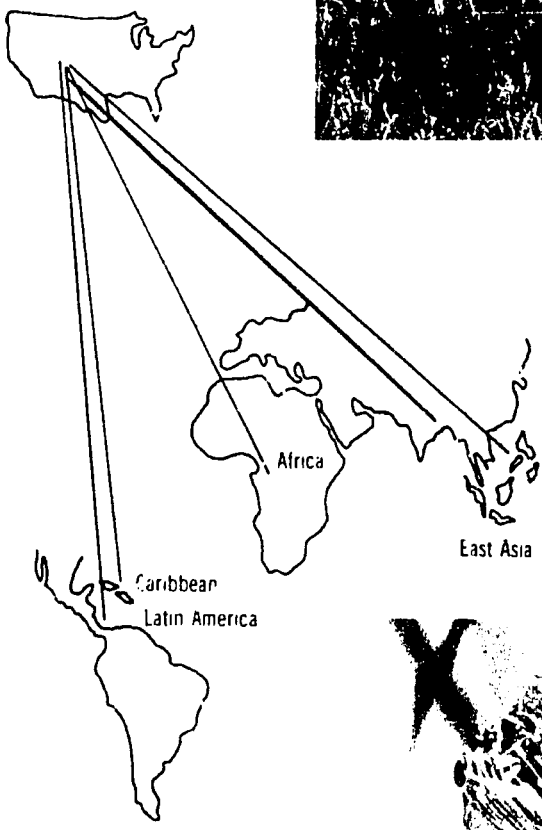
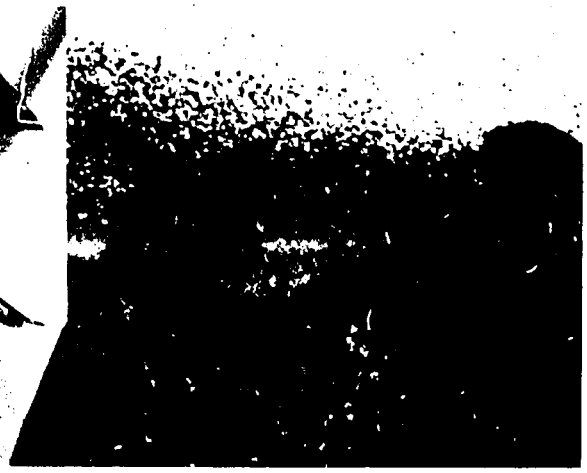
VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

ANNUAL REPORT 1982





Denver Wildlife Research Center
U.S. Fish and Wildlife Service

U.S. Agency for International Development

1982 ANNUAL PROGRESS REPORT*

SECTION OF INTERNATIONAL PROGRAMS

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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 evaluating different control methods including chemical, physical, cultural, or other techniques that have potential for providing positive benefits by reducing vertebrate damage in agriculture. The pest species, crop, farming and storage 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, severely reduces the human food supply and increases the risks to 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. The red-billed quelea in Africa is perhaps the single most important vertebrate pest species in the world.

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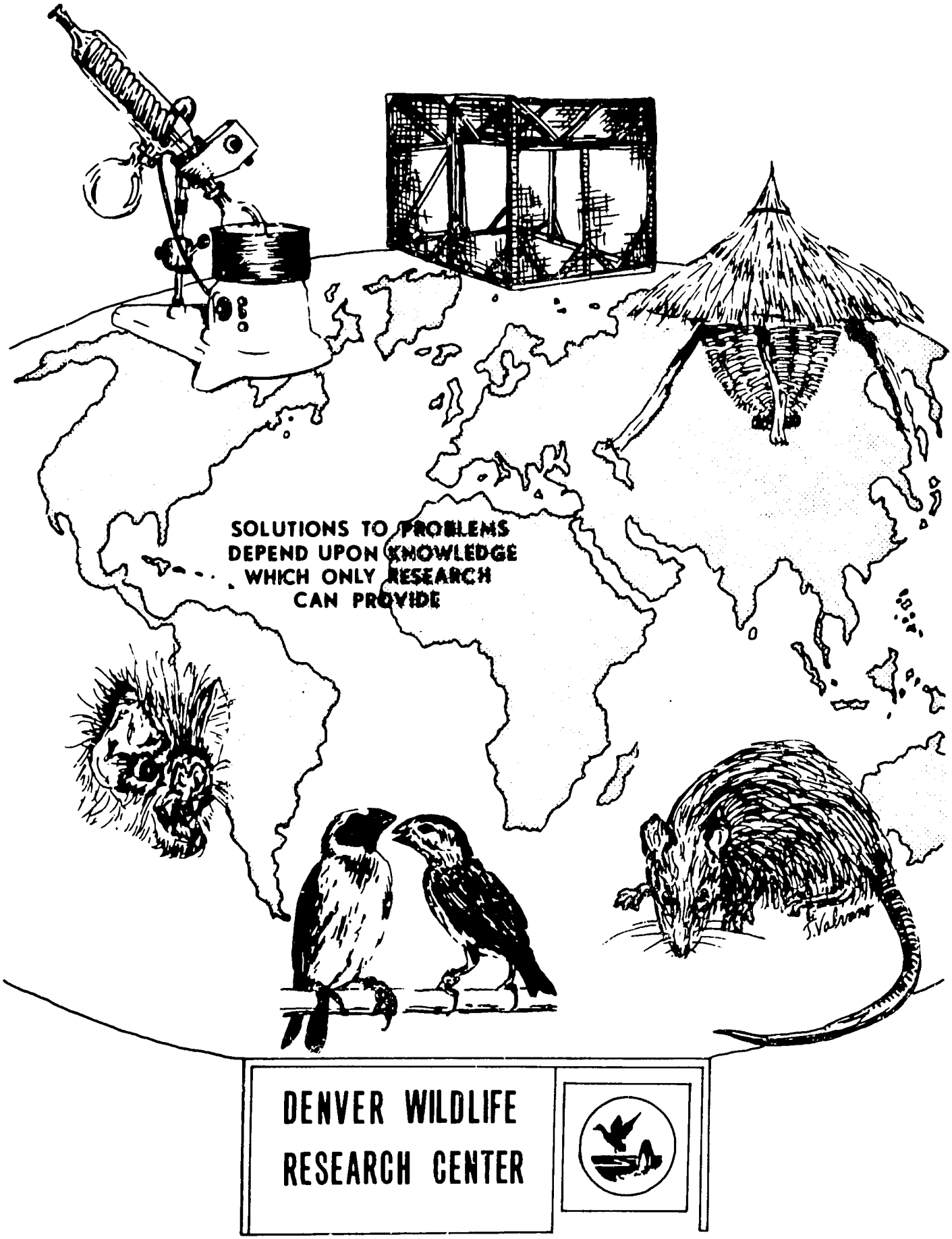
SOLUTIONS TO PROBLEMS
DEPEND UPON KNOWLEDGE
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VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

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. 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 developing and using 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 in both preharvest and postharvest situations. 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 protection.

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 composed 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.

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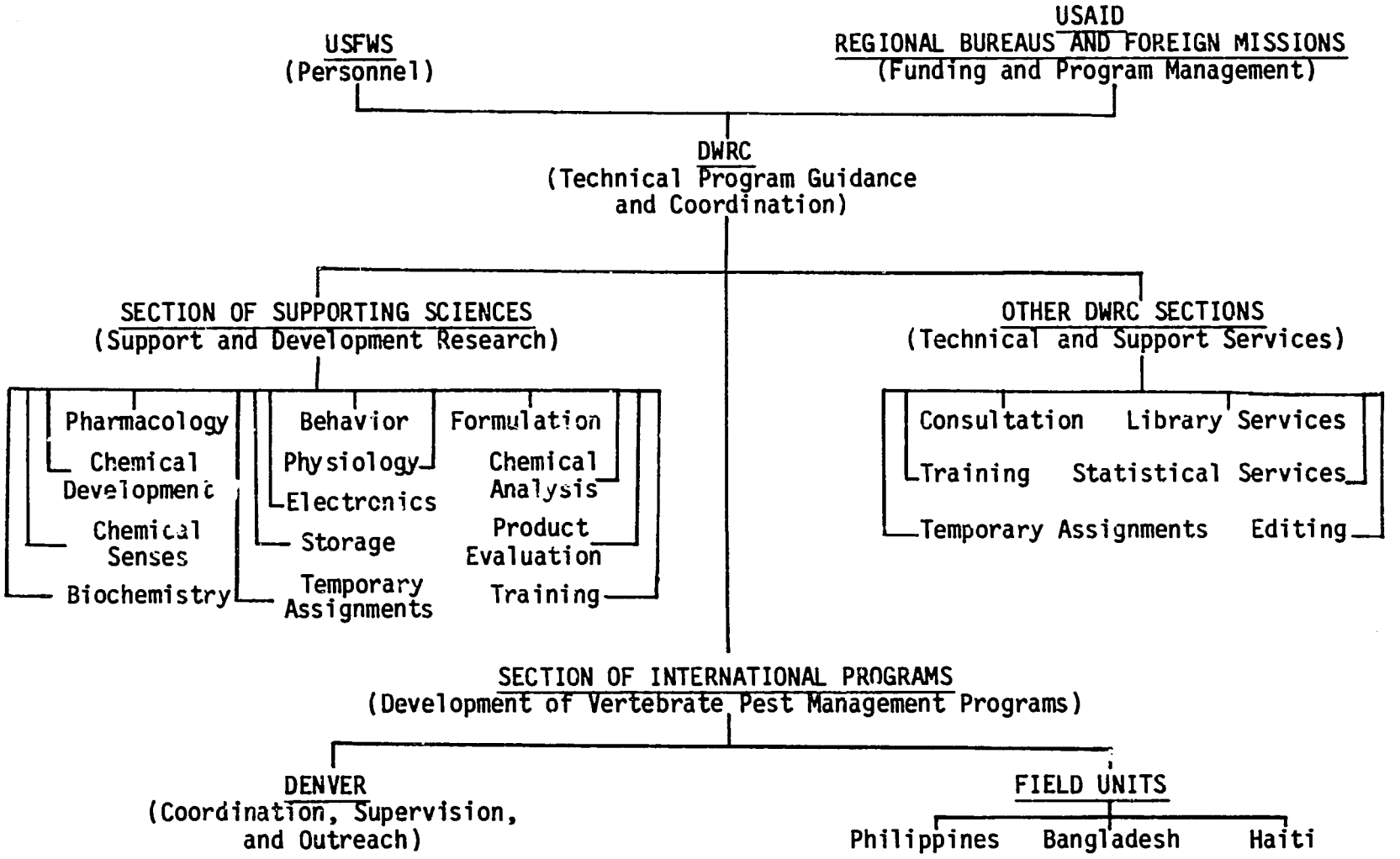

During 1982, project personnel devoted considerable time and effort to support the activities of field stations and cooperate in bird damage control research with the Food and Agriculture Organization (FAO) in Africa. Additional cooperation with the German Society for Technical Cooperation (GTZ) in vertebrate damage control research and training activities was carried on in Bangladesh and the Philippines. The staff also continued to provide program planning and technical assistance to AID in vertebrate pest management. At the request of USAID/Pakistan, USAID/Costa Rica, and USAID/Peru and Ecuador, DWRC helped the Governments of these countries assess rodent and bird problems and outline the requirements for implementing vertebrate pest management programs.

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 and other regional countries.

A project review was held in May 1982. The review team consisted of Mr. Donald Drga, AID/Washington, Mr. John De Grazio and Dr. James Keith, DWRC, and Dr. William Jackson, Bowling Green State University, Bowling Green, Ohio. The review team recommended that the project be extended and AID/Haiti agreed to fund it for FY-83. During FY-83, future plans will be developed in consultation with the Mission and the Government of Haiti.

Dr. G. Clay Mitchell, who finished a 2-year tour with the AID/Haiti project in June returned to DWRC and was replaced by Dr. James O. Keith. Project activities during the year included completing the office-laboratory building in Haiti, constructing an aviary for laboratory studies in the Dominican Republic, completing research on assessing preharvest corn losses to vertebrate pests, comparing bird damage among corn varieties, and conducting other field studies.

Philippines

The Vertebrate Pest Project, based at the National Crop Protection Center (NCPC), continued to provide assistance to the developing network of crop protection research programs throughout the country. The project continued to assist graduate student research at the University of the Philippines at Los Baños (UPLB) and helped prepare training and extension materials.

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Bangladesh

Mr. Joe Brooks completed his first year as Project Leader at the DWRC/USAID Vertebrate Pest Control project in Bangladesh. During 1982, a considerable amount of new data on both preharvest and postharvest bird and rodent problems was obtained, and preliminary investigation into postharvest losses were initiated. Whenever possible, work was undertaken with farmers. In addition, two new facilities, a pen for jackals (*Canis aureus*) and a rodent enclosure were constructed adjacent to the Vertebrate Pest Research Laboratory at the Bangladesh Agricultural Research Institute (BARI), Joydebpur. The jackal pen will permit studies on the breeding, food habits, and behavior of jackals in Bangladesh. The outdoor rodent enclosure, measuring 8 x 24 m, will permit studying damage patterns and food hoarding and will assist in maintaining a colony of bandicoot rats for laboratory testing. Two Bangladeshi graduate students received their M.S. degrees at the University of the Philippines at Los Baños and returned to the project.

Africa

Although the DWRC Vertebrate Pest Research Project in Sudan was completed in April 1981, DWRC has continued to cooperate in research of mutual interest with other organizations. This cooperation has included work with the FAO Regional East Africa and West Africa Quelea Projects on fluorescent marking techniques, residue analyses for crop protection trials, and assistance in graduate research programs.

Δ Damien - Site of Field Station

HAITI

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Three field programs, involving resident U.S. biologists, were continued during 1982 under the AID/DWRC program. These projects were located 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 preharvest and postharvest crop losses to vertebrate pests of significant regional importance 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.

HAITI

Survey of Preharvest Corn Losses to Vertebrate Pests

Corn is the major crop grown in Haiti. Production in 1978 was 250,000 ha, as compared with 165,000 ha for millet and 51,000 ha for rice. Damage surveys were conducted in the Port-au-Prince and Les Cayes regions. In each field, 10 hills of corn were sampled randomly 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. Preharvest losses in fields near Port-au-Prince were: 5.6% to Norway rats (*Rattus norvegicus*); 6.4% to Hispaniolan parakeets (*Aratinga chloroptera*) and village weavers (*Ploceus cucullatus*); and 1.7% to Hispaniolan woodpecker (*Melanerpes striatus*). These percentages were based on actual row length of kernels consumed or spoiled by vertebrate pests.

Twenty samples were collected from the Les Cayes region. Final analyses to determine percentage losses to different pests are not complete, but preliminary observations indicated that the vertebrate pest problem differed from the Port-au-Prince area. In the sample of 2,380 ears, 0.8% had Norway rat damage, 15.1% had parakeet and weaver damage, and 39.9% had woodpecker damage.

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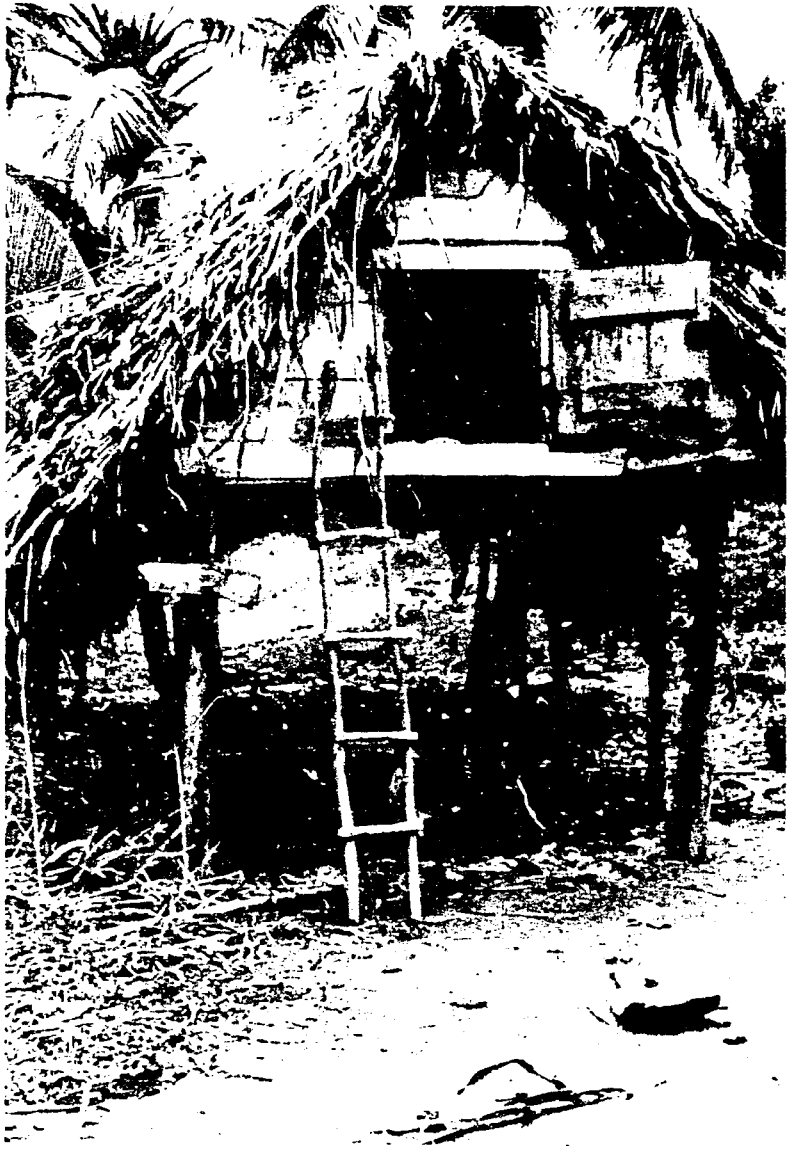

Maize is dried in trees and other cereal grains are stored in elevated structures to prevent postharvest losses in Haitian villages.

Comparing Bird Damage Among Corn Varieties

A cooperative study with Texas A&M was initiated to compare bird damage among different varieties of corn during 1982. The study was carried out in conjunction with USAID/Texas A&M's program to provide Haiti with improved varieties of corn. Twelve varieties of corn were grown in a split-plot experiment to determine their performance. One variety, Tocumen 7931/1, was eliminated from the bird susceptibility study because it had been collected differently than the others. Bird damage was measured in 480 m^2 of the field. Problem species were village weavers, Hispaniolan woodpeckers, Hispaniolan parakeets, and a suspect species, glossy cowbirds (*Molothrus bonariensis*).

Table 1 gives average yields (combined fertilized and unfertilized) and results of a palatability test. Twenty-four Haitian families participated in the palatability test. The ratings were based on fineness of grinding and taste after cooking.

Table 1. Average yields, % damage, and palatability scores of 12 varieties of corn in Haiti.

Variety	Yield (kg/ha)	Taste panel[a] results		% damage	
		Good	Inferior	PRD[b]	PWD[c]
Poza Rica 7427	2,248	18	6	10.3	9.7
Across 7726	2,372	12	12	8.4	7.9
Poza Rica 7726	2,712	4	20	7.9	7.4
La Maquina 7827	2,311	16	8	9.3	8.6
Siete Lagos 7728	2,569	24	0	11.4	10.7
Poza Rica 7928	2,736	24	0	9.6	9.2
Levy 7835	2,341	0	24	5.6	5.2
Tocumen 7926/1	2,624	24	0	9.5	9.0
Tocumen 7931/1	1,956	24	0	-[d]	-
La Maquina 7928	2,353	24	0	12.1	11.6
Les Anglais	1,034	0	24	10.8	10.2
Chicken Corn	1,757	24	0	8.4	7.8

[a] Taste panel consisted of 24 individuals.
[b] Percent surface area damaged by birds (PRD).
[c] Percent weight loss due to bird damage (PWD).
[d] Damage not evaluated.

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Although preharvest damage to the varieties ranged between 5 and 12%, statistical analysis of percent surface area (row length) damaged by birds (PRD) and estimated percent weight loss due to bird damage (PWD) indicated that there were no significant differences among the varieties. Six of the 12 varieties (Across 7726, Poza Rica 7726, Levy 7835, Tocumen 7931/1, Les Anglais, and Chicken Corn) had poor yields and/or poor results from the palatability test. Bird damage for the six remaining varieties (La Maquina 7827 and 7928, Poza Rica 7427 and 7928, Siete Lagos 7728, and Tocumen 7926) ranged from 9% to 12%. None of these six varieties could be recommended as less susceptible to bird damage than the other varieties.

Habits and Distribution of Village Weavers

The nature and intensity of crop damage by village weavers is related to their habits, ecology, and distribution. Between October and December, the species was found widely distributed in small flocks. These flocks occurred throughout the major valleys and at lower elevations in the mountains. The birds were seen feeding on ripening crops; the stomach contents of those collected contained sorghum, corn, wild seeds, and insects. In general, damage during these months was only serious locally.

Protecting Experimental Crops at Damien

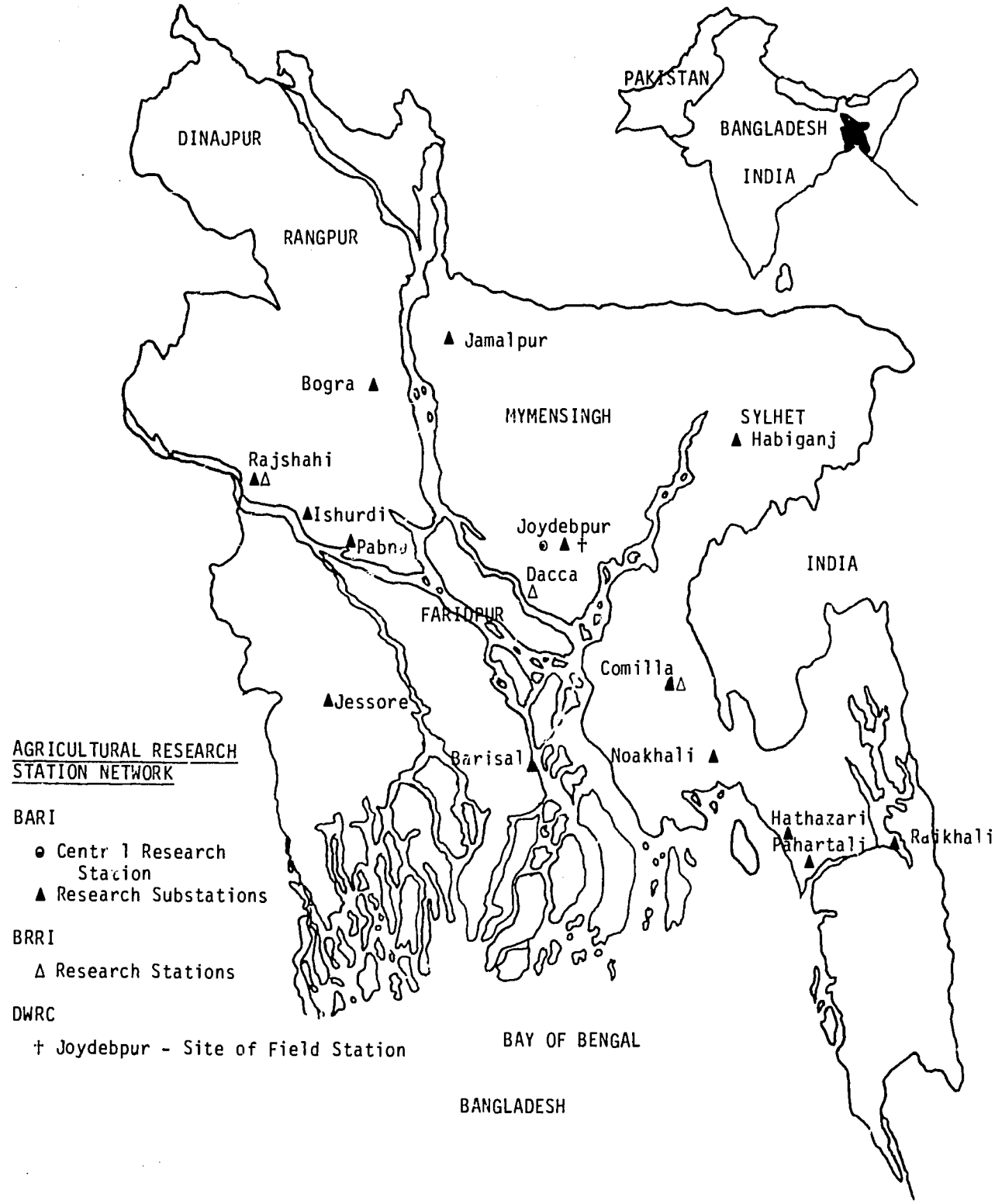
High-value experimental plantings of corn and sorghum at the Damien Experiment Station suffer damage from rats and birds. Small fields are interspersed among a variety of other native and experimental plantings; crops are grown year-round. The situation was ideal for evaluating methods for reducing crop losses to vertebrate pests.

Experimental corn and sorghum was planted in November and efforts were begun in December to protect these crops from rats and birds. Rat damage to corn and sorghum was greatly reduced by using a warfarin/ground corn bait in 7.6 x 40.4-cm stations placed around the field edges.

Extension of Rodent Control Techniques

A demonstration of the use of sustained baiting with a warfarin/corn meal formulation to protect rice from rat damage was conducted on 50 ha in the Artibonite Valley. The effort was very successful. Farmers in the study area commented on the vigor and density of their crop; farmers outside the area complained because their fields had not been chosen for the demonstration. Yields at harvest further convinced farmers of the benefits of rat control. Their confidence in the program came from evaluating its effects on the growth and yields of their rice, rather than on the number of rats found dead. Many farmers have adopted the program throughout this area of the Artibonite Valley.

Ploceus weavers form large nesting colonies, often in palm trees, and often associated with agriculture in Haiti, the Dominican Republic, and many countries of Africa.



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BANGLADESH

National Assessments of Rat Damage to Wheat

Rat damage to wheat was last assessed on a national scale in Bangladesh in 1979, when four districts were surveyed. The average damage in four districts that year was estimated to be 12.1%, or 77,000 tons of grain destroyed before harvest. Damage assessments in 1980 and 1981 were carried out in a few selected areas in Dacca and Comilla districts and indicated losses of 3% in 1980 and 7% in 1981. To once again obtain national estimates, surveys were carried out in six districts of Bangladesh in 1982.

A road transect was used to select survey fields. Stops were made every 2 km within a given thana in the district. Damage was estimated in the nearest fields on each side of the road. A second field, about 100 m distant from the road, also was selected. In these fields, five 50 x 100-cm quadrats were evenly spaced on the field diagonal and all cut and uncut stems were counted. Most fields were in late stages of maturity. Data obtained from 237 fields in 16 thanas indicated an overall damage of approximately 8.4%, representing about 81,000 tons of the 962,000 tons of wheat produced for the year (Table 2).

Table 2. Rodent damage to wheat in Bangladesh, 1982.

District	No. thanas	No. fields	No. cut stems	Total no. stems	Avg % damage
Dinajpur	3	34	582	15,256	3.8
Rangpur	1	12	179	4,101	4.4
Rajshahi	2	30	456	10,943	4.2
Tangail	5	76	2,042	30,480	6.7
Comilla	2	30	1,030	13,430	7.7
Dacca	3	55	4,099	25,504	16.1
Total/avg	16	237	8,388	99,724	8.4

About 67.5% of all fields surveyed had detectable rat damage. However, only 39.3% of irrigated fields had rat damage, compared with 76.2% in rainfed fields. Damage was only 2.6% in irrigated fields compared with 9.0% in rainfed fields (Table 3). This damage pattern indicates that deepwater rice areas, such as Mirjapur, Daudkandi, Baider Bazar, Narayanganj, and Gazaria thanas, when planted in winter wheat are more severely affected than upland sites and fields in the northwestern districts.

Table 3. Rat infestation and damage in irrigated and nonirrigated (rainfed) wheatfields in Bangladesh, 1982.

Fields	No. fields		Damage		
	Infested	Not infested	No. cut tillers	Total no. tillers	% cut
Irrigated	22	34	635	24,822	2.6
Nonirrigated	138	43	7,092	78,806	9.0

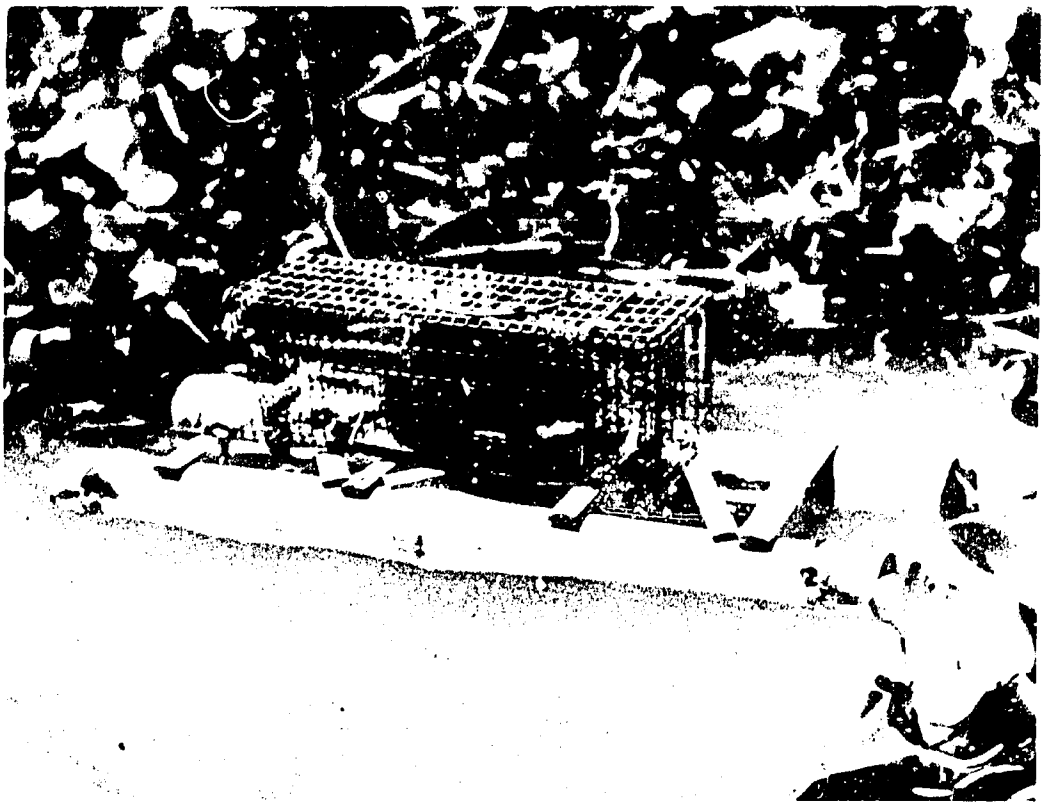
Comparative Field Trial of Two Rodenticides in Wheatfields

Two percent zinc phosphide baits have given good results when used by Bangladesh farmers to reduce rat damage to wheat. However, zinc phosphide cannot be repeatedly used in the same field because it may induce bait shyness in lesser bandicoot rats (*Bandicota bengalensis*). Brodifacoum is an alternative rodenticide which is lethal to bandicoot rats at a single exposure and can be used repeatedly without the risk of bait shyness.

The efficacy of these two rodenticides, 2% zinc phosphide and 0.005% brodifacoum as bait cakes, in reducing bandicoot rat damage to maturing wheat was compared in farmers' fields. Three areas of 10-12 fields each were used for trial sites; one site was left untreated. Treated fields were baited three times over a 3-week period during the late maturing stage of growth. Between 4 g and 6 g of bait cakes were put into all open burrows. Three days after the last baiting, all fields were sampled for rat damage by counting cut and uncut stems in ten 50 x 100-cm sampling frames laid along the field diagonals (Table 4).

Table 4. Comparison of brodifacoum and zinc phosphide for controlling rodents in wheatfields in Bangladesh.

Treatment	No. fields	Total area (ha)	No. burrows treated/week			% damage
			1	2	3	
Untreated	12	1.31	-	-	-	7.6
Brodifacoum	10	1.17	190	143	90	2.6
Zinc phosphide	12	1.27	194	158	142	4.8



Floating traps are used to census rodent populations in deepwater rice in studies in Bangladesh.

Caches of deepwater rice of almost 2 kg are being retrieved from burrow systems of lesser bandicoot rats in Bangladesh.

Brodifacoum gave better results than zinc phosphide, apparently because it did not induce bait shyness in bandicoot rats upon repeated exposure. Both rodenticides possess advantages and disadvantages for controlling rodents in wheat. Brodifacoum could be used to kill rats early in infested wheatfields and maintain these fields rat-free during the mature growth stage, whereas this would be more difficult with zinc phosphide.

Comparing Two Rodenticides on Island Villages Surrounded by Deepwater Rice

A field trial comparing two rodenticides on island villages in deepwater rice was carried out cooperatively by personnel of the Bangladesh Rice Research Institute (BRRI) and Bangladesh Agricultural Research Institute (BARI). The objectives of this trial were to compare the efficacy of 2% zinc phosphide baits with 0.005% brodifacoum baits and to devise techniques of baiting in villages during the monsoon flood period. Earlier rodenticide studies on islands in deepwater rice areas, comparing the efficacy of a 1% benzenesulfonic acid hydrazide (DRC-4575), 0.005% difenacoum, 0.005% brodifacoum, and 2% zinc phosphide, gave the following population reductions: DRC-4575, 90%; difenacoum, 94%; brodifacoum, 90%; and zinc phosphide, 87%. However, these studies compared DRC-4575, zinc phosphide, and difenacoum in rice baits and 1% coconut oil with commercially provided brodifacoum. Baits also were dispensed in 100- and 200-g amounts into bait stations, a laborious and relatively expensive procedure.

In the present trial, both rodenticides were formulated into bait cakes of 48 parts ground rice, 48 parts wheat flour, 2 parts soybean oil, and either 2 parts zinc phosphide (technical) or 2 parts brodifacoum 0.25% concentrate. This mixture was moistened with water to make a dough and rolled into 2 x 2-cm squares, 2 mm thick. The baits were sun-dried and packaged in 50-g amounts in plastic bags.

Nine island villages, comprising from 10 to 45 structures, were selected randomly in Mirjapur Thana, Tangail District, about 50 km west of Joydebpur. Two bait packets were given to farmers for each occupied structure. The farmers were asked to place five equal piles of bait indoors from one packet and five equal piles outdoors from the other packet. The baits placed outdoors were protected from poultry and livestock and picked up at dawn and replaced at dusk. Baiting was done simultaneously on all treatment islands for 3 days each poisoning period.

Pretreatment and posttreatment rodent activity was estimated by use of tracking tiles. Two tiles were placed indoors and two outdoors at nine occupied structures on each island for 2 nights. The

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average of the 2 nights' data was used as the estimate of animal activity and change in activity was assumed to be due to changes in animal numbers. Trapping was carried out on an adjacent island to determine species composition. Lesser bandicoot rats (Bandicota bengalensis), house mice (Mus musculus), roof rats (Rattus rattus), and musk shrews (Suncus murinus) were trapped.

The results of the trials are shown in Fig. 1. The initial activity assessment coincided with the beginning of the flood period. The first zinc phosphide poisoning proved ineffective because animals still were migrating to the islands from the fields as the water level rose. A decrease in population occurred on all brodifacoum-treated islands. The second poisoning took place shortly after the peak flood period in early August. The mean decline in population activity observed in late August on reference islands was 1%; on zinc phosphide-treated islands 34%; and on brodifacoum-treated sites 56%. However, the brodifacoum decline was 75% when computed from the peak activity in June.

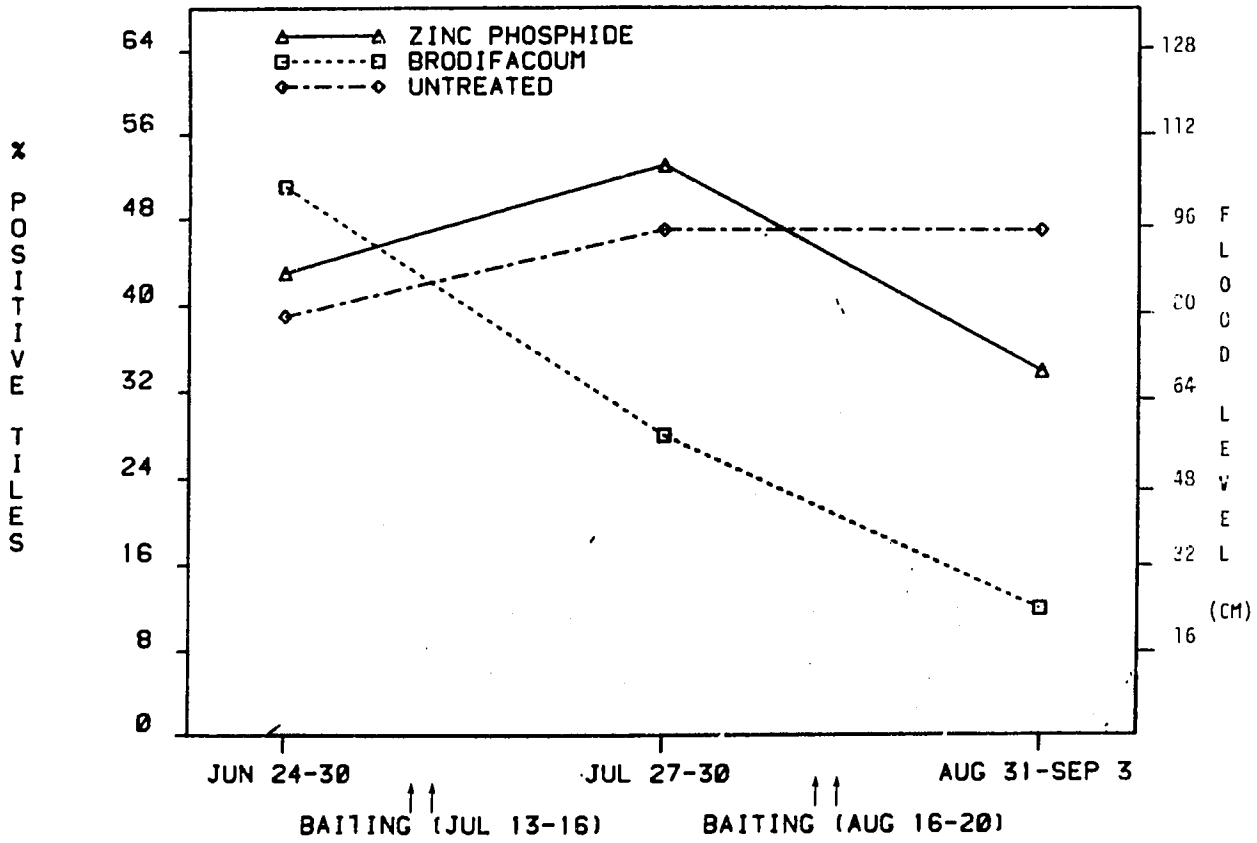
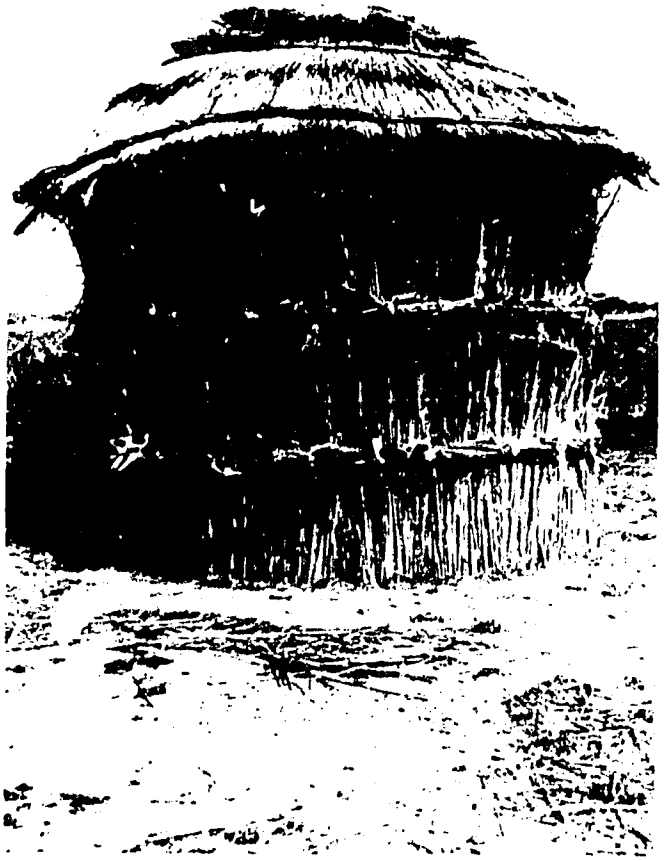


Figure 1. Rodent activity in zinc phosphide-treated, brodifacoum-treated, and untreated islands in deepwater rice growing area at Mirjapur, Bangladesh.



Studies of postharvest losses to rodents and birds are being initiated in housing clusters in Bangladesh. (Photos courtesy of W. D. Fitzwater.)

A covariance analysis of the tracking tile activity in the two poisoning periods, 24 June-30 July and 3 July-3 September gave significant treatment differences ($P < 0.01\%$). A linear regression of first night activity against second night activity, both indoors and outdoors, showed a good correlation from indoor data ($r = 0.74$) and a fair correlation from outdoor data ($r = 0.48$) indicating that 1 night's data was sufficient to estimate activity. The poorer correlation or outdoor data is not surprising because it rained during both June and July censuses.

This is the third comparative field trial in which brodifacoum has proven superior to zinc phosphide when used in the same baiting schedule. It is hoped that brodifacoum will be considered for pesticide registration in Bangladesh.

Evaluating Damage Assessment Techniques in Deepwater Rice

Methods of assessing damage in deepwater rice still need to be developed. Much rat damage occurs after the flood recedes. As fields dry, rats invade them and quickly construct elaborate burrow systems, cut rice panicles, and store many of these in the underground burrow systems. The fields before harvest are covered with a tangled mass of lodged stems, some as much as 3 m in length, making it difficult to find freshly cut stems. Rats cut the floating emergent stems beginning at the time of monsoon flood and continue cutting until harvest. Tillers cut during flood periods often respond with compensatory growth in new tiller output and panicle development. This compensatory growth does not seem to contribute significantly to yield at harvest.

Damage during the flood period has previously been assessed from boats by counting cut and uncut tillers in sampling quadrats along transects from the nearest village outward into the flooded fields. The objective of this study was to determine if the quadrat sampling method was acceptable. Therefore, damage was assessed in a 24 x 45-m field in which the actual level of damage was known. All burrow systems and runways were mapped and excavated, and all stored panicles were removed, counted, and weighed when dry.

In general, the damage in the field varied depending on when it occurred. Rat damage during the monsoon period was randomly distributed throughout the field. Fresh-cut stems were associated with the presence and proximity of the burrow openings and rat runways.

Using the 0.5-m^2 quadrats, damage was assessed by four observers at 4.81, 4.93, 6.19, and 4.08%; the actual value, obtained by counting every tiller, was 7.2%. Estimates were 3.16% for stems cut by rats during the monsoon (close to actual value of 3.52%),

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but only 1.86% for fresh-cut stems (less than the actual value of 3.75%). These stems often were cut below the mat of lodged stems and were being overlooked. Stems cut during the monsoon were more easily seen because they put up compensatory growth tillers with partially empty panicles through the mat.

The most serious drawback to using the quadrat assessment method was its inability to account for almost 4,643 fresh-cut panicles in the burrow systems under the lodged mat. The rat runways, burrow openings, and distribution of damaged stems indicated that almost all were cut within the field. If it is assumed that the 4,643 panicles represented an equal number of cut stems, then half of the total damage was overlooked. Therefore, quadrat frame sampling does not seem suitable for assessing damage in deepwater rice at harvest because the dense mat of lodged rice stems obscures many cut stems, resulting in an underestimate of damage.

Because quadrat sampling in deepwater rice underestimates the damage at harvest time, another method using the density of rat burrow systems and the average amount of cached rice/burrow system was evaluated. The method, however, does not consider damage that occurs during monsoon flood periods.

Twenty-three samples of cached rice from bandicoot rat burrow systems in deepwater ricefields were obtained at harvest by excavating entire burrow systems. After drying and hand-threshing, these samples averaged 1.7 kg/system. Data on the density of rat burrow systems/ha were obtained in seven deepwater rice-growing thanas counting all burrow systems along 30-m wide transects from the nearest high ground to distances of 300-400 m into the fields (Table 5).

Damage varied considerably among thanas. Those fields in which flood waters receded early received the heaviest damage. Rats seemed to have sought out and burrowed into those fields that were exposed first, those on slightly higher ground. The reduced amount of damage and reduced number of burrows in Rupganj, Polash, and Narsinghi reflect their high water table; even at harvest the water table was within 25 cm of the ground surface. Some fields were flooded by 2-5 cm of water. Under these conditions, bandicoot rats do not invade fields but burrow into the perimeter dikes and damage edges as the water recedes.

Table 5. Rat burrow system densities and estimates of amounts of cached rice in these systems in Bangladesh.

Locality	No. burrow systems/ha	Estimated stored rice (kg/ha)	% loss from 1,800 kg/ha yield
Manikganj	75.6	126.2	7.0
Manikganj	71.1	118.7	6.6
Manikganj	42.2	70.5	3.9
Mirjapur	60.0	100.2	5.6
Rupganj	18.0	30.0	1.7
Rupganj	10.0	16.7	0.9
Polash	21.0	35.1	1.9
Narsinghi	20.0	33.4	1.8
Daudkandi	26.7	44.6	2.5
Daudkandi	11.4	19.0	1.0
Gazaria	24.0	40.1	2.2
Gazaria	36.1	60.3	3.3
Means	34.6	57.8	3.2

Extension of Rodent Control Techniques to Wheat Farmers in Gazaria Thana

Previous studies by the Vertebrate Pest Section at BARI indicated that rat damage to wheat could be reduced by using zinc phosphide bait cakes. A premixed 2% zinc phosphide bait packet was prepared and made available to farmers to test their acceptance of the bait package, the effectiveness of the zinc phosphide bait, and to compare it to the other rat poisons farmers are using.

The study was conducted at Gazaria Thana, about 30 km southeast of Dacca. This thana is bordered by a major river system and actually is a large island. About 48 villages are located in the thana. The main crop grown from November to March is wheat intercropped with millet, potato, and other vegetables.

Zinc phosphide bait cakes were prepared and packaged in 100-g amounts in plastic bags with instructions on use and safety. In November 1981, 200 bait packets had been sold at the central market in Rasulpur at the cost of Taka 1.00 each (US $0.25). Bait again was sold at the market in January (200 packets) and February 1982 (300 packets). Each packet contained sufficient bait for 16-18 burrow openings (2-3 pieces/opening) or enough to treat one field for one season.

In March, wheatfields around 12 of the 48 villages in the thana were assessed for rat damage. In each village, nine wheatfields were selected, three along each of three preselected transect lines. Along each transect, the field nearest to 100, 200, and 300 m from the village was assessed. Cut and uncut tillers in five quadrat samples (50 x 100-cm wooden frame) were counted. A total of 108 fields was assessed for damage in Gazaria within 2 weeks of harvest. After damage was assessed, farmers were asked if they purchased the zinc phosphide bait packets, the number of packets they used, and if they also used other rodenticides.

For comparison, three other thanas, Muradnagar, Chandina, and Daudkandi were randomly selected in Comilla District. Damage was assessed in nine fields each of three villages ($\underline{n}$ = 81 fields) in these thanas, and farmers were again asked if they used any rodenticides in the fields.

Of the 108 fields sampled in Gazaria Thana, 20 (or 18.5%) had been treated with one or more bait packets; 8 others had been treated with a locally obtained rat poison. The majority of farmers, however, used no rodenticidal bait. Damage was lowest in the 20 fields where the ready-made zinc phosphide bait was used. The mean damage for all fields was 7.9% (Table 6). Although 18 fields (22%) in the thanas of Comilla District had been treated with a locally obtained rat poison, damage was comparable among treated and untreated fields in all three thanas (Table 6).

Table 6. Rat damage to wheat in Gazaria Thana where zinc phosphide baits were made available and in other thanas where farmers used locally available poisons.

Location and treatment	No. fields	No. cut tillers	Total no. tillers examined	% rat damage
Gazaria Thana				
Zinc phosphide baits	20	334	12,752	2.6
Locally available poisons	8	432	4,820	9.0
Untreated	80	4,480	48,523	9.2
Total/avg	108	5,246	66,095	7.9
Other thanas				
Locally available poisons	18	547	8,393	6.5
Untreated	63	1,676	30,465	5.5
Total/avg	81	2,223	38,858	5.7

Farmer acceptance of the ready-made zinc phosphide bait was excellent. Interviews at the central market indicated that many more bait packets could have been sold. About 3,800 bait packets would be needed to supply the entire thana. Most encouraging was the approximately 70% reduction in damage that was achieved with very little supervision. The instructions given at the time the bait was sold were the only contact made with the farmers before the preharvest survey. This study demonstrated the feasibility of providing an effective, inexpensive rodenticidal bait material to Bangladesh wheat farmers for reducing rat damage. It would seem that a larger scale demonstration is warranted.

Rat Infestation in Transplanted Aman Ricefields

Transplanted aman rice is planted in Bangladesh during the monsoon season and harvested in October and November after the monsoon. When the fields are drained and the rice is ripening, bandicoot rats invade the fields from nearby higher ground where they have lived during the flood period. Damage lasts for only a short time, but may be intense. Rat infestations in transplanted aman ricefields are easily seen following harvest because all burrows are excavated by the farmers to retrieve the cached rice. In 1982, the infestation in many districts was high, averaging 19.5% (Table 7). In the Tongi-Joydebpur area, 19.8% of the fields were infested, compared with only 8.7% in 1981. There is considerable opportunity for extension of rodent control techniques into these areas.

Table 7. Rat infestation in transplanted aman fields in Bangladesh, 1982.

District/Locality	No. fields		%
	Counted	Rat-infested	infested
Dinajpur/adjoining thanas	205	57	27.8
Rangpur/Polasbari	239	103	43.1
Dacca/Tongi-Joydebpur	344	68	19.8
Cox's Bazaar/Ukhiya	100	6	6.0
Chittagong/Banskhali-Anwara	250	19	7.6
Bogra/Kahalu	240	16	6.7
Total/avg	1,378	269	19.5

Preference of *Bandicota bengalensis* for Oils

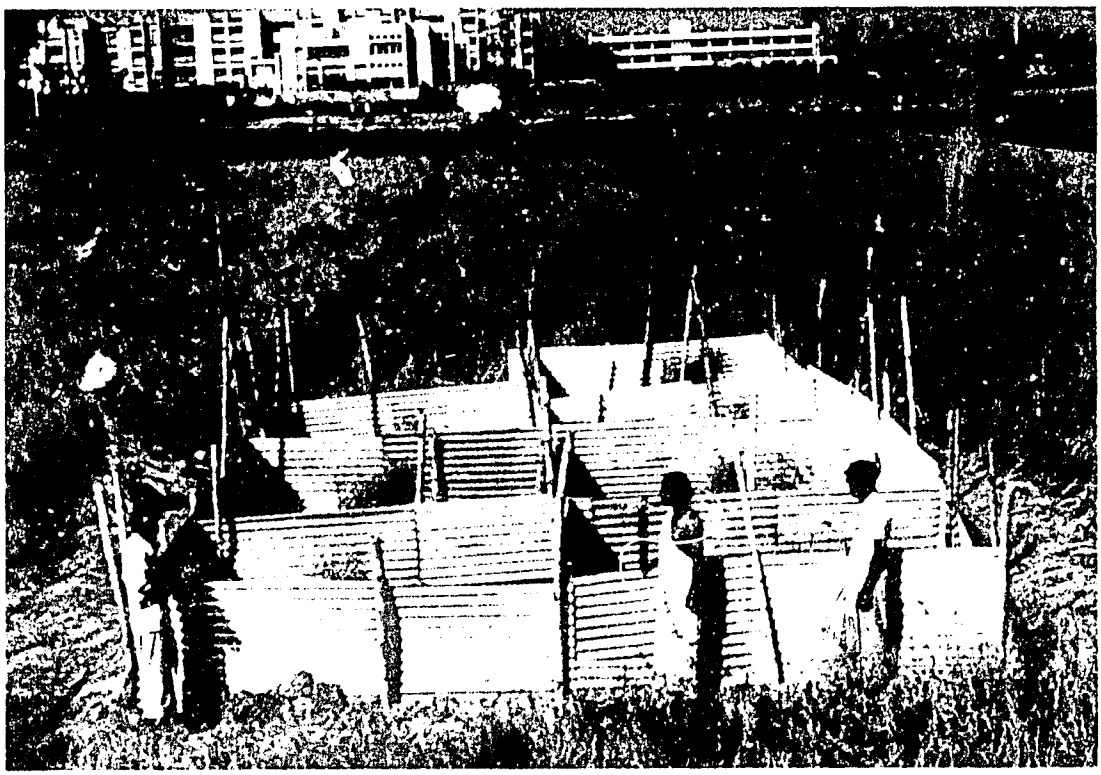
Vegetable oils commonly are added to rodent baits to increase their attractiveness and palatability. Because many oils are available at different costs in Bangladesh, an experiment was carried out to determine those oils preferred by lesser bandicoot rats (*Bandicota bengalensis*).

Individually caged lesser bandicoot rats were offered food containing a 5% concentration of one of four different oils (palm, coconut, soybean, mustard) in a no-choice test. After the rats were offered the food with oils, they were given a choice between the same food with and without the oil (Table 8).

Table 8. Amount of food (g) containing 5% oils consumed by lesser bandicoot rats ($\bar{n}$ = 5/test) in a 4-day no-choice and choice test period.

Test	Males	Females	Total
No-choice			
Palm	213.0	224.0	437.0
Soy	329.5	254.0	583.5
Mustard	212.0	249.0	461.0
Coconut	165.0	281.0	446.0
Two-choice			
Plain	33.0	100.5	133.5
Palm	151.0	173.0	324.0
Plain	102.0	46.5	148.5
Soy	186.0	108.5	294.5
Plain	176.5	70.5	247.0
Mustard	85.0	66.0	151.0
Plain	95.0	120.5	215.5
Coconut	118.0	146.0	264.0

It seemed that lesser bandicoot rats preferred oils with bland odors (to humans) and tastes (palm and soybean oils). They showed no preference for coconut oil which has an aromatic odor, and avoided mustard oil, which has an acrid, pungent odor and a strong taste. It also was apparent that the sexes react differently to oils. In no-choice tests, males preferred food treated with soybean



Crop damage and grain storage by lesser bandicoot rats are being studied in outdoor enclosures in Bangladesh.

Pied mynas (Sturnus contra) and common mynas (Acridotheres tristis) reduce production of wheat and rice in Bangladesh by eating newly sown seed and removing seed from germinated plants.

oil and avoided mustard oil; females consumed primarily food treated with coconut oil. In choice tests, males preferred palm and soybean oils and avoided mustard oil. Females also preferred palm and soybean oils but did not discriminate against mustard oil. Neither sex showed any preference for coconut oil. Therefore, because of its preference by bandicoot rats and lower price, soybean oil is recommended as a bait additive.

Bioassay of Avitrol to Parakeets and Mannikins

Avitrol (4-Aminopyridine) is a distress-producing chemical used to deter blackbirds and crows from feeding in certain food crops in the United States. In Bangladesh it may have application in certain situations, especially crops on experimental plots that are damaged by rose-ringed parakeets (*Psittacula krameri*), mannikins (*Lonchura* spp.), and perhaps baya weavers (*Ploceus philippinus*) and jungle crows (*Corvus macrorhynchos*).

The LD50 and distress-producing doses of Avitrol were determined for parakeets and white-backed mannikins (*L. striata*; Table 9). Avitrol, dissolved in propylene glycol, was administered by gavage to groups of birds. The time to first distress call and time to death were recorded for all birds (Table 9). The LD50 in parakeets was 3.1 mg/kg and the effective dose (the dose producing a distress reaction) was 10-15 mg/kg; the effective dose in mannikins was between 5 mg/kg and 10 mg/kg.

Table 9. Effects of Avitrol on rose-ringed parakeets and white-backed mannikins in Bangladesh.

Species	Dose (mg/kg)	Mean body weight (g)	Mortality	Time (min) until Immobilized	First distress call	Death
Parakeets	1.25	103	0/3	-	No response	-
	2.50	116	0.6	-	No response	-
	3.75	132	3/3	NR[a]	53	83
	5.00	118	6/6	NR	39	63
	10.00	105	3/3	NR	15	38
	20.00	111	3/3	NR	12	20
Mannikins	2.50	13.9	5/8	31.8	No response	1,020
	5.00	14.5	5/8	29.0	35 (2)[b]	504
	10.00	14.1	8/8	16.7	20.9 (7)	33

[a] NR = not recorded.
[b] Numbers in parentheses indicate number of birds giving response.

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Reducing Bird Damage in Maize With Avitrol

Maize is a relatively new food crop in Bangladesh. Wherever planted, it almost invariably is attacked at the milk stage by flocks of rose-ringed parakeets, jungle crows, and other birds. Damage ranged from 10 to 22% in experimental maize plots at the Rajbari Regional Research Farm at Dinajpur in September 1981. Fields are attacked as maize nears maturity, discouraging the wider adoption of this crop in Bangladesh.

Because the bird pest species are gregarious, it seemed feasible to use the distress-producing chemical Avitrol to frighten them from maizefields. A replicated trial evaluating Avitrol to protect maize from rose-ringed parakeets was conducted at Dinajpur in June. Five ears of maize/20 m^2 plot (six plots/treatment, three replicates) were exposed and sprayed with either 3 or 4% Avitrol dissolved in acetone. The maize was in the milk stage at the time of spraying. Sprayed ears were left on the stalks for 2 weeks until harvest. At harvest, each plot was assessed for damage by sampling every tenth ear. Damage was expressed as the number of centimeters of kernels removed relative to total number of centimeters of rows. The results indicated that both treatments provided excellent protection ($P < 0.01$; Table 10).

Table 10. Percent damage by rose-ringed parakeets to fields of maize in which perimeter ears had been treated with Avitrol at Dinajpur, Bangladesh during June and October 1982.

Date and replicate	% damage		
	3% Avitrol	4% Avitrol	Untreated
June			
1	2.3	1.6	21.0
2	2.1	1.2	13.7
3	2.3	1.4	22.3
Total	6.7	4.2	57.0
Avg	2.2	1.4	19.0
October			
1	1.5	3.3	6.0
2	5.2	4.1	8.2
3	3.7	3.2	16.8
Total	10.4	10.6	31.0
Avg	3.4	3.5	10.3

A second trial as conducted on maize at this same site in October. Avitrol was dissolved in ethyl alcohol at 2 and 4% concentrations and applied from hand-pump spray bottles onto 10 exposed ears on the perimeter of 12 x 16-m plots within a larger field. Treated ears were left in place until harvest 24 days after spraying. At harvest, every tenth ear again was sampled from each row in each plot for damage.

These results indicated that Avitrol provided some protection; damage was significantly less in the treated plots than in the untreated plot ($P < 0.01$). Damage was mainly caused by rose-ringed parakeets (*Psittacula krameri*), but red-vented bulbuls (*Pycnonotus cafer*), Indian tree-pie (*Dendrocitta vagabunda*), and the rose-finch (*Carpodacus erythrinus*) also were seen in the field. Some individuals of these species became affected by 4-AP and were unable to fly, but subsequently recovered.

Repellency of Copper Oxychloride and Methiocarb

The R50 of copper oxychloride ($CuCl_2\ 3Cu(OH)_2$) and methiocarb to individually caged pigeons (*Columba livia*) was determined. Seeds were treated with copper oxychloride and methiocarb at 0.1, 0.2, 0.4, an. 0.8% concentrations. Six birds were offered 300 treated wheat seeds for 20 h. Preliminary R50 values for copper oxychloride = 0.28% and for methiocarb = 0.12% (Table 11).

Table 11. Repellency of four levels of copper oxychloride and methiocarb to pigeons in Bangladesh.

Treatment	Weight (g) of birds (range)	No. birds repelled (% food offered that was eaten)				R50 (95% CL)
		0.1	0.2	0.4	0.8	
Copper oxychloride	268.7 (240-303)	0/6 (79)	1/6 (61)	5/6 (40)	6/6 (21)	0.28 (0.10-0.79)
Methiocarb	272.0 (241-302)	2/6 (48)	5/6 (36)	6/6 (9)	6/6 (1)	0.12 (0.05-0.31)

Reducing Bird Damage to Sprouting Wheat

A variety of trials were conducted at research farms, with farmers, and in the laboratory to evaluate several chemicals as repellents

to reduce bird damage to sprouting wheat. As a result of the encouraging field trials with BARI research farms, additional studies to evaluate three chemicals to reduce bird damage to farmers' wheatfields were carried out in Gazaria Thana, Dacca District. Replicated trials evaluating copper oxychloride (0.5%), methiocarb (0.25%), and Landrin (1.0%) as seed dressing repellents were initiated in November. Observations of bird damage during and after sowing showed that pied mynas (Sturnus contra), common mynas (Acridotheres tristis), pigeons, jungle crows, and house sparrows were the main pests to the seeds and sprouts. Except for the untreated fields, the least number of birds were counted in copper oxycloride-treated fields and the most in the Landrin-treated fields (Table 12). The bird counts for the Landrin-treated fields are misleading, however, because one flock of mynas, which stayed only a few minutes, contributed to the higher count.

Table 12. Bird counts in wheatfields treated with three chemical repellents in Gazaria Thana, Dacca District.

Treatment	Replicates I	II	III	Total
Methiocarb	20	13	12	45
Copper oxychloride	29	0	5	34
Landrin	11	35	6	52
Untreated	59	51	1	111

The best protection was obtained in the Landrin-treated fields. In the Landrin fields, only 17% of the seeds were lost compared with 49 and 48% in copper oxychloride-treated and methiocarb-treated fields; the untreated plot lost 48% of its seeds.

However, counts of wheat sprouts in the same fields 30 days after sowing were highest in methiocarb-treated fields. The sprout counts were adjusted to account for differences in farmers' sowing rates (Table 13). Germination was less in Landrin-treated fields than in the untreated fields. Germination tests of Landrin-treated wheat seed in petri dishes (3 replicates--20 seeds/dish) and in flower pot trials (3 replicates--20 seeds/pot) supported the low counts in the farmers' fields (Table 14). Two-percent Landrin had a strong inhibitory effect on germination; sprout growth also seemed delayed at most concentrations. In contrast, germination was much better with methiocarb-treated seeds at 0.1 and 0.25% levels and copper oxychloride-treated seeds at 0.5 and 1.0% also sown in flower pots (Table 15).

Analysis of variance indicated significant differences between treatments ($P < 0.01\%$). The results of this work are encouraging for using methiocarb at 0.25% and copper oxychloride at 0.5% as bird repellents on wheat seed. However, it seems that future use of Landrin as a wheat seed treatment should be confined to concentrations of $\leq 0.5\%$.

Table 13. Counts of wheat sprouts in farmers' fields in Gazaria Thana.

Replicate	% of potential sprouts[a]			
	Copper oxychloride	Methiocarb	Landrin	Untreated
I	48.3	45.7	30.1	45.9
II	48.3	66.8	33.9	42.5
III	-[b]	61.5	34.5	39.7
Means	48.3	58.0	32.8	42.7
% increase over untreated	13.1	35.8	-23.2	-

[a] % potential = % of total seed sown that germinates compared with the number of seeds sown/m^2.
[b] One field deleted because sowing rate was much higher than the rest.

Table 14. Results of germination trials of Landrin-treated wheat seeds in petri dishes and flower pots.

Landrin (% conc)	% germination	
	Petri dishes	Flower pots
0.25	86.7	73
0.5	96.7	59
1.0	81.7	75
2.0	43.3	32
Untreated	98.3	55

Table 15. Numbers of repellent-treated wheat sprouts germinating/pot in Bangladesh.

Replicate	Treatment				
	Methiocarb		Copper oxychloride		Untreated
	0.1%	0.25%	0.5%	1.0%	
1	15	14	16	16	13
2	0	15	4	12	0
3	0	13	12	2	14
4	10	16	13	2	7
5	2	12	9	2	0
6	12	11	15	13	1
7	2	6	10	10	8
8	4	9	10	12	5
9	4	15	14	14	8
10	3	4	13	12	3
Total	52	115	116	95	59
Means	5.2	11.5	11.6	9.5	5.9

Cooperation With National and International Organizations

The Vertebrate Pest Section continued to cooperate with the Bangladesh-German Plant Protection Rodent Control Programme in field, laboratory, and extension and training activities. A collaborative proposal with the Plant Protection Programme on a study of squirrel biology and ecology was drawn up and presented to the coordinating committee on vertebrate pests at the Bangladesh Agricultural Research Council (BARC). Quarterly meetings are held at BARC with representatives from the German Plant Protection Programme and staff from BRRI. Collaborative work continued with the Christian Reformed World Relief Committee (CRWRC) at Bogra on bird problems in wheat. Close liaison was established with the CARE Bangladesh Deep Tubewell Irrigation and Credit Program in Dhamrai in connection with rodent problems in irrigation canals, wheat, and boro rice crops. A working relationship has been established with the Agricultural Extension Services for disseminating training and extension information. The Vertebrate Pest Specialist at BRRI has been working collaboratively with staff of the Vertebrate Pest Section, BARI, on studies of postharvest food losses, rodent control in deepwater rice, and damage assessments in deepwater ricefields.

Personnel and Training

Md. Yousuf Mian completed his studies at the University of the Philippines at Los Baños and received an M.S. degree in Zoology. He returned to the Vertebrate Pest Section on 25 June 1982. Md. Emdadul Haque, likewise, completed his studies at the same University, and received his M.S. degree in Zoology. He returned to the Vertebrate Pest Section on 25 September 1982.

Md. Abdul Karim spent the summer in Hilo, Hawaii, carrying out his field research on rodent populations in sugarcane fields. He is continuing his work toward a Ph.D. degree at Bowling Green State University, Bowling Green, Ohio and is expected to rejoin the Vertebrate Pest Section in early 1983.

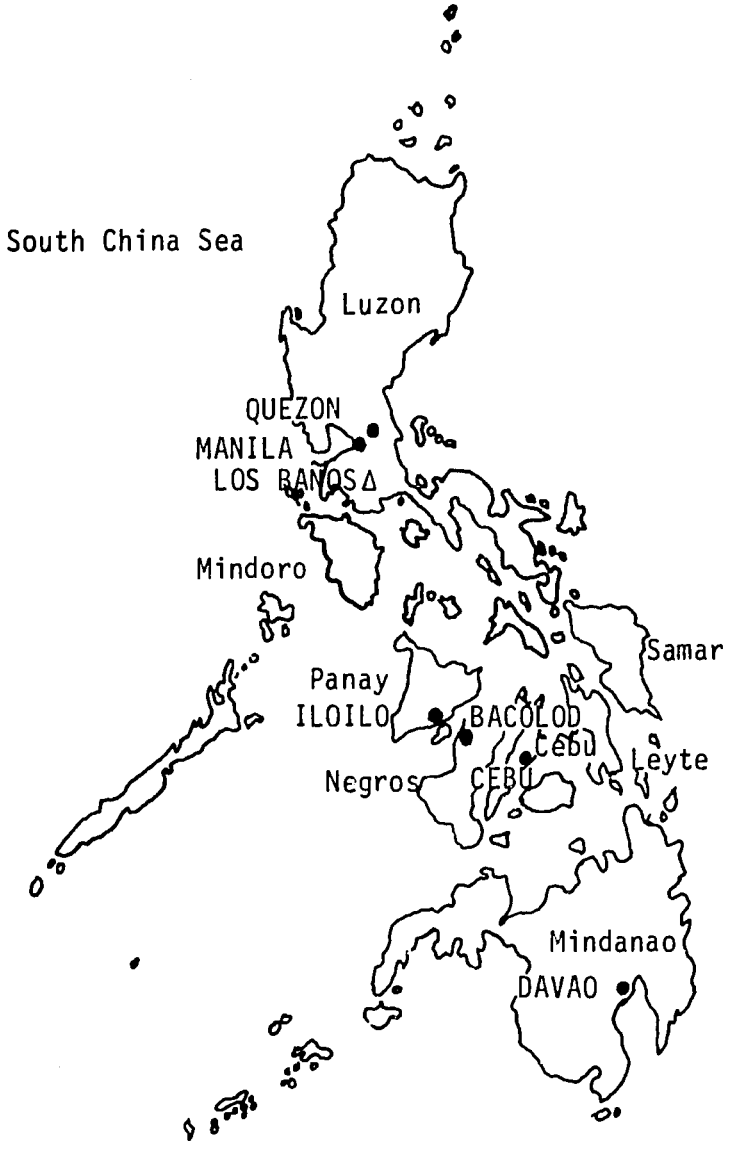
PHILIPPINES

The DWRC project personnel at the National Crop Protection Center supervised the vertebrate pest management research of four international M.A. candidates attending the University of the Philippines at Los Baños. Two Bangladeshi students completed research on topics that had practical application to rodent ecology and management in Bangladesh. Their studies looked at yield reduction in wheat with simulated rat damage and the ecology and control of rodents in villages associated with deepwater rice. A Venezuelan studied the movements of rats in marshes adjacent to cropland. A Filipino student surveyed the rodent species in Philippine port zones.

Yield Reduction in Wheat by Simulated Rat Damage (From M.S. Thesis, Emdadul Haque)

A simulated rat damage study was conducted to determine the yield loss of wheat when damage occurs at tillering, booting, dough, and mature stages. Wheat, *Triticum vulgare*, is now one of the major food crops in Bangladesh and is being cultivated in more than 300,000 ha. Preharvest rat damage has been nationally assessed at more than 12%.

The study was conducted on wheat planted in a 30 x 30-m experimental plot of 128 1-m^2 quadrats at Joydebpur, Bangladesh. Eight replications of the 16 combinations of four crop stages and damage levels (0, 10, 30, and 50%) were assigned in a completely randomized design. Normal irrigation and fertilization practices were followed. Individual quadrats were harvested, manually threshed, winnowed, sun-dried for 2 days, and weighed with the yield adjusted for moisture. In addition, wheat also was planted in two 3 x 3-m test enclosures. One male and one female lesser bandicoot rat



Δ Los Baños - Site of Field Station

THE PHILIPPINES

(Bandicota bengalensis) were released into one of the enclosures and two males and two females were released into the other. Daily stem cutting rates and amounts of stored wheat were determined.

Significant difference in yield ($P < 0.05$) did not occur until 50% damage was inflicted during the booting stage (Fig. 2). Ten percent damage inflicted during the dough stage and mature stage were significant ($P < 0.05$; Table 16).

In the test enclosures, four rats cut one-fifth as many tillers as two rats cut per day (Table 17). This was attributed to increased time spent in social interaction and fighting, reducing the time spent feeding. Comparable percentages of tiller panicles were stored.

Wheat apparently has compensatory qualities that rat damage does not overcome until at least 10% damage is inflicted in the dough or later crop stages. Rodent control during the early wheat crop stages would not be necessary. Because lesser bandicoot rats usually do not enter and damage wheatfields until the booting stage, baiting or other control activities can be postponed until then.

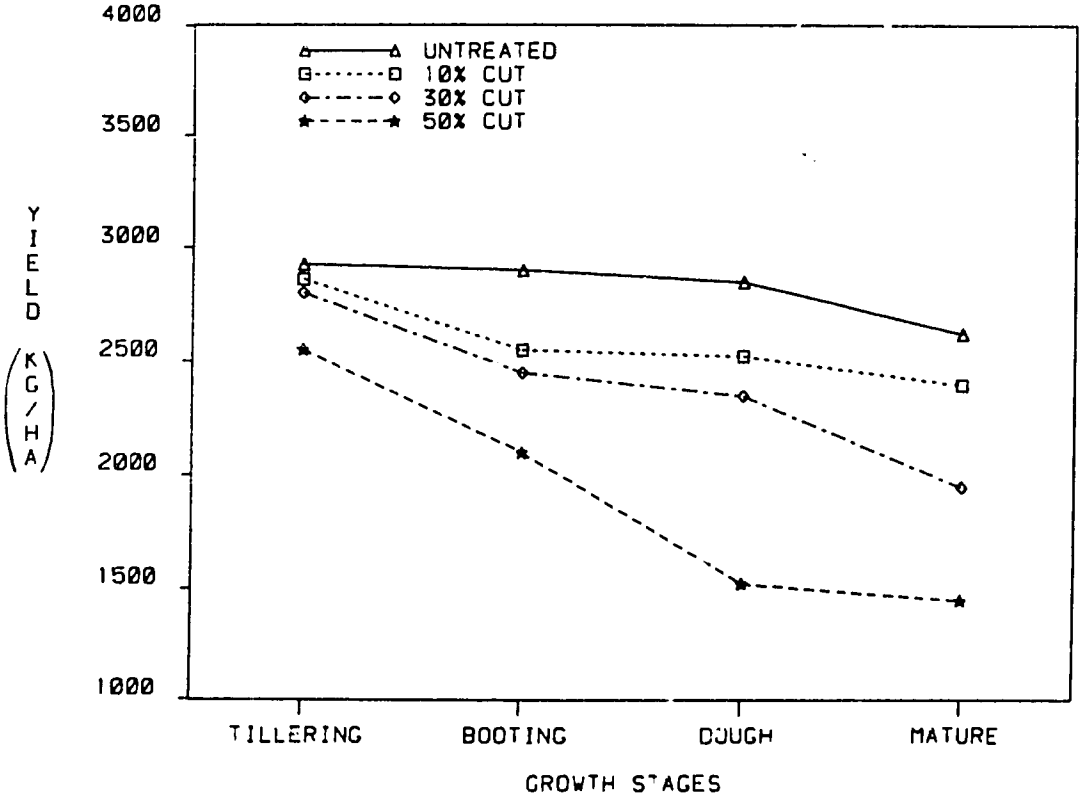


Figure 2. The effect of simulated rat damage on yield in wheat at different growth stages.

Table 16. Summary of wheat yield data (kg/ha) from 128 1-m^2 quadrats subjected to simulated rat damage by mechanical stem cutting (significant difference = $P \leq 0.05$).

Growth stage	Damage level (%)	Mean yield (kg/ha)	Test for significance: Growth stage	Test for significance: Damage level	Yield reduction (%)
Tillering	0	2,927	Untreated	Untreated	-
	10	2,889	NS[a]	NS	1.3
	30	2,812	NS	NS	3.9
	50	2,544	NS	NS	13.1
Booting	0	2,868	Untreated	Untreated	-
	10	2,537	NS	NS	11.5
	30	2,435	NS	S[b]	15.1
	50	2,140	S	S	25.4
Dough	0	2,806	Untreated	Untreated	-
	10	2,504	S	NS	10.8
	30	2,302	S	S	18.0
	50	1,526	S	S	45.6
Mature	0	2,602	Untreated	Untreated	-
	10	2,364	S	NS	9.2
	30	1,946	S	S	25.2
	50	1,406	S	S	46.0

[a] NS = Not significant.
[b] S = Significant.

Ecology and Control of Sympatric Rodents on Islands Adjacent to Deepwater Rice in Bangladesh (From M.S. Thesis, Yousuf Mian)

The purposes of this study were to identify and monitor rodent species on islands in a deepwater rice habitat in Bangladesh and to compare rodenticide baiting and snap-trapping techniques to reduce rodent populations. Deepwater rice makes up about 20% of the total rice acreage in Bangladesh. Villages in deepwater rice growing areas become isolated on small islands during the wet season. Rodents immigrate from the surrounding fields to these islands in mid-June when monsoon rains cause flooding. Rodents do not emigrate from the island villages until the deepwater rice matures into a floating mat capable of supporting their weight. The time when rodents are restricted to these islands seems to be when they are most susceptible to management techniques.

Table 17. Damage to wheat inflicted by rats in two 3 x 3-m test enclosures over a 15-day period.

No. rats/ enclosure	Total Stems	Total Stems cut	% damage	Stems cut/rat/day	Panicles stored in burrows Total	Panicles stored in burrows %	Amount grain Lost (g)	Amount grain Stored (g)	Amount grain Estimated consumed (g)[a]	Amount grain Spilled (g)
2	4,011	3,474	86.6	115.8	1,339	38.5	3,752	2,310	390	1,916
4	3,174	1,276	40.2	21.3	495	38.8	1,378	840	780	53

[a] Avg daily consumption (13 g) multiplied by number of rat days.

Rodent populations on nine similar size seasonal islands at Agrokhola near Dacca were studied. To compare rodenticide baiting and snap-trapping techniques, three islands were intensively trapped (100 trap nights/week), three were baited with 0.005% diphacinone (June-August), 0.025% warfarin (September-October), and 1.0% Vacor (November), and three were left untreated. Bait was provided weekly in 300-g amounts and consumption monitored at least weekly.

The rodent species captured, by decreasing abundance, were roof rats (Rattus rattus), lesser bandicoot rats, house mice (Mus musculus), soft-furred rats (Millardia meltada), and greater bandicoot rats (B. indica) (Fig. 3). R. rattus predominated in all months, except August when many B. bengalensis moved from flooded fields to the island villages. Most rats were captured in or near houses.

A comparison of reproductive parameters showed that B. bengalensis was less productive than either M. musculus or R. rattus (Table 18). Based on the snap-trap index, a 100% reduction of the rodent population on the baited islands and a 90.9% reduction on the snap-trapped islands was achieved (Fig. 4). Trap success (based on 9,800 trap nights) on the intensively trapped islands was 5.2%. Rodent damage in rice within 50 m of the untreated islands was 0.8%, the snap-trapped islands 0.7%, and the baited islands 0.5%. These damage levels were not significantly different ($P > 0.05$).

The concentrations of lesser bandicoot rats on island villages during the monsoon would seem to provide a susceptible period for implementing a control program to reduce damage to deepwater rice. An island-based control program also probably would reduce storage losses from lesser bandicoot rats and other village rodents.

Table 18. Annual productivity of three species of rodents captured from the study area at Agrokhola, Bangladesh, during 1979.

	R. rattus	B. bengalensis	M. musculus
Annual incidence of pregnancy	10.2	3.0	11.7
Incidence of pregnancy during 245-day study period	6.8	2.0	7.8
Mean no. embryos/female	5.2	7.0	4.5
Annual productivity	53.0	21.0	52.6
Productivity during 245-day study period	35.4	14.0	35.1

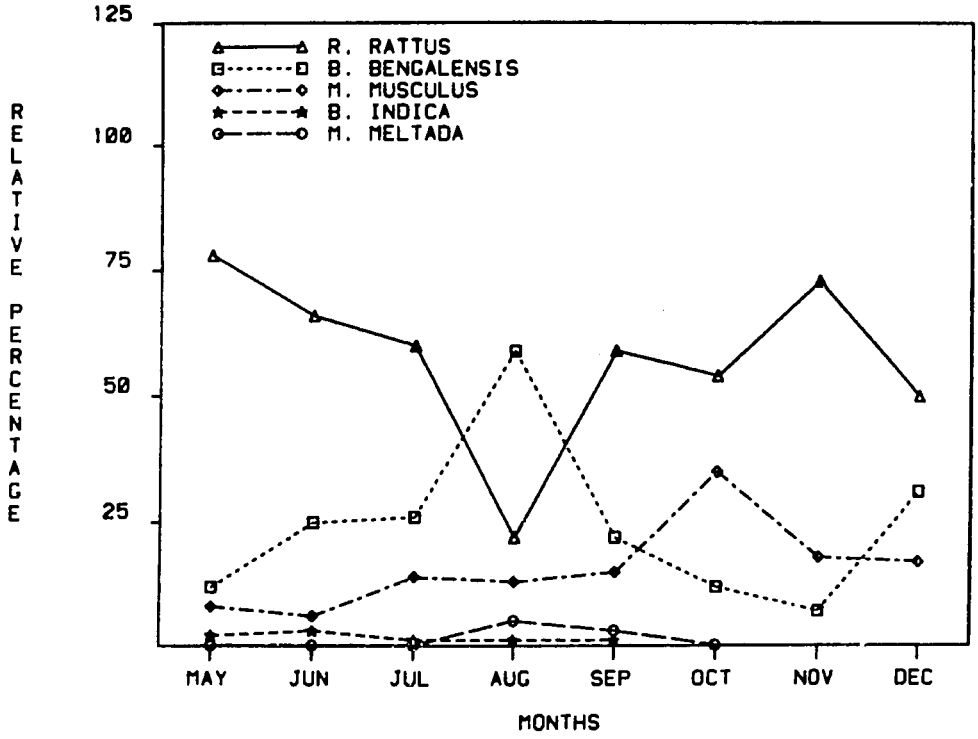


Figure 3. Species composition and their relative abundance on nine islands at Agrokhola, Bangladesh from May to December 1979.

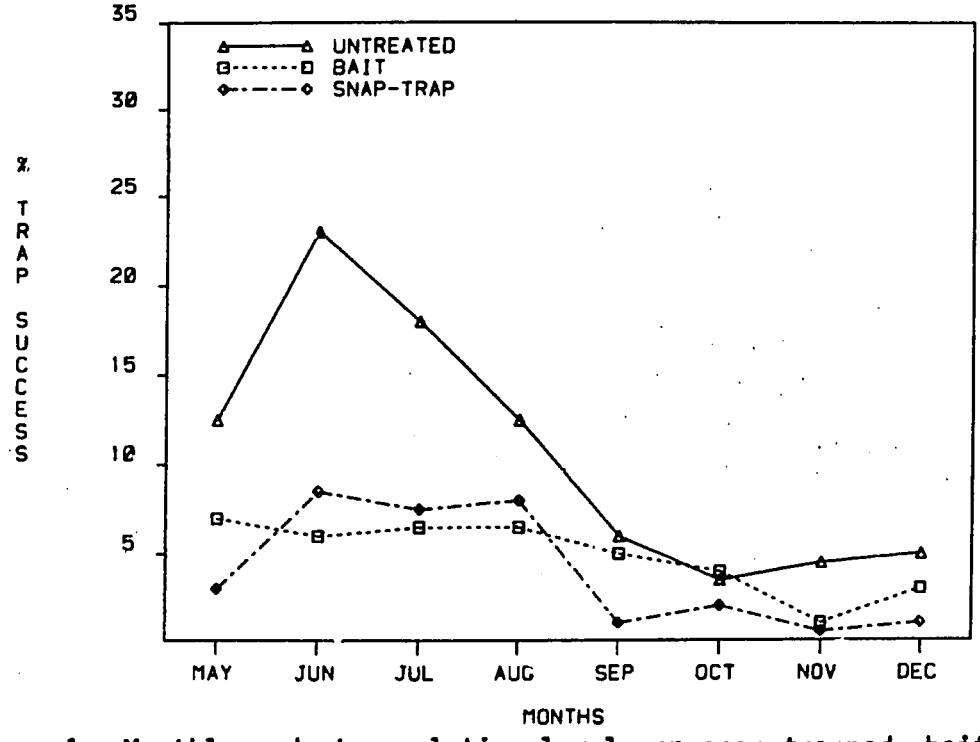


Figure 4. Monthly rodent population levels on snap-trapped, baited, and untreated islands at Agrokhola, Bangladesh from May to December 1979.

Movements of *Rattus rattus mindanensis* (Mearns) in a Rice Cropland and Freshwater Marsh Revealed by Radio-tracking (From M.S. Thesis, Ibrahim Tovar)

The objectives of this study were to determine the home range and movements of rats between ricefields and adjacent marshland in relation to the growth stages of the rice crop, habitat, and weather conditions. National surveys in the Philippines have shown that ricefields adjacent to uncultivated or marshland habitat have more rat damage than rice crops adjacent to other habitat. This habitat provides optimal food, water, and shelter for ricefield rats (*R. r. mindanensis*). Radiotelemetry was used to follow movements of these rodents during the entire 4-month cropping season.

A 6.3-ha irrigated ricefield in various development stages and bordered by marshland was selected near Bay, Laguna Province. Twenty-three adult ricefield rats were live-trapped, equipped with 5.5-g, 164 MHz radio transmitters and immediately released. Diurnal and nocturnal locations were determined from three observation huts, with AVM Instrument (Model LA-12) receivers and a three-element Yagi antenna. Lunar and weather parameters were noted and a reference transmitter was used to check telemetry equipment and direction-finding capability. Home range was determined by triangulation and the enclosed area was measured by using a compensating polar planimeter.

Rats were tracked for an average of 22 days (range 1-70) and observations were made on 36 days for 249 h. Nine hundred locations were determined from 22 of the 23 radio-equipped rats, an average of about 41 locations/rat. About 35% of the locations were in ricefields, 26% in adjacent marshland, and 22% in fallow paddies (Table 19).

The mean home range for 17 rats for which at least three locations were determined was 1.3 $\pm$ 1.2 (SD) ha (Table 20), but was biased by small numbers of locations ($r = 0.76$). Rats that were observed for at least 1 month generally moved within 1 ha, substantiating the recommended baiting point interval of 50 m for effective sustained baiting. Seventy percent of the locations of radio-equipped rats were found in IR-36 rice compared with 25% found in Malagkit, a traditional variety that covered 39% of the area. Rat damage, however, was similar in each variety--5.2% in IR-36 and 6.5% in Malagkit, and higher in both varieties when planted along the perimeter of the marsh. A sustained baiting program along peripheral areas might be appropriate in rice/marshland areas where rats in the adjacent marshland routinely visit ricefields.

Table 19. Habitat preference of 22 radio-equipped rats from 769 measured locations in Laguna Province, Philippines.

Habitat component	Locations No.	Locations %	Study area component Ha	Study area component %
Study site				
Rice paddies[a]	272	35.4	3.71	44.7
Marshy paddies	84	10.9	0.56	6.7
Fallow paddies	168	21.8	1.34	16.1
Fish ponds	42	5.5	0.69	8.3
Adjacent marsh[b]	203	26.4	2.00	24.1

[a] All crop stages.
[b] Estimate of the immediate area bordering the riceland.

Table 20. Home range size, locations, and observation period of 17 radio-equipped R. r. mindanensis, Laguna Province, Philippines; July-October 1981.

Rat no.	Sex	No. locations	Home range size (ha)	No. days Observed	No. days Observation period
12A	M	184	4.2	24	60
11A	M	178	3.0	24	70
1A	M	105	1.2	10	24
8B	M	46	3.9	8	16
10A	M	36	1.3	10	17
11C	M	33	1.2	8	15
8A	M	32	0.5	4	10
1B	M	27	1.5	7	18
8D	F	27	1.6	9	15
6	M	18	0.4	3	6
2D	M	13	0.8	2	6
7	F	12	0.9	4	5
2B	M	10	0.6	4	8
9A	M	9	0.5	1	6
2C	F	5	0.3	8	26
10A	M	5	0.2	2	5
9B	M	3	0.4	2	5
Mean			1.3		

The Rodent Species in Philippine Port Zones (From M.S. Thesis, Marcela M. Eugenio)

A survey of the rodent species in selected Philippine port zones was undertaken to determine if any new introductions of exotic species have occurred into the country and to determine the present distribution of R. argentiventer in the Philippines. The port zones selected for the survey were South and North Ports of Manila, Ports of Batangas, Mindoro, Iloilo, Cebu, Davao, and Zamboanga. Three hundred snap traps were baited with roasted coconut meat and randomly set for 3 consecutive nights in each port for a total of 900 trap nights. All ports were retrapped 1-1/2 months after the first trapping.

The rodent species collected during the survey were R. norvegicus, R. r. mindanensis, M. musculus, R. exulans, and R. argentiventer. R. argentiventer was only trapped in ports located on Mindanao and Mindoro islands. R. rattus was common to all ports and made up 78.6% of the total. No new species were found at any port despite conditions at several ports that would provide easy access for new species to enter the country. The results of the study will serve as basis for preparing specific rules and regulations to prevent the introduction of exotic rodent pest species through vessels coming from foreign countries and to prevent the further spread of R. argentiventer through interisland vessels.

Bait Consumption From Different Size Containers

The purpose of this trial was to determine if the feeding space of a bait container affects consumption rates. Three different sizes (5.1, 10.2, and 15.2 cm diameter) of plastic tube, cut to simulate the traditionally used bamboo tube bait container, were compared (Table 21). Rice shorts were used for bait. Ricefield rats (R. r. mindanensis) consumed much more bait from the 10.2- and 15.2-cm containers than from the 5.1-cm container, indicating the importance of selecting bait containers that are attractive to the pest species to enhance the effectiveness of control programs. Good bait containers must also protect the bait from rain and consumption by nontarget species.

Table 21. Consumption of rice shorts by R. r. mindanensis from different size bait containers.

Bait container diameter (cm)	$\bar{x}$ rice consumption (g/night/rat)		
	Trial 1	Trial 2	Trial 3
5.1	1.9	2.9	2.4
10.2	5.5	9.2	7.3
15.2	10.0	6.0	8.0

Behavior of Nectar-feeding and Fruit-eating Bats

The objective of this study was to determine relative population levels and frequency of return to a banana grove of *Rousettus amplexicaudatus* and *Cynopterus brachyotis*. *R. amplexicaudatus* is a nectar-feeding bat that, in the process of feeding during the flowering stage, punctures and scratches commercial bananas and, thereby, reduces their quality and exportability. Very little is known about this species and much less about how to reduce their damage.

One mist-net was positioned about 1.5 m above ground prior to sunset in a small banana grove near Masapang, Laguna Province between January and May (Fig. 5). Through May, 27 *R. amplexicaudatus* and 86 *C. brachyotis* were banded and released. During this period only three bats, all *C. brachyotis*, were recaptured. Bats were apparently attracted to nearby fruiting Chico trees (*Achras sapota*).

Nectar-feeding bats seemingly do not frequent a specific area. They seem to move throughout a wide area and visit the most attractive nectar-producing plants. The greatest number of *R. amplexicaudatus* captured in a mist-net was during the flowering of the first two banana hands. Radiotelemetry could be used to delineate the specific movement patterns and possibly locate diurnal roosting sites so that management strategies around commercial plantations could be formulated.

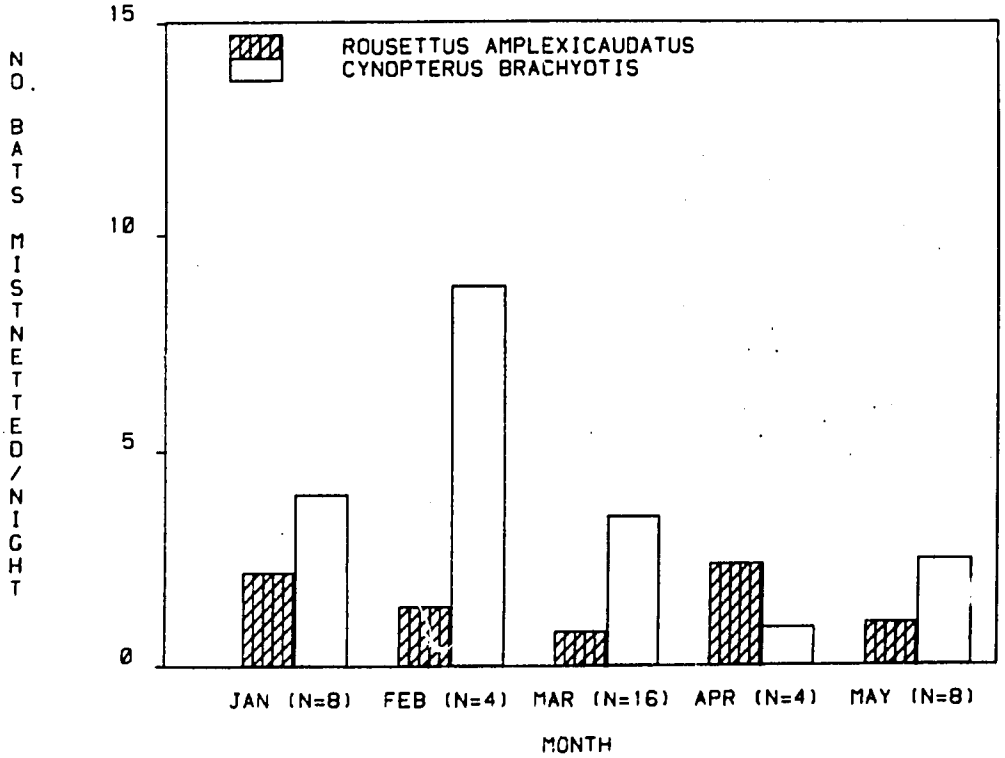


Figure 5. Number of bats mist-netted per night in a banana grove in Masapang, Laguna Province.

Chemical Repellents Reduce Bird Damage to Sorghum

Two sites of ripening sorghum were selected for comparing the repellency of methiocarb and methiocarb/wattle tannin to European tree sparrows (*Passer montanus*) and nutmeg mannikins (*Lonchura punctulata*). The sites contained a mixture of sorghum varieties and maturation stages, and had 50-100 birds in the area damaging sorghum grain. Most of the sorghum was 3-6 weeks from harvest. The sites, which ranged in area between 120 m^2 and 300 m^2, were on the International Rice Research Institute (IRRI) farm and the University of the Philippines at Los Baños experimental farm. The stalks of undamaged heads were marked with colored, plastic tape. At the time of application, these heads were scored as attacked or unattacked at weekly intervals until harvest. Final results were based on the weight of these heads compared with the weight of undamaged heads and visual estimates of the percent damage in the fields. Birds were identified and counted by flushing them from the fields during their morning and afternoon feeding periods. Some birds were captured and their crop contents analyzed. Searches for dead birds were made after each application.

Both methiocarb and methiocarb/wattle tannin gave comparable protection to undamaged sorghum and prevented additional bird damage to previously damaged sorghum. On the IRRI trial site, individual heads treated with the 0.5% methiocarb/1.0% wattle tannin formulation had less damage (<2%) than either untreated heads (28%) or heads treated only with methiocarb (12.5%) (Fig. 6). For the previously damaged heads, those treated with methiocarb/wattle tannin received only 15% more damage during maturation whereas those sprayed with methiocarb received 44% (Table 22).

Table 22. Average percent bird damage to ripening sorghum before and after application of 1.0% methiocarb or 0.5% methiocarb/1.0% wattle tannin at research fields of IRRI in Los Baños, Philippines, March and April 1982.

Treatment	% damage		
	Pretreatment	Posttreatment	Difference
Methiocarb	37	81	44
Methiocarb/wattle tannin	40	55	15
Untreated	47	68	21

In the trial at the University of the Philippines at Los Baños, entire plots in two replicates were sprayed with the repellent chemicals. Treatments were compared with both undamaged heads

Several species of mannikins (Lonchura spp.) damage ripening sorghum in Asia.

Tracking tiles are used to obtain activity indices in studies of rodent populations and in control evaluation.

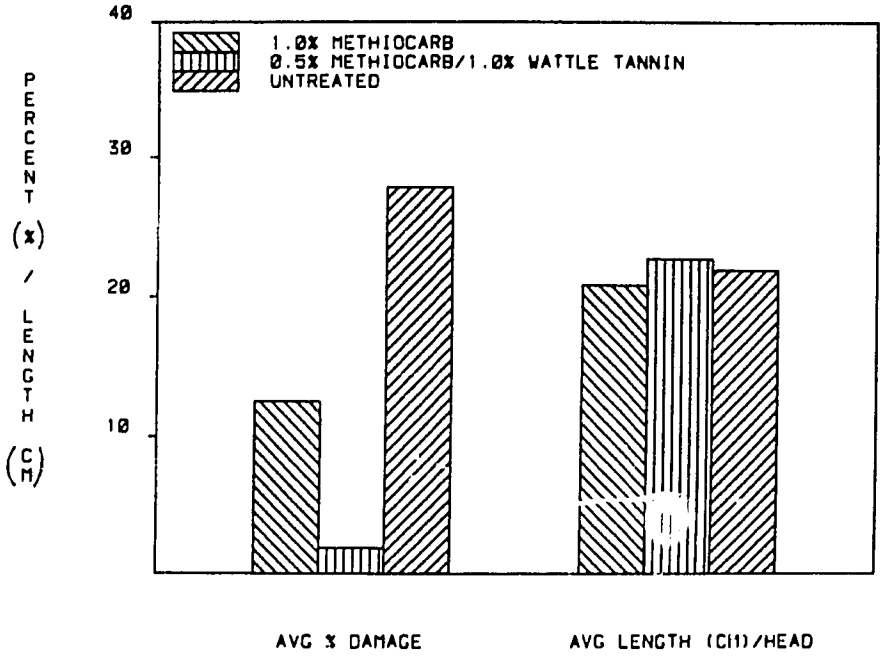


Figure 6. Average length of and percent bird damage at harvest (April 2) to 75 initially undamaged sorghum heads/plot treated with chemical repellents at research fields of the International Rice Research Institute in Los Baños, Philippines during 1982.

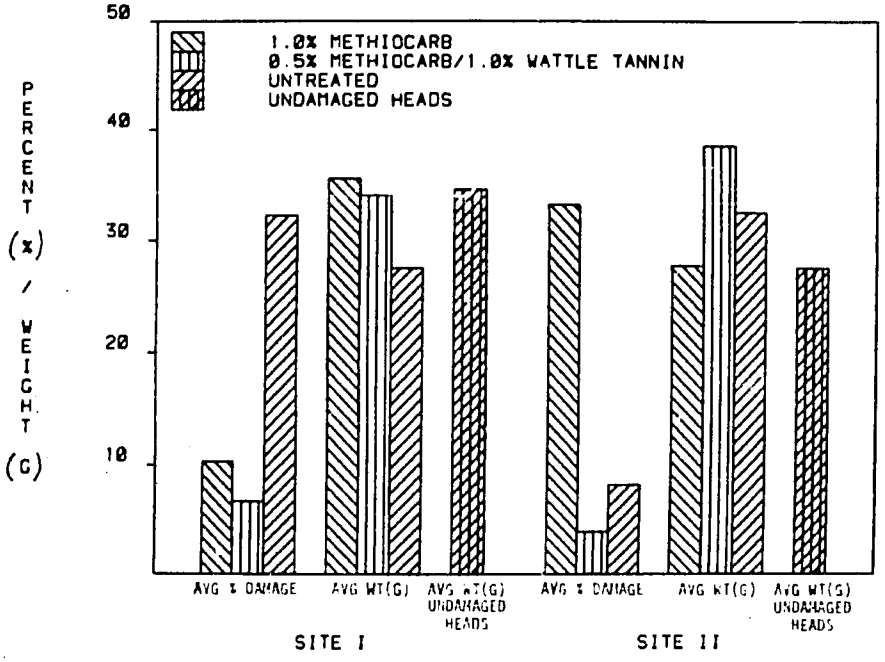


Figure 7. Average weight of and percent bird damage at harvest (April 6) to ripening sorghum at two sites in research fields of the University of the Philippines at Los Baños, Philippines during 1982.

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(which had been covered at the time of application) and untreated heads. The methiocarb/tannin combination reduced damage in both replicates, whereas methiocarb applied alone was effective in only one. About 200 birds, primarily Passer montanus, were feeding daily in the study areas.

At one trial site, the plots treated with methiocarb and methiocarb/wattle tannin again received less damage and weighed more than those left untreated (Fig. 7). At the second site, the plots sprayed with the methiocarb/wattle tannin formulation also sustained less damage than the untreated plot. However, the plot sprayed with methiocarb sustained more damage than the untreated plot, presumably due to its position adjacent to a cover. These kinds of inconsistent results have plagued many studies evaluating field applications of methiocarb. It is hoped that a methiocarb sensory cue formulation offering both primary and secondary repellency characteristics can avert this problem.

Although more field studies are needed before the methiocarb/wattle tannin combination can be recommended for widespread use, our initial studies indicate that it shows promise for economically protecting ripening cereals from birds. The addition of a cue which is detectable by the olfactory, visual, or tactile senses of a bird seems to enhance the effect of methiocarb. By finding ways to lower the costs of chemical repellents without losing efficacy, and employing economical field application techniques, farmers in developing countries may soon be able to realistically consider using repellents in particular situations to protect their crops from birds.

Rat Reinvasion of Coconut Plantations Following Termination of Crown Baiting

Preliminary data from Bagabag, Nueva Viscaya Province has indicated that gradual increase in rat-damaged coconuts occurs after crown baiting programs are terminated. The purpose of the present study was to verify this damage pattern.

Three plots near Calauan, Laguna Province were studied for 11 months. Ten percent of the trees in two plots previously had been crown baited with 0.025% warfarin in rice shorts. Rat activity was determined at the ground level with tracking tiles, and fallen nuts were examined for rat damage. No baiting with rodenticides occurred after December 1981 and visits were made in January, April, June, August, and November 1982.

The untreated plot (Plot 3) showed the cyclical nature of rat-damaged nuts in nonbaited coconut groves (Fig. 8). The number of rat-damaged nuts in Plot 1 gradually increased to the number in the

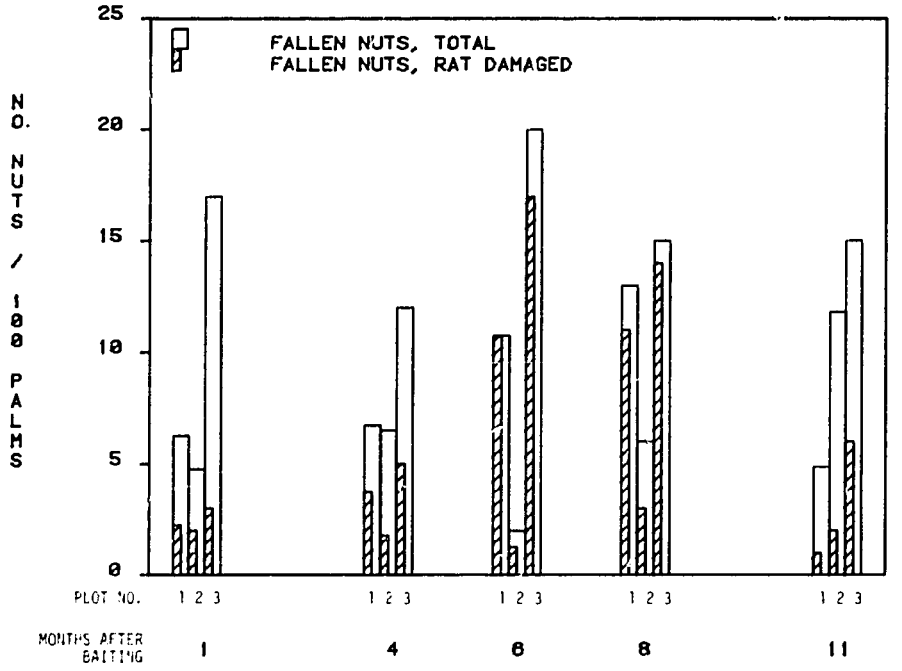

Figure 8. Total number of fallen and damaged coconuts in two plots (No. 1 and No. 2) that previously had been crown-baited with anticoagulant rodenticides and in a third plot (No. 3) that had not been baited in the Philippines.

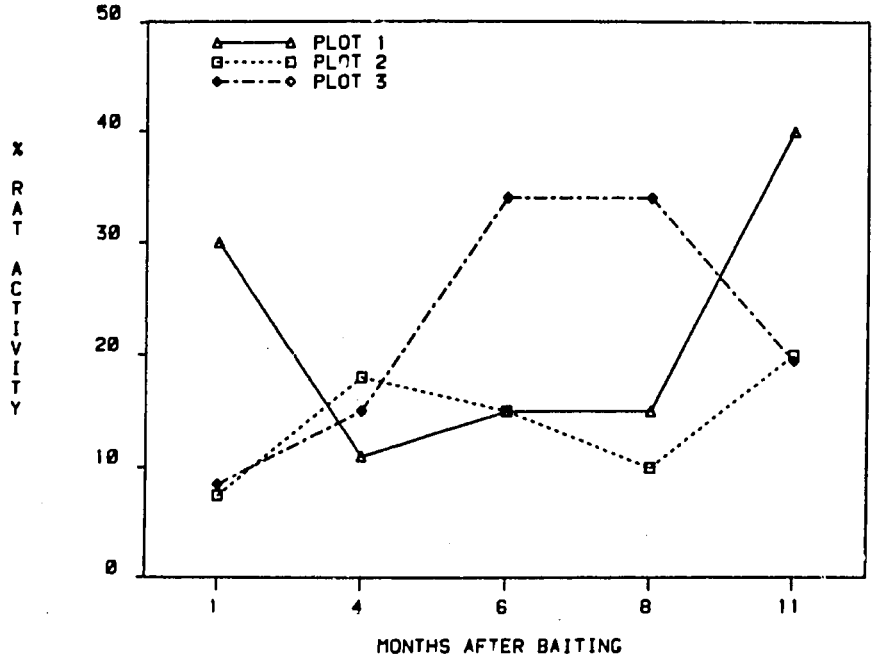

Figure 9. Percent rat activity in two plots (No. 1 and No. 2) that previously had been crown-baited with anticoagulant rodenticides and in a third plot (No. 3) that had not been baited in the Philippines.

untreated plot within 8 months (by August) after baiting was stopped. Rat-damaged nuts in Plot 2, however, did not increase, even after 11 months despite normal rat activity (Fig. 9). Neither Plot 1 nor Plot 2 approached the monthly pretreatment damage counts of more than 30 rat-damaged coconuts per 100 palms.

The results indicate rats slowly reinvade the crowns and damage maturing nuts after long-term crown baiting programs cease. In these control operations, skipping a month of baiting would probably not result in rapid increases in damage levels. Thus, it seems that coconuts may be a secondary food item, with other food items being used before they climb and gnaw on the green nuts. Baiting during the early months of the crown baiting program, however, seems to be critical for the selective removal of those rats that climb.

Cooperation With National and International Organizations

During 1982, NCPC/DWRC project personnel continued to cooperate with a variety of national and international organizations in both research and training activities. An FAO Project in Burma sent two Research Officers of the Agricultural Corporation, U Ye Nyunt and U Kyaw Myint, to NCPC for training. These individuals are involved with agricultural extension services in rodent control and high-yielding rice varieties. Their 3-month training program at NCPC included rodent identification, pest management principles, laboratory and field research, and training of crop protection personnel.

Cooperative studies were initiated this year at Kiangan, Ifugao, with the Philippine Bureau of Forest Development, Ministry of Natural Resources. The area has a history of rodent damage to transplanted seedlings of Hawaiian giant ipil-ipil (*Leucaena leucocephala*) trees. The Vexar plastic mesh tube, which has been successful in reducing mammal damage to pine seedlings in the United States, was ineffective in reducing this damage. Baiting with rodenticides still seems to be the most cost-effective method available.

Cooperative studies were begun with Ze Ya, a Burmese Department of Agriculture Junior Research Officer, as part of a 1-year special nondegree training program in rodent control with IRRI. A study of the population dynamics of rats in 15 rice plots located in the IRRI experimental farm area was completed, and a second study of burrow treatments using gas cartridges was initiated. Technical assistance also was provided to Paciencia Milan of the Department of Plant Protection at Visayas State College of Agriculture (VISCA), a Ph.D. candidate at Bowling Green State University, to study rodents in coconuts. She is evaluating rodent control methods in Leyte Province.

Two sessions were held with the Team Leader and staff of the German Technical Assistance (GTZ) program. Information was exchanged on project activities and areas for cooperative sponsorship in crop protection training were identified.

The Project, through NCPC, cooperated with the Bureau of Plant Industry (BPI) and the Philippine Coconut Authority (PCA) by contributing to a series "Philippine Recommends for Rodent Control" to be published by the Philippine Council for Agriculture and Resources Research and Development (PCARRD). This publication will provide administrators, research personnel, and students with a concise summary of current rodent control technology available for planning or teaching/training throughout the Philippines.

Personnel and Training

Eighty-one individuals representing many Asian countries received vertebrate pest training during 1982 (Table 23). In addition, a rodent biology textbook, edited by NCPC project counterpart personnel, will be published. The textbook will include chapters on rodent biology, behavior, and management. When completed, it will serve as a reference for future training.

Table 23. Summary of vertebrate pest control training in the Philippines during 1982.[a]

Sponsoring agency	No. individuals	Profession	Representing country	Man-days[b]	Length of training
IRRI	47	Research	Bangladesh India Indonesia Malaysia Sri Lanka Thailand Vietnam Philippines	20	3 months
IRRI	32	Research	Many tropical countries	2	1 day
FAO	2	Research and extension	Burma	60	3 months

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

[b] Time spent by project personnel and NCPC counterparts in training students.

Four individuals, one Filipino, two Bangladeshi, and one Venezuelan, were enrolled at the University of the Philippines at Los Banos and completed graduate level training in vertebrate pest management. One Burmese is on a 1-year research sabbatical at IRRI and is conducting his rodent research in rice under the direction of project personnel. In addition, one Filipino graduate student is conducting thesis work in Leyte Province and four others, pursuing doctoral degrees in vertebrate pest management, are enrolled in the U.S. at Michigan State University, Bowling Green State University, and North Carolina State University.

Twenty-five individuals graduated from the 10-month diploma course for crop protection specialists at UPLB in April 1982, and another group of 17 students from Philippine Agricultural Programs, primarily Ministry of Agriculture, including two international students started in June.

During 1982, DWRC staff traveled in Asia, Caribbean, Latin America, and Europe 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 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 174 man-days in the following countries:

Bangladesh	Dominican Republic	Costa Rica	Finland
Pakistan	Haiti	Ecuador	Italy
Philippines		Peru	United Kingdom

Travel dates, persons involved, countries visited, and the purpose of each trip are outlined briefly in Table 24. Detailed information is contained in individual trip reports on file at the Denver Wildlife Research Center, Section of International Programs.

AFRICA

Mass-marking Quelea With Fluorescent Particles

Numerous situations exist in Africa in which a better knowledge of the local and seasonal movements of red-billed quelea (*Quelea quelea*) and other ploceid weavers could increase the efficiency of crop protection operations. A study was planned to delineate the movements of a population of quelea in Kenya and Tanzania. The technique of aerially applied fluorescent particle markers was used to determine if birds roosting in the Tsavo National Park, Kenya during January move to Tanzania to breed in March, and if those birds which bred in Tsavo in March move to Tanzania to renest in May. The study, which was postponed until 1983, will be a cooperative venture between DWRC and FAO.

The success of marking techniques developed for use in Africa led to trials in the United States to mark red-winged blackbirds (*Agelaius phoeniceus*) and follow their movements. In mid-March, the first large-scale operational use in the U.S. was successfully conducted in northwestern Missouri. Objectives of the spray operation were to determine the seasonal movements of red-winged blackbirds as they relate to fall sunflower damage in North and South Dakota and Minnesota, to map the overall distribution of red-winged blackbirds

Table 24. International travel for technical assistance projects by AID/USFWS-DWRC personnel during 1982.

Date	Name	Location	Purpose of Visit
11-26 Jan	R. L. Bruggers	Dominican Republic	Assist counterpart personnel in bird damage control research.
9-31 Mar	R. L. Bruggers	Philippines, Pakistan	Philippines: Assist NCPC-USAID/DWRC project personnel in crop protection studies using chemical repellents. Pakistan: Meet with USAID/Pakistan and Government of Pakistan officials on developing a program of controlling bird bird pests to agricultural crops, particularly sunflowers.
3-22 May	J. F. Besser	Pakistan	Survey vertebrate pest problems in oilseed crops at the request of USAID/Pakistan.
12-20 May	J. W. De Grazio, J. O. Keith	Haiti, Dominican Republic	Review and evaluate project.
22 Jun-8 Jul	J. W. De Grazio	Peru	As part of a team of crop protection specialists requested by USAID/Peru, develop a comprehensive plan for integrated crop protection to include proposals for the establishment of linkages between government, private sector, and university and research groups, covering various ecological zones and major crops affected for each region of Peru. Mr. De Grazio functioned as the vertebrate pest control specialist. Other specialties addressed weeds, insects, and economics.

Table 24 (cont'd)

Date	Name	Location	Purpose of Visit
29 Jun-2 Aug	J. O. Keith	Costa Rica, Ecuador	Costa Rica: Advise Government of Costa Rica on pesticide/wildlife studies and discuss problems caused by vertebrate pests in agriculture. Ecuador: Assist the Charles Darwin Research Station and the National Park Service in assessments of the effects and management needs of feral animals on the Galapagos Islands.
13-24 Jul	G. C. Mitchell	Haiti	Ensure continuity of project and seek funds from USAID/Haiti for continuation of project.
15-20 Aug	J. E. Brooks	Finland	Present paper at the Third International Theriological Congress in Helsinki.
22-28 Aug	J. O. Keith	Haiti	Prepare final agreements with USAID/Haiti on funding and objectives for last year of project. Consult with counterpart staff on work program through September.
16 Nov-16 Dec	R. L. Bruggers	Italy, Bangladesh, Pakistan	Italy: Discuss cooperative work on quelea publication with FAO personnel. Bangladesh: Conduct bird damage control studies. Pakistan: Discuss cooperative bird control work with USAID/Pakistan and Government of Pakistan officials.

in the northcentral United States and Canada as they dispersed from the marking sites, and to evaluate the operational use, practicality, and durability of the markers for blackbirds.

Two cattail roosting sites, located near Squaw Creek National Wildlife Refuge, containing an estimated 15 million red-winged blackbirds, were sprayed by helicopter on two separate evenings, each with a different colored marker. The marker, a fluorescent orange resin particle visible only under long-wave, ultra-violet light, was formulated in diesel fuel and boiled linseed oil. About 9 million blackbirds were marked.

In May and June, numerous cooperators from federal, state, and Canadian wildlife agencies in 12 states and 4 provinces collected territorial male red-winged blackbirds and mailed the wings and tail feathers to DWRC for examination. More than 5,000 samples were received. By early October, about 3,000 samples were examined with approximately 23% showing markers. Marked birds were recovered from as far north as Grand Prairie, Alberta, central Manitoba, and western Ontario, Canada. All 12 states had a scattering of marked birds with North and South Dakota being the focal point.

VERTEBRATE PEST PROBLEM DEFINITION

During 1982, assistance from USAID was requested by the following organizations and countries: The Ministry of Agriculture (MOA) --Department of Biological Studies of Fish and Wildlife and the National Museum of Costa Rica to discuss pesticide-wildlife relationships and vertebrate pest problems in agriculture; the Charles Darwin Research Station and National Park Service of Ecuador to assess the effects and management needs of feral animals on natural animal populations; USAID and the Pakistan Agricultural Research Council of the MOA and the Ghee Corporation to discuss both short- and long-term technical assistance to manage vertebrate pest damage in agriculture, primarily bird pests in oilseed crops; USAID and the Government of Peru to develop a document on Integrated Pest Management in Peru under the sponsorship of the Consortium for International Crop Protection. Assistance of many individuals in all of these countries contributed to the success of these missions. Cost of travel to Costa Rica and Ecuador were paid by the World Wildlife Fund and the National University of Costa Rica.

Costa Rica

In Costa Rica, biologists of the two organizations are cooperating in several areas of research. They are investigating ways to manage wildlife for harvest to provide an additional food source. Studies are underway to perfect methods for reducing damage to crops by

several species of wildlife. Other work is directed at establishing and managing National Parks, assessing and reducing environmental pollution, and protecting and managing rare and endangered species.

There is concern about the use of pesticides in Costa Rica and their possible effects on wildlife. The intent of the group is to study reproduction in brown pelicans (Pelecanus occidentalis) to obtain an indication of pesticide contamination and its effects. The brown pelican was selected for study because other research in the United States and Mexico has shown the species to be susceptible to environmental pesticide contamination.

Coyotes (Canis latrens), which have greatly increased their range in Costa Rica in recent years, cause losses to chickens and calves, and also damage agricultural crops. Vampire bats (Desmodus rotundus) cause losses to the cattle industry. Grackles (Quiscalus and Cassidix spp.) damage rice seedlings and sorghum, whereas brown jays (Psilorhinus mexicanus) and parakeets (Aratinga spp.) damage corn. Tree-ducks (Dendrocygna spp.) are a major problem in rice and up to 10,000 have been killed in a season with aldrin and endrin. Pocket gophers (Geomys spp.) cause serious losses to a variety of sustenance crops on small farms, and several species of rats are a problem in sugarcane. A serious problem with feral animals exists on Isla del Coco, but the needs there have not been clearly identified. Possibilities of cooperation between the Department of Biological Studies of Fish and Wildlife and the DWRC were discussed.

Ecuador

On the Galapagos Islands, DWRC cooperated with the Charles Darwin Research Station, the National Park Service, and the New Zealand Wildlife Service to design a program to reduce the impact of feral animals on the breeding colony of dark-rumped petrels (Pterodroma phaeopygia phaeopygia) on Isla Floreana, to assess possibilities for controlling feral animals throughout the Galapagos Islands, and to consider how DWRC could contribute to this program.

Petrel colonies were visited on Islas Floreana, Santa Cruz, and Santiago. On another island, Isla Pinzon, rats destroy 100% of the tortoise hatchlings each year, and ways to reduce these losses are needed. These problems have existed for many years. The Charles Darwin Research Station and the National Park Service are extremely concerned about the impact of introduced mammals. Much has been accomplished, but the more difficult task of either eradicating or managing the large populations of feral animals remain to be done. A major program is needed to address these problems, and the assistance of wildlife managers experienced in population control will be needed.

Peru

During 1982, AID/Peru, acting through AID/Washington, contracted the Consortium for International Crop Protection (CICP) to bring a four-member team to focus on problems facing Peruvian agriculture. A DWRC biologist participated and assisted in developing a comprehensive Integrated Crop Protection (ICP) proposal for Peru. The team addressed such pest problems as weeds, insects, diseases, viruses, nematodes, and vertebrates that affect food crops such as rice, corn, potatoes, grain legumes, and small grains.

The ICP planning team was charged specifically to define the nature and magnitude of problems to Peruvian food crops; to assess the human, facility, equipment, and supply resources needed to carry out a national ICP program; to identify resources needed to fulfill ICP needs, and to determine if they can be met by contracts between the Government of Peru and various funding agencies (AID, Interamerican Development Bank, Food and Agriculture Organization of the United Nations, and World Bank); and then to develop a workable strategy for managing and implementing a comprehensive program. The document with accompanying budget, was completed and submitted to CICP for review and distribution to AID/Peru, AID/Washington, and the Government of Peru.

Pakistan

Pakistan is deficient in edible oil supplies and imports about 50% of its requirement annually. A campaign exists to increase oilseed production with rape and mustard seed, groundnuts, safflower, soybean, and sunflower seed. Sunflower seed production is a major component of the program; although only 4,856 ha were planned for cultivation in 1978-79, 40,469 ha are envisioned for 1984-85. A major constraint to increasing sunflower production is damage by bird pests, particularly rose-ringed parakeets (*Psittacula krameri*) which feed on the crop during the ripening stages. A recent survey of parakeet damage to sunflowers in the provinces of Punjab and Sind indicate average losses of 14-15% of the crop, with damage as high as 71%. These kinds of losses present sunflower growers with problems previously not experienced and may prevent many farmers from even trying some of the new, promising oilseed crops. Other oilseed crops, including groundnuts, safflower, mustard, and soybeans, are damaged by a variety of vertebrate pests such as crows, doves, pigeons, sparrows, wild boars, numerous rodents, and porcupines.

Nonoilseed crops such as corn, rice, grain sorghum, millet, wheat, guava, mango, lentil, and a variety of fruits are damaged by parakeets, weavers, starlings, doves, pigeons, sparrows, mynas, and bulbuls. Birds are reportedly responsible for estimated annual losses

In many countries of the world, traditional noise-making devices, such as whip-cracking, are used to frighten birds from agricultural fields. (Photo courtesy of W. D. Fitzwater.)

Bird damage to sunflowers is a concern of growers and agricultural researchers in many countries, including India, Pakistan, and Bangladesh.

to ripening cereal crops of $31.4 million and are limiting efforts by the Government of Pakistan (GOP) to achieve self-sufficiency in wheat and rice production.

The GOP also is concerned about present losses to stored grains caused by rodents and birds (estimated at 15-20%) and the possible losses of stored oilseed. Damage by birds, primarily sparrows, doves, and pigeons, to grains at threshing grounds and storage areas are estimated at $500,000 annually.

Because of this concern, GOP officials charged with increasing sunflower production, through USAID/Pakistan, requested immediate short-term assistance in terms of actual field trials and long-term assistance to formulate a comprehensive program of pest management in sunflowers. A considerable amount of information both in terms of crop protection trials and problem definition has been accumulated by researchers of the Vertebrate Pest Control Laboratory (VPCL) in MOA.

DWRC fieldwork in Pakistan during 1982 included observations on parakeet damage in fields and the use of traps and Avitrol. Parakeets seemingly are attracted to the taller sunflower heads, particularly in the border rows of sunflower plots (Table 25).

Table 25. Distribution of parakeet damage to sunflower heads in fields at Khokar Farm, Multan District, Pakistan; May 1982.

Row[a]	Location	No. heads Examined	No. heads Damaged	% damaged
1	Edge	124	40	32.3
4	Intermediate	126	19	15.1
10	Center	148	12	8.1
1	Edge	141	63	44.7
10	Center	154	3	1.9
Total/avg				
1	Edge	265	103	38.9
10	Center	302	15	5.9

[a] From outer edge bordering tilled field.

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At present, no really effective crop protection technique has been developed. Paratraps (modified Australian crow traps) have reportedly given some success, but two placed in sunflowers near Islamabad by VPCL personnel trapped only 15 and 3 rose-ringed parakeets, respectively. All 15 birds in the first trap lacked the rose collar, indicating either immatures or perhaps females. If they were immature, the use of Paratraps for damage control may be limited because experience with trapping other species has shown that immature birds are the most susceptible to decoy traps.

The only chemical that has proved useful in combating bird damage to ripening sunflowers in the United States has been a chemical frightening agent, 4-Aminopyridine (4-AP). Migratory blackbird species cause most U.S. bird problems and fields can be protected by broadcasting baits on the ground. However, parakeets seldom, if ever, accept ground baits, and initial attempts to combat orange-fronted parakeets (Aratinga canicularis) in ripening crops in Nicaragua and monk parakeets (Myiopsitta monachus) in Uruguay with chemical agents have largely been unsuccessful. Some success in affecting parakeets was attained by spraying partially husked ears of corn to protect ripening cornfields, but fewer were affected by spraying partially damaged sunflower heads with 4-AP, because the birds hulled the sprayed seeds and fed on the untreated kernel inside the hull.

A method of circumventing this problem was devised--immersing sunflower seeds for 48 h in an aqueous solution of 4-AP. This technique was tried at a 1.6-ha farm that was being visited by about 100 parakeets. After birds went to roost, about one-tenth of the heads in a 0.04-ha isolated area where birds had just begun feeding were baited by placing about 10 seeds in the bowl of about every tenth head. In addition, 100 seeds were placed in five heads that were cut and impaled on stalks. When the planting was again visited, no birds were in the treated plot and only nine birds were seen in the entire field. Many seeds from one of the impaled heads had been consumed but no dead birds were found. Bird scarers felt that the baiting was effective, but no affected birds were seen. Whether the baiting was responsible for the decrease in bird numbers is open to question. Additional work on baiting methods is needed.

This work indicated that many parakeets return to previously damaged heads. They prefer tall heads in areas with low plant population; they will accept some treated seeds placed in impaled heads; and they may also accept fruit baits. Plans are being developed for additional cooperative research assistance to GOP and the VPCL.

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 (VPM), the Department of Fishery and Wildlife Biology, Colorado State University (CSU), 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 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 philosophy 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
Department of Fishery and Wildlife Biology
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.

Developing Sorghums That are Less Susceptible to Bird Damage

Sorghum varieties that have been categorized as Group II sorghums have genetic tannin characteristics that reduce their susceptibility to bird damage during the immature stages, but yet mature with high nutritional qualities. Through collaborative work between DWRC and the University of Arkansas, three Group II sorghum varieties (KS-57 x AR 3009, AR 3011, and KS-57 x AR 3011) have been identified.

The University of Arkansas, under contract with DWRC, also has conducted biochemical studies to compare the tannin polymerization mechanism in Group II and Group III sorghums. Group III sorghums produce seed having a testa and retain an unacceptable level of tannin protein-binding activity in the mature (ripened) stage. On the basis of tannin polymerization, Group II sorghums have been separated into two classes: those with a purple testa and without brown pigment (Group IIa) and those with both a purple testa and brown pigment (Group IIb). Group IIa varieties had greater tannin activity in the immature stages than Group IIb varieties. Both groups were higher than Group III and equal to Group I in polyphenol oxidase activity in the light-dough and mature grain. Similar group comparisons existed for assays of Biuret Protein, in-vitro dry matter digestibility and true digestion of dry matter by chicks. Additional nutritional and bird susceptibility studies are planned for 1983.

Bird Repellents and Batesian Mimicry

Food aversion learning (learned avoidance of a food associated with postingestional sickness) is regarded as the theoretical basis of bird repellency. Although that basis seems sound, the broader concept of Batesian mimicry may be more useful in that it (1) incorporates food aversion learning as a fundamental mechanism by which a predator learns to avoid food, (2) incorporates other mechanisms such as observational learning (vicarious learning that occurs when one animal watches the activities of another), and (3) is derived from evolutionary theory based on the population concept. It, therefore, provides a basis for managing pest birds at the population rather than at the individual level.

It has been demonstrated that red-winged blackbirds (*Agelaius phoeniceus*) and starlings (*Sturnus vulgaris*) showed food preference and aversion learning when untreated food was paired with a distinctive color cue. It also has been shown that preferences and aversions could be acquired via observational learning. For example, interspecific observational learning did occur when

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untrained grackles learned food aversion by observing treated red-winged blackbirds and vice versa. Red-winged blackbirds that had learned to prefer a food paired with a distinctive color came to avoid it when exposed to a bird that had learned to avoid the food-color combination. Finally, red-winged blackbirds and starlings will learn to avoid a food-color combination when conditioning merely involves pairing a food-color combination with an unpalatable taste such as dimethyl anthranilate.

The findings warrant additional study in both laboratory and field settings, which could lead to improved, more economical use of methiocarb as a bird repellent. For example, the addition of color cues to methiocarb might improve its effectivenss. Birds may learn to avoid the treated crop either by ingesting treated crop and becoming sick, or by observing the effects of ingestion by conspecifics. Also, methiocarb may be less effective if application rates are not uniform and birds encounter different levels in any one field. These concepts will be evaluated in appropriate situations at project field stations during 1983.

Evaluating Taste and Color Additives to Methiocarb to Improve its Repellent Effects on Quelea

Traditional African farmers cannot afford to invest heavily in agricultural chemicals to control damage to cereal grain crops by quelea birds. In many situations, methiocarb has reduced these losses when applied as a repellent at 2-3 kg/ha. However, current costs of this chemical, US $37/kg, preclude its widespread application.

Two less expensive application methods are being evaluated. One procedure involves positioning methiocarb-treated baits or seed heads near the edges of fields to sensitize birds to the chemical, the rest of the field can then be sprayed at lower application rates. The second method involves adding taste or color stimuli to the methiocarb formulation to improve learned repellency which might then be transferred from the baits to the maturing grain. Both methods would, hopefully, increase the effectiveness and reduce the costs of using methiocarb.

Research was initiated comparing the repellency of white, red, blue, green and natural millet seed bait treated with 0.15% methiocarb. Six quelea were exposed to each color group for 2 days, then given two-choice preference tests between millet seed heads treated with both 0.05% methiocarb and one of the respective colors and untreated mixed grain. Quelea were more repelled by seed treated with the white color cue ($\bar{x}$ = 3.33% + 2.73%) than uncolored seed ($\bar{x}$ = 7.49% $\pm$ 4.23%) or seed without methiocarb ($\bar{x}$ = 61.95% $\pm$ 7.45%) (Table 26).

Table 26. Mean ± SD percent preference[a] by quelea given a choice of millet seed heads treated with a color cue vs. mixed grain. Six groups of quelea (n = 6/group) were tested.

Day	White	Red	Blue	Green	No color	No methiocarb or color
1	7.99 ± 1.69	7.48 ± 2.89	6.72 ± 1.29	18.13 ± 18.72	5.49 ± 1.33	45.35 ± 30.60
2	2.63 ± 2.04	12.18 ± 12.92	16.92 ± 19.57	22.02 ± 23.74	5.73 ± 5.75	66.85 ± 9.21
3	0.56 ± .89	6.58 ± 2.81	6.15 ± 5.47	21.18 ± 26.75	9.01 ± 10.17	58.37 ± 12.14
4	6.08 ± 3.47	26.63 ± 22.38	24.79 ± 22.26	21.04 ± 14.02	13.65 ± 20.36	65.55 ± 17.77
5	1.68 ± 1.47	18.39 ± 13.75	8.12 ± 7.13	9.54 ± 16.38	3.50 ± 2.27	60.58 ± 29.74
6	1.16 ± 1.29	30.70 ± 18.03	21.51 ± 23.90	11.21 ± 9.53	9.18 ± 21.12	65.98 ± 23.94
7	1.35 ± 1.60	16.82 ± 8.67	13.06 ± 11.45	5.57 ± 10.56	1.30 ± 1.54	64.95 ± 31.24
8	5.24 ± 4.42	30.33 ± 25.16	26.17 ± 14.71	4.14 ± 6.14	12.06 ± 16.97	67.97 ± 31.48
$\bar{x}$ ± SD	3.33 ± 2.73	18.63 ± 9.72	15.43 ± 8.13	14.10 ± 7.35	7.49 ± 4.23	61.95 ± 7.45

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

In addition, the interaction of a combination of taste (dextrose) and color (red) cues, with or without a baiting procedure, was evaluated. Four groups of quelea (n = 6/group) received either taste and color cues on both bait and millet heads treated with methiocarb (Group A), bait and heads treated with methiocarb but no cues (Group B), millet heads treated with cues and methiocarb but with no bait given (Group C), or millet heads treated only with methiocarb with no bait or cues given (Group D). As in the previous study, mixed grain was provided as an alternate food in preference tests with methiocarb-treated heads. Results are shown in Table 27. The level of methiocarb in baits was 0.15%; the methiocarb level on millet heads was 0.03%. The taste cue was 3.5% (wt/wt) sucrose, and the color cue was Durkee's red food coloring (30 drops/200 g millet).

Table 27. Mean + SD percent preference[a] by four groups of quelea (n = 6/group) for 0.03% methiocarb-treated millet seed heads with mixed grain offered as the alternate choice.

	Treatment group			
Day	A Cues on bait and heads	B No cues but bait given	C Cues on heads but no bait given	D No cues and no bait given
1	22.22 ± 3.24	16.54 ± 2.50	28.32 ± 6.07	22.32 ± 4.77
2	8.32 ± 5.79	13.97 ± 12.80	12.98 ± 4.89	14.28 ± 7.67
3	10.10 ± 9.06	36.46 ± 25.90	22.64 ± 20.62	30.93 ± 21.70
4	11.85 ± 4.63	58.08 ± 35.83	12.29 ± 4.08	31.95 ± 27.21
5	15.53 ± 6.51	39.60 ± 16.23	45.64 ± 26.69	43.20 ± 46.25
6	4.10 ± 1.90	9.50 ± 6.19	5.28 ± 3.41	22.35 ± 22.65
7	8.11 ± 2.38	21.06 ± 25.18	14.82 ± 18.46	33.08 ± 23.76
8	12.30 ± 3.97	34.65 ± 28.23	18.68 ± 20.23	26.00 ± 21.11
$\bar{x}$ ± SD	11.56 ± 5.47	28.73 ± 16.34	20.08 ± 12.46	28.01 ± 8.76

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

The results indicated that (1) baiting leads to the most sustained repellency, but only when the additive cues are used (i.e., Group A vs. Group B comparison), (2) cues without baiting enhance sustained repellency (i.e., Group C vs. Group D comparison), (3) baiting without

cues does not sufficiently sensitize or precondition quelea for enhanced sustained repellency (i.e., Groups B and D showed essentially the same levels of repellency). An implication at the study is that methiocarb repellency can be enhanced by the addition of taste and color cues to bait material. Thus, prebait exposure methods could potentially allow adequate crop protection using economical, reduced methiocarb application levels.

Systematic Assessment of Trigeminally Active Compounds as Bird Repellents

The potential of dimethyl anthranilate for use as a bird repellent in the field, aviary, and laboratory was assessed. The compound seemed to effectively repel red-winged blackbirds, starlings, and gold finches (*Spinus tristis*) from sunflowers and grapes. However, it did not seem to prevent damage to corn. Apparently, dimethyl anthranilate in either a lipophyllic starch powder or as a liquid is equally effective in repelling starlings and red-winged blackbirds in two-choice 60-min tests. Assessment of several anthranilates and comparison of the lipophyllic starch matrix with time-release microencapsulation is planned.

Nest Material as a Means of Toxicant Delivery to Quelea

In Africa, quelea nesting colonies are routinely sprayed with avicides in efforts to protect cereal grain crops. Another method of applying avicides or other control chemicals (such as chemosterilants and antimetabolites) has been investigated that uses the quelea's natural nest weaving behavior to deliver the chemical. The advantages of treating nest material include increased safety for pilots and ground crews, and increased flexibility of application periods during daylight hours.

The lethality of four avicides (fenthion, parathion, Dasanit, Volaton) was tested using the nest material delivery method on groups of male-female pairs (n = 6/group) in individual cages. Dasanit was found to be the most effective avicide with an optimal concentration level of 0.8% applied topically in acetone to 13-cm strands of cotton string. The work was completed when 25 quelea pairs were exposed as a group to 250 strands of the material for 3 successive days in a large aviary cage. Dasanit caused 92% male mortality but only 4% female mortality during the 3-day test. This sex difference was not totally unexpected because males construct nests. However, the technique probably has limited applicability to quelea because of their migratory habits and the difficulty of predicting their exact nesting location. The technique may be more applicable to controlling village weavers (*Ploceus cucullatus*), bird pests in Africa and the Caribbean region, assuming that a suitable avicide is developed and an acceptable nest material is used.

Using Treated Nest Material as a Means of Controlling Lesser Bandicoot Rats (*Bandicota bengalensis*)

The lesser bandicoot rat (*Bandicota bengalensis*) inhabits the rice and wheat growing areas of Bangladesh. This species digs extensive burrow systems, usually damaging 5- to 10-m areas of grain surrounding the burrow openings. Although a number of population reduction methods are available, including rodenticide baiting, burrow fumigants, and trapping, an alternate means of controlling this species could involve the use of rodenticide-treated nest material. Poison-treated clippings could be placed near burrows for caching by female rats during the dry season. An advantage of this rodenticide delivery method is that rats may accept treated nest material even when bait acceptance is poor due to grain hoarding or bait shyness behavior.

In a pilot test, two pairs of *B. bengalensis* established burrows in 1.5 x 3-m enclosures. The rats readily accepted straw and burlap as nest material; cotton appeared to be less preferred. Tests currently are underway using 1.0% zinc phosphide and 0.02% brodifacoum-treated straw/burlap to assess lethality of the method.

Bait-intake Patterns of Rats: A Comparative Study of Select Rodenticides

Numerous studies have shown that rats are not random feeders. Data for albino rats indicate that 60-70% of daily food intake is ingested in 6-12 meals during the nocturnal portion of the circadian cycle. Analyzing feeding patterns offers a novel approach to understanding rodent foraging strategies. Comparative data on foraging behavior of wild rodents should offer insights into ways of improving bait acceptance and lethality, as well as ways of circumventing bait shyness.

A computerized rodent feeding system was developed and tested. This system uses a minicomputer to record minute-by-minute food removal by rats from electronic balances. In addition, several validation and stability tests were conducted. Validation tests of food removal from balances showed that 96-99% were <0.02 g deviant from actual weights. Tests of stability showed that "spontaneous fluctuations" of balance recordings could be eliminated by reprogramming the "change-in-state criterion" used to compare balance shifts from 0.00 to >0.03 g. This 0.03-g value is considered the maximum accuracy of system detections.

Seven continuous days of *ad libitum* food intake measurements were collected for eight male *B. bengalensis*. These data currently are being analyzed to compare food intake differences with Nile rats

Studies of rodenticide toxicity and learned aversion are conducted using the technique of gavaging.

(Arvicanthis niloticus), cotton rats (Sigmodon hispidus), and Norway rats (R. norvegicus). In future studies, bait formulations and schedules will be evaluated for circumventing rodent bait-sampling strategies that interfere with intake of lethal dosages.

Evaluating Taste Aversion in Ricefield Rats (Rattus rattus mindanensis)

Conditioned taste aversion occurs when a rat is dosed with certain drugs shortly after tasting a novel-flavored substance. It is characterized by a sharp reduction in preference for similarly flavored food items. Research to develop conditioned taste aversion into a method for controlling rat damage to crops and stored grain continued in 1982. Previous studies indicated that ricefield rats could be conditioned to avoid saccharin-flavored rice for at least 2-4 weeks after a single exposure to saccharin-flavored lithium chloride (LiCl) bait.

Two pilot studies were conducted to evaluate the problems associated with applying the conditioned taste aversion concept to stored-food protection and to develop a method for measuring LiCl in the blood of the rats after exposure via gavage. The first test evaluated topical applications of either saccharin or LiCl plus saccharin to rice packets as a means of repelling the rats from stored food. Results were negative in both cases; only brief delays in opening the packets were observed after treatment. The second study involved measuring LiCl in the blood of exposed ricefield rats. Results showed that blood levels (ppm) peaked at 20 times the baseline values within 30 min after gavage dosings with 375 mg/kg LiCl. Circulating levels returned to baseline within 72 h postdosing.

These results imply that topical applications of aversive substances to stored food containers will not deter damage and contamination and that other methods of transferring learned aversion to stored commodities must be found.

Developing Silicon Dioxide Gels for Wildlife Management Applications

Silicon dioxide gels are potentially useful in a number of wildlife management applications. Attractant or repellent chemicals can be formulated into gels that will come in contact with pest animals and subsequently will be ingested by grooming. During 1982, studies to determine optimum formulation characteristics (viscosity, stickiness, water resistance, odor, etc.) and techniques were completed. In laboratory studies, white albino rats (R. norvegicus) crossed gel-coated tile as readily as uncoated tile and even ate several different vegetable oil gels without showing any statistically significant preferences.

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Fluorescein--A Potent Short-term Fluorescent Marker for Rodents

Fluorescein disodium salt (acid yellow 73, C.I. 45350, uranine) is a freely soluble fluorescent dye that is used to determine sources of springs and contamination of drinking water, connections between streams and sea, approximate volume of water delivered by a spring, and infiltration of soil with waste water from factories and chemical industrial sites. Because it is inexpensive and readily detectable, fluorescein disodium salt has the potential for extensive application in rodent control programs. It was, therefore, evaluated as a physiological marker in albino rats.

Two groups of five male rats were offered a choice of untreated oatmeal bait and either 0.21% fluorescein or 0.42% fluorescein for 1 night. After the first overnight feeding, three rats were killed from each group and 7 days later, the remaining two rats from each group were killed. Consumption of untreated bait was 13-14 g/rat. Consumption of the fluorescein bait averaged 11.4 g/rat at the 0.21% concentration and 9 g at the 0.42% concentration. Both concentrations marked equally well. Fluorescence was detected externally on the feet, tail, genital area, and around the whiskers. Internally, the stomach and intestines were highly marked. The urine was also highly visible in the urethra and bladder. After 7 days, internal fluorescence ceased, but external fluorescence remained on the feet.

Chemical Analyses for Methiocarb, Organochlorines, and Avitrol

The DWRC chemistry laboratory performs hundreds of chemical analyses annually in support of crop protection studies in the field. Included during 1982 were analyses conducted for USAID studies in the Philippines and Haiti and for cooperative studies with FAO in Africa. Methiocarb-treated sorghum samples from the Philippines were analyzed for methiocarb and its sulfoxide and sulfone metabolites. Measurable amounts were found in the seeds and combined glume and stalk samples at harvest, about 3 weeks after application (Table 28).

Organochlorine analyses were performed on an assortment of bird eggs in support of studies in Haiti. The eggs were analyzed for Lindane, heptachlor, aldrin, heptachlor epoxide, dieldrin, endrin, DDT, DDE, DDD, and Arochlor 1242, 1254, and 1260. Only DDT (<0.1-0.46 ppm) and DDE (<0.1-0.78 ppm) were detected in some of the eggs; other compounds were not detected.

Residue analyses were conducted on ripening wheat and on rice seed in support of two FAO-sponsored studies. In Tanzania, some confusion arose as to the actual application rate--3 kg/ha or 30 kg/ha--in a study evaluating methiocarb as a bird repellent on

ripening wheat by a Tanzanian M.A. candidate at Bowling Green State University. Therefore, the application, collection (immediately after spraying), and analysis procedures used in the Tanzania study for both application rates were duplicated on ripening wheat in North Dakota. The methiocarb residues on the wheat treated at 3 kg active ingredient (a.i.) were comparable (8 ppm on seed, 140 ppm on glume) to those from the wheat treated in Tanzania, whereas residues from the 30-kg a.i. application were considerably greater (Table 28).

Rice samples from an FAO study conducted in the People's Republic of Benin were analyzed for Avitrol. Samples of bait and rice crop reportedly formulated at 0.50% a.i. and 9 kg a.i./ha were found to contain 2.8% and 35 ppm of Avitrol, respectively.

Table 28. Residue levels of methiocarb and its sulfoxide and sulfone metabolites from ripening sorghum and wheat.

Location and crop	Application rate (kg/ha)	Methiocarb	Sulfoxide	Sulfone
Philippines				
Ripening sorghum	3.0			
Seed		3.0-80.0	0.7-9.0	<0.5-3.0
Glume and stalk		98.0-510.0	10.0-160.0	9.0-53.0
North Dakota				
Ripening wheat	3.0			
Seed		6.0	<0.5	ND[a]
Glume and stalk		96.0	5.0	ND
Ripening wheat	30.0			
Seed		32.0	<0.5	ND
Glume and stalk		640.0	13.0	ND

[a] ND = not detected.

Evaluating Experimental Rodenticide M&B 36,892A

In continuing efforts to develop new rodenticides, an acute oral, single-dose chemical that has delayed mortality in rodents was evaluated. The LD50 of M&B 36,892A in male and female wild Norway

rats (Rattus norvegicus) is 50-100 mg/kg and in lesser bandicoot rats (Bandicota bengalensis) about 150 mg/kg for both sexes. The manufacturer of the chemical plans to develop it as a commensal rodenticide in the United States and the United Kingdom. Additional toxicology and environmental hazard evaluations will be conducted to determine its applicability for agricultural field programs.

General Instrumentation Support and Services

Electronics personnel regularly provide service to the Section of International Programs research projects by maintaining electronics equipment, assisting in wildlife tracking studies, constructing radios, applying general electronic measurement techniques, and lecturing at workshops and educational programs. During the past couple years, radios were constructed for studies of rodents in deepwater rice, jackals and rodents in sugarcane, bats in banana plantations, woodpeckers in cacao plantations, and quelea in nesting colonies. In addition, Electronics Section personnel participated in a FAO-sponsored workshop on telemetry at FAO headquarters in Rome, Italy.

Manufacturing Wildlife Tracking Transmitters

A number of research programs require wildlife tracking transmitters smaller than those commercially available. During 1982, considerable effort was expended through funding provided by the Endangered Species Program to develop and improve electronic components necessary to reduce the size and weight of wildlife transmitters. A 1.1-g external radio transmitter was built and field tests are planned for it during 1983. Also, there is the possibility that certain electronic components can be further refined and optimized for this application. This transmitter miniaturization has significance to many areas of wildlife research.

Managing Postharvest Vertebrate Pest Problems in Developing Countries

A food protection project was established at DWRC to coordinate postharvest food loss research activities. This was a new area of research in the AID program for 1982. Although it will take a major effort to identify the location and extent of problems, adapt existing technology, and effectively train nationals to solve their own problems, the research capabilities at DWRC and the existing overseas projects presently working on preharvest loss problems make the extension to postharvest work natural.

Rodents are the principal vertebrate pest in storage situations but birds sometimes are involved. However, very little data on postharvest losses to vertebrate pests have been systematically collected in developing countries, primarily because techniques to assess losses have not been sufficiently developed. It has been reported in India that lesser bandicoot rats (Bandicota bengalensis) will consume enough rice in 1 year to support a human for 11 years. The amount of food contaminated by hair, urine, feces, or ectoparasites of rats is estimated to be ten times greater than that which they consume. Similarly, in the Philippines, birds tear grain sacks and eat and contaminate seed in storage facilities. The National Post Harvest Institute for Research and Extension (NAPHIRE) is studying this problem and making recommendations for alleviating it.

Cooperative studies are planned with Kansas State University's Food and Feed Grain Institute which has been involved in invertebrate postharvest loss problems in cereal grain products, and with the University of Idaho which currently conducts studies on postharvest losses in perishable food products. Both institutions are under AID contracts. DWRC also will cooperate with the Group for Assistance on Systems Relating to Grain After-Harvest (GASGA), an international association of eight organizations.

At DWRC, a 5-year plan has been developed to organize a literature file, define problems, and conduct research into estimating losses; adapt or develop appropriate control techniques; and develop training and extension programs. The following five studies are being initiated during 1983.

1. Evaluate the performance and safety of vertebrate control agents

2. Apply control chemicals to prevent food losses to rodents.

3. Assess methods for estimating rodent populations in grain storage structures.

4. Survey grain storage practices in developing countries.

5. Develop liquid bait substances for rodent control in storage structures.

Other studies will be conducted during the succeeding 4 years, some with graduate students from Colorado State University and Bowling Green State University. Field studies are underway or planned at DWRC field stations in the Philippines, Haiti, and Bangladesh, and arrangements are being developed to collaborate with Kansas State University to initiate a program in Costa Rica.

Postharvest Stored Food Losses in Villages and Farms in Bangladesh

Every year in Bangladesh stored grain is lost to rodents and birds. Because there are more than 10 million farm families in Bangladesh, compared with 2,800 grain storage warehouses, it is reasonable to assume that food losses due to vertebrates in farm structures could easily be a very significant proportion of losses that occur between farm production and consumer use. The numbers of rodents in 10 million farms must be much greater than the numbers in 2,800 grain warehouses.

A pilot study was begun to estimate postharvest losses of stored foods at the farm and village level. The objectives were to estimate densities of small mammals in farm structures, determine seasonal changes in these densities relative to climate, rainfall, crop harvests, and food storage, and determine the food habits of the small mammal species captured inside and around farm structures. Data is and will continue to be collected on the types and quantities of foods stored, the length of storage, and the kinds of storage containers used.

A method of determining animal activity using tracking tiles before and after 3 nights of snap-trapping was developed. Using a modified "Lincoln Index" method, the initial population was estimated from the decline in activity and the number of animals removed. A cluster of 12 farm families (two structures/family = 24 structures) was selected at random from a village area about 5 km west of BARI, Joydebpur. The rodents and shrews living in and around the farm structures were trapped with snap traps for three consecutive nights. Two rat traps and four mouse traps were set inside and two rat traps were set outside each house. Tracking tiles were set at each structure to give an activity index. Animals are identified, sexed, and their stomachs were removed for food habit analysis.

Animal activity increased during the fall and winter dry season and following the aman rice harvest during October-December (Table 29). Animal density increased from 4.8 to 7.1/structure, and the proportion of rodents captured in the total catch increased from 0.58 to 0.78%. Between September and December, 242 animals were collected: 21 lesser bandicoot rats (Bandicota bengalensis), 1 greater bandicoot rat (B. indica), 18 roof rats (R. rattus), 110 house mice (Mus musculus), and 92 musk shrews (Suncus murinus). The study will continue during 1983.

Table 29. Small mammal captures, activity, and densities at farm structures between September and December 1982 in Bogra Village, Bangladesh.

Measurement	September	October	November	December
% tiles active before trapping	48	42	50	50
% tiles active after trapping	25	15	23	27
No. structures trapped	24	24	26	24
No. animals captured	16	74	74	78
Estimated population/cluster	33	115	137	170
Density ($\bar{x}$ animals/structure)	1.4	4.8	5.3	7.1

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1 Fully funded under a Participating Agency Service Agreement (PASA).
2 Partially funded under a PASA except as otherwise indicated.
3 Personnel not funded under a PASA but who participated in work associated with or pertinent to this project.
4 Foreign nationals assigned to the project and funded by their respective governments except as otherwise indicated.
5 Individuals who cooperated with the project in research, extension, or project development activities or who participated as students or trainees.

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INTERNATIONAL VISITORS

Date	Name	Representing
18-29 Jan	Mr. Jean-Paul Samedy	Counterpart, Vertebrate Pest Control Project, Port-au-Prince, Haiti
6 Feb	Dr. Lee R. House	ICRISAT, Hyderabad, India
8-12 Feb	Dr. A. J. Oliver	Agriculture Protection Board Western Australia, Perth, Australia
16-19 Feb	Ing. Eduardo Ruiz Castro	Subsecretary for the Government Development of the State of Southern Baja California, La Paz, Mexico
	Ing. Guillermo Lugo Sanabria	Ministry of Agriculture, Mexico City, Mexico
	Ing. Aradit Castellanos	Wildlife Program for the State of Southern Baja California, La Paz, Mexico
	Ing. Juan Manuel Nava S.	Secretary of Hydrolic Agriculture for the State of Southern Baja California, La Paz, Mexico
2 Mar	Dr. Mike J. F. Jarvis Mr. Mike La Grange	Department of National Parks and Wild Life Management, Salisbury, Zimbabwe
3-4 Mar	Mr. Elsafi Mohamed Elmahdi	Plant Protection Department, Khartoum, Sudan
	Mr. Romeo C. Dizon	Regional Crop Protection Center, Bureau of Plant Industry, Iloilo, Philippines
	Mr. James M. Catimu	Crop Protection Branch, Ministry of Agriculture, Nairobi, Kenya

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Date	Name	Representing
3-4 Mar	Mr. Miano Francis	Ministry of Agriculture, Nairobi, Kenya
	Mr. John G. Ngondi	Pest Control Branch, Ministry of Agriculture, Nairobi, Kenya
	Mr. Ephantus I. Njeru	Crop Protection Branch, Ministry of Agriculture, Nairobi, Kenya
5-18 Mar	Mrs. Parvin Sultana	Counterpart, Vertebrate Pest Control Center, Joydebpur, Bangladesh
1-8 Apr	Mr. Mohamed Saleh Abdalla	Ministry of Agriculture, Mogadishu, Somalia
1 Jun	Dr. A. S. Adegoke	Federal Ministry of Agriculture, Maiduguri, Nigeria
1-4 Jun	Mr. Orlando G. Santos	International Rice Research Institute, Los Baños, Philippines
17-18 Jun	Mr. Sam Mukuru	ICRISAT, Tanzania
24 Jun	Mr. Martin Mannathoko	Veterinary Science Department, Gaborowe, Botswana
26 Jul	Mr. Assefa Damena	Ministry of Agriculture, Addis Abeba, Ethiopia
23-24 Aug	Mr. Pablo P. Ocampo	Graduate Student, North Carolina State University, Raleigh, NC, on leave from NCPC, Philippines
9-11 Sep	Mr. Mohamed Abdul Karim	Counterpart, Bangladesh Agricultural Research Institute, Dacca, Bangladesh
3 Dec	Mr. and Mrs. James Gardner	USAID Haiti

Ammayao, A. K. Attended Pest Control Council of the Philippines Annual Meeting; Baguio, Philippines; 6-8 May 1982.

Benigno, E. A., and F. F. Sanchez. "Rodent problems in the Association of Southeast Asian Nations (ASEAN)." Presentation by E. A. Benigno at The Organisation and Practice of Vertebrate Pest Control Conference; Hampshire, United Kingdom; 30 August-3 September 1982.

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Brooks, J. E. "Prevention of vertebrate pest damage to wheat." Presentation of training lecture to Thana Extension Officers at the Workshop on Wheat Production Methods; Central Extension Resources Development Institute (CERDI); Joydebpur, Bangladesh; October 1982.

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Fiedler, L. A., M. W. Fall, and R. F. Reidinger, Jr. "Development and evaluation of methods to reduce rat damage to coconut in the Philippines." Presentation by M. W. Fall at the 10th Vertebrate Pest Conference; Monterey, California; 23-25 February 1982.

Fiedler, L. A. "A summary of rat control trials/experiments conducted at IRRI, 1980-81." Presentation at the seminar of the International Rice Research Institute; Los Baños, Philippines; 13 May 1982.

Fiedler, L. A. Attended Third International Theriological Congress; Helsinki, Finland; 15-20 August 1982.

Kolz, A. L. and the Denver Wildlife Research Center organized a Wildlife Telemetry Workshop for 27 participants; Denver, Colorado; 27-29 April 1982.

Kolz, A. L. "Wildlife telemetry overview." Presentation as guest instructor at the Food and Agriculture Organization course "Remote Sensing Applied to Wildlife Management." Rome, Italy; 12-23 July 1982.

Libay, J. L. Attended Pest Control Council of the Philippines Annual Meeting; Baguio, Philippines; 6-8 May 1982.

Mason, J. R. "Olfaction in Birds." Presentation to a class for the Department of Biology, University of Pennsylvania, Philadelphia; 9 March 1982.

Mason, J. R., and R. F. Reidinger, Jr. "Factors influencing expression of conditioned flavor aversions in grooming." Presentation by R. F. Reidinger at the 4th Annual Meeting of the Association for Chemoreception Sciences; Sarasota, Florida; 14-18 April 1982.

Mason J. R. "Effect of color type on generalization of and preexposure decriments in aversion learning by red-winged blackbirds." Presentation at the 23rd Annual Meeting of the Psychonomics Society; Minneapolis, Minnesota; 13 November 1982.

Mason, J. R. "Evaluation and exploitation of avian defenses against dietary poisoning" and "Visual cues and social context control feeding behavior of blackbirds." Presentation at the University of Wyoming, Laramie, Wyoming; also seminar "Studies on the common chemical sense." 17-18 November 1982.

Olvida, J. L. Attended Pest Control Council of the Philippines Annual Meeting; Baguio, Philippines; 6-8 May 1982.

Reidinger, R. F., Jr., and J. R. Mason. "Evaluation and exploitation of behavioral weaknesses against dietary poisoning." Presentation by J. R. Mason at the 4th ASTM Symposium on Test Methods for Vertebrate Pest Control and Management Materials; Monterey, California; 26 February 1982.

Reidinger, R. F., Jr. "Factors influencing expression of conditioned flavor aversions in grooming." Presentation at the 3rd International Symposium on Chemical Signals in Vertebrates; Sarasota, Florida; 11-13 April 1982.

Reidinger, R. F., Jr. Presented a seminar about careers in wildlife research to students of Albright College, Reading, Pennsylvania. Was presented a National Council Citation from Albright College; May 1982.

Reidinger, R. F., Jr., and J. R. Mason. "Taste in Vertebrates." Co-coordinated a course (Biology 461) at the University of Pennsylvania, Philadelphia; 9 September-9 December 1982.

Ruelle, P., and R. L. Bruggers. "Traditional approaches for protecting cereal crops from birds in Africa." Presentation by P. Ruelle at the 10th Vertebrate Pest Conference; Monterey, California; 23-25 February 1982.

Sanchez, F. F., and E. A. Benigno. "Trends in rodent pest management." Presentation by F. F. Sanchez at Symposium on Pest Ecology and Pest Management, BIOTROP; Bogor, Indonesia; 3-4 December 1981.

Shumake, S. A., S. E. Gaddis, and M. V. Garrison. "Development of a preferred bait for quelea control." Presentation by S. A. Shumake at the 4th ASTM Symposium on Test Methods for Vertebrate Pest Control and Management Materials; Monterey, California; 26 February 1982.

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