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RODENT CONTROL IN CHINA

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ABSTRACT: Rodent pest problems and their control in China are reviewed. Three commensal species, Rattus norvegicus, R. flavipectus and Mus musculus, are important pests both in urban and rural regions. Mus musculus is the most widely distributed species in China. Its population density is cyclic, unique for a commensal species in being found in the arid Xinjiang (Sinkiang) Autonomous Region in Northwest China. In South China, R. losea and Bandicota indica are serious problems in rice and cane fields. Many different genera of field rodents are considered pests to agriculture and/or are reservoirs of rodent-borne diseases. These include Citellus, Marmota, Meriones, Cricetulus, Microtus, Apodemus, Ochotona, Myospalax, Clethrionomys, Sciurus, and Eutamias.

The ecology and control of these rodents are included. There are a series of efficient administrative organizations responsible for rodent control. Most campaigns of commensal rodents have relied on a combination of rodenticides and different types of traps, but in the case of field rodents the reliance is heavily placed on poison baits. Diphacinone (Na-salt) is most frequently used for control of commensal species. Zinc phosphide, fluoroacetimide (1081), sodium fluoroacetate (1080), glyftor and 0.2% diphacinone (Na-salt) are used for field rodent control.

Information is supplied on the susceptibility of important rodents in China to different rodenticides, including difenacoum and brodifacoum, and on other means of rodent control.

China is mainly located in the north temperate zone. Geographically, the landform is very complex including large plains, high mountains, plateaus, grasslands, deserts, forests, etc. The vertebrate fauna is very rich, but most species of Rodentia cause harm to agriculture, industry and/or transmit human diseases.

Commensal rodents, Rattus norvegicus, R. flavipectus and Mus musculus, are the most important pests both in urban and rural regions. In the tropical and subtropical region of South China, R. losea and Bandicota indica are a serious problem both in rice and sugar cane fields. Many different genera of field rodents are considered pests to crops and/or reservoirs of rodent-borne diseases in Northern China. These are Citellus spp., Marmota spp., Meriones spp., Cricetulus spp., Microtus spp., Apodemus spp., Ochotona spp. and Myospalax spp. Pests to forestry include Clethrionomy rufocanus, Sciurus vulgaris and Eutamias sibiricus. They damage the red pine seeding, often making reforestation impossible.

Before the founding of New China in 1949, there were no rodent control organizations or rodent control programs, except for some locally made traps used for rat control. Since then the Government has paid great attention to rodent control. Large-scale rodent control campaigns have been conducted every year since 1956, and they have made good progress. A brief review on rodent control in China follows:

THE ORGANIZATION OF RODENT CONTROL

Rodent control is a complicated, practical, ecological problem which deals with a wide range of knowledge, as well as habits and customs of people. It is a job for everyone to keep rodent damage at a low level. In order to push the work forward, there is a great need for an efficient administrative organization to spread propaganda among the masses and to establish effective inspection and enforcement methods.

In our country each province and county has its own Antiepidemic Station responsible for implementation and consultation of rodent control.

Another system is a series of committees of patriotic public health campaigns at central, provincial and county level, which are responsible for spreading propaganda, training and supervising the operation of the street committees and for procuring the rodenticides and traps.

THE MANUFACTURE AND SUPPLY OF RODENTICIDES

Zinc phosphide and diphacinone (Na-salt) are important rodenticides used in the control of both commensal and field rodents. They are manufactured in China and available in markets. Fluoroacetimide (1081), sodium fluoroacetate (1080), glyftor and Vacor are made locally and used mainly in field rodent control. The fumigants commonly used in warehouses, ships and rodent burrows are chloropicrin, methyl bromide and aluminum phosphide. Alpha naphthylthiourea and Promurit were used for control of rats and some field rodents years ago before some of the current rodenticides became available.

R. norvegicus, R. flavipectus and Mus musculus are the most important commensal species in China. R. norvegicus is distributed over a large area, especially in North China except the Xinjiang (Sinkiang) Autonomous Region and Tibet. R. flavipectus is mainly found in South China, south to the Yangtze River, whereas Mus musculus is the most widely distributed species; and what is unique for a commensal species, it is even found in the Xinjiang Autonomous Region and Tibet.

In North China R. norvegicus is also an important agriculture pest in the warm season. When the field crops are grown, it migrates from dwelling houses to the fields. It is a prolific breeder, averaging six to eight per litter and four to five litters per year. There are two peaks of breeding, one between March and May, another between September and October. The reproductive activity generally ceases in the cold winter months. There is an exception; they maintain their reproductive activity in cold storage when food is plentiful.

R. flavipectus is the most important species in South China and Southwest China. In Leizhou (Leichow) Peninsula, Guandong (Kwangtung) Province, of 155,200 individuals of small mammals caught in dwelling houses, 135,895 were identified as R. flavipectus (87.6%). In the tropical region of China they are found living in the wild.

Mus musculus is the most widely distributed of the commensal rodents in China. In Xinjiang and Tibet, they are common inhabitants of grassy and cultivated lands and have adapted well to living in dry deserts without any free water, where we do not find other commensal species. Mus musculus may breed all year-round with peaks in spring and fall. It was found that they did not cease breeding even during the cold winter in Xinjiang. The incidence of pregnancy of female accounted for 46.5% (272/585) from March to September. The average litter size was 5.7 ranging from 1 to 10, and 2 to 4 litters were recorded per year. There is seasonal migration in Xinjiang. They move back and forth between crops which are harvested at different times. Wheat and alfalfa fields, sesame fields, maize fields, and dwelling houses is the order of their migration. This ability to adapt to an extreme environment is of great benefit to their population. Weather, food and cover are all factors causing migration, but mature crops that provide cover for Mus musculus are most important.

In Xinjiang Mus musculus populations are cyclic in nature, reaching high numbers every 6 or 10 years. The extraordinarily high population densities occurred in North Xinjiang in 1967 to 1970. Almost all of the crops and grasses were devastated at that time. It was estimated that 300,000 tons of cereals were damaged in 1967.

A problem of particular concern is the presence of numerous Mus musculus and R. flavipectus in trains and ships, where they are extremely difficult to control.

Research is underway on commensal rodent control. These investigations include raising and breeding rats and mice in the laboratory for ecological observation and control tests, for synthesizing and screening new rodenticides, and for planning integrated control programs. Chinese millet was found to be attractive to commensal rats and mice. The preference tests showed that it was preferred to other dry cereals, including corn meal, wheat, oat meal, rye, barley, etc. Several rodenticide samples have been synthesized. Among these are warfarin, diphacinone, Pival, Norbormide, UK786, RH945, RH787, and recently reported second-generation anticoagulants, difenacoum and brodifacoum (Table 1).

Table 1. LD_{50} (mg/kg oral) toxicity tests.

Rodenticides	R.norvegicus	R.flavipectus	M.musculus
Norbormide	5.16		
UK786	7.1		
RH945		51.0	23.0
RH787		32.0	45.0
Difenacoum			
acute	1.28	3.1	2.9
chronic(X5)	0.33	0.28	0.45
Brodifacoum			
acute	0.32	0.39	0.85
chronic(X5)	0.07	0.059	0.099

A combination of rodenticides and traps are used in the urban area, but in rural areas reliance is placed on poisoned baits. The baits containing 1 to 3% zinc phosphide and 0.025% diphacinone (Na-salt) are most frequently used. The bait material used in North China is usually corn meal, and in South China rice containing 2% vegetable oil as sticker; also sweet potatoes are often used.

Rodenticides mentioned above are effective against commensal rodents, but occasionally ineffective against R. flavipectus. It appears that the R. flavipectus is a very shy species and is more tolerant of most rodenticides used than other species.

Norbormide was found not only to be effective against R. norvegicus but also against R. flavipectus, R. losea and R. hainanicus. As it is a fast-acting poison, rats eating a lethal dose died quickly near the bait station. The corpses are easy to clean up. It is suitable for the control of rat infestations on ships and trains.

The fumigant, sulfur dioxide, has been effective in the control of rat infestations in the sewage system in Chonqing (Chungking).

A kind of rat board covered with resin glue from vegetable oil traps rats and mice effectively and safely in food plants.

In pheromone tests, it was found that urine from female rats in heat could be used as an attractant to enhance the consumption of zinc phosphide bait. The urine was not mixed in the bait but placed close to it.

Since 1967 the anticoagulant diphacinone (Na-salt) has been manufactured in our country. This kind of anticoagulant was widely used and more or less replaced the zinc phosphide and other acute rodenticides in the control of commensal rodents for about 15 years. Systematic trapping of R. norvegicus, R. flavipectus and Mus musculus was carried out in Hebei and Fukien Province and Xinjiang Autonomous Region in 1980, to check the effectiveness of the anticoagulant and to obtain basic data for estimating the susceptibility to warfarin. No resistant rodent populations have been detected. R. norvegicus was fed with 0.00125% warfarin bait, R. flavipectus and Mus musculus were fed with 0.025% bait. The results are as follow:

	LFP50 and its 95% confidence (days)	LFP98 and its 95% confidence (days)
R. norvegicus	2.7(2.2-3.4)	13.2(8.1-21.4)
R. flavipectus	3.0(2.2-4.1)	17.5(12.3-24.5)
Mus musculus	2.8(2.3-3.4)	11.5(6.8-19.5)

GROUND SQUIRRELS

Only one genus, Citellus, is found in China. This genus has six different species. These are C. dauricus, C. erythrogenys, C. fulvus, C. alashanicus, C. undulatus, C. pygmaeus. Among these C. dauricus is important. It is distributed in Northeast, Northwest and North China, and found in open grasslands. In agricultural districts, it lives along the roads, field edges and near the villages. It lives singly in a burrow, except during mating season.

Ground squirrels hibernate in late fall and winter from late September to late March of following year. The hibernation is independent of the temperature of current weather but depends on their fat deposits. They do not go into estivation, even in dry, hot summers.

Ground squirrels breed shortly after emergency from hibernation. The average litter size is about six to eight young, with only one litter per year. The young disperse in July. They are active in daytime with two peaks, 9 to 10 a.m. and 3 to 4 p.m.

Trapping is the preferred control method, especially near villages. The best results have been with live traps, leg-hold traps and metal wire snares set near burrow entrances without baits.

Poisoned baits may be the most practical method of control in large-scale campaigns. Ground squirrels are very susceptible to rodenticides (Table 2).

Table 2. The susceptibility of C. dauricus to different rodenticides.

Rodenticides	LD50(mg/kg oral)
Zinc phosphide	36.3
Fluoroacetimide	0.46
Sodium fluoroacetate	0.22
Strychnine	2.94
Silatrane	1.63
Gophacide	14.1
Glyftor	4.5
Tetramine	0.61
Diphacinone (Na-salt)	0.61 (acute)
Brodifacoum	0.093 (acute)

Preference of C. dauricus for baits was evaluated in field trials. A weighed portion of each bait was placed in a container in the grassland at the beginning of the trials. Each following day the cereals were again weighed (Table 3).

Table 3. Percent of each bait consumed by C. dauricus during field trials.

Type of bait	Percent
Sunflower seeds	55
Soya bean	16
Maize	12
Oats	9
Sorghum	8

Sunflower seed baits were used in field trials, and good results were obtained at 0.4% concentration of 1080. Since then large-scale campaigns against ground squirrels were carried out in 1967 to 1968. The campaign was twice a year: one in May, after hibernation; another in September, before hibernation. The results have been excellent. The population density declined from 100 to 200 animals per 10 ha. to 1 animal per 10 ha. At that time no ground squirrels could be found over 2,000 square kilometers of grassland. The baiting was broadcast by hand. The low squirrel density was maintained for nearly 10 years.

It is well known that 1080 is extremely dangerous to nontarget animals. Owing to a well-planned program, careful operations, and by informing people on how to avoid problems, no accident has happened so far. It seems that the hazards presented by any rodenticide depends more on how it is used than on its toxicity. However, the secondary-poisoning hazard to predators, both domestic and natural, was severe. A great number of cats and dogs were killed. The population density of weasels, foxes, and hawks was drastically reduced. Some seed-eating birds, such as larks and skylarks, were killed during the campaign.

The available effective fumigants, such as chloropicrin, methyl bromide and calcium cyanide might be effective in some situations, but they were very poor in our field trials against C. dauricus. Only 50 to 70% kills were obtained. It is probable that the vapors are easily absorbed by the soil, and diffusion of these vapors to the bottom of the burrows is very slow. Artificial burrow tests showed the vapor to be absorbed within 2 hours, but it took 4 hours to diffuse to the bottom.

A kind of smoke-bomb cartridge was found to be more effective than most commonly used fumigants. Complete kills were obtained using one cartridge (50 g) per burrow-opening in field trials. The effect is more rapid and powerful than ordinary fumigants because the toxic fumes, mainly carbon monoxide, expand quickly to the bottom of the burrow. This cartridge is made of sawdust mixed with potassium nitrate powder. It is easy to get locally and is much cheaper than other fumigants.

In other field trials, 100% mortality was obtained using one cartridge per burrow for the following species: Cricetulus barabensis, C. triton, Mus musculus, Apodemus agrarius, R. flavipectus, R. losea, Bandicota indica and Suncus murinus (a commensal insectivora in South China).

In the case of Citellus undulatus, poison baits may be ineffective because this species feeds chiefly on grass.

GERBILS

The gerbils are classified as Meriones and Rhombomys in China. Meriones unguiculatus is the most important pest in Northwest and North China. It occurs from dry grasslands to semideserts and deserts, preferring sandy soil. These animals are quite social, forming large colonies with complex burrow systems which are located under bushes of legumes (Caragana arborescens). The population density along edges of cultivated lands and roads is rather high. In some areas the number of individuals may be as many as 200 to 300 per hectare.

Gerbils do not hibernate in winter; they hoard large amounts of food for their winter use. About 40 kg. of cereals and beans was found in a large burrow cache.

Gerbils have a high reproductive potential with an average litter size of five to seven and two to five litters a year. They breed year-round. Population density fluctuates drastically. They often eat corpses of their species when the population density is high. Meriones unguculatus are very susceptible to different rodenticides (Table 4).

Table 4. The toxicity of various rodenticides to Meriones unguiculatus.

Rodenticides	LD50(mg/kg oral)
Zinc phosphide	12.04
Fluoroacetimide	1.7
Sodium fluoroacetate	0.65
Glyftor	10.0
RH945	5.94
RH787	16.53
Silatrane	4.0
Tetramine	0.66
Gophacide	11.61
Diphacinone (Na-salt)	1.0 (acute)
Chlorophacine	0.05 (acute)
Difenacoum	0.05 (acute)
Brodifacoum	0.002-0.003 (acute)

Poison baits are very effective in controlling gerbils. Good control has been obtained with 0.4% 1080 sunflower seeds, 1% 1080 barley, 3 to 5% zinc phosphide, and 0.2% diphacinone oats (90% kills or more). About 0.2 g of the oats is placed near the burrow opening, or 1- to 2-g baits in the center of the burrow system when population density is low. Baits can be broadcast (2 to 4 kg per ha.) by aircraft when population density is high.

Many different types of baits substituted for cereals were carried out in field trials. These are 2% 1081 on dry carrot, 10% zinc phosphide on seeds of Corispermum hyssopifolium, 2% 1081 on extruded dry forage grass, cotton balls soaked in 2% 1081 solution, 2% 1081 talc pills that have absorbed vegetable oil, and a piece of paper absorbed with syrup and zinc phosphide. The cotton balls are special. This type of bait was laid inside the burrow opening. The target animals easily recognized the white colored baits and died near the burrow-opening through sucking or hoarding the baits.

Trapping and fumigation are commonly used also.

MARMOTS

The genus Marmota has four species in China. These are M. himalayana, M. baibacina, M. sibirica, and M. caudata. Marmots are distributed over Tibet, Xinjiang and Inner Mongolia. They inhabit high mountain grasslands ranging from 1,500 to 4,500 m. above sea level. The marmot is one of the largest rodents in China. Adult animals weigh 10 kg. or more. They are quite social with a large family colony inhabiting a burrow system.

Marmots are active in daytime. They hibernate in winter months but do not estivate in summer. In spring they emerge from hiberation and breed. The young average from four to five per litter, with only one litter a year.

Marmots are not an important agriculture pest, but are involved in transmitting plague.

Marmot feed on herbs, so cereal baits cannot be used for their control. The cartridge is an effective fumigant. Complete kills were obtained by using a 600-g. cartridge per burrow opening. Leg-hold traps and wire snares are commonly used in late fall to get their fur, which is valuable for coats.

VOLES

Microtus brandti is important in China and distributed over Northeast China and Inner Mongolia. It lives in grasslands and is rarely found in cultivated lands.

Microtus brandti is a diurnal animal and does not hibernate in winter. It is a prolific breeder. Four or more litters of 5 - 10 young may be produced each year, with the peak breeding being from April to May. The population density is cyclic with extraordinary high population densities followed by very low densities. It digs a great number of burrow systems (3,000 to 4,000 opening per hectare and 10,000 or more opening per hectare in extreme cases) in some high population density areas, causing severe damage to the pasture. Occasionally zoonosis of plague may occur.

One percent 1081 barley and 5% zinc phosphide rye are very effective for controlling Microtus brandti. Dry carrot and extruded dry herb baits are attractive to this species. Twenty percent zinc phosphide tracking powder has obtained good control in field trials.

FIELD MOUSE

Apodemus agrarius is the most abundant and well-adapted field mouse in South and Central China. It is found throughout Central China from the valley of the Yangtze River (about 300 m. above sea level) to the high mountain area (3,600 m. above sea level). It prefers living in cultivated lands with cereal crop rotations. Land with rotation of rice and wheat is its best habitat.

This field mouse is a prolific breeder, with four to five litters a year, averaging five to seven young per litter. There is a breeding peak in May. At that time the percentage of females pregnant in the population is 82%, and young animals make up 75% of the population. The population density increases and decreases dramatically.

Apodemus agrarius is an important agricultural pest and a potential reservoir of haemorrhagic fever. It is quite susceptible to RH945 (Table 5).

Table 5. The toxicity of various rodenticides to Apodemus agrarius.

Rodenticides	LD50(mg/kg oral)
1080	6.25
1081	27.74
Tetramine	0.93
Silatrane	3.7
Antu	18.8
RH945	9.4
RH787	35.0
Diphacinone (Na-salt)	59.3 (acute)
	2.36 (chronic X 3)

The 0.4% 1080 rice bait is very effective in field trials, giving 95.3% kills. Complete control was obtained in a farm located in Anhui Province of more than 1,000 hectare of cereal crop lands. The incidence of haemorrhagic fever was drastically decreased. It was a surprise to discover that the population density quickly recovered to its original level. The effect of control only lasted about 3 months.

Field mice are susceptible to the anticoagulant rodenticides; 0.025 to 0.05% diphacinone (Na-salt) rice are very effective.

PIKA

The genus Ochotona belongs to the family Ochotonidae in the order Lagomopha and is represented in China by 10 species. Among these O. daurica and O. curzoniae are the most important agricultural pests damaging pastures.

Pika are mainly distributed over Tibet, Qinghai and Sichuan (Sze-ch'wan) Province in high mountain grasslands. They are active in the daytime and do not hibernate in winter.

Pika produce one litter a year averaging four to six young, with a breeding peak in June. Population density may be as high as 200 animals per hectare.

Poison baits (Table 6) may be very effective, particularly in early spring, when grass and various herbaceous weeds have not grown. Five to ten percent zinc phosphide, 0.5% Gophacide, 0.2 - 0.4% 1081, and 0.25% diphacinone (Na-salt) formulated with rye or barley have been used effectively.

In summer, spraying systemic poisons such as 0.2% 1081 or Glyftor on grass (50 to 100 ml per sq. m.) is preferable to cereal baits, but it is hazardous to sheep, cattle and other herbivorous animals and too expensive to use in large-scale campaigns because these areas are short of water.

Table 6. The susceptibility of Ochotona curzoniae to different rodenticides.

Rodenticides	LD50(mg/kg oral)
1081	0.71
Glyftor	3.4
Tetramine	0.15
RH945	63.0
Diphacinone (Na-salt)	8.68 (acute)
	3.17 (chronic X 4)
Difenacoum	1.97 (acute)
Brodifacoum	0.14 (acute)

HAMSTERS

The genus Cricetulus has more than 10 species in China but C. barabensis and C. triton are of agricultural importance. They are widely distributed over North and Central China, and mainly found in cultivated areas.

Hamsters are active in daytime and do not hibernate in winter. They have cheek pouches for holding food and often store large amounts of variety cereals and beans in their burrow caches; 40 kg. or more have been dug out.

Acute rodenticides such as 2% 1081, 0.4% 1080 and zinc phosphide formulated with cereals have been effective in control. The poison baits should be scattered sparsely to prevent them from being carried away by the nontarget animals. Chronic anticoagulants are probably of no use. C. triton may be the most resistant species to anticoagulants including difenacoum but very susceptible to brodifacoum (Table 7).

Table 7. Susceptibility of Cricetulus triton to anticoagulants.

	LD50(mg/kg oral) toxicity tests	
	Acute	Chronic(X 3)
Difenacoum	112.4	7.14
Brodifacoum	0.86	0.11

MOLE RATS

About seven species which belong to the genus Myospalax are found in China. Among these Myospalax fontanieri is a most troublesome species. It occurs in North and Northwest China and lives in grasslands and cultivated lands.

Mole rats are well adapted for burrowing and make long tunnel systems about 10 cm. below the surface. The excavated soil is pushed above ground into crescent-shaped mounds at 4- to 6-m. intervals. They feed on roots and bulbs of grasses and a variety of vegetables, causing severe damage to the crops and pasture.

Reproductive potential is rather low. Mole rats only have one litter a year averaging two to four young with peak breeding in spring. They do not hibernate in winter.

Trapping is an effective control method. It is best to set traps in a main tunnel. Mole rats prefer to eat potatoes. One to two percent 1081 on potatoes has been effective in control. Good control was also obtained by spraying a 0.2% 1081 solution on the grasslands when population density was high, but it is very hazardous to nontarget animals and too expensive.

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LITERATURE CITED

Office of Central Committee of Patriatic Public Health Campaign: Symposium of Rodent Control, Vol. 1, 1980. pp. 1, 11, 19, 55, 62, 66, 89.

CHENG-XIN, WANG, and PAN ZU-AN: Rodent Control, People's Health Press, 1981. pp. 48-93.