Fall, M. W. 1982. Agricultural development and the ecology of rodent control. Pages 443-451 in Alternative Strategies for Desert Development and Management, Vol. 2. Proc. UNITAR Intern. Conf., Sacramento, California, 1977. Pergamon Press, New York.

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PN-AAM-037
ISN=15398

Agricultural Development and the Ecology of Rodent Control

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ABSTRACT

In many areas of the world, rodent damage to field crops causes severe reduction of human food supply and increases the risks of small-farm agriculture. In localized areas, rodents may be a principal factor limiting crop production; more often, rodents unobtrusively remove a share of production before harvest--crop after crop, season after season. Although there are more than 6,000 kinds of rodents, only about 50 could be considered important agricultural pests.

Development efforts, particularly those involving irrigation and intensification of agriculture, usually result in substantial increases in local rodent populations, frequently with a change in the pattern of reproduction. In dry environments, rodents usually breed during or shortly after the wettest season, probably in response to improved food and habitat. In year-round intensive agriculture, breeding generally occurs throughout the year--whenever local food and habitat (maturing crops) are present.

Another problem which appears to accentuate rodent damage to irrigated croplands is invasion. Rodents reproduce during the wet season over wide areas and a variety of habitats. As drying begins to occur, food supply and habitat deteriorate and gradual shifts occur in the ranges of local animals as they seek remaining food, cover, or water. In undeveloped areas, considerable population die-off probably results under such conditions. When irrigated croplands remain productive, animals that move from adjacent non-irrigated areas may cause heavy crop damage.

Examples of these situations have been evident in many parts of Africa and Latin America during the past 2 years, and have again called attention to the need to consider a pest control program as an integral part of agricultural development. This program should be based on a thorough knowledge of the ecology of rodent species associated with agricultural development, appropriate techniques to reduce crop damage by rodents, and personnel trained to supervise and carry out long-term crop protection programs.

RODENT PROBLEMS IN AGRICULTURE

Rodents damage a variety of agricultural crops throughout most developing regions of the world. At least 50 species of rodents are involved although relatively little information is available from most areas of the extent of damage. Rice is perhaps the most severely affected crop; damage is also reported in corn, sorghum, wheat, peanuts, coconut palm, oil palm, cacao, sugarcane, and many other vegetable and fruit crops. Although most countries have at least rudimentary research and operational control programs, few have developed sufficient information or sufficient numbers of trained personnel to

undertake effective crop protection programs on a national scale. This paper summarizes some of the information obtained in the course of several years' work with agricultural rodent problems in less-developed countries by U.S. Fish and Wildlife Service (USFWS) biologists and cooperators at the Rodent Research Center (RRC) in the Philippines.

Because economic losses caused by rodents are difficult to estimate and cannot usually be determined on experimental station plots, research on the control of rodent damage has been given much less attention than research on control of insects and plant diseases. Rodent damage often appears in two basic patterns, one superimposed upon the other. The first is chronic damage, which occurs every year in every area and may be highly variable, even from field to field. The second pattern, which is poorly understood, is that of exceptionally heavy damage associated with rapid increases or "outbreaks" of rodent populations over wide areas.

Little information is available on chronic losses caused by rodents. Preharvest damage surveys conducted over a 3-year period (1970-1972) in nearly 1,600 rice fields distributed throughout the Philippines revealed some rodent damage in about 90% of the fields. Counts in these fields showed that cut stems averaged about 3.5% of the total stems at harvest, but much early damage is missed in such surveys because early cuts are no longer visible at harvest. Stem cutting in the survey paddies ranged as high as 58%. Considerable variation in the extent of damage is common, even from paddy to paddy. Fields near unfarmed areas and those bordering roads or irrigation canals often have heavier damage than others, presumably because of the additional rat harborage. It is commonly observed that fields maturing much earlier than the surrounding ones or isolated fields which mature late receive heavier damage because of localized movement of rats.

Reports of rodent population outbreaks usually stem from the sudden appearance of spectacular numbers of animals and the devastation of crops over wide areas. Although similar reports are available from every continent, involving a variety of rodent species, the occurrence of rodent outbreaks in any particular place or with any particular species is intermittent, and largely unpredictable. It is clear, however, that most outbreaks do not develop as rapidly as is commonly believed and that improved surveillance could provide sufficient warning to deal with such occurrences in an organized manner--as opposed to the ad hoc manner with which they are usually approached. Different approaches may be required to reduce crop losses associated with rodent population outbreaks than those considered as chronic problems.

A central difficulty in the development of field rodent control programs in many countries has been a tendency to ignore the importance of species and environmental differences and to attempt to apply control methods of the Norway rat (Rattus norvegicus) in temperate cities directly to tropical crop situations involving other species. Work in the Philippines has shown that this approach is not productive for crop protection. Variation in the behavior of individual rodents under different environmental conditions, coupled with the occurrence of different species in the various countries, suggests that attempts to use control methods for one country on another should be approached cautiously and only with careful field evaluation.

Additional considerations in developing effective agricultural rat control programs for less-developed countries are differences in farming practices, in farmer attitudes, and in the capabilities of local plant protection agencies. In most situations, an understanding of these factors

is probably of equal importance to an understanding of the rodent populations themselves. Research and evaluation projects aimed at assisting countries to develop control programs which effectively prevent crop loss (as opposed to simply killing large numbers of rodents) should be planned with the assumption that a broad understanding of the problem will be required in each situation.

EFFECTS OF AGRICULTURAL DEVELOPMENT

Efforts to increase agricultural production in the less-developed countries have involved environmental changes which appear to influence the types and degrees of rodent damage problems encountered. A principal means for countries to increase agricultural production has been to bring new lands under cultivation by clearing forest, scrub, or marsh areas. Rodent population outbreaks have often been associated with such habitat disturbance, and new farmers on marginal lands may suffer serious crop losses during the critical first years of cultivation. Further, chronic losses may be accentuated when rodents move from adjacent uncultivated lands to exploit the newly available food sources in cultivated fields.

Various approaches to increasing production on land already under cultivation have also appeared to have major influences on agricultural rodent problems. Irrigation, which allows year-round planting in areas formerly dependent upon seasonal rainfall, results in changes in the behavior of rodent populations. Although most of the rodent species considered as agricultural pests are capable of reproduction throughout the year, physiological or behavioral mechanisms appear to restrict reproduction to periods during or after rainy seasons when the quality of food and cover improves. In areas with one crop per year, considerable mortality of rodents may occur during the long dry season. In such situations, this seasonal mortality may act to keep chronic crop damage at relatively low levels. Abnormally prolonged rainy seasons resulting in a longer period of food availability, increased cover, and reduced mortality may set the stage for a population outbreak in the next season when reproduction begins again from a higher population base. Year-round planting may allow some species to breed throughout the year, raising the general levels of populations, and accentuating chronic damage. Construction of bunds and canals creates additional favorable habitat for burrowing rodents close to agricultural fields. Occasionally, rodents damage the irrigation systems by these burrowing activities.

Elimination of the natural scheduling of planting season on irrigated areas, coupled with the availability of high-yielding crop varieties with short growing seasons, often results in crops of different ages in close proximity. Rodents inhabiting a field being harvested may easily move to nearby areas which continue to provide adequate food and cover. Fields maturing earlier or later than those of the surrounding area may receive particularly heavy damage in such situations.

Another effect may be observed in some areas with small-scale seasonal irrigation or in irrigated areas surrounded by uncultivated land. Rodents reproduce over wide areas and a variety of habitats during the wet season when food and cover are available. As drying begins to occur, food supply and habitat deteriorate and gradual shifts occur in the ranges of local populations as they seek remaining food, cover, or water. This same process, which results in increased natural mortality in nonirrigated conditions can result in intense rodent pressure on crops remaining on the small irrigated areas.

Postharvest loss problems caused by rodents may be increased in somewhat the same way. Storage facilities may be inadequate or almost nonexistent in areas where development processes are helping former subsistence farmers produce crops for sale. Stores in open fields, houses, or village granaries may receive serious rodent damage when rodents seek cover and food sources after harvest.

The variable and unpredictable nature (particularly from the farmer's standpoint) of rodent damage to crops introduces an important additional risk factor for small-farm agriculture that should be considered in addition to the actual crop losses suffered. It appears that the risk of rodent damage may often be most threatening at the time when farmers are being encouraged to change farming practices, grow new crops or varieties, and contract loans to finance new technologies.

DEVELOPMENT OF RODENT CONTROL METHODS

If rodent control is considered in a broad context, a nearly overwhelming variety of control methods has been used or proposed (Table 1).

Table 1. Methods and Techniques of Rodent Control

Physical	Chemical	Biological	Others
Barriers	Poison Baits	Sanitation	Bounties
Trapping	Tracking Powder	Parasites	Harvest
Flooding	Poison Sprays	Diseases	Appeasement
Electrocution	Repellents	Predators	Insurance
Drives	Poison Grease	Habitat Modification	
Hunting	Systemics	Cultural Practices	
Clubbing	Reproductive Inhibitors	Buffer Crops	
Crushing	Fumigation	Ultrasonics	
Frightening Devices	Wetting agents	Lethal Genes	
	Drugs	Biosonics	
	Glues	Resistant Plants	
	Frightening Agents		

Table 2. Summary of Costs and Returns for Farms Carrying Out Sustained Baiting Programs and Nearby Farms Using Traditional Rat Control Methods in Various Areas of the Philippines.

	Pangasinan - 1973		Mindoro Or. - 1974		Mindoro Or. - 1974		Laguna - 1974	
	Treated Farms(15) ($/ha)	Untreated Farms(15) ($/ha)	Treated Farms(12) ($/ha)	Untreated Farms(11) ($/ha)	Treated Farm ($/ha)	Untreated Farm ($/ha)	Treated Farm ($/ha)	Untreated Farm ($/ha)
Land Preparation	18.1	11.4	31.9	12.6	24.3	42.9	57.0	33.6
Seeds	10.0	7.9	10.9	10.4	10.7	10.0	22.6	14.3
Planting	10.0	7.1	16.9	18.4	20.0	17.1	17.0	4.7
Weeding	0.0	0.0	18.6	11.3	14.1	11.4	11.9	10.0
Herbicides	3.2	1.6	3.6	3.3	5.0	0.0	0.0	0.0
Insecticides	3.7	1.9	8.6	8.9	7.9	8.6	8.7	2.3
Irrigation	0.0	4.0	1.0	0.0	0.0	0.0	22.9	45.4
Fertilizer	10.7	9.0	0.0	0.6	3.4	3.4	8.7	0.0
Harvesting	18.4	13.7	57.1	28.6	71.	45.7	15.3	0.0
Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	14.4	0.0
RAT CONTROL	1.4	0.3	2.9	0.9	3.6	1.3	5.1	0.0
Total Production Cost	76.0	54.0	151.5	117.0	160.6	110.4	137.1	111.3
Gross Value of Crop	441.6	312.7	310.1	166.4	378.6	192.9	490.0	17.9
Profit	368.6	278.1	158.5	49.4	218.0	82.5	410.9	-93.4

Most of the research and evaluation efforts in development of rat control methods have been directed toward commensal rodents in temperate cities and towns where the principal pest species is Rattus norvegicus. Nearly all of the commercial effort to develop rodent control materials and chemicals has been directed at this market. In urban situations, where the principal rationale for rodent control involves public health and nuisance considerations, the objective of a control program is to reduce the rodent population over a target area and maintain it at a low level indefinitely. Thus, most of the efforts to develop rodent control methods have been directed at developing more efficient means of killing rodents. From the program standpoint in urban rat control, it has become almost axiomatic that a successful long-term program can only result if the environmental carrying capacity for rodents is lowered by improving sanitary services, reducing food supply, and eliminating rodent harborage. Economics may play a relatively minor role in developing urban rodent programs. Programs are often organized to meet legal or political requirements within the limits of available funds or depend upon optional financing by individuals with intolerable problems.

Attempts to extend existing rodent control technology and program approaches from the temperate urban situation to rural areas have been notably ineffective. The density and wide distribution of tropical rodent species over many habitats, coupled with their ability to make rapid local shifts in principal habitat and to reproduce rapidly under relatively poor habitat conditions, essentially mean that short-term killing programs, whether based on use of rodenticides or other methods, do not have sufficient impact to measurably reduce crop damage. More complex rodent control programs based on alteration of habitat or use of high-technology approaches could probably not be sustained by either farmers or government institutions at an effective level.

The further qualification that control methods used in an agricultural system must be effective within the bounds of funds available to farmers for crop production, and must have the potential of providing positive economic benefits in relation to cost, greatly limits the range of methods and techniques that have real potential for practical field use. If farmers or plant protection agencies are expected to use particular control methods in operational situations, the methods must be, from the earliest stages of research or adaptation, evaluated in terms of efficacy from the standpoint of protecting crops and in terms of their cost in relation to the total cost of crop production. As the physical area and time span of proposed control operations are increased, such evaluations become increasingly difficult to the extent that the techniques are probably lacking to make a benefit-cost analysis of, for example, a large-scale introduction of a rodent predator.

Evaluation of Rodent Control Methods in the Philippines

In the course of developing methods for agricultural rodent control in the United States as well as in other countries, many of the wide range of potential methods have received various degrees of evaluation. Among the methods for controlling rodents in rice fields in the Philippines, some consideration has been given to most physical approaches; to a variety of rodenticides and baiting techniques; to reproductive inhibitors; to field sanitation, parasites, and predators; to habitat modification and changes in cultural practices; to genetic modification of rodents; to the potential for developing resistant plants; and to bounties or other means

of harvesting rodent populations. The only approaches which have reached the stage of serious field evaluation under the program carried on jointly by the Philippine Rodent Research Center and the U.S. Fish and Wildlife Service have involved nonlethal barriers, acute or chronic rodenticides, and field sanitation. Of these, only sublethal barriers (still in the early stages of research) and the use of chronic rodenticides have appeared to have potential for practical, economical use under rice field conditions. A principal reason that the field sanitation approach is impractical is the difficulty of maintaining control throughout most of the crop period on a small-farm scale for a very low cost. The use of chronic rodenticides or anticoagulants in a sustained baiting system in which bait use is closely coupled to the actual invasion of rodents at any crop stage appears to be a method which fits most of the criteria for a practical, economically beneficial method of protecting rice crops from rat damage in the Philippines.

Sustained Baiting with Anticoagulants

A principal problem in carrying out a long-term baiting program for rodent control is the ability of rodents to learn to associate poisoning symptoms with a bait material. The use of anticoagulant rodenticides, such as warfarin, avoids this problem because they are effective at low concentrations and do not produce symptoms until regular feeding has taken place over a period of several days. However, because of high population density in rice field areas, continued invasion of new rodents throughout the crop period, and competitive interactions among rodents using bait stations, specific baiting techniques must be used to make a sustained baiting program effective from the crop protection standpoint. The total material cost is very low because even poor-quality grain material is well accepted by *Rattus rattus mindanensis* and *Rattus argentiventer* in preference to green vegetation. Suitable bait stations under most Philippine conditions may be constructed at no cost from locally available materials such as bamboo or coconut husks, and by rather simple procedures, a farmer may adjust bait placement so that no more bait will be used than is required to limit rodent activity in his fields.

The program devised to incorporate these findings, while arbitrary in some respects, has sufficient flexibility to remain effective with minor modification by farmers or supervising technicians. Key features of the approach developed for rat control in rice fields are:

- Baiting should begin at the time of transplanting or shortly after--*before* any rat activity is evident.

- Baiting should be maintained until grain heads are fully developed and hardened, approximately 2 weeks before harvest in most situations; however, if bait consumption remains high during this period, baiting can be continued. Bait consumption generally increases for several weeks as more and more rats invade the fields, then usually declines sharply when grains mature.

- Excess bait must be available at all times so that rats consume bait regularly over several days. The amount of bait should be adjusted to the intensity of rat activity by using several small stations at each baiting point. This allows rodents to establish a regular feeding pattern and helps to decrease the effects of competition at the food source.

- A wide variety of bait carriers can be used. Milled rice, polished rice, broken rice, or brewers' rice work well. Rough rice should not be used because rats remove the hulls in feeding and do not ingest toxicants coated on the surface.

- Any of several anticoagulant rodenticides commercially available and already in use for rice field rat control in the Philippines are suitable; simple changes in the methods by which these materials are used can result in effective crop protection.

In addition to the developmental research carried on with sustained baiting approaches since 1972, several field evaluations have been carried out on farms in major rice-growing regions of the Philippines within the ranges of the two major pest species--Rattus rattus mindanensis and Rattus argentiventer. Table 2 summarizes these field trials which were carried out on small farms involving "treated" farms where the sustained baiting method was used and "untreated" where farmers carried on their usual rodent control activities. These farms, however, do not represent random selections of Philippine farmers; rather, field trials involving both rodent species were carried out in areas which had a history of serious rodent damage at variable levels from year to year. The 1974 trial in Laguna was in an area with such heavy rodent pressure that farmers generally had difficulty in producing wet-season crops because of invasion of rats from adjacent marshes. Because actual operating farms were used in the trials, it was not possible to standardize all production inputs as might be typically done on small plot evaluations of insecticide treatments on an experiment station. Therefore, it must be recognized that in all of these trials, production increases cannot validly be attributed solely to rodent control treatments but may be partially due to differences in other production practices. Nonetheless, these trials taken as a whole provide a good indication of the types of benefits obtained by effective rodent control programs.

In all instances, farmers obtained major production increases in the areas where sustained baiting practices were followed. Production increases between comparison plots ranged from 34% in the 1973 trial in Pangasinan to more than 3,000% in the area with heavy rat pressure in Laguna in 1974.

The cost of carrying out the sustained baiting procedure (excluding the value of farm labor) in these trials was less than 3% of gross production costs. The calculated materials cost for sustained baiting in the trials ranged from $1.86 to $5.29 per hectare, compared with materials cost from $0.29 to $1.28 over the methods employed by farmers in the reference areas (except in Laguna where the reference farmers employed no rodent control measures). Benefit/cost ratios calculated on the value of the total production increase on treated areas in relation to the cost increment of sustained baiting over other methods ranged from 68-110 in these field trials. The value of the average production increases to the farmers selling sacks of rough rice ranged about $90-$500/hectare. The actual increase in harvested paddy (rough rice) averaged nearly 1 metric ton/hectare in three of the trials, while in the Laguna area under heavy rat pressure, an additional 3.6 metric tons of rice/hectare was harvested.

It should be noted that the sustained baiting program is a preventive approach to rodent control and that, in situations where rodent damage does not become significant in a particular season or area, the costs of following such a program would be almost negligible. It is also expected that considerable savings in cost of rodent control methods might be realized if a

number of farmers over a wider area were carrying on baiting programs simultaneously; however, no data are available to suggest what further savings might be realized.

APPLICABILITY OF THE PHILIPPINE EXPERIENCE

The basic approach developed for small-farm rodent control in the Philippines, at least from a technical standpoint, would appear applicable to many irrigated or rain-fed areas where cereals are grown. However, many problems with effectiveness or suitability in situations involving different rodent species, differing agricultural practices and economies, and differing attitudes among farmers are likely to exist.

In the Philippines and other areas, a principal difficulty with farmer acceptance of this approach may be a tendency for farmers to evaluate the results of toxicant application by the number of dead rats found. With chronic rodenticides applied over a cropping period, few dead rats are found because the slow-acting materials allow the animals time to return to burrows or seek shelter among plants when toxic symptoms develop. Farmers often prefer to use an acute rodenticide which provides visible, immediate results. Many rodent control programs in less developed countries are organized toward killing large numbers of rats during periods of peak visibility, usually after harvest in one-crop areas.

Difficulties involving species differences have been evident in preliminary field trials in Nepal. This work has suggested that the behavior of local pest rodent species (*Bandicata bengalensis* and possibly *Rattus brunneus*) is sufficiently different that acceptance of surface bait applications is negligible during the growing period of crops. Field damage does not appear prevalent until cereal crops are nearly mature, when the abundant grain appears to be preferred over bait material.

In parts of Africa and Latin America much cereal production is carried out on large commercial farms where labor intensive methods are no longer practical or economical. Subsistence farmers in these same areas may consider the material cost and labor requirements to be too high for their use. Availability of materials--both toxicants and bait bases--may be a problem for small farmers in many areas, particularly since proper timing of applications and availability of excess bait throughout the crop period are essential for satisfactory results.

Finally, this approach, simple as it seems, appears very complex and laborious to many farmers and extension technicians accustomed to using other means of killing rats in agricultural areas. Training and demonstration are probably essential in most areas to gain even preliminary acceptance outside small commercial farms and experiment stations.

PLANNING FOR INTEGRATED DEVELOPMENT

During the past 2 years rodent population increases coupled with movement of animals to crop areas resulted in serious crop damage in many parts of Africa and Latin America. In Africa, particularly, efforts to develop rodent control programs were started after much damage had already occurred, and the lack of basic ecological information, materials, transportation, and trained personnel--despite considerable international involvement--made program organization difficult and the results of control efforts largely unsatisfactory.

Opportunities exist in many areas to consider the development of pest control systems concurrently with other development activities. This is particularly important for the farmer, who must, ultimately, be the one to integrate the many new agricultural practices and overcome potential risks, in order to harvest successfully. Because rodents have generally been considered serious agricultural pests only intermittently, when populations reach outbreak proportions, major gaps of information exist. This situation should be rectified through a comprehensive effort in many countries to gain information on the ecology of rodent species associated with representative agro-ecosystems and to devise, adapt, and evaluate control methods which are appropriate for use by small farmers. Training of research and extension personnel to organize, supervise, and carry out crop protection programs is an immediate need in most countries. Planners should recognize that rodent damage is a problem for serious consideration in the development process--one which changes as development proceeds and one for which no single, simple solution can exist.

ACKNOWLEDGMENTS

This work was supported by funds provided to the U.S. Fish and Wildlife Service by the U.S. Agency for International Development under the project "Control of Vertebrate Pests: Rats and Noxious Birds," PASA ID/TAB-473-1-67, and by funds and facilities provided by the University of the Philippines at Los Banos, the Philippine Bureau of Plant Industry, and the Rodent Research Center.

I thank Dr. Fernando F. Sanchez, Director, Rodent Research Center, for permission to extract data from unpublished reports and gratefully acknowledge the cooperative work of the staffs of the Denver Wildlife Research Center and the Rodent Research Center. Discussions with Dr. Russell Reidinger, USFWS Team Leader, Rodent Research Center, and Mr. J. P. Sumangil, Assistant Chief, Plant Protection Division, Philippine Bureau of Plant Industry, have been particularly helpful in developing this paper.