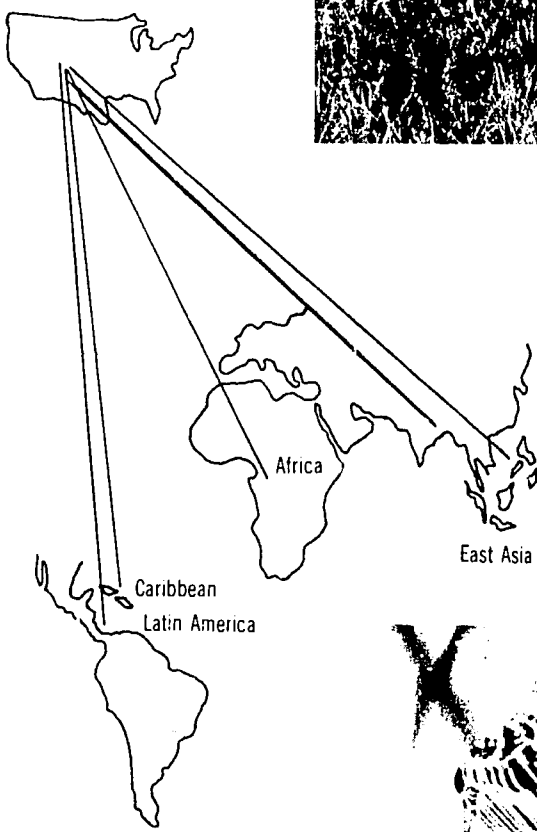
VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

ANNUAL REPORT 1981



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THE COVER

The cover illustrates the broad international scope of the AID-sponsored International Programs of the Denver Wildlife Research Center (DWRC) and two of the most severe animal damage problems under investigation. Research at DWRC and in the field involves evaluation of different control methods including chemical, physical, cultural, or other techniques which have potential for providing positive benefits by reducing vertebrate damage in agriculture. The pest species, crop, farming methods, environmental factors, and a host of other considerations may influence the manner in which a particular problem is approached.

Vertebrate damage in agriculture involves a variety of crops and species of animals, primarily birds and rodents. Direct losses occur typically at planting and sprouting, during the milk or dough stages (for grains), just before harvest, or under posthavest storage conditions. Field programs are involved in trying to reduce or alleviate this damage in several countries of South and Central America, Africa, and Asia.

In many areas of the world, rodent damage to field crops such as rice in Asia causes severe reduction of the 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 can be considered significant agricultural pests.

Losses to birds are less well documented than those to rodents. Various species of parrots, parakeets, blackbirds, weavers, doves, seedeaters, pheasants, and waterfowl are among the types of birds known to cause damage in agriculture around the world. Actual losses are difficult to assess because damage is usually concentrated in limited areas and, due to the mobility of birds, is often seasonal, sporadic, and hard to predict. Red-billed quelea in Africa are perhaps the single most important vertebrate pest species in the world.

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VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

INTRODUCTION

Increasing food production is one of the most important challenges facing mankind. In some developing countries, the disparity between available food and population is both widespread and acute, despite the fact that about one-half of the world's population is actively engaged in agriculture. Millions of people in scores of nations still suffer hunger, malnutrition, and starvation. The reasons are many and complex, but certainly vertebrate pests (primarily rodents and birds) are important factors. Historically, they have not received the degree of attention given to other agricultural pests so that, with few exceptions, little reliable information on the species involved, degree of damage, and the economic impact, is available. Damage is, however, unquestionably calculated in hundreds of millions and perhaps billions of dollars annually.

In recent years, the role of vertebrate depredations in agriculture is attracting more interest in developing nations. Recognizing this, the U.S. Agency for International Development (AID) has supported a research program at the Denver Wildlife Research Center of the U.S. Fish and Wildlife Service (USFWS), since 1967 under a Participating Agency Service Agreement (PASA) as provided for in Section 632B of the Foreign Assistance Act of 1961 (Table 1). The program goal is to evaluate these situations and, when circumstances warrant, develop methods to reduce or eliminate the damage. For many years, DWRC has been recognized as a leading organization in researching vertebrate pest damage problems and developing useful tools for vertebrate pest management. Its problem-solving team approach has led to the development and use of new methods, materials, and techniques for vertebrate pest control, resulting in monetary savings in several developing countries.

The overall objective of this project is to increase the available human food supply in developing countries by reducing losses to vertebrate pests. The ultimate aim of the pest management research program is to develop safe, effective, and economical control methods which are suitable and practical for traditional farmers and acceptable in the broader context of agricultural development. Self-sustaining, in-country programs are the expected end result of this project. Program goals are accomplished by (1) in-country programs, (2) outreach activities from the DWRC as requested by AID/Washington, AID Missions, or host countries, (3) supervisory and administrative functions from the DWRC and AID Washington, and (4) problem-oriented research activities at DWRC through the Sections of Supporting Sciences, Bird Damage Control, Mammal Damage Control,

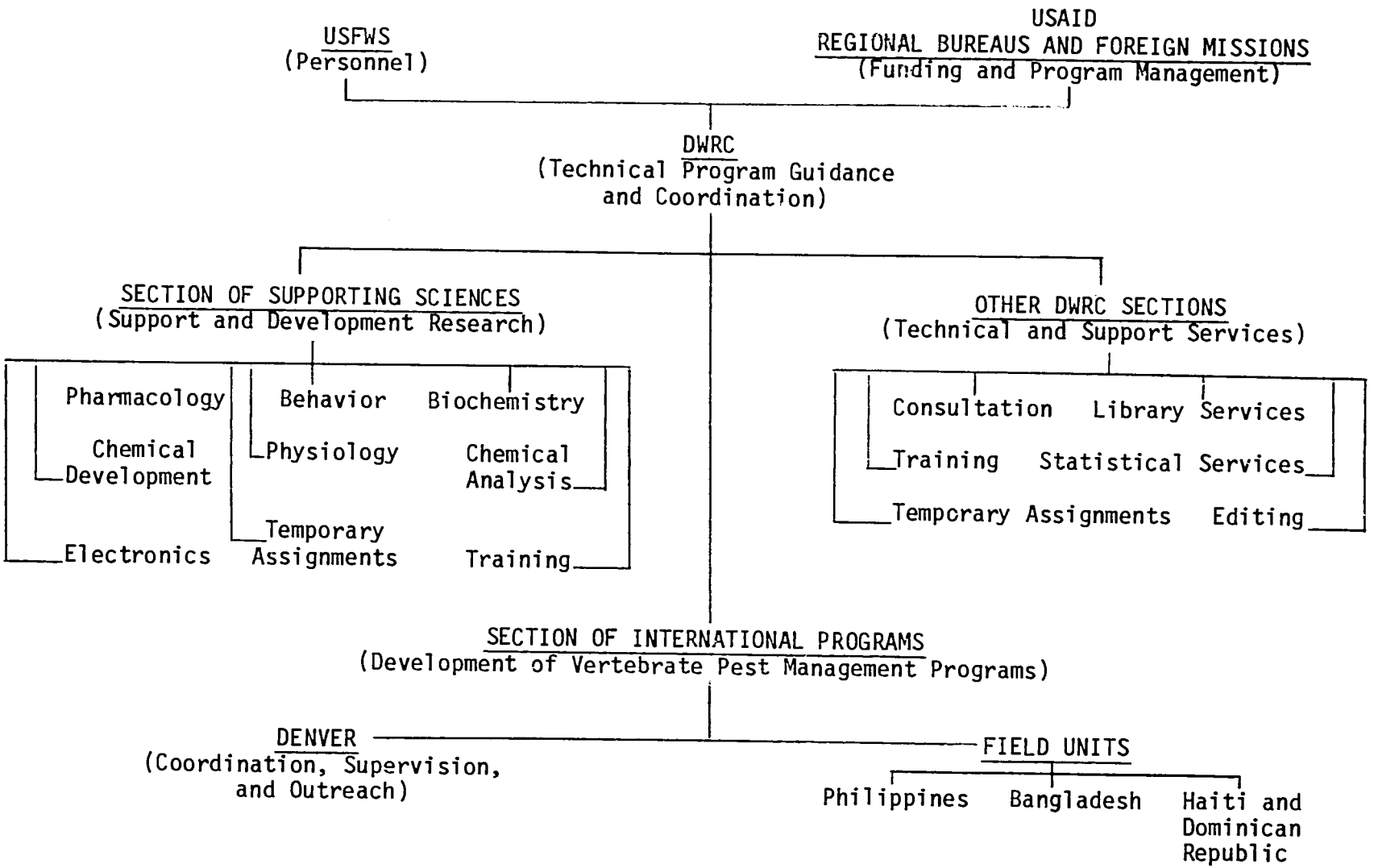
and other components of the Center. Vertebrate damage problems in Africa, Asia, and Latin America are continuously reviewed with the aim of adapting current techniques or materials to specific problem situations in a crop protection-oriented management program which will provide an effective means of long-term crop loss reduction.

The project incorporates a balanced but flexible program of applied research, technology transfer, and training. Research activities incorporate coordinated laboratory investigations at DWRC and selected laboratories in developing countries with associated field trials at appropriate sites in specific problem areas. A team approach, using the services of an interdisciplinary group of scientists and technicians with diverse backgrounds and experience, coupled with active involvement of foreign investigators, results in practical solutions suited to local requirements. In addition, it creates a favorable climate for continuing cooperation with indigenous institutions. Training of local counterparts and institutionalization of both research functions and implementation programs are viewed as integral parts of the overall project.

The Section of International Programs of DWRC provides support and direction to field personnel, assists in establishing relevant research objectives for laboratory personnel, and coordinates the team efforts of DWRC and cooperating scientists. The experienced DWRC staff is comprised of specialists in diverse fields such as ecology, physiology, pharmacology, wildlife biology, nutrition, statistics, animal psychology and behavior, chemistry, and electronics. Several staff members have foreign experience and fluency in foreign languages. Denver Center laboratories are well equipped with the instrumentation necessary to conduct research in each of the disciplines involved. General administrative support is provided in the areas of fiscal management, personnel matters, commodity procurement, records management, and coordination of correspondence, reports, and manuscripts. Related activities include representing the program to other organizations, coordinating DWRC-based training for AID participants, briefing visitors, developing cooperative programs with international organizations, providing technical information to USAID Missions or other cooperators, and assisting AID personnel in program development and negotiations with foreign governments.

Throughout the report, reference to trade names does not imply endorsement by U.S. Government or cooperating foreign agencies.

Table 1. Organizational chart.



During 1981, project personnel devoted considerable time and effort to implementing and supporting the activities of field stations and cooperating in bird damage control research with the Food and Agriculture Organization (FAO) in Africa. Additional cooperation with the German Society for Technical Cooperation (GTZ) and the World Health Organization (WHO) in vertebrate damage control research and training activities was carried on. In addition, the staff continued to assist AID in planning and technical assistance activities involving vertebrate pest management. At the request of USAID/Managua and USAID/Cairo, DWRC again helped the Governments of Nicaragua and Egypt assess rodent problems and outline the requirements for implementing a vertebrate pest management program.

Latin America

To address the problem of vertebrate pest damage to agriculture in the Caribbean Region, the USAID Bureau for Latin America and the Caribbean, AID/Washington, and DWRC established in 1979 a regional program with special emphasis placed on those crops which are predominantly produced by traditional farmers. The project headquarters is in Port-au-Prince, Haiti to serve the specific needs of Haiti, the Dominican Republic, and other regional countries. During its first complete year, construction of the office and laboratory building was nearly completed and preliminary damage evaluations and pest surveys were continued.

Sudan

The Vertebrate Pest Research Project, which began in Sudan in May 1977, was terminated in April 1981. Liaison was maintained with the AID Mission and Government agencies in Sudan, and bird pest research continued in cooperative ventures of mutual interest with other organizations based in African countries. The research of one Sudanese graduate student from Bowling Green State University, Bowling Green, Ohio was conducted at DWRC. He will return to Sudan in February 1982.

Philippines

The Vertebrate Pest Project, based at the National Crop Protection Center (NCPC), in the Philippines continued to provide assistance to the developing network of crop protection research programs throughout the country. The project participates in research and training activities, information exchange, and extension.

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Bangladesh

Mr. Joe Brooks assumed leadership of the program in Dacca in May 1981. He continued the intensive field program on rodent damage control and evaluation and initiated studies on bird pests.

Three field programs, involving resident U.S. biologists, were continued during 1981 under the AID/DWRC program. These projects were located in the Caribbean (based in Haiti), the Philippines, and Bangladesh. The broad goals of these programs are to increase food production and to reduce the risk of severe agricultural losses caused by vertebrate pests in developing countries. Specific objectives are to:

1. Establish the technical capabilities and support within governments and the agricultural sector to conduct programs in vertebrate pest research and management.

2. Develop new and adapt existing practical low-cost methods and technology to evaluate and reduce crop losses to vertebrate pests under local conditions.

3. Provide onsite training in research and operational methods of damage assessment and control.

4. Provide training at DWRC and appropriate universities to perfect capabilities of counterparts to conduct programs in vertebrate pest management.

CARIBBEAN

In Haiti, construction of the office and laboratory facilities is underway and due for completion in early 1982. Field studies in progress include evaluating sustained baiting programs for rodents in rice and corn, conducting a national survey of rodent damage to corn, and determining the nesting distribution of village weavers (*Ploceus cucullatus*) relative to agricultural production areas and cereal crop development.

In the Dominican Republic, project funds were used to purchase vehicles for fieldwork and to complete an aviary at San Cristobal. This aviary will permit continuing testing bird preferences for natural foods and different varieties of grain crops. Tests also will be made of different formulations and con- centrations of repellents. One pen will be used to establish a breeding colony of village weavers for studying a variety of approaches that affect reproductive success. Field studies in progress include determining the nesting and local damage patterns of village weavers, and documenting the biology and pest status of Hispaniolan woodpeckers (*Melanerpes striatus*) to cacao production.

Village weavers (Ploceus cucullatus) were introduced into Hispaniola near the turn of the century and cause extensive local damage to cereal grains.

Rodents can seriously damage corn, as shown by these damaged ears which were harvested from research station fields in Haiti.

Photos Pete Hugo Fleury

Surveys of Village Weaver (*Ploceus cucullatus*) Nesting Colonies and Damage Patterns

A DWRC biologist spent 3 months in Haiti and the Dominican Republic on studies of the village weaver. This species was introduced many years ago from Africa and now causes damage to rice, sorghum, corn, and other crops. In Haiti, long-term observations were made at colonies to document the reproductive biology and habits of this species. During the breeding season in August and September birds seldom foraged in cultivated crops. Of 52 active breeding colonies, most were in nonagricultural areas; birds fed primarily near colonies. Some nonbreeding birds fed on crops in August, and their numbers increased in cultivated areas as colonies dispersed in September.

In the Dominican Republic in late September, birds were largely dispersed in maturing rice crops. Only 12 of 75 colonies were active in late September and November, but birds could be observed each day in ricefields.

Breeding colonies and feeding flocks were composed of relatively few birds. Village weavers were not found in numbers that would pose a serious threat to rice farms. Flocks fed along the edges of ricefields, and their forays seldom took them more than a few hundred meters into fields. As a result, damage by village weavers was very localized.

The intensity of damage and its impact on individual farmers was highest in the small plots of upland rice bordered by native vegetation. The effects of village weavers on rice production appeared to be minimal. However, their impact on small, subsistence farmers, who can least afford losses, can be critical.

Techniques for alleviating losses to village weavers must be designed primarily to benfit small farmers, and must be inexpensive and practical. Consideration should be given to trapping techniques, frightening devices, and agronomic/phenologic modifications. Existing techniques should be modified and adapted for use in the countries to protect crops from village weavers.

Survey of Preharvest Corn Losses to Vertebrate Pests

Agriculture in Haiti is classified as valley (0-300 m) and mountain (above 300 m). During several preliminary visits to these areas, no damage to mountain corn by vertebrate pests was observed. Therefore, surveys are being conducted on valley corn only, primarily near Port-au-Prince and Les Cayes, where vertebrate pests reportedly are a major problem.

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Sustained baiting programs, using anti-coagulants placed in coconut husk bait stations, are showing promise in reducing rodent damage to field crops in Haiti.

Woodpeckers (Melanerpes striatus) damage cacao pods in the Dominican Republic and corn in Haiti.

Fifteen fields were sampled in the area near Port-au-Prince. In each field, 10 hills were sampled along each of five transects for a total of 50 hills. Because planting was not uniform, planting density was estimated in 25 m^2 plots along the transect. Rat (Rattus norvegicus) damage in the only field for which analysis is completed represents a 15% loss in yield. Fifty-four percent of the ears in the field had sustained some damage. The damaged to these ears averaged 29.7%.

Evaluating Sustained Baiting for Rodent Control in Maturing Rice

Sustained or continual baiting has been very effective in reducing preharvest rice losses to rodents in the Philippines. The simplicity of the method enabled Filipino farmers to adopt this practice without cultural change. Rice culture in Hispaniola easily lends itself to this control strategy.

In the Artibonite, the major rice-producing valley in Haiti, a preliminary investigation of the sustained baiting technique was evaluated in 6-ha of rice. Bait stations made of coconut shells, using 0.05% warfarin-corn meal, were placed in the paddies. Damage, based on counts of the total number of tillers, number of cut tillers, and number of unproductive tillers, was evaluated just prior to harvest.

The cost of the sustained baiting program was approximately $9.20/ha. Damage in the 6-ha area averaged between 0.4% and 1.7%. More detailed evaluations are planned for 1982.

Evaluating Sustained Baiting for Rodent Control in Maturing Corn

A cooperative study with a Texas A&M University agricultural team in Haiti was undertaken to reduce preharvest losses to rodents in corn, sorghum, casava, beans, and sweet potatoes on a 1-ha experimental farm plot. Bait stations, containing 0.05% warfarin in corn meal, were placed every 50 m along the perimeter of the field. Rodents consumed bait only from containers near the corn. Damage to all ears along 106 rows was measured and compared to damage in eight adjacent untreated fields. The data are being analyzed.

Cooperation With U.S. Peace Corps in the Dominican Republic

In the Dominican Republic, U.S. Peace Corps works with the Division of Plant Protection, Secretary of Agriculture. The AID-funded regional Vertebrate Pest Control Project is cooperating whenever possible to facilitate the research activities of these organizations on vertebrate pests. Two studies, conducted by Peace

Corps volunteers Brent Mitchell and Beth Floyd, with some DWRC technical and material support, involved evaluating woodpecker damage to cacao and rat and woodpecker damage to coconuts. Brief summaries of their findings follow.

Woodpecker Damage to Cacao:--The Hispaniolan woodpecker has long been considered a pest to agriculture, especially to such crops as cacao and citrus in the Dominican Republic. Cacao is a major export crop in the Dominican Republic. In 1980, 21,935,760 kg of cacao were exported with a cash value of US $50,787,000. The official Government estimate of damage caused by woodpeckers is 4%, representing 86,943 kg, valued at $2,031,480. The objectives of this study were to assess the damage caused by woodpeckers, investigate the biology of the species, and determine a suitable and economical method of reducing losses to cacao.

From food habit analyses, the Hispaniolan woodpecker appears to be extremely omnivorous. No relationship has been determined between the insect parts found in the stomachs of woodpeckers and the insects present in damaged cacao pods.

Radiotelemetry was used to obtain information on home range and movement patterns of woodpeckers. Radios, weighing 4.5 g, were attached to the tail feathers of two female birds. These females occupied home ranges of up to 1 km^2, used predictable roosting cavities, and sometimes roosted on exposed branches. Additional radio tracking data are being obtained during the nesting season.

The current control practice consists of paying bounties for woodpeckers. Alternative methods of crop protection, such as sight and taste repellents, are being evaluated.

Rat and Woodpecker Damage to Coconuts:--Roof rats (*Rattus rattus*) and Hispaniolan woodpeckers are the vertebrate species most responsible for losses to coconut throughout the island of Hispaniola. Woodpeckers damage the coconut by drilling a small hole in the outer husk. If this hole penetrates the coconut shell, the coconut will putrify. Between January and October 1981, a study was conducted on four farms in the zone of Barahona, southern region, to determine the annual damage caused by these species. The distance between the farms was about 5-7 km. On each farm, 100 palms were randomly selected, numbered, and damage was measured monthly. The percent damage was calculated on the basis of an annual production of 100 nuts/palm and found to range between 0.3% and 11% (Table 2). This rat damage situation may be controllable using anticoagulant baits in the crowns of the trees as originally developed in Colombia and the Philippines.

Table 2. Incidence of damage by rats and woodpeckers to coconuts on four farms in the Dominican Republic.

Species	Farms			
	Canoa (%)	Fundacion (%)	Peñon (%)	Cabral (%)
Rat	11.0	4.0	8.0	4.5
Woodpecker	0.3	1.5	2.1	4.4

Personnel and Training

Michelle Rimpel attended a course entitled "Agricultural Research Methodology" at Kansas State University, Kansas, 8 June-24 July 1981.

Radio transmitters were used to obtain information on the home range and foraging patterns of woodpeckers relative to cacao damage in the Dominican Republic.

BANGLADESH

Assessing Damage to Agriculture by Lesser Bandicoot Rats (*Bandicota bengalensis*)

Assessment of damage by vertebrates to food crops in Bangladesh continued during 1981. Estimates were made of rodent damage to barley, wheat, and deepwater and transplanted rice. In February, barley fields, at booting stage, at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, were assessed for lesser bandicoot rat (*Bandicota bengalensis*) damage. The variety Mona was slightly more mature and received more damage than the others (Table 3).

Several varieties of wheat were subjected to different levels of irrigation and amounts of nitrogen at Dinajpur. As the density of wheat stems increased in response to these treatments, the level of damage by rats also increased (Table 4).

Table 3. Damage by rats to barley varieties in 4 x 5-m test plots at BARI, Joydebpur, February 1981.

Variety	Stems		%
	Total	No. cut	damage
Mona	1,607	497	30.9
Mona	1,557	485	31.1
Mona	1,478	439	29.7
V-33	1,560	45	2.8
V-67	1,499	42	2.8

Table 4. Increase in rat damage (% of cut stems) to wheat with increase in stem density.

Stem density/m^2	Total stems cut/m^2	% damage
152	9	5.9
197	15	7.6
200	15	7.5
312	34	10.9
386	39	10.1
546	104	19.1
561	113	20.1
605	131	21.6

Tracking tiles are used to obtain information on rodent activity in efficacy evaluations of rodenticides in Bangladesh and other AID/DWRC projects.

Caches of deepwater rice of almost 2 kg have been found in the burrows of lesser bandicoot rats in Bangladesh.

Data on rat damage to wheat also are now available from assessments during several growing seasons from Gazaria and Comilla Thanas (Table 5). The level of damage fluctuates annually, depending upon distribution and amount of rainfall during the growing season. Heavy rains in the spring of 1980 flooded many fields in Gazaria Thana, forcing rats out of burrows and contributing to the low damage observed that year.

Table 5. Damage by rats to wheat in Gazaria and Comilla Thanas.

	Gazaria Thana			Comilla Thana	
	1979	1980	1981	1979	1981
No. fields assessed	20	6	88	21	81
Total tillers	25,620	8,205	53,343	28,896	38,858
No. cut (damaged) tillers	3,292	262	4,912	3,756	2,223
% damage	12.8	3.2	9.1	13.0	5.7

Deepwater rice losses were assessed by digging up the burrow systems of lesser bandicoot rats in two different areas of Gazaria Thana and retrieving the cut and stored rice heads (Table 6). The number of burrow systems/ha was estimated in the field. The rice retrieved from the burrows was air-dried, threshed by hand, and weighed. All heads on 20, randomly selected 1-m^2 quadrats from harvested fields were used to estimate yield. Rats cut and stored an average of 1.8% of the deepwater rice yield during this 2-week period. Losses are sufficiently substantial that farmers frequently retrieve this rice from the burrow systems.

Table 6. Quantitites of deepwater rice removed from rat burrows in Gazaria Thana, October 1981.

Area	No. burrow systems excavated	Amt (kg) of stored rice/burrow system	No. of burrow systems/ ha	Extrapolated amt (kg) of stored rice/ha	Obs. yield (kg) of rice/ha	% yield loss
I	10	1.13	30	33.9	1,980	1.7
II	10	1.97	25	49.3	2,721	1.8

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Fields of transplanted rice were assessed for rat damage along a road transect between Joydebpur and Tongi in late November. Sampling sites were located at 0.5-km intervals. Fields were selected perpendicular to both sides of the road at 100-, 200-, and 300-m distance. Five 50 x 100-cm sampling units were equally spaced in the field, and all cut and uncut tillers were counted. A total of 55,404 rice tillers in 102 fields were sampled. Cut tillers (323) were found in nine fields, giving a damage level of 0.6% of the crop. No damage was noted before 90 days. Few rat burrows were found in the fields, probably due to the dry climatic conditions; no rain had fallen during the previous 2.5 months.

Anticoagulant Rodenticide Studies

Anticoagulant toxicities to rats were compared by recording mortality during a no-choice feeding test for 4 days on anticoagulants that were offered in a food base at geometric progressions (doubling or halving) of concentrations (Table 7).

Table 7. Mortality of *Bandicota bengalensis* offered three anticoagulants in a no-choice, 4-day test.

Rodenticide	Concn (ppm)	Mean body wt (g)	Mortality ratio	Mean dose consumed (mg/kg)	Mean days until death
Diphacinone	10	289	2/6	1.9	10.5
	20	260	4/6	3.4	9.2
	40	263	5/6	8.1	7.4
	80	252	6/6	15.4	7.7
Coumatetralyl	2.5	294	2/6	0.6	7.5
	5	231	4/6	1.5	7.0
	10	232	6/6	2.0	6.8
	20	234	6/6	3.9	6.0
Brodifacoum	0.3	206	0/6	0.1	-
	0.6	227	3/6	0.15	13.0
	1.25	249	7/12	0.3	12.0
	2.5	258	11/11	0.7	7.2
	5	234	11/11	1.4	7.4
	10	225	6/6	2.5	5.5
	20	214	7/7	5.3	6.1

Zinc phosphide and brodifacoum baits are prepared and packaged for comparative rodenticide trials and operational control in Bangladesh.

A 4-day test period was used because rats normally will feed fully on anticoagulants for 4 days before becoming ill and discontinuing feeding. The dose-response curve was plotted on log-probability paper and the 4-day LD50 (lethal dose in mg/kg which kills 50% of the test animals in the exposure period) was read directly or computed from standard dose-response calculations. The calculated toxicities of brodifacoum, coumatetralyl, and diphacinone against B. bengalensis are compared in Table 8. The 4-day LC50 (lethal concentration in ppm which kills 50% of the test animals in the exposure period) of brodifacoum was 0.8 ppm, which is approximately 18 times less than that for diphacinone, and 4 times less than that of coumatetralyl; the same relationship held for the 4-day LD50. The first two materials could be recommended for use in the control of lesser bandicoot rats in Bangladesh.

Table 8. Comparative 4-day toxicity of three anticoagulant rodenticides to Bandicota bengalensis (95% CL in parentheses).

Rodenticide	LC50 (ppm)	LD50 (mg/kg)
Brodifacoum	0.81 (0.56-1.16)	0.2 (0.14-0.28)
Coumatetralyl	3.60 (2.3-5.6)	0.9 (0.62-1.3)
Diphacinone	14.50 (7.4-28.3)	2.6 (1.5-4.4)

Rodent Ecology in Sugarcane

Sugarcane is a 12-month crop in most areas of Bangladesh and reportedly sustains rodent damage. A study of rodent ecology in sugarcane was initiated in collaboration with the Australia-Bangladesh Sugar Industry Project farm at Muladuli, about 10 km north of Ishurdi. Fields planted in early December 1980 were sampled for rodents every other month for 10 months by setting snap traps at 8-m intervals in parallel lines (approximately 5 m apart).

During 1,122 trap nights, 12 rats were captured (10 Millardia meltada, 1 Rattus rattus, 1 Nesokia indica). The capture of one Nesokia is not an indication of its scarcity because it rarely travels above ground; it was seen in moderate numbers in ditches along the fields. Stomach contents analysis revealed that M. meltada was feeding mainly on weed seeds, stems, and insects; neither was cane found in the alimentary canal of R. rattus. However, N. indica had eaten roots of cane plants beginning 4 months after planting, resulting in the loss of all plants (about 2% of the total) in some rows. Damage was confined to the first 10 m from the field edge. B. bengalensis did not occur in this study

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area, and its impact on sugarcane will be evaluated in a future study.

Comparative Field Trials of Two Rodenticides in Village Housing Clusters

During the monsoon season, rodents temporarily desert the flooded fields and concentrate in elevated areas. Bandicoot rats move close to, or actually into, human dwellings. Resident household rodents are the roof rat (*R. rattus*) and the house mouse (*Mus musculus*). An insectivore (Soricidae), the musk shrew (*Suncus murinus*) also occurs around housing areas. This monsoon period appears to be a logical time to attempt to control rodents and presents an excellent opportunity to test the comparative efficacy of rodenticide baits.

Three housing clusters were divided into three randomly selected treatment areas. One housing cluster served as an untreated reference area in each trial. The efficacy of zinc phosphide (2%) and brodifacoum baits (0.005%) when applied at weekly intervals, was compared. At the Vertebrate Pest Research Laboratory, 50-g zinc phosphide and brodifacoum baits were prepared and packaged in plastic bags. One packet was provided to each house owner with advice that he divide it into five parts and place each in a different location.

Tracking tiles were set inside and around houses for 2 nights to obtain data on pretreatment and posttreatment animal activity (Table 9). Following poisoning, snap traps were set at all houses to determine the identity of those species that escaped poisoning and to verify the tracking tile activity.

Brodifacoum gave consistently greater reduction in animal activity than zinc phosphide in each housing cluster. Based on the tracking tile data, the overall reduction was 97% for brodifacoum and 86% for zinc phosphide; reference houses showed a 39% increase in activity. The results suggest that a large-scale baiting program during the monsoon season should be able to reduce rodent populations to nondestructive levels by the onset of the dry-season cropping period.

Bird Damage to Sweet Corn

Damage to sweet corn at Rajbari, Dinajpur Regional Agricultural Research Station by rose-ringed parakeets (*Psittacula krameri*) and jungle crows (*Corvus macrorhynchos*) was quantified in September. Damage was heaviest along the border rows and differed by variety (Table 10).

BARI/DWRC personnel distributing rodenticide bait to farmers in the central market of Gazaria Thana, Bangladesh.

Table 9. Rodent activity across tracking tiles before and after application of zinc phosphide and brodifacoum in three villages of Bangladesh.

Village and treatment	No. houses	Pretreatment No. tiles placed	Pretreatment % positive	Posttreatment No. tiles placed	Posttreatment % positive	% change in activity
Lokhipur						
Zinc phosphide	13	75	37	45	11	-71
Brodifacoum	12	34	91	52	4	-96
Reference	15	73	33	76	56	+70
Samantapur						
Zinc phosphide	16	91	57	55	4	-93
Brodifacoum	14	66	68	58	0	-100
Reference	15	87	40	72	54	+35
Jugitola						
Zinc phosphide	41	176	64	176	10	-85
Brodifacoum	42	156	61	156	4	-94
Reference	39	151	54	151	61	+13

Table 10. Incidence of damage by pest birds to sweet corn varieties in 4 x 5 m test plots at Dinajpur. All ears in each plot were counted.

Variety	% damage	Variety	% damage
Sandaf	10.3	Los Baños 7622	15.4
Suwan	12.3	Pozarica 7927	16.5
Sarhad	13.2	Pozarica 7926	17.7
JC-2	13.3	Across 7534	19.8
Suwan 2	15.0	Savar 1	21.9

Bird Damage Control in Sprouting Wheat

Wheat is becoming an increasingly important grain crop in Bangladesh and is being attacked by birds. Bird pests of sprouting wheat include common myna (*Acridotheres tristis*), Asian pied starling (*Sturnus contra*), rock dove (*Columba livia*), collared dove (*Streptopelia decaocto*), house sparrow (*Passer domesticus*), large-billed crow (*Corvus macrorhynchos*), and house crow (*C. splendens*).

Field trials, using the chemicals methiocarb, applied at 0.25% and 0.5%, and copper oxychloride (a registered fungicide in Bangladesh), applied at 1.2%, as seed dressings, were carried out in wheat multiplication fields at Muladuli, Ishurdi, Sibrampur, and Dinajpur. Methiocarb applied at 0.5% and copper oxychloride applied at 1.2% were compared in farmers' fields at Bogra with the cooperation of the Christian Reformed World Relief Committee (CRWRC).

Treated plots in the seed multiplication fields measured between 1,225 m^2 and 1,600 m^2 and were separated by untreated areas at least 30 m wide. Individual farmer's fields varied from 175 m^2 to 1,300 m^2. In all locations, seeds were treated, hand broadcast, and covered with soil using bullock-drawn rakes. Plots and fields were sown between 19 November and 22 December, and sampled for bird damage by counting the number of wheat sprouts in 10 randomly selected sampling units, approximately 4-6 weeks after sowing.

Both methiocarb and copper oxychloride are potentially effective bird repellents to wheat seed (Tables 11 and 12). No mortality was observed with methiocarb at 0.25% or with copper oxychloride. The 0.5% methiocarb concentration killed some Asian pied starlings, collared doves, and rock doves.

Table 11. Number of wheat stems counted 4-6 weeks following seed treatments with methiocarb and copper oxychloride to protect them from bird damage in Bangladesh.

Location	Reference field	Chemical and treatment level: Methiocarb 0.25%	Methiocarb 0.5%	Copper oxychloride 1.2%
Muladuli				
No. stems/m^2	120.0	164.0	182.6	101.2
% difference from reference	-	+36.7	+52.2	-15.7
Ishurdi				
No. stems/m^2	126.2	171.6	212.8	133.4
% difference from reference	-	+36.0	+68.6	+5.7
Sibrampur				
No. stems/m^2	103.2	197.6	256.4	182.8
% difference from reference	-	+91.5	+148.4	+77.1
Dinajpur				
No. stems/m^2	196.2	258.2	312.4	218.6
% difference from reference	-	+31.6	+59.2	+11.4
Means	136.4	197.9	242.0	159.0
% difference from reference	-	+45.1	+77.4	+16.6

Table 12. Number of wheat stems in farmers' fields at Bogra 1 month after seed treatments with methiocarb and copper oxychloride to protect them from bird damage in Bangladesh.

Treatment	No. fields	Potential no. stems/m^2	Obs. no. stems/m^2	% of potential
Reference	5	307	125	41
Methiocarb (0.5%)	5	397	185	47
Copper oxychloride (1.2%)	6	346	213	61

Cooperation With National and International Organizations

The Vertebrate Pest Section staff continued to cooperate with the Bangladesh-German rodent control project and the Bangladesh Agricultural Research Council (BARC), in field, laboratory, and training activities. As previously mentioned, collaborative work on reducing bird damage to sprouting wheat and studying rodent ecology in sugarcane was carried out with Christian Reformed World Relief Committee at Bogra, and the Australia-Bangladesh Sugar Industry Project at Muladuli, respectively.

Mr. Brooks spent 2-1/2 weeks in Rangoon, Burma in November as a guest lecturer at a WHO-sponsored training course on the Biology and Control of Rodents of Economic and Public Health Importance. Twenty-four individuals participated from countries in the Western Pacific, South Asia, and Southeast Asia.

Personnel and Training

In December, counterpart personnel presented a training lecture to 24 participants in the Rice Production Specialist Training Course on the biology and control of rodents that damage food crops at the Bangladesh Rice Research Institute (BRRI). On 30 November, Bangladesh TV filmed a 30-min program in Bengali language on rodent control and research activities of the Vertebrate Pest Section at BARI. This program was shown nationwide.

Several individuals are in the process of completing graduate degree programs. Md. Abdul Karim is continuing a Ph.D. program at Bowling Green State University, Bowling Green, Ohio, USA in Vertebrate Pest Management, and is conducting his field research at the DWRC Field Station in Hilo, Hawaii. Md. Yousuf Mian and Md. Emdadul Haque are nearing completion of their M.S. program in Vertebrate Pest Management at the University of the Philippines at Los Baños. Both will return to the VPS in 1982. Md. Matiur Rahman, Scientific Officer, BARI, joined the VPS staff in late March and has carried out work on the comparative efficacy of rodenticides in small housing clusters.

PHILIPPINES

Developing and Evaluating Methods to Reduce Rat Damage to Coconut

Based on findings from studies conducted over almost a decade, crown baiting, wherein bait containing an anticoagulant is placed monthly in the crowns of palms in a coconut plantation, holds the potential of providing highly economical protection from rat (*Rattus rattus mindanansis*) damage.

Three plots of 100-300 trees each were selected at farms in Calauan, Laguna beginning in 1980. One of 10 trees in two plots (Plots I and II) were treated with 0.025% warfarin bait, and one plot (Plot III) was left untreated. Each month, rat activity estimates were obtained using tracking tiles and damage was estimated by counting the number of fallen, rat-damaged nuts.

In both 1980 and 1981, rat damage and activity were much lower in the two treated plots than in the untreated plot, although the differences were not as great during 1981 (Figs. 1 and 2). These results demonstrate the interrelationship between agronomic practices and successful control practices. In Plot I the ground cover was never cut; in Plot II it was cut once during August and September, after which rat activity dropped sharply.

In Plot I, damage was greatest in coconuts nearest the rice plots. During and shortly after land preparation of adjacent ricefields, an increase in rat activity and damage occurred. When paddies were flooded and during harvest of grain crops, rats regularly moved to areas with suitable cover. Contrastingly, Plot II, which was adjacent to previously planted pineapple fields, was relatively unaffected.

Recommendations for using 10% crown baiting for coconut adjacent to ricefields might include provisions for higher baiting rates during the months of land preparation and harvest. The success of the method in various field trials appeared related, in part, to selective removal of rodents that feed in the palms, and to the use of baits that were preferred over growing nuts. Additional field trials are needed to confirm the optimal treatment levels for different coconut-growing regions in the Philippines.

Reinvasion of Rats Following Termination of Crown Baiting in Coconut

In previous evaluations of the crown-baiting technique in coconuts we have been able to reduce rat damage within 4 months. With monthly baiting, low rat damage apparently can be sustained indefinitely. However, we know little about the rate at which rat damage increases if crown baiting is terminated. The purpose of

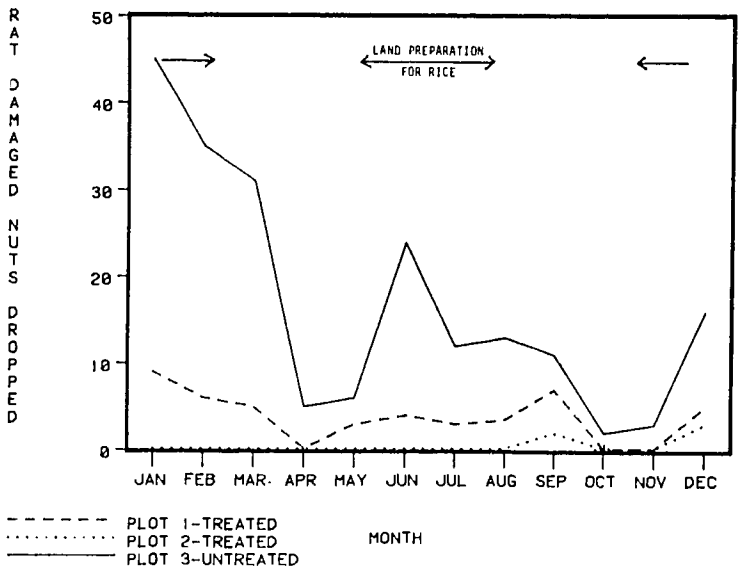


Figure 1. Comparison of the number of rat-damaged coconuts/100 trees in one untreated plot and two plots in which the crowns of 10% of the trees were treated with 0.025% warfarin bait at Calauan, Laguna, during 1980. The period of land preparation for adjacent rice paddies is indicated.

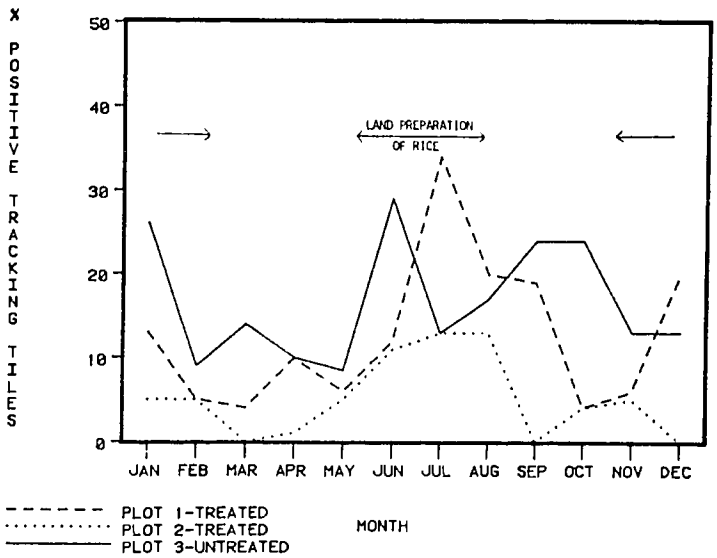


Figure 2. Comparison of rat activity in one untreated plot and in two plots in which the crowns of 10% of the coconut trees were treated with 0.025% warfarin bait at Calauan, Laguna, during 1981. The period of land preparation for adjacent rice paddies is indicated.

this study was to document damage in coconut after crown baiting had been terminated.

Baiting was terminated in three plots of coconuts near Bagabag, Nueva Viscaya, in December 1980. During baiting, the plots had sustained damage levels of about 10 rat-damaged nuts/plot/month. Prior to this baiting, the plots had 60-130 rat-damaged nuts/plot/month. Damage, based on the number of fallen, rat-damaged nuts was assessed in each plot at 3, 5, and 7 months after control efforts stopped. Rat activity again was determined with tracking tiles.

Although rat activity increased in all three plots to the 20-30% pretreatment activity levels (Fig. 3), the number of damaged nuts increased only slightly and remained below pretreatment damage levels (Fig. 4). This suggests that reinvasion of rats into treated areas may not necessarily result in an immediate increase in damage. Rats may only climb trees and damage nuts under stress of reduced food, or competition for space.

Relationship of Weeds to Rat Damage in Corn

Field studies with many crops, including rice and corn, have shown that crops with weeds receive more damage than crops without weeds or crops with low weed density. Herbicide trials conducted by the Philippine Weed Control Project (International Plant Protection Center, Oregon State University) reported heavy rat damage in plots as small as 10 x 10 m with weeds; these plots were within 10 m of adjacent plots without weeds that received little or no damage.

Locations with a history of rat damage to corn were selected near San Roque, Batangas Province, and Mamburao, Occidental Mindoro. Three replicates of three treatments were used at each location. Treatments included herbicide use, normal cultivation, and no weed control. Treatment plots were about 600 m^2 with a weed-free buffer zone of 5 m between replicates. San Roque was planted with corn on 28 October 1980 and Mamburao on 15 December 1980.

Rat damage to corn occurs sporadically. Most fields either have high or very little damage, depending on the abundance of rats during the susceptible period. In both study areas, a relatively low rat population was present.

The results of the trial at Mamburao were inconclusive due to minimal rat damage. More rat damage was found in the San Roque plots; rats showed a preference for ears of corn in plots with weeds. The mean damage at San Roque for the three plots without weed control was 142 ears/plot (range = 31-355) compared to a mean of 3 ears/plot (range = 2-5) for normally cultivated plots, and 2 ears/plot (range = 0-6) for herbicide-treated plots (Fig. 5).

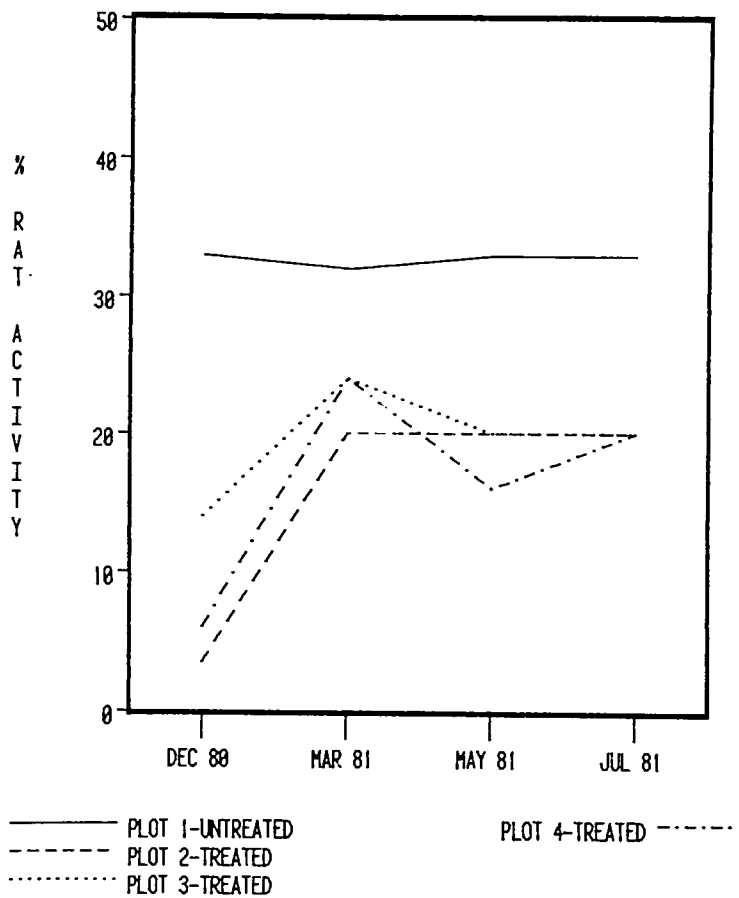


Figure 3. Incidence of rat activity from tracking tiles placed in coconut plots following termination of crown baiting with warfarin at Bagabag, Nueva Viscaya.

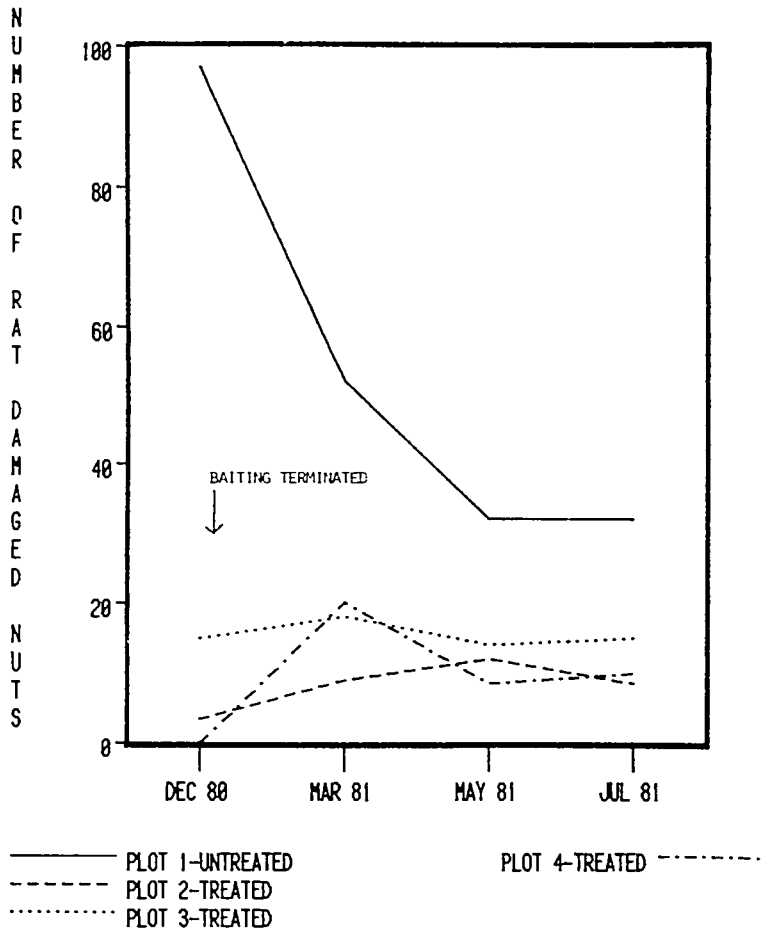


Figure 4. Number of rat-damaged nuts counted for 7 months after crown baiting with warfarin had been terminated at sites in Bagabag, Nueva Viscaya.

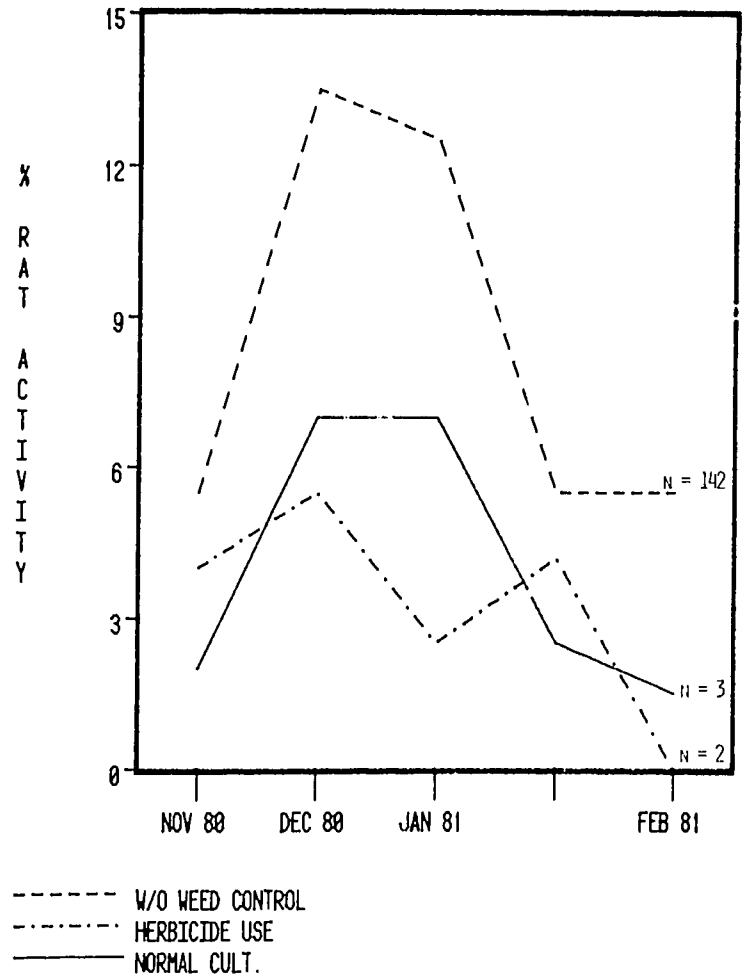


Figure 5. Comparison of rat activity (based on tracking tiles) and damage in three replicate fields of corn, with or without herbicide applications, from 2 weeks of planting through harvest at San Roque. N = no. damaged ears of corn at harvest.

It appears that weed control could reduce rat damage and should be considered in cost:benefit determinations of weed control in corn. More data correlating weed levels with rat damage and yield need to be collected.

Efficacy of Fumigant Cartridges to Control Ricefield Rats (*Rattus rattus mindanensis*) in Burrows

Burning vegetation and fumigating or flooding burrows are methods frequently used by farmers and rodent control teams to reduce rat damage to rice. In Philippine ricefields, only a portion of the rat population (usually nesting females) occupy burrows. Burrow treatments have not adequately been evaluated to reduce rodent populations and, ultimately, damage. The efficacy of a fumigant cartridge, developed at DWRC, was tested on *R. r. mindanensis* at the International Rice Research Institute (IRRI).

Two sites of 3-4 ha each, located in the upland area of IRRI with comparable rat populations and similar characteristics of size, plant age, and variety were chosen. Each site was enclosed by chicken wire covered with a sheet of galvanized iron. The plots were baited with anticoagulant rodenticides by IRRI personnel. All burrows were marked with bamboo sticks and plugged with mud. Burrows that were reopened or newly excavated the following morning were considered active. One DWRC 85-g gas cartridge, consisting of 10.8% sulphur, 17.3% charcoal, 3.3% red phosphorous, 14.1% mineral oil, 43.4 % sodium nitrate, 3.5% sawdust, and 7.6% inert materials, was lit and inserted in each active burrow system. Burrows were fumigated when the crop was in the flowering, vegetative, and mature stages. All openings were then closed with soil. Two hours after fumigation, randomly selected burrows were dug up to estimate rat mortality. Activity was estimated from tracking tiles positioned for 3 nights before and after fumigation.

A total of 84 burrows were fumigated; 22 in Plot II and 62 in Plot I. About 87% of the dead rats were females. Rat activity was reduced 50% when active burrows were fumigated during the vegetative stage (Fig. 6). However, little or no reduction in activity was achieved when burrows were fumigated during the flowering and mature stages. The effectiveness of fumigant cartridges for providing immediate protection from rat damage appears questionable. However, burrow treatments timed to the reproductive season, in combination with baiting programs, might sufficiently reduce the population to a level that protection could be achieved. Due to the continual reinvasion of rats from surrounding areas, burrow treatments would need to be implemented over large areas to achieve an effect.

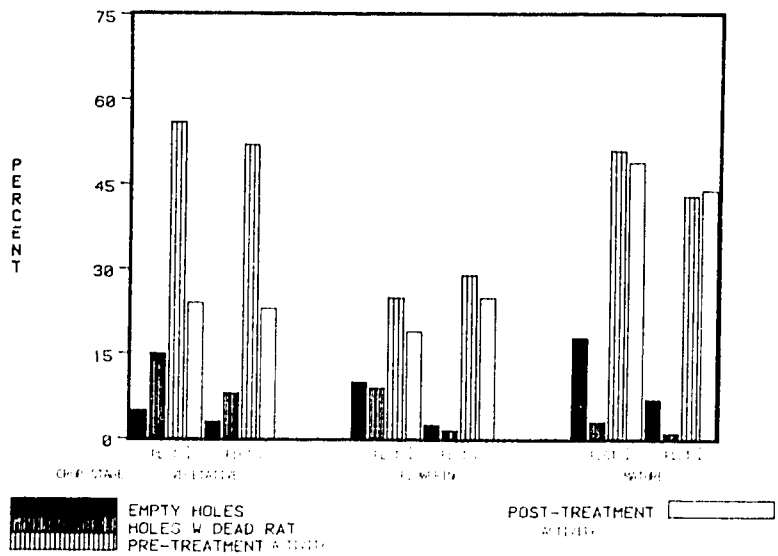
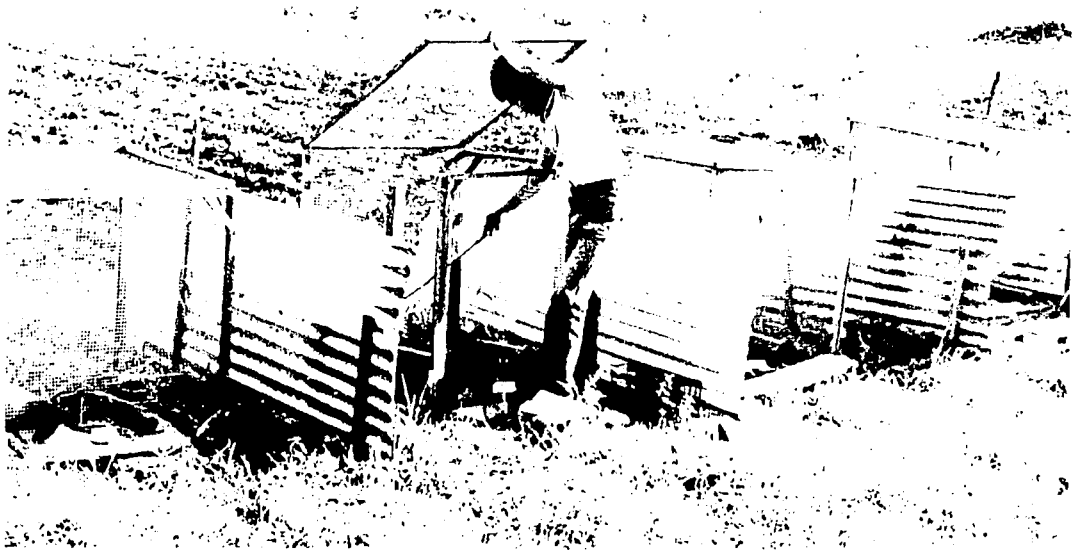


Figure 6. The effect on rat activity of fumigating burrows with the DWRC gas cartridge in two plots of rice during three growth stages.

Lethal or sublethal electric barriers are being evaluated for protecting rice from rat damage in the Philippines.



Bait containers that are inexpensive and locally available are important to the success of rodent control work. Cage trials, testing different bait container designs for rodent control, are being investigated in the Philippines.

Evaluation of Rat Control Techniques in Experimental Fields of the International Rice Research Institute (Sayed Ahmed, M.S. Thesis)

One of the most difficult places to control rat damage is on large experimental rice farms where many different crop stages offering food and shelter exist, yet, where damage is intolerable. Rats easily move among maturing rice paddies, feeding on rice, and avoiding any bait. The cost:benefit ratio of the effectiveness of control techniques has not previously been evaluated on research stations.

Four rat control techniques--baiting with coumachlor, baiting with brodifacoum, lethal electric rat barrier, and nonlethal electric rat barrier--were evaluated during the 1980 wet season and 1981 dry season on experimental farms of IRRI. Damage to rice tillers, rat activity, and costs of the control methods were evaluated.

Ten experimental plots, about 0.25 ha each, and at least 90 m apart were selected in each season. Each control technique was replicated twice each season, beginning 4 weeks after transplanting.

Rat damage was determined near harvest by counting cut and uncut tillers in 200 hills/plot. Rat activity was determined from 10 tracking tiles that were placed along the inner side of the border dikes on 3 consecutive nights. In plots with electric barriers, 10 tracking tiles also were placed outside the fence. Manpower and material costs were recorded for each method. A survey was conducted of 51 IRRI research personnel from seven departments to determine the importance of rat damage to their trials.

Damage (<1%) and rat activity in plots protected by the lethal electric barrier were lower than in plots protected by the other three techniques. Damaged tillers averaged >9%, and activity also was highest in reference plots. Rat activity closely followed damage in all plots. However, baiting methods were much less expensive than the barriers. The lethal electric rat barrier was the most effective method, but, unfortunately, the most expensive.

Our survey also indicated that of 173 rice experiments conducted in 1980, research data were totally lost in 6.4% and partially lost in 60% due to rat damage. Researchers were able to collect their intended data in only 34% of the experiments.

Rat Damage to Hawaiian Giant Ipil-Ipil (*Leucaena leucocephala*) Trees

Rat damage to Hawaiian giant Ipil-Ipil (*Leucaena leucocephala*) trees, which are grown for fuel for thermo-generating plants at the Pilot Dendro Thermal Plant Project in Daclolo, Occidental Mindoro, was evaluated. A rodent control program including damage appraisal,

snap trapping, anticoagulant baiting, species composition identification, and training of project personnel was initiated. The pest species were identified as R. r. mindanensis, R. exulans, and R. argentiventer. The 3- to 4-year-old trees (10 cm in diam) had scars of earlier rat damage. Younger trees (about 2.5-3 m in height and 5 cm in diam) had numerous fresh rat damage; rats had stripped the bark, about 6 mm deep, along young branches. The most severe damage occurred to newly planted seedlings or saplings of 1 m in height, causing numerous replantings. Damage was preliminarily evaluated as 60%. An anticoagulant baiting program is underway.

Rat Damage to Coffee (Coffea robusta)

Coffee farmers in northern Luzon experience rat damage to coffee (Coffea robusta) trees between the months of October and December. Damage to the coffee trees begins during the flowering period when new growth is present. Secondary and tertiary branches are cut, stripped, or girdled. After a few weeks, severe defoliation and loss of bean production occurs. Eighteen of 20 plantations visited during October 1980 had visible signs of rodent damage. Preliminary studies to confirm the damage, identify the rat species, and initiate control measures were undertaken.

Three coffee plantations were selected in Kiangan, Ifugao Province for study. Twenty-five snap traps were set in each plantation for 1 night on seven occasions between October 1980 and December 1981. Damage was estimated by counting the number of rat-damaged branches in 40 randomly selected trees. Eight baiting points (trees) were selected in which two coconut husk bait holders, containing an anticoagulant rodenticide in rice shorts or whole rice, were placed. Bait was added as needed by farmers who checked the holders twice weekly.

Several species of rodents are responsible for damage to coffee. During 175 trap nights, 50 R. everetti, 12 R. exulans, and 10 R. r. mindanensis were caught. Traps set in trees caught only R. everetti.

Damage probably can be reduced with baiting programs. The number of damaged branches in Plots I, II, and III before treatment were 206, 180, and 318, respectively, and 32, 501, and 0 after treatment. Plot II was not treated. The harvest from treated plots was twice as great as during the previous 2 years, while yield in the untreated plot was comparable. Monthly bait consumption in the treated plots declined from October 1980 through April 1981 before rising in November and December 1981. Similar damage reportedly occurred in coffee grown in Mindoro and Mindanao.

A recent vertebrate pest problem, Rattus everetti damage to coffee, is being investigated in the Philippines. Rats, such as the one captured in a snap trap placed in a coffee tree, gnaw, strip, and cut terminal branches, causing damage and reduced bean yield.

Evaluating Methiocarb as a Repellent Against Philippine Bird Pests

Two studies were conducted to determine the repellency of methiocarb to three species of mannikins, pests to rice in the Philippines. In the first study, the R50 values of methiocarb to three species of mannikins were determined. The value for each species was: *Lonchura malacca*--0.043% (CL 0.069% - 0.027%), *L. punctulata*--0.057% (CL 0.088% - 0.037%), and *L. leucogaster*--0.036% (CL 0.049% - 0.026%). The chemical apparently could be used economically under field conditions.

In the second study, methiocarb was evaluated as a seed treatment for reducing bird damage to hand-sown rice seeds in Mamburao, Occidental Mindoro. IR-26 seed rice was treated with 0.25% methiocarb seed treater, sown, and germinated according to farm practices in one plot. Another plot was left untreated. Twenty-five sampling points/plot were established and the number of seeds/sampling point counted. Bird counts were made immediately after sowing and for the next 18 days.

This demonstration indicated the potential of 0.25% methiocarb seed treatment in reducing bird damage to hand-sown rice seeds. Damage at the conclusion of the study showed 5.3% damage to the treated plot and a significantly ($P < 0.01$) higher damage level of 61.7% in the untreated plot. Bird counts remained high in the untreated plot, whereas, in the treated plot, no birds were observed feeding after the fourth day (Table 13; Fig. 7). Additional cost:benefit studies are needed to develop specific recommendations for using methiocarb in bird damage situations.

Table 13. Average number of birds ($\bar{x}$) and rice seedlings ($\bar{x} \pm SD$), and damage from a demonstration at Mamburao, Occidental Mindoro, Philippines, in which 0.25% methiocarb seed treater was applied to hand-sown rice seed.

Plot	Avg no. Birds/day	Avg no. Seedlings/sampling point	% damage
Treated	21	21.6 ± 7.2	5.3
Untreated	426	46.3 ± 10.8	61.7

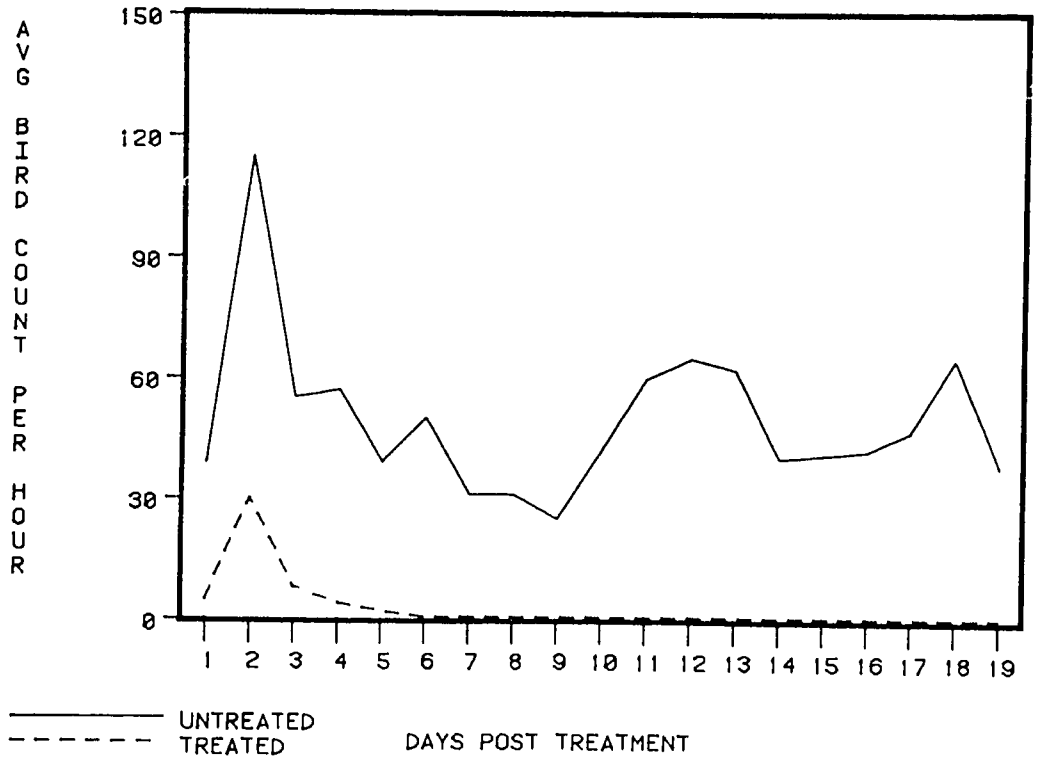
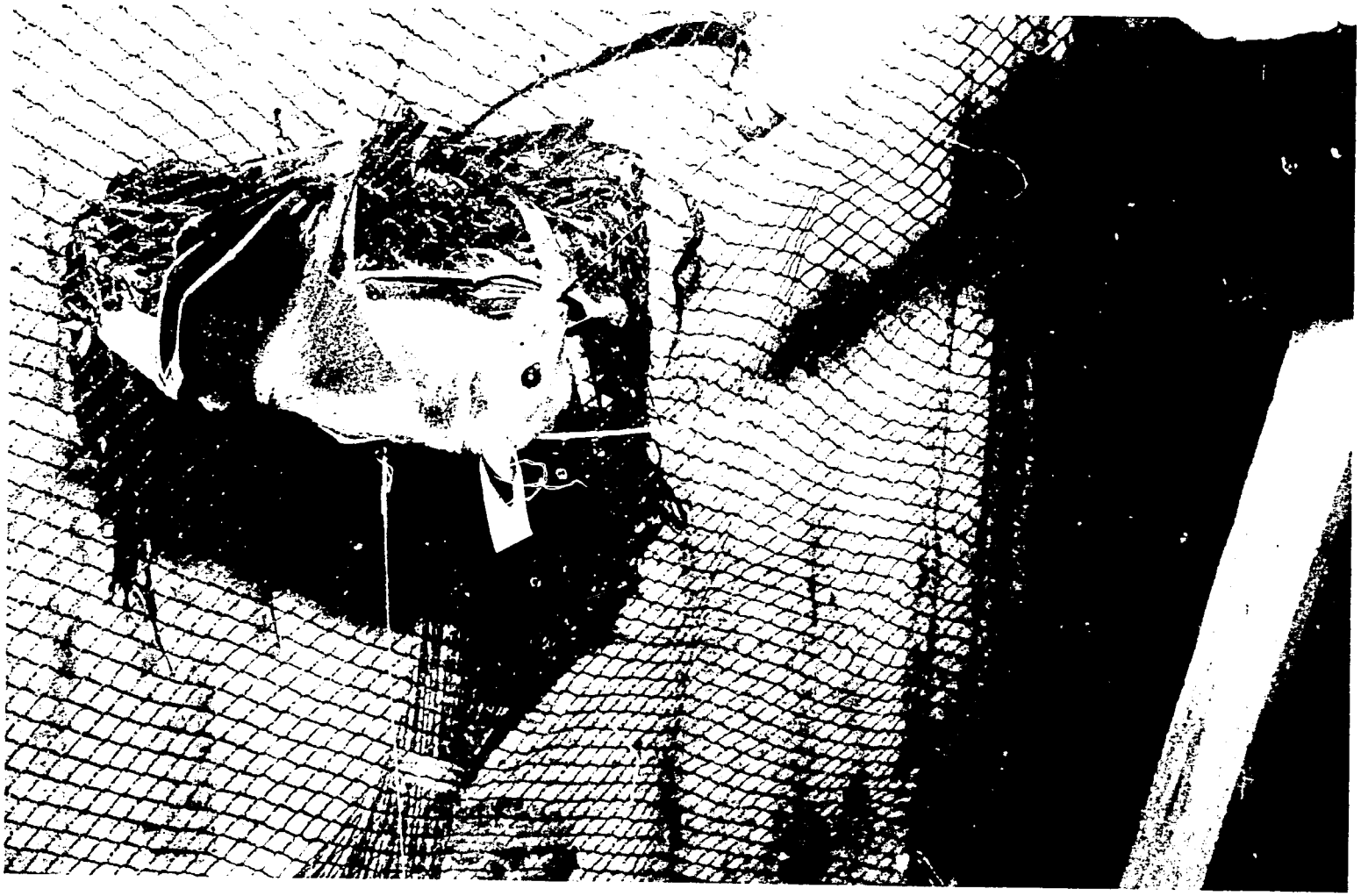


Figure 7. Average number of birds/hour in a plot sown with methiocarb-treated rice seed and in a field sown with untreated rice seed in the Philippines.

Evaluating Plastic Leg Streamers as Markers for Mannikins and Sparrows

On 23 and 24 June 1981, 76 birds of three species of mannikin (*L. punctulata*, *L. malacca*, and *L. leucogaster*) and one species of sparrow (*Passer montanus*) were marked with 1 x 3.5-cm plastic, fluorescent SAFLAG^R or FACILON^R leg streamers (weighing 0.2 g) to determine their utility as markers for these species which sometimes are pests to cereal crops in the Philippines. The leg streamers were attached to the tarsus using 0.1-g aluminum leg bands (3 mm internal diam). The mannikins were put in a communal 2.0 x 2.0 x 2.0-m screened cage; the sparrows were put in a 2.5 x 2.0 x 2.1-m cage enclosed with fish net. Unmarked birds of all species also were put in the cages. Both cages were outdoors. The birds were checked once weekly for streamer loss and mortality.

Most of the mannikins remained alive and retained their streamers for 6 months. However, after this time, both marked and unmarked birds began to die, presumably due to cooler climatic conditions associated with seasonal changes. Most of the sparrows escaped from the cage within 1 week. Yet, for the next 4-5 months, between three and five marked sparrows were observed regularly in the vicinity of the other caged birds.



Nectar-feeding bats, Rousettus amplexicaudatus, which damage bananas in the Philippines, were maintained in captivity to test attachment glues for radio transmitters.

The results indicate that leg streamers can be used for marking both mannikins and sparrows. It is planned to use streamers in population studies of sparrow damage to stored grain in warehouses and in movement studies for all species in crop protection evaluations.

Cooperation With National and International Organizations

A year-long demonstration of crown baiting in coconut was completed with the Crop Protection Center in Pili, Camarines Sur Province. Treated and untreated plots were established; monthly records were kept of rat damage, rat activity, and harvested coconuts. The study area was used for demonstration and extension of techniques of baiting and censusing.

At the request of commercial banana growers in Mindanao, damage caused by nectar-feeding bats is being investigated. These bats (*Rousettus amplexicaudatus*) scratch young bananas in the process of feeding on the nectar of the banana flower, making the bananas unacceptable for market. Bat populations apparently were reduced by mist net collections during a 1-year period; more than twice as many females as males were captured.

Personnel and Training

Training continued to be an important component of the Vertebrate Pest Project during 1981 (Table 14). In addition, two manuals were prepared in cooperation with IRRI for use in pest management training courses and for publication and distribution.

Six individuals, including five international students, were enrolled at the University of the Philippines at Los Baños (UPLB) for graduate level training in vertebrate pest management. Four Filipino students, also pursuing doctoral degrees in vertebrate pest management, enrolled in the U.S. at Michigan State University, Bowling Green State University, and at North Carolina State University.

Seventeen individuals were graduated from the 10-month diploma course for crop protection specialists which started in November 1980. The course again was offered in June 1981 to 25 students, including one Indonesian. The course is funded by a USAID Training Grant through the National Crop Protection Center, College of Agriculture, UPLB. Several Southeast Asian countries have expressed an interest in participating in future courses.

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Table 14. Summary of vertebrate pest control training in the Philippines during 1981.[a]

Sponsoring agency	No. individuals	Profession	Representing country	Length of training
FAO	3	Research	Indonesia	2.5 months
National Food Authority	1	Research	Philippines	2.5 months
National Food Athority	15	Research and operational control	Philippines	3 days
International Rice Research Institute (IRRI)	18	Research	Indonesia, Bangladesh, Burma, Malaysia, Philippines, India	6 days
IRRI	40	Crop production	Many tropical countries	0.5 day
University of the Philippines at Los Baños	25	Student	Philippines, Indonesia	4 days
Baybay National College of Agricultural Technology, Laguna Province	300	Student	Philippines	0.5 day
"	72	Farmer	Philippines	0.5 day

[a] Seven students were given assistance in special problems related to vertebrate pests at the University of the Philippines at Los Baños (UPLB).

DWRC staff traveled in Africa, Asia, Caribbean, Latin America, and Europe during 1981. Travel was undertaken in conjunction with ongoing field research activities and at the request of foreign governments through AID Missions or AID Washington, to participate in international meetings, assess vertebrate pest problems, or to review, evaluate, and coordinate present and future research programs. TDY activities from the DWRC have become an increasingly important part of the project and DWRC will continue to respond to such requests through AID. Many types of short-term evaluations and cooperative studies with host-country scientists may be carried out expeditiously in this manner. This travel involved 385 man-days in the following countries:

Kenya	Bangladesh	Dominican Republic	Nicaragua	Italy
Sudan	Philippines	Haiti		United Kingdom
Egypt	India			
Ethiopia	Burma			

Travel dates, persons involved, countries visited, and the purpose of each trip are outlined briefly in Table 15. Detailed information is contained in individual trip reports on file at the Denver Wildlife Research Center, Section of International Programs.

Table 15. International travel for technical assistance projects by AID/USFWS-DWRC personnel during 1981.

Date	Traveler	Destination	Purpose of Visit
22 Jan-14 Feb	L. A. Fiedler	Bangladesh	Conduct ongoing studies in the field and at the laboratory at Bangladesh Agricultural Research Institute (BARI) in Joydebpur. Consult with BARI officials. Plan and coordinate activities until arrival of new Project Leader.
17 Feb-10 Mar	R. M. Poché	Egypt, Italy	Assess vertebrate pest problems in Egypt and make recommendations for control. Discuss vertebrate pest problems with FAO officials in Rome.
7-24 Mar	R. F. Reidinger	Nicaragua	Assess problem of rodent damage to agricultural crops and make recommendations for solutions.
12-28 Mar	L. A. Fiedler	Bangladesh	Complete field study "Evaluation of rat control in wheat" initiated November 1980. Consult with BARI and USAID officials re Vertebrate Pest Project.
25 Apr-11 May	J. W. De Grazio	Sudan, Kenya	Close USAID/DWRC Vertebrate Pest Project in Khartoum, Sudan. Discuss cooperative bird control research with FAO, USAID, and Government of Kenya officials.
25 Apr-22 Jun	J. O. Keith	Sudan, Kenya	Participate in closing of USAID/DWRC Vertebrate Pest Project in Khartoum, Sudan. Participate in quelea research studies with FAO officials in Kenya.

Table 15 (cont'd)

Date	Traveler	Destination	Purpose of Visit
10 May-3 Jul	R. L. Bruggers	Ethiopia, Kenya, Philippines	Assist U.N. Food and Agriculture Organization personnel conduct an extensive bird survey and bird-marking technique tests in Ethiopia. Meet with Bowling Green State University graduate students in Kenya. Review bird control research in the Philippines.
19-23 May	J. W. De Grazio	Haiti	Review progress and discuss future activities of newly established Vertebrate Pest Project.
28 Jun-25 Jul	D. L. Hayes	Haiti, Dominican Republic	Assist Project Leader and Haitian counterparts in surveys of rodent damage to rice and corn and evaluate sustained baiting technique in Haiti. Assist vertebrate pest control specialists in Dominican Republic with sampling procedures for sorghum damage.
10 Aug-31 Oct	J. O. Keith	Haiti, Dominican Republic	Evaluate effects of pesticides on birds and wildlife in Haiti. Conduct radiotelemetry studies on birds. Evaluate ways to reduce animal damage to seedlings in a reforestation project in Haiti. In the Dominican Republic, assess damage to crops caused by birds and species and crops involved.

Table 15 (cont'd)

Date	Traveler	Destination	Purpose of Visit
23 Aug-2 Sep	R. L. Bruggers	Dominican Republic, Haiti	Guide Dominican Republic vertebrate pest control specialists in bird damage control research. Discuss bird control research studies underway in Haiti and the Dominican Republic with USAID/DWRC Project Leader.
14 Sep-4 Oct	J. W. De Grazio	Philippines, Bangladesh	Review administrative and program activities with Project Leaders, USAID, and host Government officials in Philippines and Bangladesh.
12 Oct-8 Nov	R. L. Bruggers	Ethiopia, Kenya, India, United Kingdom	Conduct quelea control research studies in Ethiopia with FAO biologists. Discuss future cooperative research studies with FAO officials in Kenya. Present paper on bird pests in Africa at the Symposium of the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in India. Discuss Curb, a chemical bird repellent, with manufacturer.
16-27 Nov	J. E. Brooks	Burma	Guest lecturer in World Health Organization Interregional Course in Rodents of Economic Importance and Public Health Importance.

AFRICA

The USAID/DWRC-sponsored Vertebrate Pest Project in Sudan closed during 1981. Consequently, all DWRC quelea research activities in Africa were conducted during TDY's from the Denver Wildlife Research Center. In Ethiopia, studies were conducted involving radiotelemetry with red-billed quelea (*Quelea quelea*) and village weavers (*Ploceus cucullatus*), fluorescent particle mass-marking of quelea nesting colonies, and methiocarb repellent trials on ripening sorghum. In Kenya, quelea nesting colonies were surveyed and feather samples of quelea were obtained for determination of their movements by matching patterns in levels of trace elements.

Special thanks are due to Agriculture Development Department of the Ethiopian Ministry of Agriculture, the Ethiopian Sorghum Improvement Project, the Desert Locust Control Organization for Eastern Africa (DLCO-EA), the UNDP/Food and Agriculture Organization Quelea Projects in East Africa and Senegal, and Safari Helicopters for making this work possible. The studies offered an ideal situation and truly unique opportunity to combine DWRC research advances (radiotelemetry, marker dyes) and FAO Quelea Project knowledge of the bird situation, logistical support, and facilities (vehicles, personnel, a fixed-wing aircraft, and helicopter).

Radiotelemetry With Quelea

Radio transmitters, developed at DWRC and weighing 1.8 g, were attached to quelea in Ethiopia to determine the feasibility of this technique for rapidly locating nesting colonies and studying local movements. Quelea weigh only 20-22 g, making them the smallest birds to which external transmitters have been attached. The radios were glued to the base of the tail of 19 birds (15 males and 4 females). Their movements were followed over the period from 7 May (prenesting) to 28 June (adult departure) with a Bell-47 helicopter and from observation towers in the nesting colony.

The data obtained have important crop protection implications, and are very interesting from a biological viewpoint. Briefly, some of these conclusions are:

- Quelea could carry the radios (which weigh 8-9% of their body weight) after a short acclimation period.

- Four nesting colonies were located during the 2- to 3-day nest construction stage by tracking the radio-equipped males. This stage is not normally found because of its brevity, the remoteness of the colonies, and the blending of the green nest rings with the trees. The results indicate that radios can be used to locate colonies, that may

otherwise not be found using conventional ground or aerial surveys. The early detection of colonies also allows for almost 30 days to organize control operations, if they are justified.

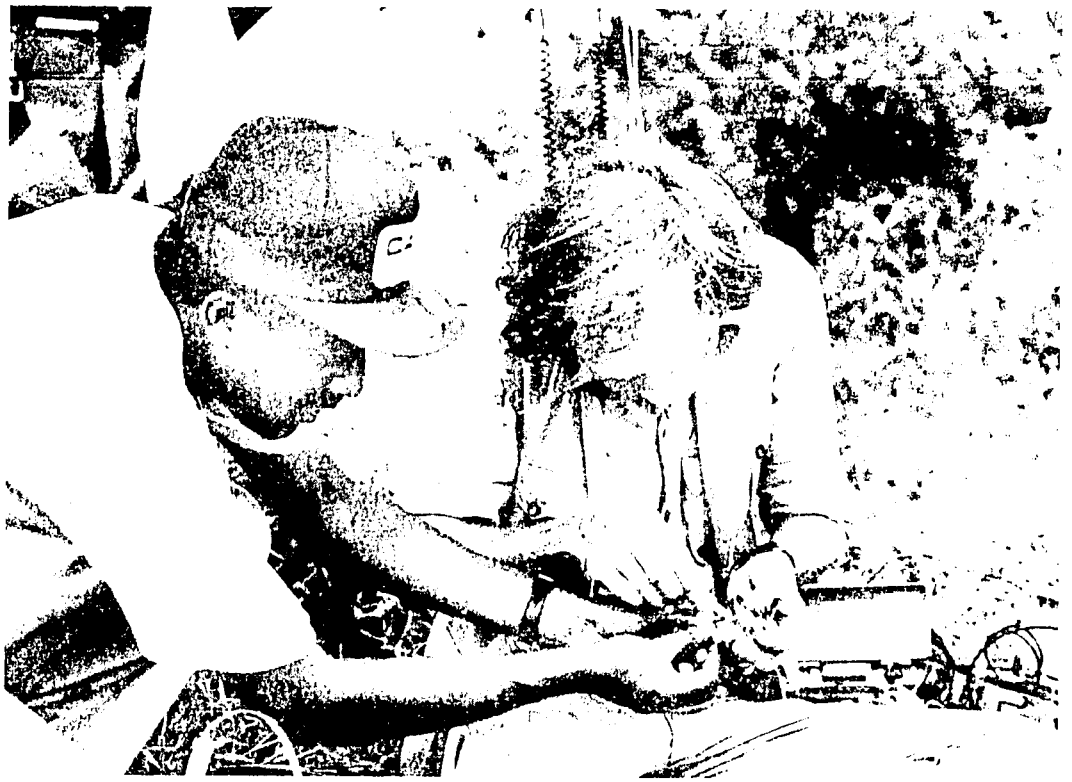
- Colonies are formed successively (not simultaneously) by the part of the population that is ready to breed when suitable habitat is found. Extensive daily movements and colony interchange occur at this time.

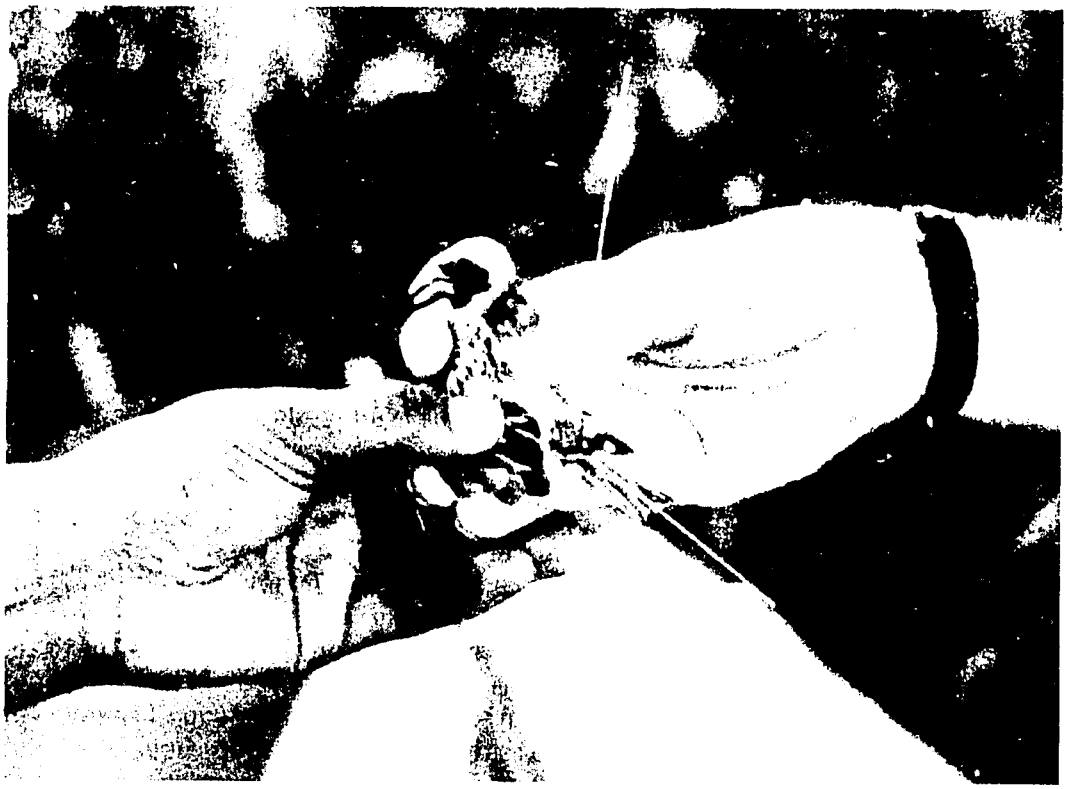
- The feeding movements at this stage are usually less than 1.6-3.2 km. The fact that birds remain close to the colonies during the approximately 3-week nestling and fledgling stage also reduces the chance that ground survey teams will locate them.

Radiotelemetry With Village Weavers

The objectives of this study in Ethiopia were to evaluate the usefulness of colored leg streamers and radio transmitters for studying the movements and behavior of village weavers and masked weavers (P. intermedius) that were nesting together. Nesting and movement information is particularly scarce for both of these species, and neither has been studied using marked birds. A total of 135 birds of both species were marked with plastic leg streamers, and four village weavers, weighing 35 g, were equipped with 1.8-g radio transmitters. Radios were glued to the tail. The nesting chronology of this colony and three other masked weaver colonies in the area was determined, the colonies were mapped, and nesting birds were observed intensively. The movements of radio-equipped and streamered birds were regularly monitored from the ground; on two occasions continuously from dawn to dusk. Additional locations were obtained using the helicopter.

The study demonstrated the usefulness of both leg streamers and radio transmitters for studying ploceid weavers. It provided new and interesting behavioral observations, some very similar to those observed with quelea, on the nesting biology of these species. Briefly, like quelea, groups of village weavers bred sequentially, in successively formed colonies, indicating that individuals reached breeding condition at different times. Streamered birds were found nesting in all four colonies, although marked in only one. Their movements while feeding nestlings were predictable and in close proximity to the colonies. One particularly good feeding area was used by birds from all the colonies, indicating the possibility of information exchange. Females made more than 35 feeding trips/day to their nests. The males of these species are polygamous and assisted in feeding nestlings, but appeared to do so at only one nest. Adults dispersed and formed roosts immediately at the time the young fledged.





Miniature transmitters, weighing 1.8 g, were attached to the tail feathers of red-billed quelea (Quelea quelea) for movement studies in Ethiopia.

Mass-marking of Quelea

Knowledge is needed of the pattern and timing of migratory movements in the Ethiopian Rift Valley of red-billed quelea, the principal bird pest to African agriculture. Therefore, a technique was developed for marking large numbers of birds in May and June breeding colonies in southwestern Ethiopia. The birds had to retain the markers for at least 2 months to determine if they moved into the Awash Basin.

During 1980, DWRC cooperated with the FAO project by supplying Microtaggants[R] for such a marking study. However, because hand sprayers had to be used, only 6,321 birds were marked, an inadequate number considering that several million quelea probably nested in that area. Likewise, it was only possible to inspect a similar number of recaptured birds for the Microtaggants, so that the study was inconclusive.

A method of aerially applying a marker to massive numbers of breeding birds appeared necessary. During June 1981, formulations of Day-Glo[R] fluorescent particles (with particle sizes of 4-5 μm) were sprayed on three nesting colonies of quelea in southern Ethiopia using a DLCO-EA Beaver equipped with Micronair blades. The application method was similar to that commonly used in avicide sprays of quelea nesting colonies so that no major modifications were needed.

More than 1.2 million nesting quelea were marked with aerially applied fluorescent particles. Thirteen marked birds from five nesting colonies or roosts were captured during August, September, and October in the Upper and Middle Awash River Valley, up to 100 days after spraying operations and between 500 and 700 km from the original marking locations. These captures confirm the hypothesized migration route in the Rift Valley and are the first observations of the phenomenon of itinerant breeding of quelea in Africa. This knowledge of the temporal and spatial distribution of quelea in relationship to susceptible sorghum in the Rift Valley has important implications in developing an effective crop protection strategy for Ethiopia. Numerous situations exist in Africa in which the mass-marking techniques can lead to a better understanding of the movement patterns of quelea and, therefore, provide a basis upon which selective population reduction strategies can be formulated.

Quelea Colony Surveys

In May and June, a DWRC biologist worked with biologists of FAO and the Kenya, Sudan, and Tanzania Ministries of Agriculture to survey quelea breeding colonies in the northern frontier of Kenya. Historical evidence suggests that quelea breed along the Ethiopian

border where much suitable habitat exists, but no systematic surveys have been conducted.

The border country between Moyale on the east and the Uganda border on the west was traversed by helicopter and land rovers. Quelea colonies were located wherever suitable habitat (low Acacia trees, lush grass stands, and open water) was present. No such country was found west of Lake Turkana and no quelea were present. Between Lake Turkana and Moyale, 10 breeding colonies of quelea were located. The area was only partially surveyed.

Feather Trace Elements

DWRC biologists initiated a study to evaluate the chemical composition of feathers from quelea throughout Africa. The composition of chemicals in feathers can reflect the geographical areas in which birds live. As the chemical composition of soils differs between areas, accumulations of trace elements in plants, seeds, and birds tend to be unique. If the composition of trace elements in feathers of quelea actually provides a physiological marker by which populations can be recognized, it will greatly assist in management of the species.

A relatively small percentage of the quelea population damage agricultural crops. Efforts to reduce this damage can be greatly facilitated if the distribution and movements of problem populations are known. Management practices to reduce crop losses could then be applied to those specific aggregations that are known to move into crop areas and cause damage.

DWRC and FAO biologists collected feathers from birds of different ages and sexes, both in breeding colonies and in agricultural areas in Ethiopia, Tanzania, Sudan, Kenya, and Senegal. Initially, analyses will be made to test the ability of chemicals to differentiate between the major subspecies of quelea in Africa. If tests are successful, the ability of feather chemicals to distinguish between local populations will be explored. Additional laboratory analyses may be conducted at DWRC to determine if age and sex variations occur. As birds of different sex and age often are segregated during the molt, their feather chemistry may differ. Analyses of the chemical composition of feathers from quelea collected in Ethiopia, Tanzania, and Senegal were begun at DWRC in late 1981 and the results will be available in 1982.

Methiocarb Repellent Trials

For the fourth consecutive year, the repellent methiocarb was tested against quelea in Ethiopia in cooperation with the Ethiopian Sorghum Improvement Project (ESIP). The 12-ha experimental plot at

Fluorescent resin particles are inexpensive, dust-sized particles that are easily applied by aerial spraying to nesting colonies of red-billed quelea (Quelea quelea). Thousands of birds can be marked to determine local or migratory movements so as to improve management practices.

Damage assessments provide important information needed for understanding vertebrate pest situations and suggesting crop protection methods.

Melkassa contained several thousand breeding lines and varieties of sorghum with different maturing dates. As in previous years, methiocarb was applied to individual heads in alternate 5-m bands of from 50- to 100-m length. The application covered approximately 50% of the area. Two complete applications were undertaken.

The ripening sorghum came under heavy quelea attack. Although the quelea aggregations were later effectively destroyed with aerial spraying, the methiocarb provided excellent protection for almost 2 weeks before the control operations could be undertaken. At harvest, only an estimated 14.1% of the sorghum had been lost to the birds. The efficacy of methiocarb in protecting sorghum was similar to that obtained in trials during the previous 3 years. In 1976, without the use of methiocarb an estimated 42% of the crop was destroyed. The combined use of methiocarb and population reduction techniques continues to provide good protection to ripening sorghum in this area where farmers do not normally plant sorghum because of bird damage. Lowland sorghum is well suited to this drought-prone area, and it is hoped that, in the future, these techniques will allow for increased cereal production.

VERTEBRATE PEST PROBLEM DEFINITION

During 1981, the Ministry of Agriculture (MOA) of the Arab Republic of Egypt and the Ministry of Agricultural Development and Agrarian Reform (MIDINRA) of the Government of Nicaragua requested assistance from USAID to examine the extent of rat problems in these countries and to formulate recommendations to mitigate the situation. The DWRC was requested to perform the evaluation. The gracious assistance of many individuals in the Government and USAID in both countries contributed to the success of these missions.

Egypt

The status of vertebrate pest research and control was examined in Egypt between 18 February and 7 March. Most of the crops grown in the country experience some type of animal damage. Most fields and all temporary storage sites visited showed signs of rodent problems. Rats damaged sugarcane, maize, beans, vegetables, wheat, rice, fruits, cotton, and many other crops. The major rodent pests responsible for grain loss were the Nile rat (*Arvicanthis niloticus*) and roof rat (*Rattus rattus*), and to a lesser degree, the spiny mouse (*Acomys cahirinus*) and Norway rat (*Rattus norvegicus*).

Birds, mainly house sparrows (*Passer domesticus*), European sparrows (*Passer hispaniolensis*), common starlings (*Sturnus vulgaris*), and doves (*Streptopelia* spp.) consume enormous amounts of cereal crops each year, both in storage and in fields. Fruit bats (*Rousettus* spp.) contribute to heavy losses in annual fruit crop production.

Vertebrate pest research needs and recommendations included: studying the distribution of pest species; developing accurate techniques for assessing crop damage and monitoring rodent abundance; conducting laboratory studies of LD_{50} and rodenticide bioassays; and evaluating rodent control techniques in small-scale field trials to develop safe and economically affordable control techniques which can be used by farmers.

Nicaragua

Nicaragua suffers chronic in-field losses to rodents in all major crops, including rice, corn, beans, sorghum, sugarcane, melons, vegetables, and cotton. Methodology for annual systematic assessments of damage is only now being developed for several crops.

The cotton rat (*Sigmodon hispidus*) is reported most frequently as the major agricultural pest. It is commonly identified and described by farmers by its scientific name. Cotton rats were the major pest encountered in ricefields. Damage in the form of cut stems along dikes was evident by the second or third month after germination, and appeared to increase in intensity for the duration of the growing season. Runways, cut stems, and piles of unhulled grains were common within dry, maturing paddies. Gravid rats and young litters also were common both in maturing ricefields and at surface level in weedy areas adjacent to the fields.

Serious and intensive efforts were being made by most farmers to reduce rat damage. On some farms, dikes were destroyed and rebuilt to eliminate burrows. Rats are killed as they emerge from these dikes, in the fields during the growing season, and during harvest. On many farms, dikes and uncultivated land adjacent to ricefields are burned, plowed, cut, or sprayed with herbicides to reduce rat harborage.

The most commonly used approach to chemical control is the application of bait containing an acute rodenticide (zinc phosphide or endrin), followed by continuous applications of an anticoagulant bait for the remainder of the growing season, or until the bait was no longer eaten. Acute and chronic rodenticides sometimes are alternated throughout the growing season. The most common form of preparation was to packet 2-4 oz of bait in small plastic bags. On several farms, the bags were coated with a material such as vegetable oil or ground bone-meat meal to make the packet attractive to rats. Bags usually were placed along tops of dikes. On several farms, a mixture of endrin and honey (or molasses) was being sprayed on vegetation along dikes. Farmers reported that rats became soiled while moving along the dike and, subsequently, groomed the material and died. Most farmers felt that their control efforts, though intensive, were only partly successful.

Cotton rats also are considered the major pest to sugarcane. Damage was present in fields 3 months or older. Rats gnawed through the internodes of standing cane, usually near the base, causing the cane to break and fall, with secondary infection sometimes occurring. On one plantation, about 24% of the canes were damaged resulting in about 4% loss in sugar content.

Plantations rely almost exclusively on zinc phosphide, anticoagulants, and endrin for control, and on trap success to measure the effectivenss of a given control procedure.

S. hispidus, and some smaller rodents, were considered common pests to cantaloupes, watermelons, and gourds by eating newly planted seeds (necessity reseeding) or gnawing maturing fruits. Damage in one cantaloupe field was estimated at over 30%.

TRAINING

Because of the importance of vertebrate pests to food production and storage in most countries of the world, there is an increased need for specialists to define, research, and manage these problem species. Recognizing the need for graduate training in the newly emerging field of Vertebrate Pest Management, the Department of Fishery and Wildlife Biology, Colorado State University, has developed a cooperative arrangement with the U.S. Fish and Wildlife Service's Denver Wildlife Research Center for individuals seeking advanced education in Vertebrate Pest Management (VPM) and fields related to the control of animal damage. A special effort has been made to address the individual needs of international participants in managing vertebrate pest problems in their home countries. This effort supplements programs presently existing at other universities.

The academic program consists of courses such as

- Principles of Wildlife Management
- Wildlife Management Techniques
- Vertebrate Pest Management
- Wildlife Ecology
- Statistics
- Wildlife Biology Seminar
- Independent Study in Vertebrate Pest Management
- Mammalogy
- Ornithology
- Animal Behavior
- Wildlife Population Dynamics
- Wildlife Nutrition
- Public Relations in Natural Resources
- Economics of Natural Resources

The graduate research may be conducted at Colorado State University, at the Denver Wildlife Research Center, or at various cooperating field stations in the United States or other countries. In the latter cases, a research scientist at the field station, who also is an appointed CSU affiliate faculty, will be designated to supervise the student's progress.

Prospective students engaged in rodent or bird control operations or related research in VPM in tropical countries are urged to consider this offering for specialized graduate education. Programs lead to the master of science or doctor of philisophy degrees.

For additional information including the General Catalog, International Student Information Brochure, and detailed application procedures, contact:

Dr. Julius G. Nagy, Professor of Wildlife Biology and
Coordinator for International Activities
College of Forestry and Natural Resources
Colorado State University
Fort Collins, Colorado 80523 USA
Telephone: (303) 491-5901

In addition, DWRC continued to assist graduate research in Vertebrate Pest Management at Bowling Green State University. Two M.A. theses evaluating sensory cue enhancement of methiocarb repellency and the use of methiocarb for protecting ripening wheat in Tanzania, were undertaken by a Sudanese and a Tanzanian FAO-sponsored student.

Enhancing Bird Repellency to Methiocarb by Adding Sensory Cues

Chemicals which serve as visual, olfactory, or tactile cues have been shown to enhance the bird repellent properties of methiocarb. As white visual cue showed promise on sunflowers against damage by red-winged blackbirds (*Agelaius phoeniceus*), a formulation of interior white latex paint and calcium carbonate ($CaCO_3$) pigment was tested. This formulation and a methiocarb-wattle tannin (tactile cue) formulation were tested by a Sudanese M.S. candidate from Bowling Green State University, Elsafi Mohamed Elmahdi, on wheat, rice, and sorghum against red-billed quelea (*Quelea quelea*). Wheat was chosen for additional tests. Both 0.32% and 0.40% $CaCO_3$ in one test, and both 0.32% $CaCO_3$ and 0.5% wattle tannin in another test enhanced 0.008% methiocarb formulations on wheat (Table 16). Both materials are suitable for field testing on cereal grains with methiocarb; the choice depends upon the crop and the cost and availability of the chemical.

Table 16. Mean % preference by quelea for methiocarb-treated millet and methiocarb cue-treated millet compared with untreated millet.

Test	Formulation: Methiocarb (%)	Formulation: Cue (%)	% preference[a]
1	0.008	$CaCO_3$ 0.16	42.97 a
	0.008	$CaCO_3$ 0.24	47.59 ab
	0.008	$CaCO_3$ 0.32	32.27 bc
	0.008	$CaCO_3$ 0.40	21.97 c
2	0.008	no cue	50.19 a
	0.008	$CaCO_3$ 0.32	32.22 b
	0.008	Tannin 0.50	43.24 b

[a] Percent preference = $\frac{\text{treatment consumption (g)}}{\text{total food consumption (g)}} \times 100.$

In each test, means followed by the same letter are not significantly different at the $P < 0.05$ level.

Genetic Development of Less-Susceptible Varieties of Sorghums

Worldwide, many varieties of sorghums that are less susceptible to bird damage are unpopular because of their poor nutritional qualities. DWRC has conducted numerous chemical and behavioral studies during the past 4 years, often in cooperation with other laboratories, to identify more acceptable varieties. Collaborative genetic studies presently are underway with the University of Arkansas to develop sorghum varieties which are less susceptible to bird damage during the milk and dough stages, yet, retain high nutritional quality when mature. A breeding experiment at the Fayetteville, Arkansas nursery yielded eight F_1 hybrid candidates for advanced evaluations. These eight hybrids, and a few from other ihstitutions, will be screened in laboratory chemical-behavioral studies at DWRC. The four top-ranked varieties will be further evaluated in field enclosure studies during 1982. The most promising hybrids will be tested at one of the AID field stations in 1983.

Repellency Characteristics of Plant Substances

The dry leaves and a steam distillate of wild ginger have shown repellency against several species of mammals. Both preparations also were highly repellent to red-billed quelea; they apparently cause a "numbing" sensation in the mouth. High Pressure Liquid Chromatography (HPLC) was used to isolate and identify the active component(s) responsible for this sensation. The steam distillate of wild ginger was separated into three large fractions. Each fraction was then surface-coated on millet and preference-tested against millet coated with control distillate. Most of the activity seemed to reside in the early emerging fraction. The project will be continued during 1983.

Developing Silicon Dioxide Gels for Wildlife Management Applications

Silicon dioxide gels have potential application as rodenticide carriers. During 1980, the viscosity-tack (stickiness) relationships were determined for corn oil gels of 10 silicon dioxide products. In 1981, 15 additional silicon dioxides, a clay product, and aluminum stearate were similarly evaluated. Tack is the most desirable property for most gel formulation uses and, consequently, the primary ranking factor for the silicon dioxide products.

Water resistance was measured by dipping gel-coated tiles 1,500 times into water and determining weight loss of the gel layer. Amorphous silicon dioxide corn oil gels were completely lost under these extreme conditions. However, amorphous silicon dioxide paraffin oil gels weathered well. Paraffin oils are composed mainly of nonpolar and highly water-immiscible hydrocarbons, whereas vegetable oils have polar carbonyl groups which make them

more easily emulsifiable in water. Water-resistant properties can be imparted by special processing of silicas; corn oil gels of Tullanox 500, Aerosil R-972, and Sipernat 17 showed negligible weathering.

Silicon dioxide gels were evaluated as carriers for rodent toxicants. Laboratory white rats were gavaged with Syloid 244 (nonhydrophobic) corn oil gel preparations of zinc phosphide and brodifacoum. Zinc phosphide, an acute toxicant, had an LD50 of 19.95 mg/kg (CL 30.3 mg/kg - 13.2 mg/kg) and brodifacoum had an LD50 of 0.5 mg/kg (CL 0.6 mg/kg - 0.4 mg/kg). Both values are consistent with those reported for corn oil formulations of these two toxicants. Corn oil gels from other silicon dioxide products were evaluated by gavaging six white laboratory rats with 30 mg/kg or 45 mg/kg doses of zinc phosphide in the respective gel (Table 17).

Table 17. Oral toxicity of gel formulations containing zinc phosphide in white laboratory rats.

Test component	% formulation[a]	Zinc phosphide concn (mg/kg)	Mortality rate
Tullanox 500	100	30	1/6
	25	30	4/6
	25	45	5/6
Aerosil R-972	100	30	1/6
	100	45	0/6
	85	45	0/6
	70	45	2/6
	55	45	5/6
	40	45	3/6
	25	45	5/6
Sipernat 17	100	45	1/6

[a] Corn oil gel formulations of viscosity 265 ± 10 mm/10 penetration, either with test component alone, or in combination with Syloid 244 amorphous silicon dioxide.

Because hydrophobic properties are important considerations when rodenticides are used in high rainfall areas, the possible inhibition of zinc phosphide toxicity needed to be evaluated. Tests of combinations of Syloid 244 and the hydrophobic products indicated that 25% Tullanox and 75% Syloid 244 provided adequate water

resistance without seriously inhibiting the toxic properties of zinc phosphide. Gels can be formulated with desirable odor, flavor, and water-resistant properties, and their physical properties of viscosity and tack can be manipulated to meet particular use conditions. They have potential use in both food storage and field damage situations. Some of the silicon dioxide powders appear useful for wildlife management applications and additional investigations are planned.

Nest Material as a Means of Delivering Avicides

In Africa, quelea roosts and nest sites routinely are sprayed with avicides (fenthion or parathion) to protect ripening cereal crops from bird damage. A method of applying control agents using the quelea's natural nest-weaving behavior as a means of delivering the chemicals currently is under investigation. This method offers increased safety for pilots and ground crews during application and allows application to be made during daylight hours. Testing with potential avicides (fenthion, parathion, Dasanit^R, and Volaton^R) involves presenting avicide-treated nest material (13-cm strands of cotton string) to male-female pairs of quelea, observing changes in weaving patterns, and assessing mortality after a 2-hour exposure at 1-, 2-, 4-, and 24-hour intervals. Volaton-treated material has shown to have very low toxicity to quelea. Exposure was fatal only to one bird at levels above 30% when diluted with acetone.

The LD50 level of Dasanit on nest material was determined as 3.2%. To further define the LD50, 1.25% and 0.39% levels were tested using acetone as a dilutant. Ten of 18 birds died at a 1.25% level, and 5 of 18 birds died at a 0.39% level. Dasanit, therefore, appeared to hold the most potential as an avicide for quelea control when applied to nesting material. The method may also have application to control of the village weaver which causes crop losses in both Africa and several Caribbean countries.

Evaluating Commercial Ultrasonic Rodent Repellent Devices

High-frequency sound and ultrasonic rodent repellent devices have been marketed for 20 years as a means of controlling rodent infestations in buildings and damage to stored grain. Many testimonial claims of the effectiveness of these devices exist. Under an Interagency Agreement between EPA and USFWS, research was initiated to objectively measure efficacies of seven ultrasonic devices under closed-colony and field conditions. A 69-m^2 room was modified for testing, instrumented with photocell sensors, and checked for acoustical characteristics. Formal efficacy evaluations will be carried out in this room and under actual field conditions during 1982.

Breeding Nile Rats (*Arvicanthis niloticus*) and Lesser Bandicoot Rats (*Bandicota bengalensis*) in Captivity

A breeding colony of Nile rats (*Arvicanthis niloticus*) was established at DWRC. Known-age individuals were sent to Bowling Green State University for studies to correlate standard morphological measurements (body weight, sex, total body, ear, tail, and hind foot lengths) with age through 1 year. Currently, no age determination method exists for this pest rodent which inhabits the arid regions of North Africa.

Special shipping cages and breeding facilities were developed for lesser bandicoot rats (*Bandicota bengalensis*) from Bangladesh. Separate male-female pairs were housed in individual 1.5 x 3-m enclosures with nest material and large cover boxes to minimize fighting, injury, and death. Nesting boxes were added as young were born. Over 150 young have been produced. These animals will be used for biological, behavioral, and rodenticide toxicity research.

Evaluating Taste Additives to Enhance the Repellency of Methiocarb to Quelea

The traditional African farmer cannot afford to invest heavily in agricultural chemicals for control of quelea damage to cereal crops. Although methiocarb has proven to be an effective bird repellent when applied to crops at 2-3 kg/ha, the cost of the chemical often limits its use.

An alternate, economical, and possibly more effective approach to standard application techniques is being evaluated and involves applying the chemical to grain (millet seed) baits or to ripening heads at the field edges at high concentration levels. The rest of the field would be treated with low levels of methiocarb. To improve the transfer of learned repellency by quelea from bait or peripheral heads, taste and/or color stimuli could be incorporated into the methiocarb-spray formulation.

The first phase of this study involved determining the extent to which quelea transfer learned repellency from millet seed bait to millet seed heads. Two quelea groups (N = 10 birds/group) were individually given 2 days of exposure to 0.15% methiocarb-treated millet seed. The two groups were then given 8 days of preference testing between either millet seed (0.05% methiocarb) and sorghum seed, or millet heads (0.05% methiocarb) and sorghum. There were no overall group differences in the average amount of methiocarb-treated seed consumed. The preference tests indicated that quelea

were more repelled by 0.05% methiocarb on millet heads (13.9%) than on millet seed (5.1%), suggesting that learned methiocarb repellency was easily transferred from the seed bait to millet heads.

In a second phase of the study, five quelea groups (N = 6 birds/group) were exposed for 2 days to millet seed treated with 0.15% methiocarb plus one of four taste stimuli (3.0% dextrose, 0.5% fenugreek extract, 1.0% millet seed oil, or 0.5% paprika oleo) or untreated millet seed bait. All birds were given a choice between 0.5% methiocarb-treated heads or mixed grain for 8 days. The mean dosing levels varied among groups during the exposure period (dextrose = 47 mg/kg, fenugreek = 18 mg/kg, millet oil = 25 mg/kg, and paprika = 8 mg/kg).

Enhanced repellency was noted for the dextrose group (7.6%) compared to 29.2% for untreated seeds on the first test day. Repellency was greatest for all groups after the first day of exposure (Table 18). A formulation of color cues with reduced amounts of methiocarb on millet seed bait will be evaluated next. Combining taste and color cues may sufficiently enhance methiocarb repellency so that normal field application rates can be reduced.

Table 18. Mean % (± SD) preference for millet heads compared to mixed grain seed bait by quelea given previous exposure to methiocarb and flavor agents.

	Flavor agents (taste stimuli)				
Day	Dextrose	Fenugreek	Millet oil	Paprika oleo	Untreated
1	7.6 ± 4.9	13.1 ± 3.6	19.7 ± 8.4	14.6 ± 3.9	29.2 ± 6.0
2	5.9 ± 3.7	7.2 ± 6.8	3.8 ± 2.9	7.5 ± 6.6	4.3 ± 2.8
3	8.8 ± 12.1	4.8 ± 4.0	3.6 ± 2.4	5.3 ± 5.8	6.7 ± 3.7
4	5.5 ± 7.4	6.8 ± 16.7	0.9 ± 0.9	9.3 ± 10.9	2.1 ± 3.2
5	3.9 ± 4.3	2.5 ± 3.8	1.5 ± 1.7	1.7 ± 1.7	3.3 ± 5.1
6	1.4 ± 2.2	9.6 ± 14.6	2.5 ± 1.7	9.3 ± 8.5	2.9 ± 5.2
7	0.8 ± 1.7	7.7 ± 11.4	5.2 ± 4.8	1.8 ± 2.8	1.8 ± 2.2
8	1.4 ± 1.9	16.2 ± 14.4	5.1 ± 5.6	6.3 ± 3.2	9.1 ± 3.1

Learned Aversion Responses of Rats

The computerized data recording system, established in 1980, has continued to provide useful information regarding the feeding patterns of wild rats. Data analyses of comparative, minute-by-minute feeding patterns of groups of Nile rats (*A. niloticus*), cotton rats (*Sigmodon hispidus*), and Norway rats (*R. norvegicus*) continued. A BASIC-Language program was prepared that tabulates the amount eaten by rats during successive minutes of feeding. Data from the feeding pattern study are being summarized using this statistical program. Additionally, an RS-232 compatible telephone modem, including necessary transmission software, was wired to the system.

A pilot study to assess the feeding responses of rats fed lithium chloride (an illness-causing drug used to induce learned taste aversion) was completed. Six ricefield rats (*R. r. mindanensis*) were adapted to the test apparatus, and then presented ground rice mixtures containing 0.3% sodium saccharin and 3.0% lithium chloride. All rats stopped eating within 6 to 12 min. During subsequent presentations of saccharin-treated and untreated rice, the rats refrained from ingesting saccharin-treated rice for several days. The rapid cessation of feeding on lithium-treated rice, and the quick development of a learned taste aversion response suggest that the learned aversion responses should be evaluated for protecting crops and stored food.

Waterproofing 4-Aminopyridine Tableted Bait

The concentration of 4-aminopyridine is known to be more uniform in tableted baits than cracked corn baits. However, field trials revealed that rainfall, moist ground, and dew caused rapid deterioration of the tableted baits, despite a wax coating. Therefore, tests were initiated to develop a tableted 4-aminopyridine bait that will not deteriorate under moist field conditions. A variety of potential coating materials, tableting matrices, and coating procedures were examined and many resins, varnishes, waxes, and plastics were evaluated. None of the coatings on Avitrol^R tablets proved acceptable. One matrix, dicalcium phosphate dihydrate, remained intact under severe moist conditions but, unfortunately, was not accepted by starlings in standardized laboratory bioassays. Additional coatings and matrices will be tested.

Testing the Commercial Bait Vizon^R on EPA Protocol

The commercial bait Vizon (0.021% warfarin) was evaluated on wild Norway rats (*R. norvegicus*) and ricefield rats (*R. r. mindanensis*) according to EPA test protocol OPP Designation: 1.203 - Standard

Norway Rat Anticoagulant Dry Bait Laboratory Test Method. Consumption of Vizon was highly variable by both rat species (Table 19). Consumption in Norway rats ranged from 1% to 99% in males and from 2% to 61% in females; consumption in ricefield rats ranged from 0% to 81% in males and from 0% to 56% in females. All Norway rats consumed Vizon, whereas six of the ricefield rats (three males, three females) did not consume any of it. Vizon appeared to be a potent rodenticide if consumed, but for both species it did not meet the EPA test standards of 33% bait acceptance and 90% mortality. Under some field conditions, with a limited food supply, the rodenticidal properties of Vizon would probably be acceptable.

Table 19. Avg % mortality and % acceptance of Vizon by Norway rats and ricefield rats on EPA test protocol OPP Designation 1.203.

Rat species	Avg % mortality rate		Total mortality rate (%)	Acceptance of Vizon (%)
	Male	Female		
Wild Norway	40	60	50	14
Ricefield	50	60	55	10

Grooming Behavior and Conditioned Bait Aversion in Rats

Evidence indicates that behavioral defenses such as neophobia, primary food aversion, and food aversion learning are particularly well suited for protecting rodents during ingestion, the most common means of delivering rodenticides to the rodent. However, these defenses appear less effective during grooming, nest building, and gnawing. Grooming has been used in the control of vampire bats. Use of tracking dusts and tracking powders may increase the efficiency of rodenticides in some situations. Rodents tend to ingest these materials during grooming better than during drinking and feeding. Therefore, the relationship of grooming behavior to the animal's defenses against dietary poisoning was evaluated.

It appears that laboratory Norway rats (R. norvegicus) perceive the taste of a material and gather information on its concentration and quality while grooming it from the fur. Rats also developed learned aversions to a taste perceived while grooming, and generalized it to drinking. Similar results were obtained with laboratory strains of mice (M. musculus). It also was found that pine voles (Microtus pinetorum), that had groomed an aversive tastant from their own fur but not from the fur of a cage mate, had increased blood levels of

corticosteroids. Because corticosteroids are believed to stimulate a strongly stereotyped form of grooming in rodents, grooming in the presence of an aversive tastant may have more uses in rodent control than previously considered. For example, through grooming it might be possible to introduce some of the chemosterilants, emetics, and acute rodenticides that previously have been judged impractical because of poor acceptance.

Relationship of Stored Fats to Diets of Selected Vertebrate Pests

Fatty acid composition appears related to the long-term diets of rats. This relationship suggests that it might be possible to use fatty acid composition to identify pests in certain types of agriculture such as coconut and macadamia groves. In a preliminary study, laboratory rats (*R. norvegicus*) were fed various w/w diets of corn and coconut oil for 5 weeks: 5% corn/0% coconut, 20% corn/0% coconut, 15% corn/5% coconut; 10% corn/10% coconut, 5% corn/15% coconut, and 0% corn/20% coconut. The rats were then sacrificed and adipose samples analyzed for free fatty acid composition (expressed as percentages of total fatty acids). Overall, oleic-linoleic acids accounted for over half of the fatty acids present. Amounts of lauric, myristic, and oleic-linoleic acids in the adipose were strongly associated with the amount of coconut oil in the diet (r^2 = 0.83, 0.88, and 0.75, respectively), indicating that these fatty acids might be good predictors of coconut oil in the rat's diet.

In a second preliminary study, the overall composition of fatty acids in the adipose tissue of rats which had been fed macadamia nuts in the laboratory and rats which had been collected in macadamia groves was similar. Mongoose that had been fed rats collected from sugarcane fields had a fatty acid composition, different from that of macadamia nuts. Mongoose that had been fed rats collected in a macadamia grove had a fatty acid composition intermediate between that of the other mongoose and that of macadamia nuts.

Taste Qualities of Rodenticides to *Rattus norvegicus*

Using a conditioned aversion paradigm, learned aversion by laboratory Norway rats (*R. norvegicus*) was assessed for the rodenticides strychnine, thiosemicarbazide, scilliroside, arsenic, and warfarin to the tastants sucrose, sodium chloride, sucrose octaacetate, quinine sulfate, and hydrochloric acid. The rats were adapted to water deprivation and paired consumption of small quantities of the five rodenticides in aqueous solutions (experimental groups receiving tastants), or water (reference groups with LiCl) was measured on 5 successive days. The order in which the tastes were

presented was determined by Latin Squares. Differential suppression of drinking by the experimental animals relative to the reference animals was used as an indication of similarities between the nontoxic tastes and the tastes of the rodenticides.

The results suggested that (1) strychnine was principally bitter (i.e., conditioned aversions to the taste of strychnine generalized to quinine sulfate and sucrose octaacetate); (2) thiosemicarbazide was principally bitter and sweet (i.e., aversions generalized to quinine sulfate and sucrose); and (3) scilliroside was sour and bitter (i.e., aversions generalized to hydrochloric acid and quinine sulfate). The results of the generalization tests pairing warfarin and arsenic with LiCl were less clear and require additional studies.

Sodium bicarbonate also appears ineffective as an agent for masking the bitter taste of strychnine for rats. For example, four rats conditioned with strychnine containing sodium bicarbonate still avoided quinine sulfate, relative to reference rats, in subsequent drinking tests; four rats, also conditioned with only strychnine, avoided quinine sulfate containing sodium bicarbonate in subsequent drinking tests. The method could be used for assessing taste qualities of other rodenticides to other rodents, and for objectively assessing such bait additives as taste enhancers and masking agents.

Acute Oral Toxicity and Structure Relationships of Monosubstituted Anilines and Pyridines in Animals

Structure activity relationships (SAR) of chemicals have been used for several years to develop pharmaceutical agents, industrial chemicals, and pesticides. In a cooperative study with the Section of Bird Damage Control, data have been obtained suggesting that SAR can be used as predictors of toxicity of some chemicals to mammals and birds. The acute oral toxicity (LD50) of 63 monosubstituted anilines and pyridines and their three parent chemicals (aniline, pyridine, and pyridine-1-oxide) was determined for albino rats (*R. norvegicus*), albino mice (*Mus musculus*), European quail (*Coturnix coturnix*), common starlings (*Sturnus vulgaris*), house sparrows (*Passer domesticus*), and red-winged blackbirds (*A. phoeniceus*). Repellency values (R50) also were determined for red-winged blackbirds.

Although generalized SAR patterns existed for many of the compounds, considerable species variation was present. Previous reports of SAR, based on chemical properties, may apply only in isolated situations and for specific species. The data are still undergoing analysis and interpretation.

Developing Analytical Methods

The increasing use of methiocarb as a crop protection chemical has necessitated further studies to develop a reliable analytical method for determining low residue levels of the chemical. The most sensitive methods commonly used employ gas chromatography. Currently, there are two procedures available for measuring methiocarb by gas chromatography. One involves derivatization of methiocarb and its sulfoxide and sulfone metabolites, with a silylating reagent, bis(trimethylsilyl) trifluoroacetamide (BSTFA) and quantification with a flame photometric detector. In the second procedure, methiocarb and each of the carbamate and phenolic metabolites are acetylated with trifluoroacetic anhydride (TFAA) and quantified with an electron capture detector. Evaluations of the two procedures indicated that the BSTFA procedure was more reliable. Several problems were encountered in the TFAA procedure, including inconsistent yields of the derivatized products (particularly of the sulfoxide and sulfone derivatives), and large background interferences in the gas chromatographic analysis. Additional developmental work is needed before the TFAA procedure can be used satisfactorily for routine analyses.

Analyzing Methiocarb, Zinc Phosphide, and Compound 1080 Residues

Methiocarb analyses were conducted on wheat samples in support of crop protection studies in Tanzania. The BSTFA gas chromatographic method was used. Ripening heads were collected at several different time intervals from time of application and were analyzed for methiocarb and its sulfoxide and sulfone metabolites. Methiocarb residues were <1 ppm in seeds collected 25 days after application. Sulfoxide and sulfone residue levels were 3 and <1 ppm, respectively. Higher residue levels were found in the glumes. Concentrations of methiocarb, the sulfoxide and sulfone metabolites were 10, 50, and 5 ppm, respectively, in the 25-day samples.

Zinc phosphide bait samples were analyzed to support rodent control studies in Bangladesh. The bait samples, formulated at 2% active ingredient (a.i.) at the Pocatello Supply Depot, Idaho, were assayed to determine stability under storage. One bait sample contained 1.7% ($\pm$ 0.1) a.i. and the other 1.5% ($\pm$ 0.07) a.i.

A sensitive analytical method was developed for Compound 1080, an extremely toxic chemical, sometimes used as a rodenticide. The electron capture gas chromatographic method is capable of determining 0.1 ppm of 1080 in 1 g of animal tissue. Average recoveries of 90% were obtained from tissue samples fortified with 0.1-100 ppm 1080.

Analyzing Zinc Phosphide Residues in Rats

Although zinc phosphide is the most widely used acute rodenticide, there is a paucity of information about its metabolism and distribution in tissues of animals poisoned by it. Residues from the analysis for the gas phosphine in tissues of rats poisoned with an acute 100 mg/kg dose of zinc phosphide are presented in Table 20.

The high concentrations of zinc phosphide in the stomach and intestines were expected, but its absence in the blood and other tissues was not. In the intestinal tract, phosphine is produced from zinc phosphide and probably is transported by the blood. However, phosphine may be binding to proteins in the blood and other tissues so that it is not extracted by present analytical methods.

Table 20. Residues of phosphine gas from zinc phosphide in tissues of rats.

Tissue	No. rats	Residue (ppm) $\bar{x}$ and range
Blood	3	Not detected
Kidney	3	" "
Liver	3	" "
Lung	3	" "
Brain	3	" "
Stomach	5	60 (49-111)
Small intestine	5	43 (31- 81)
Large intestine	5	15 (8- 26)

Designing and Producing Wildlife Tracking Transmitters

There is a need to develop wildlife transmitters which weigh approximately 1 g for small birds and rodents. However, the two large components of every transmitter, the battery and quartz frequency crystal, generally exceed this 1-g design goal. The state of the art in battery technology suggests that there is little chance of finding an improved lightweight battery. A company was found that was willing to try to develop a smaller quartz crystal to DWRC specifications, and a successful prototype crystal, which measured 3 mm in diam x 8 mm long and weighed 0.330 g, was constructed. A smaller crystal, 3 x 6 mm and 0.147 g, also was developed, but with marginal electrical characteristics. These are the smallest crystals ever used in the construction of wildlife transmitters. Additional electronics design will be conducted in this area next year.

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[2] Partially funded under a PASA except as otherwise indicated.

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2 Apr	Dr. Durgadas Datta	National Information Centre, Electronics Commission, New Delhi, India
11-18 Apr	Mr. Po-yu Wang	Taiwan Sugar Research Institute, Taiwan, Republic of China
11-18 Apr	Mr. Kwo-yang Fan	Department of Agriculture and Forestry, Taiwan, Republic of China
11-18 Apr	Mr. Chin-Chung Lin	Plant Protection Center, Taiwan, Republic of China
11-12 May	Dr. R. C. Bigalke	University of Stellenbosch, South Africa
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3-7 Aug	Mr. Y. Juimale and Mr. A. Warsame	FAO-sponsored students from Somalia
7-14 Aug	Mr. Julio Barthelemy	Program Manager, Ministry of Agriculture, Port-au-Prince, Haiti
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17 Dec	Mr. Ron Hartley	Department of National Parks and Wildlife, Salisbury, Zimbabwe

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Bruggers, R. L., J. O. Keith, M. Jaeger, and W. Erickson. "Cooperative DWRC/FAO quelea research in Eastern Africa." Presentation by M. Jaeger at the 3rd Annual FAO/Regional Quelea Project (RAF 77/042) Technical Meetings, Nairobi, Kenya; 2-6 November 1981.

Bullard, R. W., J. O. York, and M. Price. "Comparison of tannin characteristics in Group II and Group III sorghums." Presentation by J. O. York at the 12th Biennial Grain Sorghum Research and Utilization Conference, Lubbock, Texas; 25-27 February 1981.

Bullard, R. W. Attended ACS Conference in Atlanta, Georgia; 29-30 March 1981.

Bullard, R. W. "Bird-resistant sorghums." Presentation at the University of Arkansas, Fayetteville, Arkansas; 31 March 1981.

Fagerstone, K., G. Matschke, and D. Elias. "Radiotelemetry to evaluate effectiveness of a new fumigant cartridge for controlling ground squirrels." Presentation by K. Fagerstone at the 3rd International Conference on Wildlife Biotelemetry, Laramie, Wyoming; 28 July 1981.

Kolz, A. L. "Wildlife telemetry development for the Fish and Wildlife Service." Presentation for Washington Office Directorate and Chiefs of Divisions and Offices; Washington, D.C.; 20-23 January 1981.

Kolz, A. L. Conducted biotelemetry classes at the Air Force Academy, Colodado Springs, Colorado; 29-30 April 1981.

Kolz, A. L., and R. E. Johnson. "The human hearing response to pulsed-audio tones: implications for wildlife telemetry design." Presentation by A. L. Kolz at the 3rd International Conference on Wildlife Biotelemetry, Laramie, Wyoming; 28 July 1981.

Reidinger, R. F., Jr. "Conditioned aversion to a taste perceived while grooming." Presentation at the Third Annual Meeting of the Association of Chemoreception Sciences, Sarasota, Florida; 22-26 April 1981.

Reidinger, R. F., Jr. Presented seminars on the current status of vertebrate pest problems (birds and rodents) to research and development staff at Campbell Soups, Inc., Newark, New Jersey; 18 December 1981.

Rimpel, Michelle. Attended a course entitled "Agricultural Research Methodology" at Kansas State University, Kansas; 8 June-24 July 1981.

Savarie, P. J. "Criteria used for the selection and development of predacides." Presentation at the Annual Meeting of the Western Regional Coordinating Committee (WRCC-26), Twin Falls, Idaho; 11-12 August 1981.

Schafer, E. W., Jr., and P. J. Savarie. "The relationship of toxicity to structure of 63 monosubstituted anilines and pyridines in six animal species." Presentation by E. W. Schafer, Jr. at the Second Annual Meeting of the Society of Environmental Toxicology and Chemistry, Arlington, Virginia; 22-25 November 1981.

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