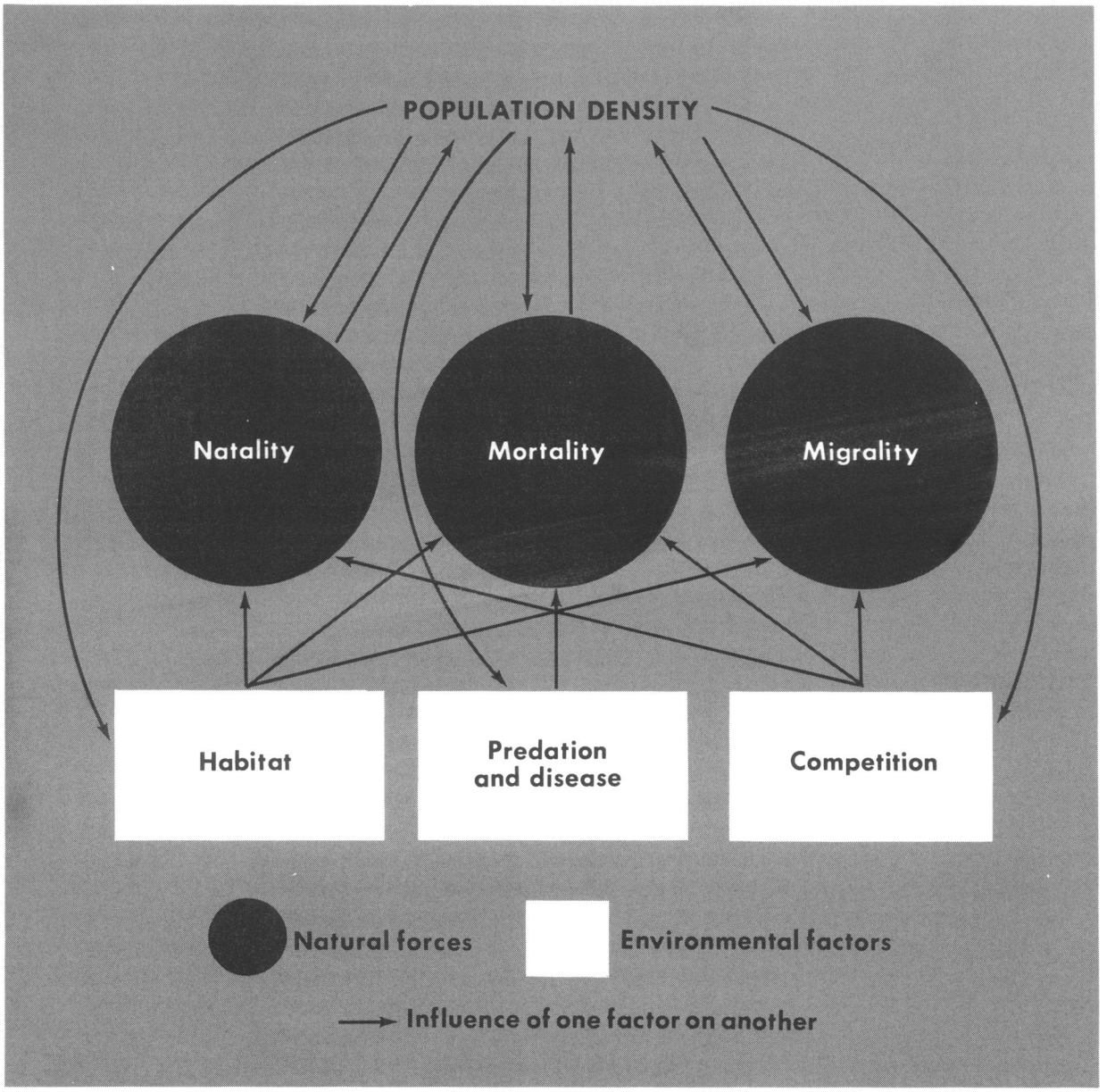
Three natural forces determine the size of a rat population: natality, mortality, and "migrality" (*2*). The extent to which these forces operate in a given population is diminished or increased by the environmental factors of predation, disease, and competition. Although, for the sake of clarity, each natural force and environmental factor is discussed separately, it should be remembered that they all act simultaneously on each other and on a given population (see chart).

Natality. Natality refers to the birth rate of a given population. The species *R. norvegicus* reproduces rapidly. It breeds all year long, with peaks in the spring and fall (*3*). The gestation period is 22–25 days. The average litter is six to nine rats, and sexual maturity is reached 6 months after birth. A rat can become pregnant while still suckling a litter (*4*). The breeding capacity of *R. norvegicus* is such that a given population of this species can increase by 50 percent in 1 month (*5*); on the average, the female produces 35.7 offspring a year (*4*).

Mortality. The annual mortality rate in *R. norvegicus* populations is estimated at 95 percent (*2*). Prenatal mortality is estimated to be about

Rat burrow in cracked concrete

Interaction of natural forces which determine the population of rats in urban areas



16 percent (*4*). In a population which changes this frequently, genetic adaptation to environmental pressures occurs rapidly.

Migrality. The in-migration and emigration of rats in a given area is called migrality. Of the three natural forces, migrality is the least understood because it is the most difficult to study. Rats are known to have a limited home range, with a radius of about 100 to 150 feet (*3*). They seldom move from this area, except under extreme stress. Migrating rats usually experience a higher mortality rate than nonmigrating rats.

Environmental Factors

Natality, mortality, and migrality influence population size, which also is influenced by environmental factors or characteristics of the habitat.

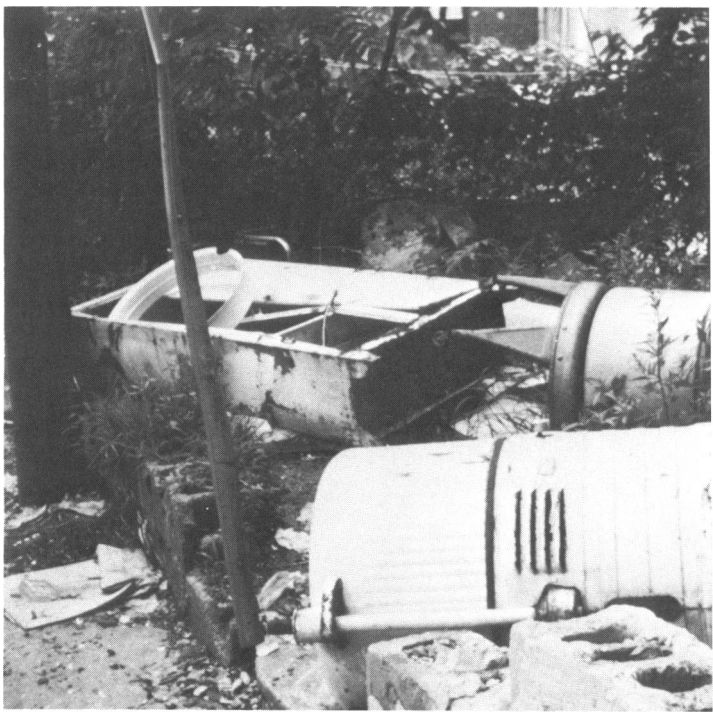
Habitat. The characteristics of a habitat and the rat population level which it will support are directly related to each other. The three main elements of a habitat which determine the density of a rat population are food, water, and shelter. Since each habitat has a limited amount of these elements, each has a limited rat-supporting capacity.

Food requirements and preferences. The adult *R. norvegicus* requires only ¾ to 1 ounce of dry food a day and ½ to 1 ounce of water (*3*). Rats are omnivorous, but prefer grain to other food (*6*). In addition, they like meat and eggs. They do not like spicy foods or raw vegetables such as onions. However, choice of food is largely determined by what is available, and rats readily adapt to a great variety of foods (*7*). Norway rats have regular eating habits—they begin to eat shortly after sunset (*8*). If their habits are disrupted by the introduction of a new food source, they often become suspicious and avoid the new food until it becomes familiar to them (*9*). This tendency to be wary of unfamiliar food or new food sources often causes rats to avoid poisoned grain or meal, and is commonly referred to as "bait shyness."

Harborage. Rats usually choose old burrows or holes for their nesting places. They select these places very carefully, because they occupy them for more than 20 hours a day (*10*). The types of harborages vary tremendously; they are known to include sewers, refuse heaps, garbage dumps, crevices in alleyways, buildings (especially the lower floors), burrows in backyards and riverbanks, and spaces between walls.

The specific characteristics of an ideal harborage are difficult to determine. Many different variables seem important. For example, it is known that soil quality is one factor in determining the desirability of an area. In one eastern European city, 19 of its 22 districts have many rats while the remaining three have practically none. The scarcity of rats in these three districts is believed to be due to the composition of the soil, which is loose sand (*10*), and consequently burrows are rare.

A rat population, unhampered by man, usually will expand beyond a habitat's supporting capacity. The crowding which results causes increases in predation, disease, and competition which in turn reduce the population by increasing the mortality rate and decreasing the natality rate (*2*). Environmental factors have a great effect on biological mechanisms. Even when adequate food (but not shelter) is available, crowded rat populations have a high infant mortality rate. Infant mortality can rapidly change from a range of 30–40 percent to 90–100 percent in response to a change in habitat and social conditions. Crowded rat populations show increased aggressive behavior, increased competition, nest destruction, parental desertion, and often cannibalism (*4*).



Abandoned appliances and weeds offer comfortable resting places for rats

Accumulation of trash in alley is home to great numbers of rats

Predation and disease. Predation and disease reduce population density by increasing mortality rates. For this reason, they are discussed together. Davis (*11*) explains the effects of predation and disease as follows.

> The particular predators or pathogens operate in approximately the same way; they kill individuals and increase the mortality rate or at least make the individual sick so that some other factor may operate to increase the mortality rate.

In urban habitats the indigenous predators are dogs and cats. Some authors disagree on the extent to which dog and cat predators reduce rat populations (*2, 7, 12*). All observers agree, however, that the effect of predators on a rodent population is temporary. The diseases known to be fatal to rats, such as bubonic plague and salmonellosis, are also temporary in their effect on *R. norvegicus* populations. Several rats usually survive these epizootic outbreaks, and they are capable of restoring the population to its original density within about 1 year.

Competition. There is competition for food and shelter within any rat population. The closer a population density is to reaching the supporting capacity of the habitat, the more intense the competition becomes. Competition translates the pressures of limited harborage and food supply into increased mortality rates and decreased natality rates. In each habitat, rats rank themselves socially through direct conflict. Fighting rats rarely inflict mortal wounds, but the loser is usually seriously weakened. In addition, the strongest rats usually occupy areas closest to food and shelter, and the weaker rats are forced to live on the periphery of the colony and to travel farther to the food source. Thus, the weaker rats are not only more susceptible to disease but are also more vulnerable to predators (*11*).

In high-density populations, more time and energy is needed to obtain food than in populations of lower density. It has been shown that at high population densities, competitive fighting is very easily provoked, and that stress is most acute at the food source (*7*). This competition produces a number of physiological effects that are not fully understood but are being studied. According to Davis (*11*):

> The sequence of events, in general terms, is that the aggressive behavior acts through the brain on the pituitary to stimulate the hormonal production of the adrenal glands. In addition, a number of direct effects occur on the hormones of the pituitary itself. This change in production of hormones acts in two directions. One sequence of events is an increase in susceptibility to infection resulting from an increased production of corticoids. These hormones reduce resistance by action on antibodies and thereby set the stage for an increase in mortality due to some pathogen. Another aspect that contributes to an increase in mortality is the development of physiological disease such as kidney and heart problems. As yet, these aspects are poorly known in rodents but perhaps contribute in the long run to an increase in mortality. In another direction, these hormonal changes affect the population through their action on birth rate. The hormones from the pituitary and from the adrenal cortex have effects on the gonads and may reduce the number of young born. These actions can come about through interference with the development of the gonads in young individuals, through a delay in the estrous cycle, through increased resorption of young, or through effects on lactation of the female. For our purposes, the important point is not the actual details of how these hormones affect the reproductive rate but the fact that in many ways, there is an opportunity for competition among individuals to reduce the reproductive rate.

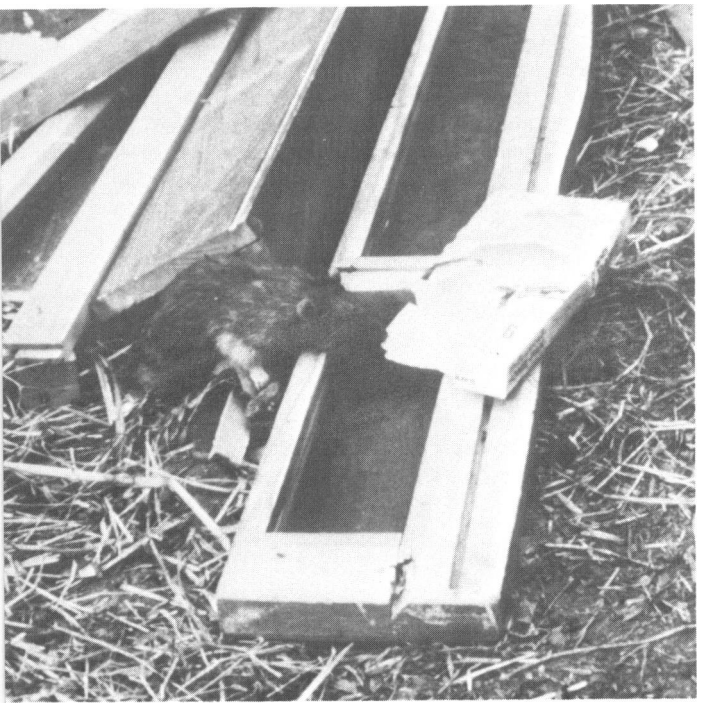
Current Rat Control Techniques

The most frequently used method of rat control is poisoning. We discuss here only the most commonly used poisons, with emphasis on their use as rodenticides.

Anticoagulants. Anticoagulant rodenticides such as warfarin and Pival are used extensively in most poisoning programs. They are slow acting, and they require about 4 days of repeated ingestion to kill Norway rats. Anticoagulants inhibit the production of prothrombin, thus resulting in massive hemorrhaging, shock, coma, and death. Usually, anticoagulants are mixed with cereal or cracked corn and placed in bait boxes. Bait shyness is rarely encountered with the use of anticoagulants, because rats do not identify the poison's effect on them with the bait they have eaten (*13*). Resistance to anticoagulant rodenticides has been reported in Europe (*14*) and the United States (*15*).

Red squill. Red squill is used primarily against the Norway rat. It is most effective when used for one-shot, or single-application, baiting, because its bitter taste often produces bait shyness in rats (*13*). Red squill has a digitalis-like action which causes heart paralysis (*13*). An important safety feature of this poison is that it is a natural emetic and thus causes vomiting when ingested (*3*). Since rats cannot regurgitate, they retain the poison and die. Children, dogs, and cats, however, will regurgitate the poison and will experience little harm. Thus, red squill can be used in areas densely populated by people.

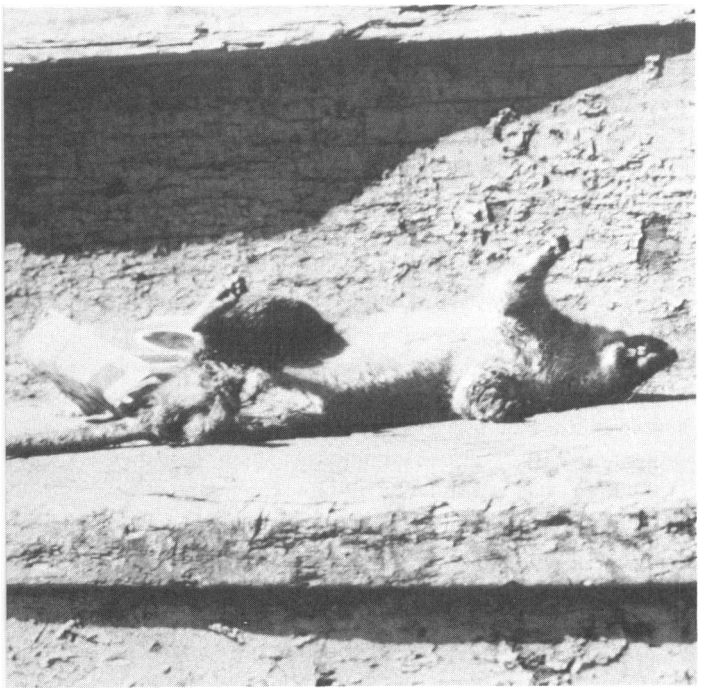
Zinc phosphide. Zinc phosphide is a fine black or greyish-black powder with a strong gar-



Rat emerges from harborage in stacked lumber

Photos on pages 18, 20, and 22 are from the Federal Rat Control Project's offices in Washington, D.C., Philadelphia, and Baltimore

Rat killed by poison will soon be replaced, as long as food and shelter are available



lic-like odor, which is nonetheless attractive to rodents (*16, 17*). It is fast acting and causes heart paralysis, gastrointestinal disorders, and liver damage (*3*). Although a tartar emetic is usually added to the bait mixture, zinc phosphide is hazardous to people. For this reason, it is usually used only in paraffin formulations as sewer bait. Brooks (*16*) discusses the uses and effectiveness of zinc phosphide and other rodenticides in considerable detail.

Although the poisons discussed are effective and fast acting, they are expensive to use because they have only a temporary impact on the rat population. A poisoning campaign, if carefully and systematically carried out, will wipe out about three-fourths of the population. The remaining fourth, however, will be able to restore the population density to its original level in about 6 months (*5*).

Southwich (*4*) believes that poisoning may serve to maintain the reproduction rate at its most efficient level. In addition, reports of recent research indicate that some rats are developing resistance to anticoagulants (*14, 15, 18–20*). These poisons have been considered the most effective and safest to use and are heavily relied on in most rat control programs. One report states that resistance to anticoagulants is a genetic trait linked with the color of the rat's coat (*18*).

The problem of pests developing resistance to pesticides is a recurring one. This problem will be avoided only when focus is placed on controlling the population by managing the habitat rather than on exterminating the individual rodent.

Chemosterilants. The purpose of chemosterilants is to sterilize rodents without harming them in any other way. Sterile rodents can be released into the environment to compete with normal rats for available food and shelter. If enough sterile rats are released into the environment, the birth rate will become lower than the death rate (*21*). Ultimately, the species will die out. There are two classes of chemosterilants—those which sterilize the female and those which sterilize the male.

Among the chemosterilants which are aimed at the female rat, mestranol, an estrogen compound, has been one of the most thoroughly investigated. Mestranol inhibits ovulation, and it is transmitted through the mother's milk to newborn rats. The young who receive enough of this contaminated milk are permanently sterilized. Unfortunately, when tested in the field, this drug caused strong

bait shyness (*22*). Progestogens which inhibit ovulation are orally more acceptable to rats, but they need to be ingested daily to maintain effectiveness. Progestogens, therefore, are not very promising as a control technique for the time being. Clomiphenes and several diphenylindene derivatives have also been experimented with as antifertility drugs. Unfortunately these drugs have also caused bait shyness (*21*).

If progestogens that do not need to be ingested daily are developed, or if estrogens or estrogen-like compounds can be made acceptable to rats, chemosterilants which sterilize female rats may become a promising control technique. For the time being, however, their effectiveness is extremely limited.

Most of the chemosterilants developed for male rats are antispermatogenic, that is, they block the production of sperm. The four groups of compounds that have been tested are nitrofurnans, thiophenes, halogenated diamines, and dinitropyrroles. Bait shyness is a great problem with the use of these drugs. Other antifertility drugs are being developed for male rats, but, as yet, they have not been tested in the field (*21*).

On the whole, even if made more effective, chemosterilants are not the answer to rodent infestations. Even under the best of circumstances, where bait shyness is overcome, it would take between 6 months to 1 year to decimate a rodent population. In addition, most chemosterilants require repeated ingestion to be effective. Chemosterilants should be used primarily in areas where environmental improvement is impractical, such as dump sites or old sewers (*22*).

Environmental Improvement

Poisons, predators, and chemosterilants are directed at the rat rather than at the conditions which support him. For this reason, these methods have not been completely successful. A study conducted by Davis in Baltimore clearly demonstrated the superiority of environmental improvement over the use of poisons as a rat control technique (*6*). From 1943 to 1950, Davis studied rat population levels of one block in Baltimore. At first, he tried to lower the population level by using poison. The poison did substantially reduce the population temporarily. However, even after three poisoning campaigns, the rats continued to restore the population to its original level.

Davis then began a program of environmental sanitation, which consisted of abating existing sanitation and housing code violations and insuring that no new violations occurred. As a result of these efforts, the rat population sharply declined and remained very low. By drastically lowering the supply of available food and shelter, Davis forced the rats to compete vigorously for what remained. The increased competition affected the natural forces of natality, mortality, and migrality, which in turn exerted pressure on the rat colony. This pressure resulted in a decreased population level.

Rat infestations cannot be eliminated until harborages, such as this neighborhood offers, are eliminated

A more detailed explanation of how intense competition does reduce population levels was given earlier. The important finding in Davis' study was that by properly maintaining the environment in a block in Baltimore, he could drastically reduce the rat population and keep it at that low level. Chemosterilants and predators which, like poison, do not reduce available food and shelter also have only a temporary affect on the rat population (*2, 7, 12, 21*).

Environmental control is the best rat control technique for combating the rat problem in the inner cities (*3, 23, 24*). It is also the only technique which offers an extremely valuable byproduct—a clean, well-maintained neighborhood.

Conclusion

Deteriorated neighborhoods are inhabited by large rat populations because they offer much food and shelter. Rats, in fact, have been used as an indicator of neighborhood deterioration. Previous attempts to eliminate rat infestations have failed. Temporary control measures such as poisons and traps have been used to little avail. Rats still endanger human health in all large U.S. urban centers.

This situation cannot be alleviated until significant changes are made in the environment which supports the rat. If available food and harborage are reduced, the rat population will be reduced. Programs which use environmental improvement as a primary control technique must have sufficient funds allocated for this large task. Programs which are concentrating on other techniques should be encouraged to focus on environmental improvement. Only by attacking the disease, rather than the symptoms, can the rat problem be solved.

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