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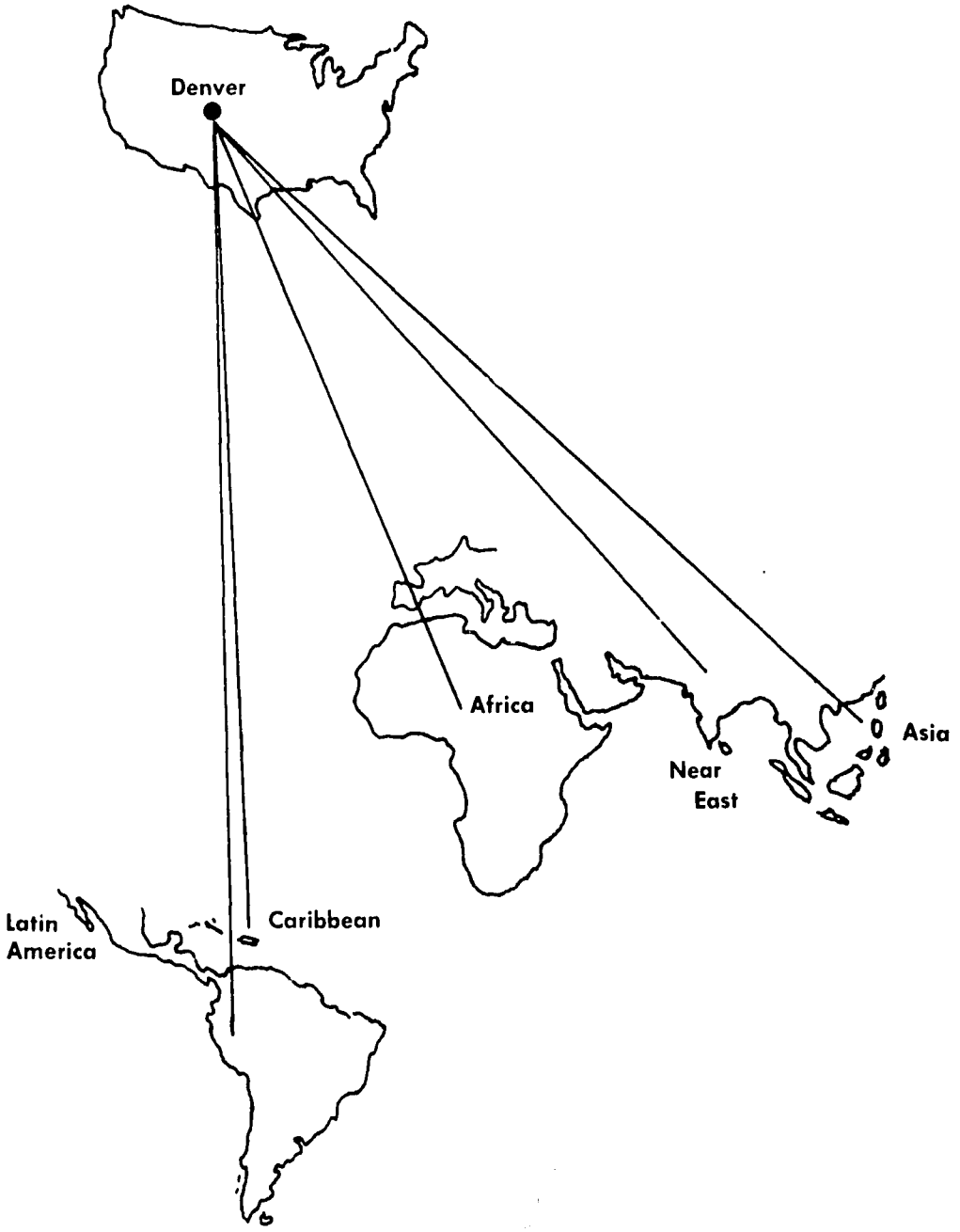
PROGRESS OF VERTEBRATE PEST MANAGEMENT IN AGRICULTURE, 1966–1982

PROBLEM SOLVING RESEARCH TECHNOLOGY TRANSFER EXTENSION
TRAINING CONSULTANCIES DOCUMENTATION



U.S. FISH AND WILDLIFE SERVICE
DENVER WILDLIFE RESEARCH CENTER

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

PROGRESS OF VERTEBRATE PEST MANAGEMENT IN AGRICULTURE, 1966-1982

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FINAL REPORT

CONTENTS

	Page
CONTENTS	i
ABBREVIATIONS AND ACRONYMS	ii
ABSTRACT	1
INTRODUCTION	5
DWRC ORGANIZATIONAL STRATEGIES	9
PRINCIPAL ACCOMPLISHMENTS	15
OTHER SIGNIFICANT RESEARCH ACCOMPLISHMENTS	29
PROJECT TRAINING AND EXTENSION ACTIVITIES	47
LESSONS LEARNED	55
IMPORTANT, UNSOLVED VERTEBRATE PEST PROBLEMS	57

APPENDICES

A. TECHNOLOGY AVAILABLE FOR TRANSFER	1
1. Control of Rodents in Rice	1
2. Control of Rodents in Coconut	7
3. Control of Bird Damage to Emerging Cereal Grains	9
4. Control of Rodents in Wheat - An Example of a National Campaign	11
5. Control of Vampire Bats	12
B. LIST OF PROJECT PUBLICATIONS	1-18
C. OUTREACH ACTIVITIES FROM DWRC	1-5
D. OUTREACH ACTIVITIES FROM THE PHILIPPINES, 1968-1982	1
E. FOREIGN GRADUATE PROGRAMS IN VERTEBRATE PEST MANAGEMENT ASSOCIATED WITH USAID/DWRC PROJECTS	1-2
F. PROJECT MILESTONES, 1966-1982	1-56
G. BUDG T SUMMARY, 1967-1982	1
H. COMMON AND SCIENTIFIC NAMES OF VERTEBRATES	1-2

ABBREVIATIONS AND ACRONYMS

ARC	Agricultural Research Center
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BPI	Bureau of Plant Industry
BPPD	Bangladesh Plant Protection Department
BRRI	Bangladesh Rice Research Institute
CARE	Cooperative for American Remittances to Everywhere, Inc.
CDC	Center for Disease Control
CIAT	Centro Nacional de Investigaciones Agropecuarias
CICP	Consortium for International Crop Protection
COPR	Centre for Overseas Pest Research
DWRC	Denver Wildlife Research Center
EAC	East African Community
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
GASGA	Group for Assistance on Systems Relating to Grain After-Harvest
GOB	Government of Bangladesh
GOP	Government of the Philippines
GTZ	German Society for Technical Cooperation
IADS	International Agricultural Development Service
ICA	Instituto Colombiano Agropecuario
IRRI	International Rice Research Institute
MOA	Ministry of Agriculture
NCPC	National Crop Protection Center
OECD	Organization for Economic Cooperation and Development
ODA	British Overseas Development Administration
PAHO	Pan American Health Organization
PASA	Participating Agency Service Agreement
PCA	Philippine Coconut Authority
RRC	Rodent Research Center
S&T	Bureau for Science and Technology
SRI	Bangladesh Sugarcane Research Institute
TDY	Temporary Duty
TPRI	Tropical Pesticides Research Institute
UNDP	United Nations Development Programme
USAID (AID)	United States Agency for International Development
USAID/W	United States Agency for International Development/Washington
USDI	United States Department of the Interior
USFWS	United States Fish and Wildlife Service
UPLB	University of the Philippines at Los Banos
VPM	Vertebrate Pest Management
WHO	World Health Organization

ABSTRACT

The Denver Wildlife Research Center (DWRC) is recognized as a leading organization in research, development, and information transfer of vertebrate pest management (VPM) and control. Its practical, problem-solving team approach has led to the development and use of new methods, materials, and techniques for vertebrate pest management in several developing countries.

The project, funded by the United States Agency for International Development (USAID), incorporates a balanced but flexible program of applied research, technology transfer, and training. Research activities consist of coordinated laboratory investigations at DWRC and selected laboratories in developing countries with associated field trials at appropriate sites in specific problem areas. 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 and international organizations. Training of local counterparts and institutionalization of both research functions and implementation programs are viewed as integral parts of the overall project.

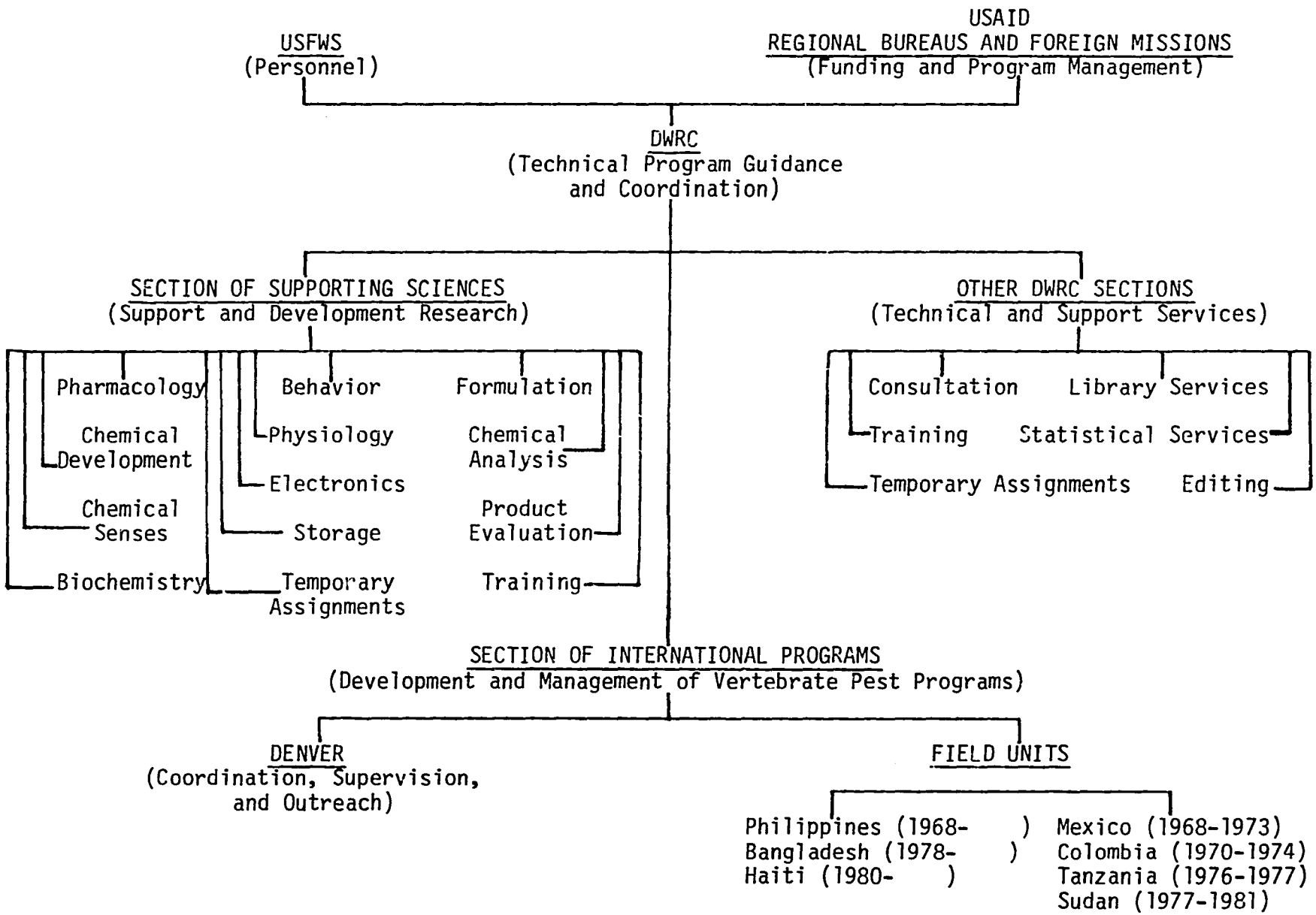
The experienced staff is comprised of specialists in fields of ecology, physiology, pharmacology, wildlife biology, nutrition, statistics, animal psychology and behavior, chemistry, and electronics. Several staff members have foreign experience and fluency in foreign languages. Denver Center laboratories are well equipped with the instrumentation necessary to conduct research in each of the disciplines involved in support of overseas activities. Cost and time of duplicating this capability at overseas stations or with another international organization or group in the United States would be exorbitant, impractical, and prohibitive.

Since inception of the project, resident biologists have been stationed in the Philippines, Mexico, Colombia, Tanzania, Sudan, Bangladesh, and Haiti. DWRC has also provided a variety of vertebrate pest management activities and services to 45 nonproject developing countries.

Studies have included work on a wide array of methods, materials, and control strategies pursued both in the laboratory at Denver and in the field through outreach assignments overseas. In addition to vertebrate pest activities, other studies of endeavor have historically included the sciences of ecology, physiology, wildlife biology, pharmacology, toxicology, animal behavior, biometrics, taxonomy, chemistry, and electronics as well as extension, training, and information transfer. More specifically, types of studies done included life history of pest species, crop phenology, food habits analysis, population dynamics, movement patterns, basic species behavior and physiology, socioeconomics, crop damage assessments, survey techniques, trapping methods, baiting techniques, field and laboratory evaluation of baits and bait formulations, chemical screening of vertebrate pest agents, bait

placement, chemical residue analysis, and secondary hazard evaluations of control agents.

Examples of selected USAID/DWRC achievements in reducing vertebrate pest losses include development, evaluation, and implementation of techniques for reducing rat damage to rice, coconuts, and wheat, bird damage to emerging grains, and vampire predation on livestock.


USFWS
(Personnel)
USAID
REGIONAL BUREAUS AND FOREIGN MISSIONS
(Funding and Program Management)
DWRC
(Technical Program Guidance and Coordination)
SECTION OF SUPPORTING SCIENCES
(Support and Development Research)
Pharmacology
Chemical Development
Chemical Senses
Biochemistry
Behavior
Physiology
Electronics
Storage
Temporary Assignments
Formulation
Chemical Analysis
Product Evaluation
Training
OTHER DWRC SECTIONS
(Technical and Support Services)
Consultation
Library Services
Training
Statistical Services
Temporary Assignments
Editing
SECTION OF INTERNATIONAL PROGRAMS
(Development and Management of Vertebrate Pest Programs)
DENVER
(Coordination, Supervision, and Outreach)
FIELD UNITS
Philippines (1968-)
Bangladesh (1978-)
Haiti (1980-)
Mexico (1968-1973)
Colombia (1970-1974)
Tanzania (1976-1977)
Sudan (1977-1981)

INTRODUCTION

Vertebrates, as well as other organisms, offer unique challenges in situations where they conflict with human interests and are termed pests. Such challenges result from biological and behavioral attributes of the vertebrates as well as the cultural, sociological, and political contexts in which rodents, birds, or bats cause damage. Biologically, vertebrates are sufficiently long-lived to complicate genetic manipulations that are sometimes possible to use in the control of insects. Vertebrate pests can be sedentary or mobile. Some vertebrate pests, particularly birds such as the red-billed quelea (*Quelea quelea*), migrate hundreds or even thousands of miles.

Unlike some pests, which offer the biologist a reliably predictable fixed action pattern or stereotyped response, vertebrates, particularly rodents, exhibit learning ability and offer rapid and sometimes intraspecifically varied responses to biological or chemical insults.

Also unlike most other pests, cultural and sociological factors contribute to the challenge of managing vertebrate pests. Birds and rodents are highly visible pests to farmers in developing countries. Where economies are largely based on agriculture, sound practices in vertebrate pest management sometimes give way to token handouts of rodenticides and bounties that are politically expedient.

Many land grant or other universities in the United States have major educational programs that support agricultural activities in weed science, applied entomology or nematology, soil science, and applied agricultural microbiology, while the number of universities in the U.S. that offer academic curricula in vertebrate pest management can be counted on one hand. Of interest to many and to the credit of both USAID and its Participating Agency Service Agreement (PASA) with DWRC, the University of the Philippines at Los Banos (UPLB) now offers a program in vertebrate pest management at the M.S. and Ph.D. level. During the past decade, the program has achieved regional and international recognition, accepting students from Asia and South America. The students have been supported by their parent countries, international organizations, and USAID.

Although on a worldwide basis, vertebrate pests have received a relatively small portion of the resource and expertise that has been invested in agricultural development, most experts would agree that vertebrates constitute a major component of pest problems in the developing world. USAID has supported improved practices in vertebrate pest management through its PASA with the DWRC since 1967.

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

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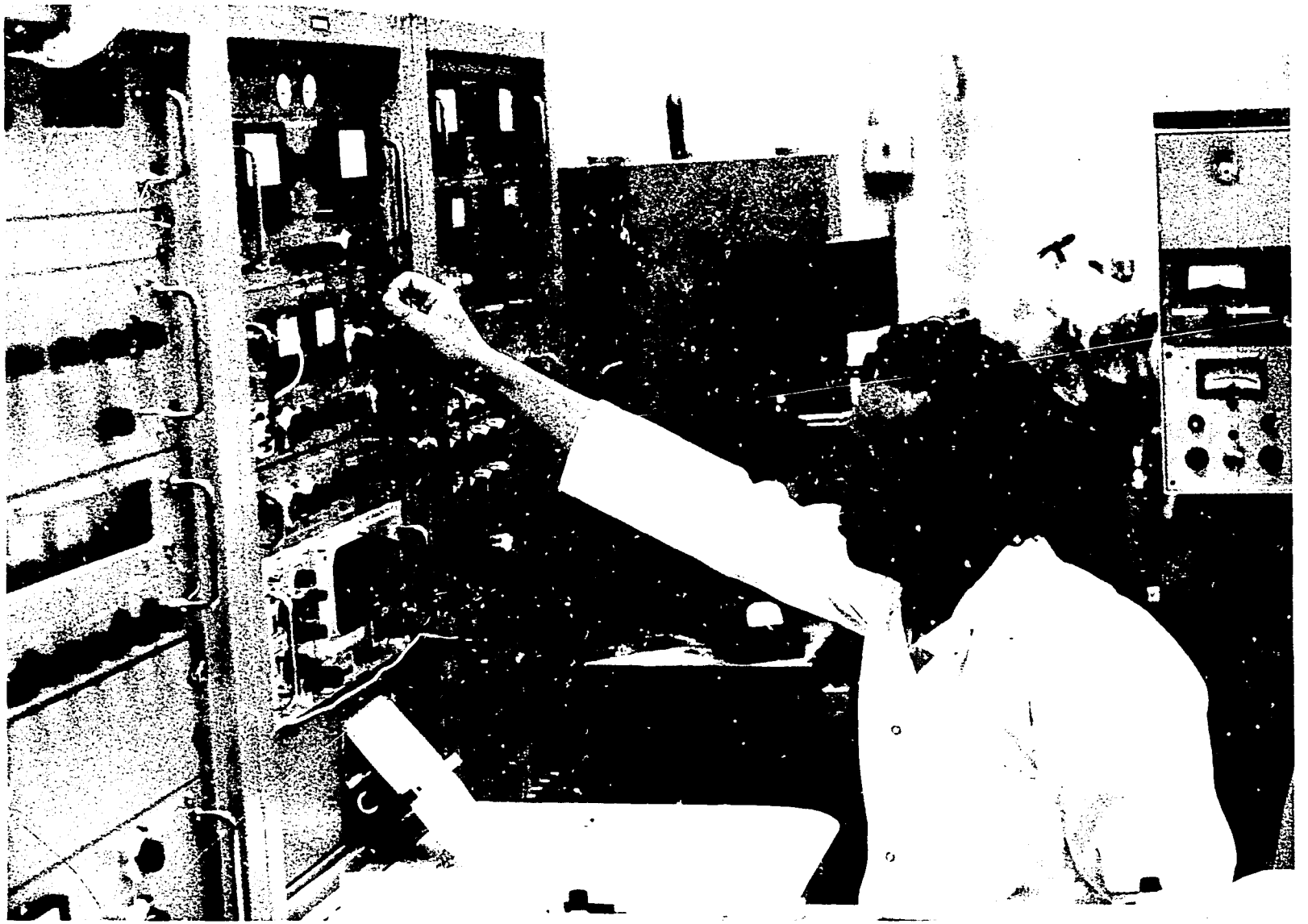

At DWRC, a multidisciplinary team of specialists, using a broad spectrum of sophisticated laboratory equipment and specialized facilities, provides supporting research for overseas field programs. Cost of duplicating this capability at overseas project field stations would be exorbitant and impractical.

DWRC ORGANIZATIONAL STRATEGIES

During the 16 years of cooperation (1967-1982), USAID Bureau and Mission investments in the international vertebrate pest program of the DWRC have amounted to about $9 million. To provide some perspective on this figure, contributed funds to the International Rice Research Institute (IRRI), an organization well-known worldwide for its contributions to the Green Revolution, were reported at $7 million and $16 million for the years 1974 and 1979, respectively.

To optimize technological gains for USAID, Missions, and developing countries from this level of investment, the DWRC, in concert with suggestions of USAID, has used an organizational structure that involves three key elements:

1. In-country projects are established and maintained based on interest and needs of Missions and host countries. To minimize costs, the in-country projects are staffed by as few as one expatriate scientist. As required for the success of the project, additional expertise is provided, through temporary duty (TDY) assignments, usually by scientists from DWRC.

2. A central core of staff is maintained in the Section of International Programs at DWRC to conduct research, provide technical assistance to countries not having in-country projects, and respond to USAID and Mission requests.

3. An interdisciplinary group of supporting scientists, located at DWRC, represents a broad range of collective expertise and is located mostly, but not exclusively, within the Section of Supporting Sciences.

The organizational structure offers fiscal and other advantages. Because placing expatriate scientists in-country is costly, using as few as judged practical minimizes costs. The in-country individuals serve not only in their own technical specialty, but as VPM generalists and as links between country needs and the pool of backup expertise available at DWRC.

Response to short-term requests from Missions and countries are accomplished mostly through TDY's by staff at DWRC. In the 16 years of cooperation, DWRC scientists have made 134 consultancies to 45 nonproject countries. Examples include numerous trips to Africa to collaborate with the Food and Agriculture Organization (FAO) of the United Nations and country programs in the study and control of quelea and to assist FAO in the review of vertebrate pest problems in Southeast Asia; numerous trips to Latin America to evaluate vampire bat predation and to participate in training sessions for the control of vampire bats; and recommendations for temporary measures of control during rodent outbreaks that have occurred in countries such as Senegal.

Supporting scientists at DWRC provide the breadth of expertise required to meet the challenge of vertebrate pests without the need to duplicate such efforts in every country. Countries having permanent facilities are

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encouraged and supported, however, to build their own capabilities. For example, the original Philippine Rodent Research Center (RRC), supported by USAID, developed into the National Crop Protection Center (NCPC), with a local staff of about 100 and a network of 12 field stations supported by the Philippine Government.

In addition to fiscal appropriateness, the organization offers other advantages as well. For example, research involving new or experimental chemicals is conducted at DWRC. This approach avoids the extensive use of experimental chemicals in foreign countries and keeps the project within the appropriate USAID mandate. The organization also provides an unusual flexibility, allowing rapid shift in research direction. From time to time, USAID has requested a shift in emphasis of DWRC research assistance, for example, to more work on birds. Most recently, DWRC was asked to increase emphasis on postharvest losses. Such changes can be made, reversibly, by involving staff who already have the expertise and are already on board for domestic programs.

Beyond its own internal organization, the DWRC has also attempted to optimize limited resource and expertise in vertebrate pest management through cooperative planning and complementary research with both domestic and international organizations that are also involved with integrated pest management. An example has been the collaborative efforts of FAO, DWRC, and several governments of African countries to study the migratory paths of quelea. Birds are marked using techniques developed and materials provided by scientists at the DWRC. Marking birds, recapturing them, and analyzing results is the cooperative venture of all organizations involved. Collaboration also occurs within countries on a much smaller scale. For example, during 1982, an FAO project in Burma sent two research officers for 3-months of training in vertebrate pest management to the NCPC; a Burmese scientist was similarly involved with 1-year training in rodent control with IRRI in collaboration with DWRC; and cooperative research efforts were conducted or planned with the German Society for Technical Cooperation (GTZ) in the Philippines and in Bangladesh.

Further, the DWRC has collaborated with two U.S. universities (Colorado State University, Fort Collins, Colorado, and Bowling Green State University, Bowling Green, Ohio) in developing VPM curricula and in the conduct of research by foreign graduate students. Individual scientists at DWRC also collaborated with colleagues at universities such as Purdue, Lafayette, Indiana; Texas A&M, College Station, Texas; and the University of Arkansas, Fayetteville, Arkansas, in the development of bird-resistant sorghum; the University of California, Berkeley, California, regarding integrated pest management; the University of Pennsylvania, Philadelphia, Pennsylvania, and Cornell University, Ithaca, New York, regarding the taste qualities of rodenticides; and with Kansas State University, Manhattan, Kansas, on postharvest losses (mostly information from Kansas State University to DWRC regarding granaries).

Bird and rodent damage to sacked and stored grains is a serious, worldwide problem, particularly to small-farm storage. Local storage practices can sometimes be effective in preventing losses.

DWRC has, since its cooperative venture with USAID, adopted a research and development philosophy that has been complementary to and consistent with USAID's overall interests in pest management and with the domestic programs of the U.S. Fish and Wildlife Service (USFWS).

Central to the program for research assistance has been the concept that the final measure of an effective method for vertebrate pest management is increased yield rather than accounts of vertebrate mortality. The concept encourages a highly selective approach to control, aiming specifically at the pest itself when lethal methods are required, and minimizing impact on nontarget organisms. Concommitant with the approach, amounts of chemicals used are reduced from those required for more traditional methods, lessening human and environmental hazards, and minimizing impact on nontarget organisms that dwell within the agroecosystem. Further, the concept encourages the development of nonlethal repellent techniques. The methods developed for control of vampire bats are an example of the use of this concept. These methods are aimed specifically at bats that parasitize cattle, and not at other vampires or other bat species. Another example is the development of crown-baiting techniques for control of rodent damage to coconuts in Colombia and the Philippines.

Central to the program for developmental and research assistance has been the concept of integrated pest management. Thus, DWRC at the NCPC, collaborated with weed scientists at the IRRI in a study of interactions between weeds and rodents in rice paddies. From the developmental perspective, Denver core staff have provided vertebrate pest components of proposals for integrated pest management in Peru and Pakistan. Similarly, the development of a vertebrate research program in Bangladesh was incorporated as an amendment to an existing Project Paper on integrated pest management and as a Vertebrate Pest Division of the Bangladesh Agricultural Research Institute (BARI), by the Government of Bangladesh (GOB), specifically to facilitate the development of that institute as part of an integrated pest management program for Bangladesh.

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PRINCIPAL ACCOMPLISHMENTS

Through this organization, developmental and research philosophy, and through the efforts of the staff, the USAID/DWRC venture has had successes in contributing through both research accomplishment and program development.

1. One accomplishment, a joint Filipino/American effort, was the development of the sustained baiting method for reducing rodent damage in ricefields. Development of the method illustrated how a more detailed understanding of rodent behavior can lead to improvements in control. The technology has been implemented by the Philippine Government, both as a requirement under the small-farm credit program for rice production (Masagana-99) and under the regular operational pest control program of the Ministry of Agriculture and Natural Resources. Based on figures from field trials, the planned implementation of sustained baiting on 500,000 ha, with the goal of reducing average rodent damage from 5.5% to 1.1%, was calculated to have a potential benefit of $3.2 million in one 4-month crop season--more than double USAID's 10-year investment. The RRC, initially established under this project, has now become part of a more recently established NCPC and enjoys continued enthusiastic support and participation from the Philippine Government.

2. Another accomplishment involved initial research conducted on coconut plantations in Colombia and a series of long-term studies conducted in the Philippines. Early work indicated that crown-baiting in coconut trees with anticoagulant rodenticides could produce dramatic increases in nut production. Subsequent adaptive studies in the Philippines have shown that application of this technology could more than double coconut production in some situations with a cost:benefit ratio of 1:28. The Colombian Government has continued to fund the Vertebrate Pest Control Project as an active unit within that country's Institute of Agricultural Research, more than 8 years after USAID/DWRC direct participation ended.

3. Successful tests for reducing bird damage to emerging crops were accomplished in several developing countries. In Uruguay, damage by doves and pigeons to sprouting soybeans was reduced from 34% on the reference plot to only 0.6% on a methiocarb-treated plot. Similar results in Uruguay were demonstrated with methiocarb on dove damage to emerging soybeans and waterfowl damage to emerging rice. Effective methiocarb treatments for emergents were also evident on emerging corn being damaged by ring-necked pheasants (*Phasianus colchicus*) in Texas and New York, on emerging rice being damaged by blackbirds in Louisiana, and in ricefields in Senegal.

4. In Bangladesh, intensive efforts on the biology of rodent pests, damage patterns and distribution, extent of losses, and toxicological and field evaluations led recently to a method using zinc phosphide to reduce rodent damage in wheat. This technology was recently

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Rodent damage to rice is widespread throughout the rice-growing regions of the world. Because much rice is grown on small farms, even moderate damage can be a serious economic problem for the individual farmer. Two billion people use rice for one-fourth or more of their diet.

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Rat damage is a common, worldwide problem in coconut plantations and is a special concern in the Philippines, the world's leading exporter of copra. A crown-baiting method has been developed to eliminate severe rat damage and more than double harvested nuts at very low cost to the farmer.

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Bird damage to newly planted and emerging cereal grains is a worldwide problem. Treating seed with a repellent chemical has proven to be an economical method of reducing damage.

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Project personnel distributed rodenticide bait to farmers in the central market of Gazaria Thana, Bangladesh, to demonstrate the effectiveness of one method of rat control in wheat. The method is being implemented into a national rat campaign that project personnel helped plan, organize, and evaluate.

incorporated into a national "rat control campaign." The campaign involved the joint efforts of the Government of Bangladesh, Department of Agricultural Extension, Plant Protection Division; Bangladesh-German Plant Protection Programme; and the USAID/DWRC Vertebrate Pest Section.

5. One early accomplishment was the development of methods for reducing vampire bat (Desmodus rotundus) predation on livestock in Central and South America, and the extension of methods to affected countries. Two methods were developed and are now in wide use throughout the Latin American tropics where vampires, as vectors of paralytic rabies and other diseases, were responsible for livestock losses estimated at $350 million annually. Discovery and evaluation of the methods involved the collaborative efforts of Mexican and American scientists, at a field station in Mexico, and backup research involving such aspects as feeding behavior of vampire bats and development of chemical analytical methods by DWRC personnel. Extension efforts, training workshops, and demonstrations contributed to the establishment of active vampire control programs in about 16 countries affected by the pest. The research program established in Mexico is still operating, 7 years after active participation by USAID/DWRC ended. An independent evaluation of the Nicaraguan vampire bat control program, based on this technology, revealed a cost:benefit ratio of 1:18.6, signifying a high payoff for this USAID-sponsored program. USAID's total investment for research, program development, and training over a 10-year period was $1.5 million. Benefits for Nicaragua in 1 year, one of the 16 countries involved, was $2.4 million.

An economically inestimable, but important contribution that the DWRC Project frequently makes to USAID, host countries, and other countries, is advice on new control devices and methods. The DWRC continually assesses, under USAID, Environmental Protection Agency (EPA), and other auspices, potential control devices that range from new chemicals to electromagnetic or ultrasonic devices as ways of managing "super" rats. For example, the governments of the Philippines and Bangladesh were approached regarding multimillion-dollar investments in devices that DWRC experts had already demonstrated as marginally effective, or completely ineffective, or at high risk for environmental hazard. Fortunately, contact was made with DWRC before purchase was agreed, and, fortunately, sufficient data also were available to substantiate this advice.

Secondly, DWRC personnel have had extensive involvement in training programs sponsored by USAID, host governments, and international organizations. In 1982, the Center assisted in training 14 graduate students, 5 counterpart or host government personnel, and 20 visiting scientists from 12 countries. USAID-sponsored research and outreach at DWRC has resulted in 240 formal publications in addition to annual and special reports, brochures, and media material. DWRC probably has the world's largest library in the science of vertebrate pest control and management.

Thirdly, DWRC personnel have assisted USAID/W and USAID Missions develop project documents. DWRC has also cooperated with the private sector in the development of chemicals and other vertebrate pest management tools.

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The common vampire bat has long been a scourge to livestock producers of Latin America. DWRC scientists developed two control methods that are safe, selective, economical, and practical. As of 1978, 13 of 18 countries, which suffer vampire bat problems, had their own country-funded control programs.

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OTHER SIGNIFICANT RESEARCH ACCOMPLISHMENTS

Since the project started, accomplishments in research methodology, techniques, and material development have been detailed in Annual Progress Reports and research publications by DWRC personnel and counterparts. Summarized below are some significant research findings obtained during outreach and in-country project activities.

Activities from DWRC

Demonstrated that rhodamine B is a highly effective marker for rodents when used in a grease formulation.

Demonstrated that Microtaggant plastic particles can be incorporated into baits to mark birds and rodents. Developed a technique for using coded micro paint particles to mass-mark social bird species.

Developed miniaturized radiotelemetry equipment for studying ranges, activity, and long-distance movements of small rodents, birds, and bats. Numerous other electronic devices were developed for monitoring field research.

Developed methods of assessing rodent and bird damage to various agricultural crops.

Developed the technique of using inked tracking tiles to determine rodent activity in relation to crop damage or to evaluate control methods.

Developed standardized laboratory techniques for comparative evaluation of candidate toxicants and repellents on rodent and bird species.

Developed a more effective bird repellent enhancement method by adding taste or color compounds to the formulation.

Developed an inexpensive gas fumigant cartridge for control of burrowing rodents.

Developed biochemical test procedures to determine bird resistance and nutritional characteristics of sorghum varieties.

Developed a computerized cage system for comparing feeding patterns of different rodent species in relation to different rodenticides or bait formulations.

Instigated a new project on postharvest food losses. Basic literature search completed and study plans developed.

Philippines

Completed national surveys of rodent damage to rice and determined distribution of rodent pests.

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Established vertebrate pest control research and training within the National Crop Protection Center and its regional field stations. About 25 graduate students completed thesis work in association with the project.

Reorganized government operational rodent control programs to incorporate improved methods developed by project personnel.

Developed rodent control techniques for corn damage.

Investigated fumigant cartridge formulations for use in developing countries, and developed a simulated burrow system for evaluating fumigants.

Investigated anticoagulant wax bait formulations for use in small-farm situations.

Developed a nonlethal electric barrier to prevent crop damage by agricultural rodents.

Evaluated high-energy fence chargers for field use in the tropics.

Supported field programs with specialized equipment and technical expertise for radio tracking animals.

Investigated grooming behavior of rodents in relation to the use of acute rodenticides in grease or dust formulations.

Developed analytical techniques for determining warfarin and diphacinone concentrations in plant, soil, and water samples and demonstrated that these chemicals do not accumulate during field baiting.

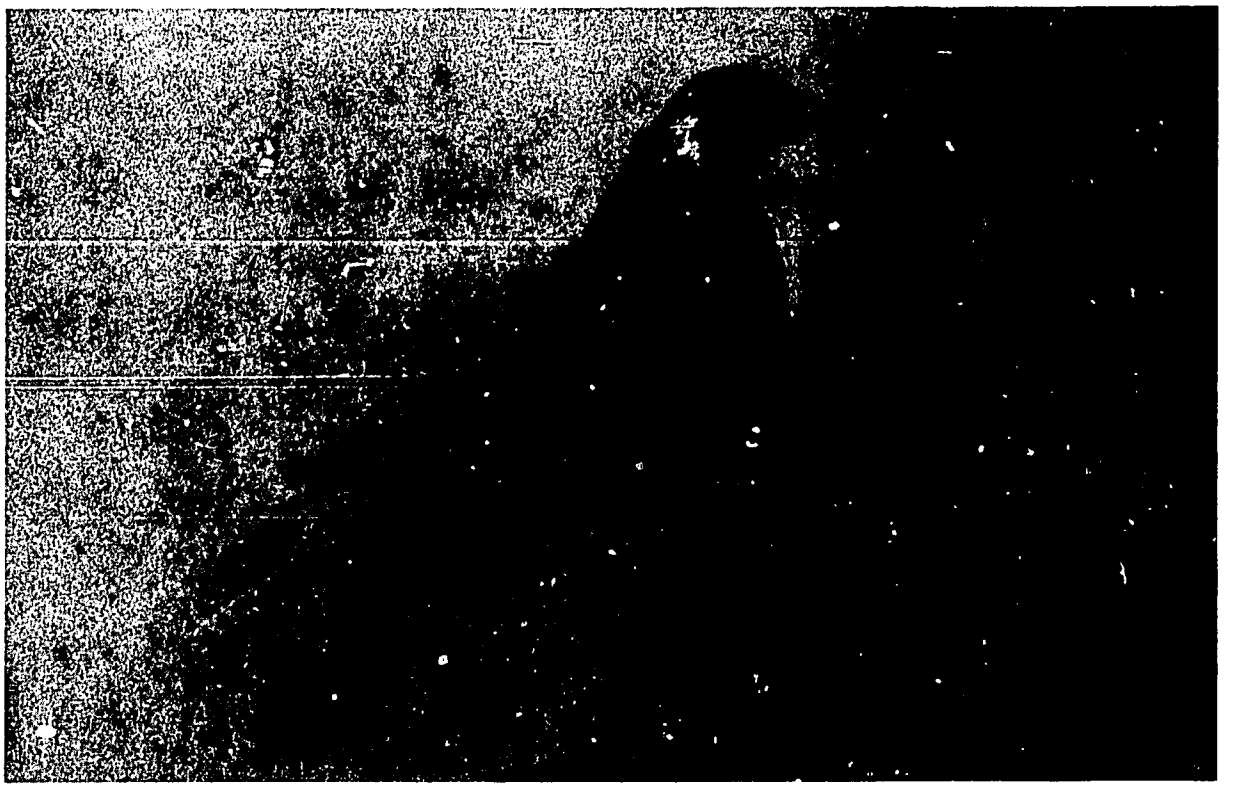
Africa

Studies conducted in eastern Africa indicated that some maturing crops can be protected from feeding birds by using the chemical repellent methiocarb at relatively low levels and with economical application techniques. In Ethiopia, methiocarb protected ripening sorghum from quelea damage until lethal control operations of roosting birds could be undertaken.

DWRC biologists developed techniques and demonstrated, in cooperation with FAO and Ethiopian Government biologists, that bird pests can be mass-marked with fluorescent dye particles. The approach is a major technological breakthrough and is currently being applied to obtain information on migratory movements of quelea and other pest species in Africa and the United States.

Compiled information on crop losses and economic impact of bird damage in Sudan and other African countries.

Obtained information on population reduction efforts as practiced by various organizations. It was found that these overall efforts are largely ineffective in reducing damage except in some local areas.



Microtaggant particles (above) fluoresce on a marked bird under ultraviolet light. Fluorescent resin particles (below) are inexpensive, dust-sized particles. Both can be easily applied by aerial or ground spraying to large concentrations of roosting or nesting birds. Thousands of birds can be marked to determine local or migratory movements to improve management practices.

Numerous electronic devices, including miniature radio transmitters, have been designed by DWRC to study the movements and feeding activities of pest species relative to crop damage. In Ethiopia, DWRC biologists worked with FAO personnel to determine daily movements of quelea in relation to control operations.

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Tracking tiles are used to obtain activity indices in studies of rodent populations and in control evaluations. Rodents crossing the inked portion of the tile leave footprints on the clean side.

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A ricefield rat jumps back after receiving a nonlethal shock from an experimental electric barrier in a DWRC laboratory. Barriers are one of many techniques available to reduce rodent damage to agricultural crops (Photograph by James L. Stanfield, National Geographic Society).

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

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Determined that the most important agricultural rodent pests in Sudan are Arvicanthis spp. and Mastomys spp. They damage sorghum, wheat, groundnuts, and vegetables.

Developed miniature radio transmitters and attachment method for quelea.

Completed laboratory studies on quelea.

Established colonies of Arvicanthis niloticus and conducted laboratory investigations.

Demonstrated in Ethiopia that red-billed quelea can be mass-marked with fluorescent paint particles to obtain information on their migratory movements relative to crop damage patterns.

Demonstrated in Ethiopia the feasibility of using 1.8-g miniature radio transmitters for rapidly locating nesting colonies and understanding local movements of red-billed quelea.

Bangladesh

Organized Vertebrate Pest Section within Bangladesh Agricultural Research Institute; established cooperative ties with other agencies; assigned counterpart personnel to project.

Established new laboratory, office, and pen facilities.

Held several workshop and training sessions for government personnel.

Completed national survey of rodent damage to wheat and rice. The countrywide loss to wheat was valued at about $15 million and to rice about $128 million.

Began national survey of vertebrate pest problems on small farms and started pest identification and analysis of their distribution.

Completed preliminary laboratory evaluation of candidate rodenticides and bait formulations.

Conducted a variety of baiting studies in small-farm crops.

Completed studies of burrow systems and behavior of fossorial rodents.

Conducted test trials to determine the most effective method of monitoring field rodent populations including live and snap traps, and tracking tiles.

Demonstrated that experimental plots of maize can be protected from rose-ringed parakeet (Psittacula krameri) damage with Avitrol.

Determined the toxicity and repellency of several repellents to pest birds and demonstrated the effectiveness of three chemicals as seed dressings on sprouting wheat in experimental and farmers' fields to prevent bird damage.

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Haiti

Organized Vertebrate Pest Project within Haitian Ministry of Agriculture; established cooperative ties with Dominican Republic Ministry of Agriculture including the assignment of counterpart personnel.

Established new laboratory and office building.

Counterparts received training at DWRC.

Assembled initial information on vertebrate pests and associated problems in agriculture in Haiti and the Dominican Republic. An extension brochure describing the technique was developed to assist local rice farmers.

Demonstrated sustained baiting of rodents in rice is feasible in the Artibonite Valley.

Gathered information through the use of radiotelemetry on the biology of the village weaver (*Ploceus cucullatus*).

Obtained basic information on the use of pesticides in Haiti and the Dominican Republic.

Documented vertebrate pest losses in maturing corn.

The red-billed quelea is a serious pest to cereal crops in Africa. Quelea range over about 20% of the continent and adversely affect the economy and food production of 20-25 nations.

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Rat "outbreaks" occur irregularly and unpredictably in tropical habitats resulting in populations that can completely destroy a ricefield. Rat "drives" are a traditional method used by some Asian farmers when high rat numbers occur. Some use the meat as a source of protein.

PROJECT TRAINING AND EXTENSION ACTIVITIES

Introduction

In the developing countries of the world, individual farmers are often totally dependent on the harvest from their small fields for sustenance and income. Vertebrate pests play a major role in limiting agriculture production and often have the greatest impact on the poorest farmers in marginal production areas. Because of the importance and magnitude of the problem, the USAID/DWRC project has included training and extension of research recommendations as a major part of the overall program.

Training

An estimated 250,000 individuals, particularly in the Philippines, have received training in many aspects of vertebrate pest management. These include farmers, extension agents, technicians, biologists, veterinarians, administrators, and others concerned with agricultural production. The training took many forms--from informal workshops, demonstrations, or seminars to short-term training at DWRC, at the various USAID/DWRC field stations, or at other cooperating institutions. Approximately 150 individuals from developing countries have received short-term training in vertebrate pest control and crop protection at DWRC.

On-the-job Training: Day-to-day interactions between counterpart personnel and resident biologists occurred in the Philippines, Mexico, Colombia, Tanzania, Sudan, Bangladesh, and Haiti. Counterpart personnel were involved in all phases of the research process which included planning, execution, data collection and analyses, reporting, and extension.

In-country Training: In-country training is designed for either resident or nonresident individuals wishing to receive training in vertebrate pest management. This includes arrangement with a local university (for example, UPLB) on a special problem, overseen and in cooperation with the resident biologist. A 3-month, nondegree training course, and a 36-week diploma course in crop protection is offered in the Philippines in cooperation with UPLB and the NCPC.

Short-term Study Programs: Special arrangements are made for individuals from developing countries concerned with various aspects of vertebrate pest management. This could include library research at DWRC, orientation in standard laboratory procedures at DWRC, assisting in a laboratory study at DWRC, orientation or assisting in field studies at one of DWRC's domestic field stations or at one of the USAID/DWRC international field stations.

Formal Training: Thirty-five counterpart personnel from 10 countries have received graduate training leading to advanced degrees (M.S. or PH.D.) during the 1966-1982 period. Many of these individuals now hold positions of importance and influence in their respective governments. M.S. or Ph.D. programs in VPM are offered at three U.S. universities: Colorado

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State University, Fort Collins, Colorado, Bowling Green State University, Bowling Green, Ohio, and the University of California at Davis, California. In some instances, thesis research can be accomplished at DWRC or at one of its field stations. In special cases, a nondegree program can be arranged.

Extension

Information transfer took many forms and included workshops, demonstrations, seminars, training manuals, brochures, annual reports, formal publications, media materials, and responding to written requests from interested individuals or agencies worldwide.

Examples of DWRC extension materials and activities are as follows:

1. 25,000 copies of a training manual (written in Spanish) on vampire bat control were distributed in Latin America.

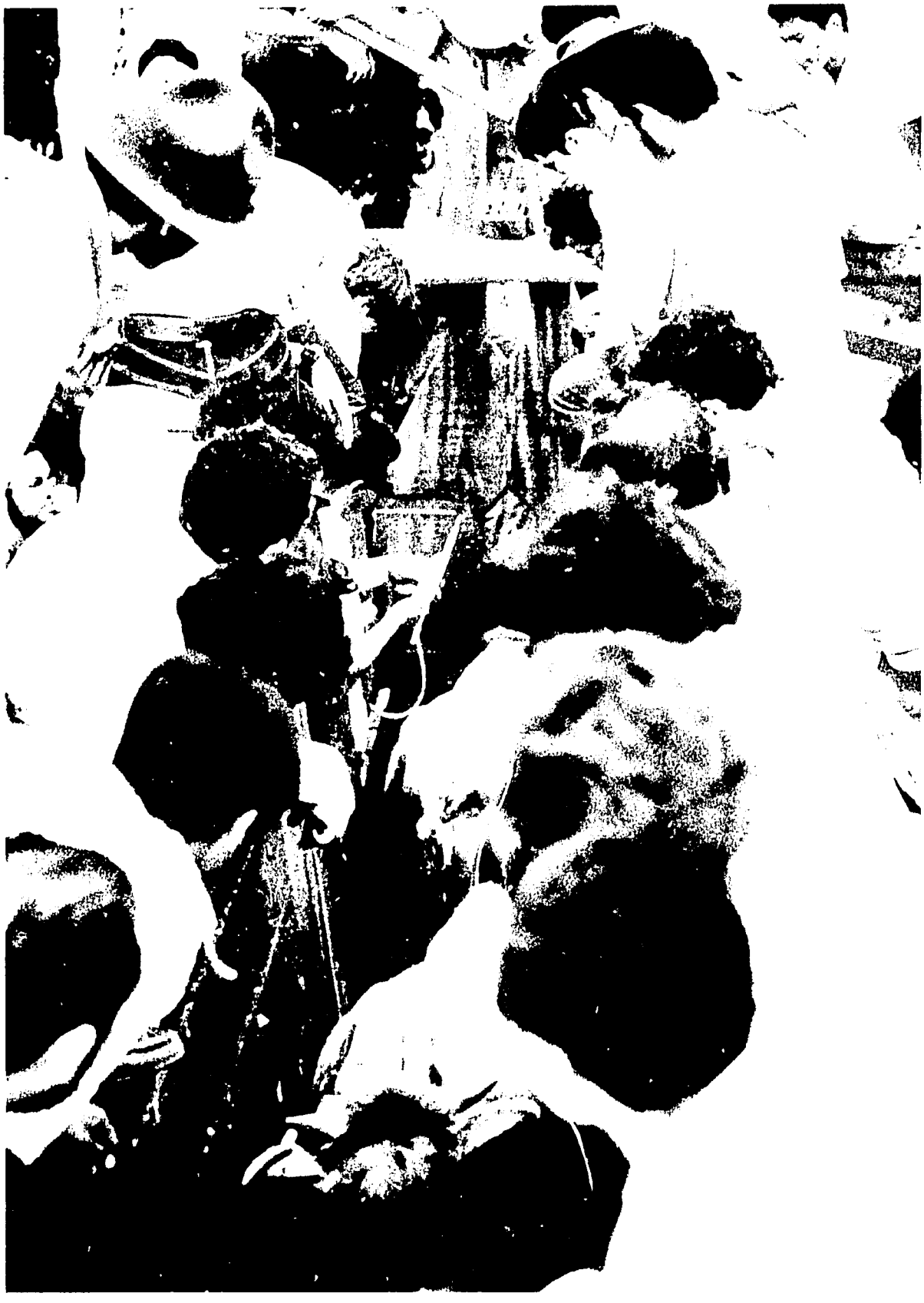
2. In Bangladesh, about 100,000 wheat farmers participated in a national rat damage control campaign. About 450,000 leaflets, posters, and other informative materials (written in Bengali) were distributed.

3. About 1,500 copies of a booklet on rat control in tropical rice have been distributed worldwide.

Institutionalization

The NCPC, in which the DWRC was instrumental in establishing, is now the leading institution of rodent control training for international participants, particularly in Southeast Asia.

Thousands of individuals, including farmers, extension agents, technicians, biologists, veterinarians, administrators, and others concerned with agricultural production, have received both formal and informal training in many aspects of vertebrate pest management. Filipino counterparts learn the fundamental techniques used in field studies. Proper identification of species and a knowledge of their habits are important to develop and implement effective control procedures.



Extension of research recommendations and transfer of technology are major parts of the project. Here, Nicaraguan veterinarians are being instructed on how to apply an anticoagulant chemical, by the injection method, which controls vampire bats feeding on cattle.

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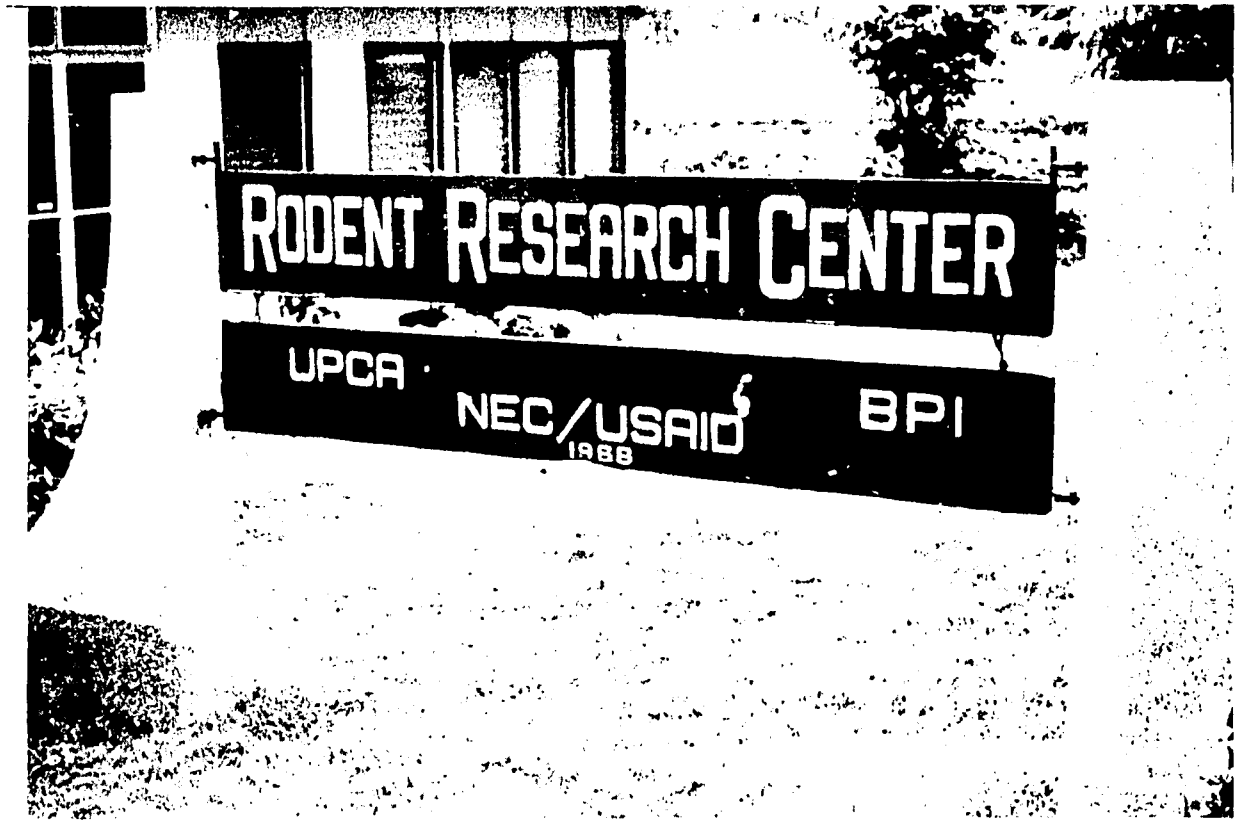

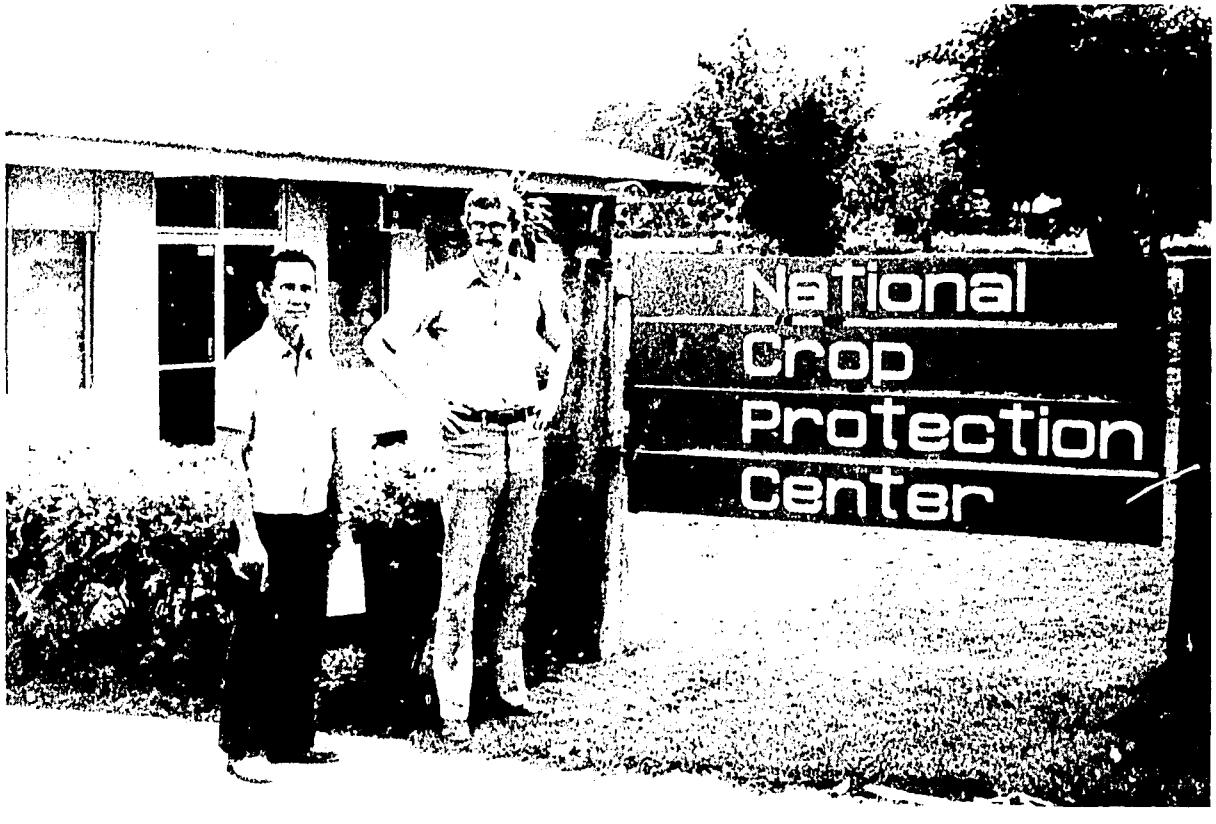

The Rodent Research Center (RRC), established in the Philippines in 1968 with a staff of three Americans and three counterparts, developed into the National Crop Protection Center (NCPC) with a local staff of about 100 and a network of 12 regional field stations.

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LESSONS LEARNED

Program Planning and Linkages

A well-defined memorandum of understanding between USAID, host countries, and DWRC describing project objectives and each agency's responsibilities is essential. As personnel changes occur, so do attitudes and opinions. A detailed document can prevent problems and misunderstandings.

Project linkages should be established and affiliated with a national plant protection agency in addition to a local research organization or university in order that technology can be transferred on a national basis more quickly.

USAID-funded DWRC projects should routinely involve all local sectors, international organizations, and volunteer agencies as appropriate.

Since VPM research is a specialized field and encompasses a wide variety of complex problems worldwide, a long-term, centrally funded program is conducive to continuity and successful implementation of project mandates.

Mission-funded projects are best suited to adaptive research and technology transfer. For example, the Mission-funded project in Bangladesh developed several control solutions rapidly as a result of project experiences in the Philippines.

A research utilization activity is often needed for effective program implementation after initial research is accomplished. This should be recognized and addressed in the project planning stage. This function is sometimes suitable for a follow-on project; for example, the vampire bat training and extension activity in Latin America.

The team approach to problem solving has led to the successful development of several practical and cost-effective control methods. A relatively small field staff with limited equipment and facilities can call upon the resources, services, and expertise of more than 100 DWRC professional and support personnel. This approach avoids duplication of personnel and major equipment.

USAID administrators and interns can become better informed of international VPM activities, objectives, and capabilities by visiting DWRC and field projects.

Personnel

Hiring individuals suited and capable for overseas positions is extremely important. Orientation research at DWRC is essential for new staff members to become acquainted with the research team approach.

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The employee and family members should have the ability to adapt to different cultures and social conditions. Overseas assignments require family support, interest, and understanding.

TDY assistance to field stations by Denver-based personnel is very important. Assistance from scientists specialized in particular disciplines enables the research team to find solutions more rapidly.

Counterparts

Sufficient numbers of counterpart staff are necessary to allow time for some individuals to receive long-term training and return during the project period. The project leader should have a major role in selecting counterparts. A bilingual secretary adds to project continuity and success.

Counterparts should be given a gradually increasing role in program development and project management to insure future institutionalization. Counterpart success means project success. Counterparts should also receive on-the-job training and graduate degree training and represent the project at international meetings. They should visit other research institutions to become better acquainted with outside capabilities and the scientific process.

Operational Considerations

Vertebrate pest management operations involve not only development of safe and effective control methods; they also include other important, related components such as ecological factors, species variability, and environmental assessments.

Experimental design should be written so it can be easily comprehended by the counterparts.

Data collecting processes should be simple, so that even the uneducated worker can participate.

The final solution has to be simple, safe, available, and cost-effective.

Vertebrate pest management strategies that will be accepted should be used in developing technology. Consider local solutions to problems.

Testing and developing control methods should be accomplished in farmers' fields to identify practical and cultural problems associated with local farming practices.

IMPORTANT, UNSOLVED VERTEBRATE PEST PROBLEMS

Although many significant accomplishments have been made in vertebrate pest research and control as a result of the joint USAID/DWRC venture, much remains to be done. It is clear that vertebrate pests cause tremendous economic losses of food, fiber, and the investments made for production, processing, and storage of these materials. In addition, vertebrate pests, worldwide, are also often responsible for human health problems acting as vectors and reservoirs of endemic and epidemic diseases. Most developing countries still operate meager rat or bird control programs in a virtual vacuum despite recent inroads made in vertebrate pest management.

Summarized below is a brief, objective listing of important, unsolved problems and their related activities that warrant future attention.

Field Problems

Rodents

1. Conduct standardized field trials of the sustained baiting technique in countries where rat damage may play a major role in limiting rice production (primarily Asia).

2. Conduct standardized field trials using the method developed for controlling rat damage to coconuts (select countries in each continent; i.e., Jamaica, New Guinea, Colombia, Maldives).

3. Conduct standardized field trials using the method for controlling rat damage to maturing corn (select countries).

4. One of the most difficult places to control rat damage is on experimental farms where a variety of crop stages and crops are present year-round. Expensive research plots and valuable crop production data are routinely destroyed (i.e., 6% of IRRI experiments were completely lost and 69% partially lost in 1980). This problem needs to be addressed worldwide since USAID funds much of this research.

5. Nile rats (*Arvicanthis* sp.) and multimammate rats (*Mastomys* spp.) damage various food crops in Africa south of the Sahara. Cricetid rodents, primarily cotton rats (*Sigmodon* and *Geomys* spp.), are serious pests in Central and South America. Gerbills (*Meriones* spp.) damage crops in arid and semiarid areas from Morocco to India. Research programs should be established and projects developed encompassing the above species on problems of regional importance. These activities should include problem description, damage assessments, evaluation of current control methods, and adaptation of alternate methods.

6. Many tropical countries need to quantify postharvest on-farm storage losses in order to determine the magnitude of the problem.

Most agree there is a problem, but little data exist as to the extent of the problem. Methods need to be developed and improved for estimating rodent densities, grain consumption losses, and contamination effects in food storage structures.

7. Because of extreme price fluctuations in world copra/oil exports, coconut farmers are being encouraged to intercrop with one or more other crops which are also susceptible to rat damage. Identification of damage patterns and a pest management strategy need to be developed for this situation which will (or has) provide(d) a synergistic potential for increased damage.

8. Indonesia is approaching self-sufficiency in rice production. High-yielding varieties, fertilizers, irrigation, and insect pest control have contributed to this; but all these inputs are being limited because of serious, nationwide rat damage. Long-term technical assistance should be considered to nationalize rat control as was done in the Philippines.

9. With most of the prime lowland agricultural land already in use, increased attention has been given to upland area agriculture in developing countries; particularly with root crops. Cassava and camote are examples of root crops very susceptible to rat damage.

Birds

1. Develop and field test the use of additive cues to enhance methiocarb formulations in border applications to reduce bird damage to ripening small grains for use by traditional farmers.

2. Intensive field studies are needed on the problem of monk parakeets causing damage to ripening corn and sorghum in South America, and on other species of parakeets causing the same problem in Central America and the Near East.

3. The impact of lethal control on the actual amount of crop saved needs to be documented in many situations, but particularly in Africa.

4. Further develop control techniques, particularly chemical repellents, for woodpeckers causing problems to ripening corn and cacao in the Caribbean region.

5. Laboratory and fieldwork is needed to improve the adhesive qualities of the fluorescent marking technique, and improve present and develop new uses for marking birds to study their movements.

6. Further develop spraying equipment for lethal control of birds and for marking birds.

7. Develop and field test sorghums having genetic characteristics that potentially can lead to bird resistance.

8. Fieldwork with miniature transmitters is needed to determine the behavior of birds "repelled" from fields treated with repellents. Do they leave the area or damage adjacent fields?

9. Conduct surveys and make recommendations on the problem of bird hazard to jet aircraft at select developing countries' airports; specifically Clark Air Force Base, Philippines.

General

1. Assess vertebrate pest impact on agriculture in selected developing countries to determine current economic and personnel resources devoted to vertebrate pest control activities; evaluate cost and efficacy of control methodology in current use; and develop economic guidelines for operational programs and future control methods development activities (worldwide).

2. Examine the feasibility of nonchemical control methods of vertebrate pests, including resistant varieties, natural and synthesized substances, cultural practices, habitat alteration, and planting cycles.

3. Conduct a follow-up review on the current status of vampire bat control programs in Latin America to determine what countries currently have vampire bat control programs; what institutions fund these programs; what countries developed programs that are no longer active and why; and what countries never developed a program and why.

4. Investigate and make recommendations on the problem of vertebrate pests causing damage to reforestation projects in developing countries, specifically Haiti.

5. Conduct pilot field studies to determine the influence of vertebrate pests on limiting reproduction of endangered species in island habitats. Specifically, rats feeding on the eggs and young of endangered sea birds and turtles on the Galapagos Islands. Other species on other islands are similarly threatened by introduced rats, but only token notice has been given.

6. Establish a subproject to address the problem of other vertebrates causing significant damage in agriculture including crows in fruit crops (Maldives); fruit bats in fruit crops (worldwide); wild pigs (southern Philippines, Indonesia, Pakistan, and many other countries); and rabbits (Uruguay and Argentina).

7. Utilize newly developed electronic devices enhancing the gathering of critical information in field studies. For example, wildlife tracking transmitters, weighing as little as 1.1 g and having a battery life of 25 days, are now available.

Related Laboratory Activities

1. Conduct an in-depth evaluation of existing and develop suitable new chronic and acute rodenticides, avicides, and lower-cost repellents, specifically for agricultural situations in developing countries. Investigate simplification of methods of synthesis, formulation, and quality control for use in these countries.

2. A 5-year program dealing with postharvest food losses in developing countries has been outlined and initial phases of the study are underway. Specific future, high priority needs include: development of low-cost physical exclusion techniques; evaluation of electric barriers, ultrasound, and frightening devices; optimizing rodent exposure to control chemicals; role of bait shyness in eradication of rodents at food storage sites; bait enhancement properties of vegetable oils; studies with toxic amorphous silicon dioxide gels; utilization of liquid baits for rodents in storage situations; testing of new flavorants as bait enhancers for rodents; population dynamics of rats and mice in and near grain storage situations; determining rodent-produced filth in food products; use of fumigants in grain storage situations; categorization of storage situations; and development of training and extension materials.

3. Develop methods to optimize rodent exposure to control chemicals. Studies would include those designed to reduce bait shyness, increase bait consumption (e.g., attractants, liquid baits), and evaluate feasibility of alternate chemical contact delivery systems (e.g., grooming agents, nest material treatments, and tracking materials).

4. Refine a number of analytical procedures for chemical compounds currently being used as vertebrate pest control agents in developing countries.

5. Review literature and draft a report on reproductive inhibitors/ chemosterilants and reexamine feasibility for use on vertebrate pests causing problems in agriculture.

Information Gathering and Technology Transfer

1. Prepare a data base on known chemical control agents, species intended for, and a method of control and application. Frequently, DWRC receives inquiries from developing countries on the use of a chemical for control of a specific vertebrate causing problems in a small, localized area or in unusual circumstances. DWRC could be better prepared to provide a quick, accurate response if a data base were assembled on minor uses of chemicals.

2. Any VPM technology that is "ready" (vampire bat control, seed treatments, rodent control in coconut, etc.) should be "packaged" and made available to appropriate countries.

3. Simple, yet useful assessment techniques are needed in most developing countries to quantify damage and estimate losses. National surveys conducted annually provide long-term trends and monitor the effectiveness of programs, along with identifying localized problem areas. They help government officials justify investment in vertebrate pest programs for increased food production.

4. Through the use of extensive literature-retrieval efforts, identify the subset of major vertebrate pests. Prepare comprehensive maps and citation ledgers for each species. Use available information to outline distributional range maps showing areas of greatest species diversity and potential agricultural hot spots.

5. Determine the effects of cultural practices, crop growing cycles, and host-country economic incentives upon preharvest and postharvest food losses to vertebrate pest species in at least 10 developing nations. Develop optimization models for altered levels of current control practices and for adoption of transferred technology.

6. Assign project personnel to one or more of the international centers for a period of 3 years.

7. Conduct one 2- to 3-week seminar each year for the next 5 years in representative developing countries.

8. There is currently very little opportunity for countries within regions to share vertebrate problems and solutions. South and Southeast Asia, Central and South America, and East and West Africa are central areas with common vertebrate problems that would benefit from a regional Vertebrate Pest Control conference.

9. Most crop protection disciplines have developed or are developing computer models in order to predict and understand pest populations and damage parameters. Modeling provides opportunities to test various hypotheses on computer programs and save valuable time and money in eliminating unnecessary field experiments. Such modeling for vertebrate pests in tropical crops should be initiated.

10. DWRC needs to continue to assist international graduate students in their degree and nondegree programs at American universities, particularly Colorado State University.

11. Where needed, provide input to developing countries needing advice and assistance in documenting reports and protocols for enhancement of wildlife resources, conservation practices, environmental assessments, establishment of wildlife refuge areas, and endangered species.

APPENDIX A. TECHNOLOGY AVAILABLE FOR TRANSFER

1. Control of Rodents in Rice*

Problem Description

Many species of rodents damage rice throughout its growing season. They cut or pull newly transplanted seedlings and cut or open growing stems to reach the developing heads. When the grain heads have developed, rats cut or pull down plants to eat the grain.

A sustained or continual baiting program developed in the Philippines has proven to be very effective in reducing preharvest losses to rats. This baiting program requires only a small part of the farmer's activities for about 10 weeks during the growing season.

Cost:Benefit

Annual surveys showed an average of 3.67% preharvest losses to rats in the Philippines (1971-75). In 1975, sustained baiting techniques were made available and field technicians were trained throughout the country. From 1976 to 1980 preharvest losses averaged 0.49%. This is an annual savings of $14 million.

Use Procedures

1. Use locally available anticoagulant rodenticides. Prices and package size vary considerably, but all the materials have similar action.

2. Mix the concentrate as recommended with the bait material. Select a suitable bait material such as rice shorts.

3. Local materials can be used for the bait containers. Sections of bamboo, 1-L cans, or discarded 1-quart oil cans, opened at both ends, make good containers. See attached listing of bait stations.

4. Select five baiting locations for 1 ha of riceland to be protected. The locations should be at least 50 m apart. Containers can be placed on or along dikes or supported above water level in the paddy.

5. Begin baiting as soon as fields have been transplanted. Place one container at each location and put 6 tablespoons of bait inside. After 3 days check the bait containers. If all of the bait has been eaten at one location, place two additional containers and put 6 tablespoons of bait in each of the three containers, check again in 3-4 days. If the bait is gone, place three additional containers at the locations where this happened and maintain about 6 tablespoons of bait in each.

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*Adapted from "The Philippines Recommends for Rice - 1976."

Previously plagued by chronic and severe damage, this Philippine farmer has lost only negligible amounts of rice to rats since he began using the recommended sustained baiting program developed by project personnel. This cost-effective method was incorporated into national rice production recommendations by the Philippine Government.

6. Continue to check the bait containers twice a week. If rats continue to consume most of the bait at some of the locations, increase the amount of bait in each of the containers. A 1-L can will hold up to 18 tablespoons. Try to anticipate increases in consumption such that some of the bait will still be in the containers each time you check. Add additional full containers if necessary. This is important! If bait is not available after rats have learned to come to the stations, there may be heavy feeding on nearby plants.

7. Remove and replace bait that becomes moldy or excessively wet.

8. Because the few remaining rats which comprise less than 10% of the original population, will prefer the developing grains to the bait, baiting may be stopped at least 2 weeks before harvest unless bait consumption remains high. When bait consumption begins to decline, some of the stations at each point may be removed.

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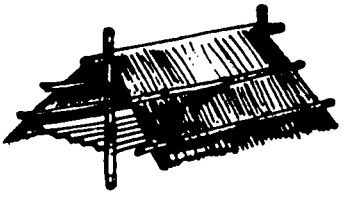
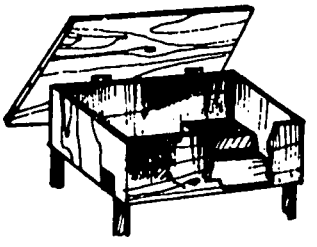
Tin Huts

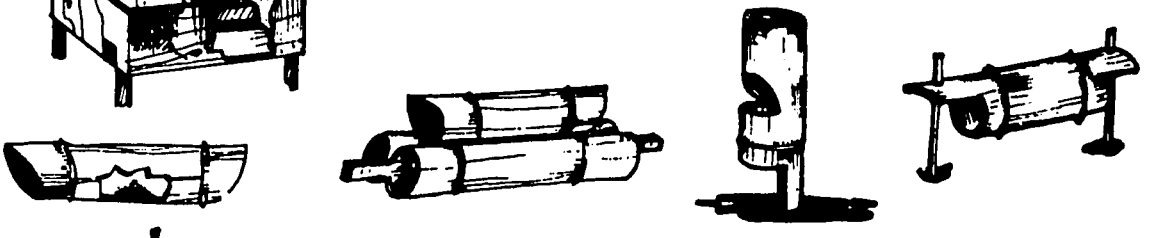
Grass Hut



Wooden Box

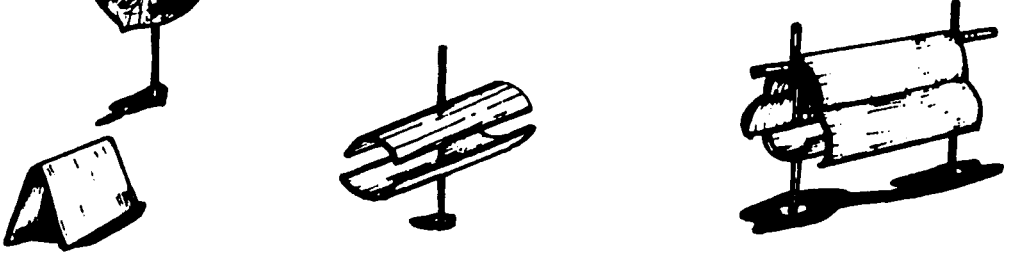


Bamboo Sections

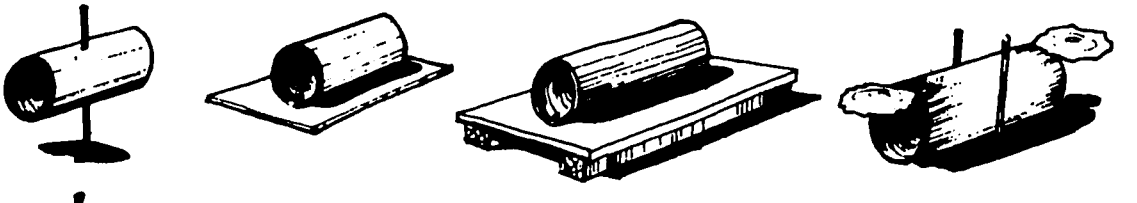


Coconut Husk

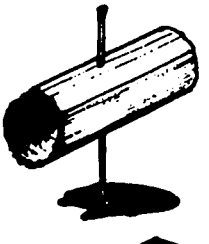
Banana Stalk



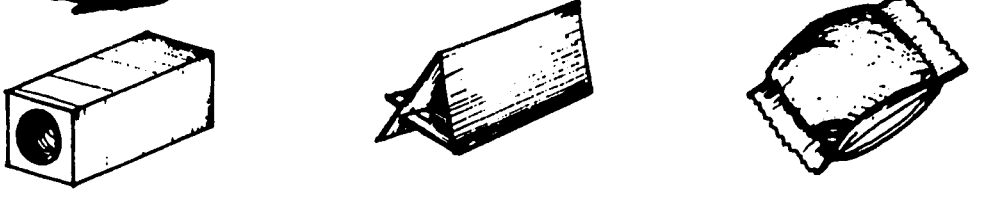
Cans



Cardboard



Commercial



Rat baiting stations for rice farms. (Local materials can usually be obtained at little or no cost for making baiting stations.)

2. Control of Rodents in Coconut*

Problem Description

Rats damage coconuts by climbing the palm, entering the crown, and chewing holes in the green, developing nuts. When fronds or leaves overlap, rats will use them to move to adjacent crowns and damage those nuts also. When the rat gnaws through the outer husk and shell, the nut will fall in about 5-7 days. The rat-damaged nuts can easily be distinguished on the ground from other fallen nuts that are not rat-damaged by the characteristic hole.

The methods of banding trees with metal sheets and baiting with rat poison in bait holders placed on the ground have been used to reduce rat damage with good results, but at high costs. Placing bait directly in the crown (crown baiting) is more specific in that only the rats that climb the palm to damage the nuts are affected, hence, presents less potential hazard to nontarget animals than ground baiting. The technique also reduces the cost because less bait material and labor are needed, and bait needs to be applied to the crown of only 1 of every 10 trees. .

Cost:Benefit

The cost of crown baiting a 100-palm plantation is about US $0.95 per month at 1983 prices of materials (rice, rodenticide, plastic bags, bamboo poles) and cost of labor (2 man-hours/month). For every $0.09 invested for rat control, as high as $1.28 may be gained if each nut is worth $0.05, or $1.93 if price of nuts is $0.07 each. (One Philippine peso ₱ = US $0.09.)

Use Procedures

1. Select a suitable bait material such as rice shorts, corn grits, or whole rice.

2. Mix the bait material with available anticoagulant rodenticide (e.g., Ratoxin, Racumin, Tomorin, Diphacin, Liphadione) following label instructions.

3. Place about 10 heaping tablespoons of the mixed bait into small plastic bags.

4. Mark 10 palms to be baited for every 100 palms present (one out of 10 palms). The marked trees should be evenly distributed within the plantation.

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*Based on Leaflet Series No. 8, produced by the National Crop Protection Center Vegetable Pest Management Team, Los Banos, Philippines. February 1983.

5. Place one packet of bait in the groove of a frond near the center of the crown of the marked palms with the aid of a long bamboo pole or a climber.

6. Add one bait packet to each marked palm, once every month. Baiting should be built into the regular maintenance activities of the plantation.

Recommendations

The crown-baiting technique seems to have the potential to provide highly economical protection of coconuts from rat damage in the Philippines. The approach warrants additional evaluation on the following:

1. bait placement methods,

2. reinvasion of rats and damage following discontinued baiting,

3. regional efficacy, and

4. environmental hazards.

Evaluation of regional efficacy and environmental hazards are prerequisites to recommending this technique for widespread use.

3. Control of Bird Damage to Emerging Cereal Grains

Problem Description

A variety of birds cause serious losses to many kinds of sprouting grains in many parts of the world. Internationally, emerging rice and corn are among those most heavily damaged. In some areas, damage is so severe that some farmers have had to replant fields two or three times. Birds can damage freshly sown seed that is not covered or by digging the covered germinating seed. Damage to the germinating seed usually occurs from the time of planting until the plant is about 10-14 days old or about 10-15 cm tall.

The most practical method of reducing these losses seems to be chemical repellents applied as seed coatings before planting. The use of chemicals on crop and tree seeds to repel birds dates back almost 150 years. Numerous chemicals have been available for decades and include coal tars, red lead, aniline dyes, and thiram. Some have been effective, while others were either ineffective or reduced or retarded germination. The most promising present technique is applying the repellent methiocarb (a carbamate compound) to seed along with an adhesive. Methiocarb is registered in the U. S. for a variety of crop applications. Copper oxychloride has also been used successfully on the problem of birds destroying emergents in Bangladesh.

Cost:Benefit

In Uruguay, damage to untreated emerging soybeans caused by three species of doves and pigeons was 34% compared to only 0.6% damage on methiocarb-treated plots. On sprouting grain sorghum, eared dove damage was 83.3% on untreated plots and 0.2% on methiocarb-treated plots. White-faced tree ducks, speckled teal, and rosy-billed pochards damaged 519 emerging rice plants on untreated plots and only 16 plants on methiocarb-treated plots. In Senegal, treating newly sown rice seed for prevention of bird damage resulted in 1.5 times more yield at harvest than in untreated plots.

Seventy percent protection was afforded with methiocarb on emerging corn being damaged by pheasants in Texas and 83% protection against pheasants, blackbirds, and crows in New York. In Louisiana ricefields, blackbird damage was reduced 68%. There are numerous other successes of the effectiveness of methiocarb treatments.

Use Procedures

1. For all seeds, except rice, a hopper box treatment (HBT) of 50% methiocarb is available from the Chemagro Division of Mobay Chemical Company. Recommended treatments are 0.25-0.50% of 50% HBT methiocarb.

2. For rice, 75% wettable powder (WP) methiocarb is recommended at 0.25%, mixed with about 0.025% adhesive, such as Rhoplex or Latex, and diluted with water. In some rice-growing areas, seed is soaked in

water for 24-36 h to stimulate germination. The same procedure is recommended for soaked seeds.

Recommendations

Treating rice seed with 0.25% methiocarb can provide excellent protection to newly sown seed and emergents from bird pests. At this low level, it is safe, easily applied, and economical. However, additional field trials are necessary to determine its efficacy on other grains and on the great variety of bird species throughout the world causing this type of damage.

4. Control of Rodents in Wheat - An Example of a National Campaign

Problem Description

Wheat is becoming an increasingly important crop in Bangladesh. Annual production has increased from 215,000 long tons grown on 150,000 ha in 1976 to about 1 million tons from 591,000 ha in 1982. Wheat is replacing the traditional dry-season crop which was boro rice.

Along with the increased area planted to wheat and its rise in production has come an increase in rodent damage to the growing crop. In 1983, a national rodent control campaign was held in Bangladesh.

Program Implementation

In Bangladesh, a national rat control campaign was completed based on field trials and recommendations by project personnel. About 250 plant protection assistants and other Government and extension personnel in 11 wheat-growing districts were given simple instructions in rodent control methods. They were also given multimedia campaign materials to distribute ready-made zinc phosphide baits to sell to farmers. The multimedia campaign used motivational and instructional posters, school comic leaflets, farmers' leaflets, radio messages, TV coverage, newspaper articles, and farmer meetings to create awareness and motivation among farmers for the need for rodent control in wheat and other food crops. The 11 districts selected for the campaign produce 92% of the wheat grown in Bangladesh. The Bangladesh-German Plant Protection Program had responsibility for carrying out the campaign in eight districts and the USAID/DWRC program had responsibility for the other three districts. A total of 28,600 motivational and instructional posters, 94,000 farmers' leaflets, and 343,100 school comic leaflets were distributed. Over 200,000 bait packets were distributed to be sold at Tk 2.00 (US $0.08) each, 84,000 by the two projects and the rest by three private formulators.

Cost:Benefit

Surveys of farmers' fields and interviews with farmers in two districts showed that farmers who had used the ready-made bait packets (16.8% of the total interviewed) had kept rat damage to 1.92% in their fields, while farmers using other poisons had 2.92% damage and farmers doing no control had 3.09%. Parallel surveys made in a noncampaign district revealed that farmers who used other poisons had 3.84% damage, and farmers doing no control had 2.67% damage. The 1.17% less damage (less than farmers doing no control) suffered by farmers using the ready-made baits represent a savings of 1.64 kg of wheat/800 m^2 field, worth about Tk 12.00. The cost of control for this size field equals the cost of one 50-g bait packet, Tk 2.00. The cost:benefit was 1:6.

Follow-up

An evaluation of the media material was made interviewing 305 farmers. Fifty-six percent knew about activity on rat control from media material. The radio, especially the morning farm news, was the best means of reaching farmers.

5. Control of Vampire Bats

Problem Description

Before 1974, all 20 Central and South American countries (except Chile) reported bovine losses resulting from vampire bat-transmitted rabies. At that time, it was estimated that approximately 1 million cattle were lost annually. By 1978, 16 countries had some kind of vampire control program employing one or both control methods developed by the USAID/DWRC project.

Use Procedures

Two control methods were developed and utilized the anticoagulant diphenadione. Diphenadione has effectively reduced vampire bat populations in problem areas without harming other animals. Low doses of the chemical are sometimes used in human medicine to reduce blood clotting.

One method, topically treating vampires with diphenadione, requires capturing bats with mist nets that are set at night around corralled cattle, human dwellings, or at cave entrances. Approximately 1.5 cc of a petroleum jelly-diphenadione mixture is placed on the dorsal surface of each captured bat, then the bat is released. The bats return to their roost, and because they live in compact colonies, physically pass the chemical from one to another. The bats die after ingesting the chemical during grooming. It is estimated that 20-25 bats are killed by each treated bat.

The other method, systematically treating cattle with diphenadione, required injecting cattle intraruminally with 1.0 mg diphenadione/kg of body weight. The drug is absorbed and circulates in the blood. Any vampire bat that feeds from a treated animal within 72 h after treatment, receives a lethal dose of the drug. Treating all cattle in a herd gives 90-95% reduction in fresh bites. In Nicaragua, intraruminal treatment of a herd of 414 cattle reduced bites from 1,560 to 7/night.

Cost:Benefit

A female vampire bat gives birth to one young/year. This can be compared with a female rodent which, under optimum conditions, can have 6 litters/year with an average of 6 pups/litter. Due to the low reproductive potential of vampires it takes several years for a population to return to a precontrol level once control methods have been applied. Each vampire bat feeds once per night. Thus, counting the number of fresh bites on a herd of cattle can be used as an estimate of the bat population (100 bites = 100 vampire bats).

In Nicaragua, before control an average of 45 fresh vampire bat bites per 100 animals were counted. After control, this dropped to 4 fresh bites per 100 animals. The average was 11 fresh bites per 100 animals 3-1/2 years after treatment. In comparison, if rodent control was applied only

one time, one would expect the population to return to a precontrol level within a few months.

Recommendations

DWRC will continue to provide assistance and guidance on vampire bat control upon receiving requests from Latin America. Recently, DWRC provided injectable diphenadione to a cattlemen's association in Guatemala. Through the Center for Disease Control (CDC) in Atlanta, DWRC provided control methods for a group of Catholic Missions in Peru where children were being preyed upon by vampire bats.

It has been almost 10 years since the control methods were released by USAID and 5 years since the DWRC has been involved in an extension program.

DWRC believes this would be an excellent time for USAID to conduct a follow-up review of vampire bat control programs in Latin America.

It is desirable to obtain information on the following questions: What countries in Latin America have active vampire control programs? What institutions fund these active programs (national and/or international)? What countries with a vampire bat problem currently do not have control programs?

APPENDIX B: LIST OF PROJECT PUBLICATIONS (1969-1982)

Ahmed, S. 1981. Evaluation of rat control techniques in experimental fields of the International Rice Research Institute. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 62 pp.

Alfonso, P. J., and J. P. Sumangil. 1970. Control of ricefield rats, Chapter 15. Pages 204-211 in Rice Production Manual. University of the Philippines, College of Agriculture.

Alviola, P. L. III, F. F. Sanchez, and E. A. Benigno. 1973. Notes on the feeding habits of three species of Philippine weavers of the genus Lonchura. Kalikasan (Philipp. J. Biol.) 2:149-153.

Anonymous. 1976. Rodent control saves crops. War on Hunger 10(6):5-7.

Anonymous. 1976. Poisoned rice in Philippines proves success. Rice J. 79(5):6-7.

Barbehenn, K. R., J. P. Sumangil, and J. L. Libay. 1973. Summary of Philippine rodents collected from February 1969, through December 1971. Rodent Research Center, College, Laguna, Philippines. 7 pp.

Barbehenn, K. R., J. P. Sumangil, and J. L. Libay. 1973. Rodents of the Philippine croplands. Philipp. Agric. 56:217-242.

Barbehenn, K. R., J. P. Sumangil, J. L. Libay, and M. W. Fall. 1972. Distribution of agricultural rodent pests in the Philippines. Proc. Pest Control Counc. Philipp. 3:58-59.

Benigno, E. A. 1972. Estimating population parameters of the ricefield rat (Rattus rattus mindanensis Mearns). Unpublished M.S. Thesis, University of the Philippines at Los Baños. 49 pp.

Benigno, E. A. 1979. The assessment of infield damage to crops caused by rats. Unpublished Ph.D. Thesis, University of the Philippines at Los Baños. 124 pp.

Benigno, E. A. 1980. Rat damage distribution in rice and corn fields. Philipp. Agric. 63(3):239-250.

Benigno, E. A. 1980. Assessing crop damage caused by small mammals. Pages 139-148 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

Benigno, E. A. 1980. Methods of assessing small mammal pest population. Pages 149-156 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

Benigno, E. A., P. L. Alviola III, F. F. Sanchez, M. M. Hoque, and G. V. Llaguno. 1975. Damage potential of three species of Philippine weavers (Lonchura). Kalikasan (Philipp. J. Biol.) 4:141-144.

Benigno, E. A., R. F. Reidinger, J. L. Libay, and F. F. Sanchez. 1976. Sustained baiting with anticoagulant rodenticides in cornfields and assessment of rat damage. Proc. 7th Natl. Pest Control Counc. Conf. 7:146.

Besser, J. F. 1978. Improvements in the use of 4-aminopyridine for protecting agricultural crops from birds. Proc. 8th Vertebr. Pest Conf., Sacramento, California, 8:51-53.

Besser, J. F., J. W. De Grazio, and K. H. Larson. 1970. The dickcissel--a problem in ripening grains in Latin America. Proc. 5th Bird Control Semin., Bowling Green, Ohio, 5:141-143.

Bohl, W. H. 1978. The Sudan quelea research project. Proc. Symp. Crop Pest Manage. Sudan; Khartoum, Sudan; February 6-8, 1978.

Bruggers, R. L. 1979. Summary of methiocarb trials against pest birds in Senegal. Proc. 8th Bird Control Semin., Bowling Green, Ohio, 8:172-184.

Bruggers, R., J. Ellis, J. Sedgwick, and J. Bourassa. 1981. A radio transmitter for monitoring the movements of small passerine birds. Proc. 3rd Intern. Conf. Wildl. Biotelemetry, Laramie, Wyoming, pp. 69-79.

Bruggers, R. L., and W. B. Jackson. 1981. Suggested methods for determining the efficacy of vertebrate control agents in developing countries. Vertebrate Pest Control and Management Materials, ASTM STP 752, E. W. Schafer, Jr., and C. R. Walker, eds., American Society for Testing and Materials, pp. 15-28.

Bruggers, R., J. Mat e, J. Miskell, W. Erickson, M. Jaeger, W. B. Jackson, and Y. Juimale. 1981. Reduction of bird damage to field crops in eastern Africa with methiocarb. Trop. Pest Manage. 27(2):230-241.

Bruggers, R. L., and M. M. Jaeger. 1982. Bird pests and crop protection strategies for cereals of the semi-arid African tropics. Pages 303-312 in J. Mertin, ed., Sorghum in the Eighties: Proc. International Symposium on Sorghum; Patancheru, A. P., India; November 2-7, 1981; ICRISAT.

Bruggers, R., and P. Ruelle. 1982. Efficacy of nets and fibres for protecting crops from grain-eating birds in Africa. Crop Prot. 1(1):55-65.

Bullard, R. W. 1970. Variation of chemical concentration in surface-coated and tableted grain baits. J. Wildl. Manage. 34:925-929.

Bullard, R. W., ed. 1978. Flavor Chemistry of Animal Foods. ACS Symp. Ser. No. 67, American Chemical Society, Washington, D.C. 175 pp.

Bullard, R. W. 1979. Laboratory investigations of bird repellency in sorghums--II. Sorghum Newsletter 22:98.

Bullard, R. W. 1979. New developments in bird-resistant sorghums. Proc. 8th Bird Control Semin., Bowling Green, Ohio, 8:229-234.

Bullard, R. W., and D. J. Elias. 1980. Sorghum polyphenols and bird resistance. Pages 43-49 in J. H. Hulse, ed., Polyphenols in Cereals and Legumes. IDRC-145e, International Development Research Center, Ottawa, Canada. 72 pp.

Bullard, R. W., M. V. Garrison, S. R. Kilburn, and J. O. York. 1980. Laboratory comparisons of polyphenols and their repellent characteristics in bird-resistant sorghum grains. J. Agric. Food Chem. 28(5):1006-1011.

Bullard, R. W., and G. Holguin. 1975. Flavor components of unprocessed rice (*Oryza sativa* L.). 170th Natl. Meet. Am. Chem. Soc., Chicago, Ill. (Abstr.)

Bullard, R. W., and G. Holguin. 1977. Volatile components of unprocessed rice (*Oryza sativa* L.). J. Agric. Food Chem. 25(1):99-103.

Bullard, R. W., G. Holguin, and J. E. Peterson. 1975. Determination of chlorophacinone and diphenadione residues in biological materials. J. Agric. Food Chem. 23(1):72-74.

Bullard, R. W., J. E. Peterson, and G. Holguin. 1971. Determination of chlorophacinone in blood plasma by gas-liquid chromatography or UV spectrophotometry. 27th Annu. Southwest Reg. Meet. Am. Chem. Soc., San Antonio, Texas, 27:14. (Abstr.)

Bullard, R. W., and E. W. Schafer. 1979. Chemical repellency interactions in bird resistant sorghums. Proc. 11th Biennial Grain Sorghum Research and Utilization Conf., Wichita, Kansas; February 28-March 2, 1979.

Bullard, R. W., and S. A. Shumake. 1973. Food temperature preference response of *Desmodus rotundus*. J. Mammal. 54(1):299-302.

Bullard, R. W., and S. A. Shumake. 1977. Food base flavor additive improves bait acceptance by ricefield rats. J. Wildl. Manage. 41(2):290-297.

Bullard, R. W., and S. A. Shumake. 1979. Two-choice preference testing of taste repellency in *Quelea quelea*. Vertebrate Pest Control and Management Materials, ASTM STP 680, J. R. Beck, ed., American Society for Testing and Materials, pp. 178-187.

Bullard, R. W., S. A. Shumake, D. L. Campbell, and F. J. Turkowski. 1978. Preparation and evaluation of a synthetic fermented egg coyote attractant and deer repellent. J. Agric. Food Chem. 26(1):160-163.

Bullard, R. W., S. A. Shumake, and G. Holguin. 1972. Fingerprinting rat preputial gland exudate. 28th Annu. Southwest Reg. Meet. Am. Chem. Soc., Baton Rouge, Louisiana, 28:20. (Abstr.)

Bullard, R. W., and R. D. Thompson. 1977. Efficacy and safety of the systemic method of vampire bat control. Interciencia 2(3):149-152.

Bullard, R. W., R. D. Thompson, and G. Holguin. 1976. Diphenadione residues in tissues of cattle. J. Agric. Food Chem. 24(2):261-263.

Bullard, R. W., R. D. Thompson, and S. R. Kilburn. 1977. Diphenadione residues in milk of cattle. J. Agric. Food Chem. 25(1):79-81.

Bullard, R. W., R. D. Thompson, and S. A. Shumake. 1972. Response of vampire bats (Desmodus rotundus) to olfactory stimuli. 3rd Annu. N. Am. Symp. on Bat Res., San Diego, California. (Abstr.)

Bullard, R. W., J. O. York, and S. R. Kilburn. 1981. Polyphenolic changes in ripening bird-resistant sorghums. J. Agric. Food Chem. 29(5):973-981.

Bullard, R. W., J. O. York, and M. L. Price. 1981. Comparison of tannin characteristics in group II and Group III sorghums. Proc. 12th Biennial Grain Sorghum Research and Utilization Conf., Lubbock, Texas; February 25-27, 1981.

Burns, R. J. 1970. Twin vampire bats born in captivity. J. Mammal. 51:391-392.

Burns, R. J. 1972. Crecimiento y denticion del murcielago vampiro (Desmodus rotundus) en cautiverio. Tecnica Pecuaria en Mexico 20:33-37.

Burns, R. J. 1973. Controlling Vampire Bats. Tech. Bull. No. 9. Agricultural Technology for Technical Assistance, Agency for International Development. Washington, D.C. 6 pp.

Burns, R. J., and R. W. Bullard. 1979. Diphacinone residue from whole bodies of vampire bats: a laboratory study. Bull. Pan Amer. Health Organ. 13(4):365-369.

Burns, R. J., and R. W. Bullard. 1980. Residuos de difacinona en cadaveres de murcielagos vampiros: Un estudio de laboratorio. Bol. Ofic. Sanit. Panamer. 88(5):396-401.

Burns, R. J., and R. Flores Crespo. 1975. Local movement and reproduction of common vampire bats in Colima, Mexico. Southwest. Nat. 19(4):446-449.

Cadieux, C. L. 1969. Bats, rats, birds and hunger. War on Hunger 3(8):9-11.

Calvi, C., J. F. Besser, J. W. De Grazio, and D. F. Mott. 1976. Protecting Uruguayan crops from bird damage with methiocarb and 4-aminopyridine. Proc. 7th Bird Control Semin., Bowling Green, Ohio, 7:255-258.

Castro, F. B. 1978. Management of limiting factors in sustained anticoagulant baiting of lowland ricefield rats. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 43 pp.

Caudill, C. J., and S. E. Gaddis. 1973. A safe and efficient handling device for wild rodents. Lab. Anim. Sci. 23(5):685-686.

Corner, G. W., and E. W. Pearson. 1972. A miniature 30-MHz collar transmitter for small animals. J. Wildl. Manage. 36:657-661.

De Grazio, J. W. 1970. The problems of birds as pests (book review). J. Wildl. Manage. 34:479-480.

De Grazio, J. W. 1978. World bird damage problems. Proc. 8th Vertebr. Pest Conf., Sacramento, California, 8:9-24.

De Grazio, J. W., and J. F. Besser. 1970. Bird damage problems in Latin America. Proc. 4th Vertebr. Pest Conf., Davis, California, 4:162-167.

De Grazio, J. W., and J. F. Besser. 1974. Wild birds eat millions of dollars. World Farming 16(10):14.

De Grazio, J. W., and J. F. Besser. 1974. Los pajaros silvestres se comen millones de dolares. Agricultura de las Americas 23(6):10,15,29.

De Grazio, J. W., J. F. Besser, J. L. Guarino, and C. P. Stone. 1977. (Untitled summary of method of assessing bird damage to corn.) In Crop Loss Assessment Methods, Supplement 2, No. 131. Commonwealth Agricultural Bureaux by arrangement with FAO. 2 pp.

De Grazio, J. W., and S. A. Shumake. 1982. Controlling quelea damage to small grains in Africa with methiocarb. Pages 452-456 in Alternative Strategies for Desert Development and Management, Vol. 2. Proc. UNITAR Intern. Conf., Sacramento, California, 1977. Pergamon Press, New York.

De la Paz, A. M. 1979. Assessment of rat damage to corn. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 37 pp.

Dizon, R. C. 1978. Diffusion of a rat control innovation among Masagana 99 farmers in Laguna, Philippines. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 69 pp.

Elmahdi, E. M. 1982. Sensory cue enhancement of methiocarb repellency to the African weaver-finch (*Quelea quelea*). Unpublished M.S. Thesis, Bowling Green State University, Bowling Green, Ohio. 94 pp.

Elias, D. J., and B. E. Johns. 1981. Response of rats to chronic ingestion of diphacinone. Bull. Environ. Contam. Toxicol. 27:559-567.

Elias, D. J., R. D. Thompson, and P. J. Savarie. 1978. Effects of the anticoagulant diphenadione on suckling calves. Bull. Environ. Contam. Toxicol. 20(1):71-78.

Elias, D. J., and D. Valencia G. 1973. Control de roedores en el cocotero. In ICA Informa No. 8. Instituto Colombiano Agropecuario, Bogota, Colombia.

Elias, D. J., and D. Valencia G. 1973. Control de roedores en el cocotero. In Revista Esso Agricola. Vol. XIX, No. 4., Italgraf. Bogota.

Elias, D. J., and D. Valencia G. 1973. Evaluacion y control de dano de roedores en coco en Colombia I-IV Partes. Agricultura de las Americas: Una publicacion tecnica de Colombia para las Americas.

Elias, D. J., and D. Valencia G. 1982. Unusual feeding behavior by a population of black vultures. Wilson Bull. 94(2):214.

Erickson, W. A., M. M. Jaeger, and R. L. Bruggers. 1980. The development of methiocarb for protecting sorghum from birds in Ethiopia. Ethiop. J. Agric. Sci. 2(2):91-100.

Estioko, B. R. 1978. Sugarcane yield losses due to rodents with reference to species distribution, infield stalk damage, varietal preference, and movement under Philippine conditions. Unpublished Ph.D. Thesis, University of the Philippines at Los Baños. 76 pp.

Fall, M. W. 1971. Seasonal variations in the food consumption of woodchucks (Marmota monax). J. Mammal. 52(2):370-375.

Fall, M. W. 1974. The use of red light for handling wild rats. Lab. Anim. Sci. 24:686-687.

Fall, M. W. 1977. Rodents in tropical rice. Tech. Bull. No. 36. College of Agriculture, University of the Philippines at Los Baños. 37 pp.

Fall, M. W. 1980. Vertebrate damage control in agriculture. Proc. UC/AID Workshop "Curso de Entrenamiento/Taller en Control Integrado de Plagas." Tapachula, Chiapas, Mexico.

Fall, M. W. 1980. Management strategies for rodent damage problems in agriculture. Pages 177-182 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

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

Fall, M. W., G. A. Hood, and J. W. De Grazio. 1972. A vertebrate pest management workshop program in East Asia. Rodent Research Center, College, Laguna, Philippines. 27 pp. (mimeo)

Fall, M. W., A. B. Medina, and W. B. Jackson. 1971. Feeding patterns of Rattus rattus and Rattus exulans on Eniwetok Atoll, Marshall Islands. J. Mammal. 52:69-76.

Fall, M. W., and F. F. Sanchez. 1975. The Rodent Research Center. PANS. 21(2):206-209.

Fall, M. W., and J. P. Sumangil. 1980. National rat control program in the Philippines. Pages 9-15 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

Fall, M. W., and R. R. West. 1973. Vertebrate pests in Southeast Asia. Proc. Pest Control Counc. Philipp. 4:18.

Fall, M. W., R. R. West, and A. L. Kolz. 1973. Plastic fasteners for rapid attachment of radio transmitters to rats. Philipp. Agric. 56:263-266.

Ferrer, L. S. 1973. A laboratory study on juvenile growth of the common ricefield rat. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 48 pp.

Ferrer, L. S. 1975. Growth of Rattus rattus mindanensis. Philipp. Agric. 59(1&2):37-42.

Fiedler, L. A. 1982. Vertebrate Pest Control. Pages 81-111 In Integrated Pest Management in Rice. Training Manual. International Rice Research Institute, Los Baños, Philippines.

Fiedler, L A., M. W. Fall, and R. F. Reidinger, Jr. 1982. Development and evaluation of methods to reduce rat damage to coconut in the Philippines. Proc. 10th Vertebr. Pest Conf., Monterey, California, 10:73-79.

Flores Crespo, R., R. J. Burns, and S. B. Linhart. 1970. Load-lifting capacity of the vampire bat. J. Mammal. 51:627-629.

Flores Crespo, R., R. J. Burns, and S. B. Linhart. 1971. Comportamiento del vampiro (Desmodus rotundus) durante su alimentacion en ganado bovino en cautiverio. Tecnica Pecuaria en Mexico 18:40-44.

Flores Crespo, R., R. J. Burns, and S. Said Fernandez. 1972. Evaluacion de una tecnica para el combate de los vampiros en sus refugios. Bol. Ofic. Sanit. Panamer. 76(5):427-432.

Flores Crespo, R., and S. Said Fernandez. 1972. Reduccion de la dosis de anticoagulante (Difenadiona) para el control de los vampiros. Tecnica Pecuaria en Mexico 23:19-22.

Flores Crespo, R., S. Said Fernandez, R. J. Burns, and G. C. Mitchell. 1974. Observaciones sobre el comportamiento del vampiro comun (Desmodus rotundus) al alimentarse en condiciones naturales. Tecnica Pecuaria en Mexico 27:39-45.

Flores Crespo, R., S. B. Linhart, and R. J. Burns. 1971. Comportamiento del vampiro (Desmodus rotundus) en cautiverio. Southwest. Nat. 17:139-143.

Flores Crespo, R., S. B. Linhart, R. J. Burns, and G. C. Mitchell. 1972. Foraging behavior of the common vampire bat related to moonlight. J. Mammal. 53:366-368.

Flores Crespo, R., and Jose Morales R. 1974. Metodos para combatir los vampiros y prevenir la rabia paralitica bovina. Special Publication, Instituto Nacional de Investigaciones Pecuarias 29:73-80.

Gaddis, S. E., and S. A. Shumake. 1982. A long-haul transport container with water provision for individually caged rats. Lab. Anim. Sci. 32(2):173-174.

Garrison, M. V., A. Ammayao, and J. L. Libay. 1982. Evaluation of 4-Aminopyridine as a bird control agent in the Philippines. Philipp. Agric. 65(1):53-58.

Garrison, M. V., and C. P. Breidenstein. 1970. Digestion of sugarcane by the Polynesian rat. J. Wildl. Manage. 34:520-522.

Garrison, M. V., and B. E. Johns. 1975. Antifertility effects of SC-20775 in Norway and Polynesian rats. J. Wildl. Manage. 39(1):26-29.

Garrison, M. V. and J. L. Libay. 1982. Potential of methiocarb seed treatment for protection of sprouting rice from Philippine bird pests, Lonchura spp. Philipp. Agric. 65(4):363-366.

Guarino, J. L., and E. W. Schafer, Jr. 1973. A program for developing male chemosterilants for red-winged blackbirds. Proc. 6th Bird Control Semin., Bowling Green, Ohio, 6:201-205.

Gonzales, R., and G. C. Mitchell. 1976. Vampire bat control programs in Latin America. Proc. 7th Vertebr. Pest Conf., Monterey, California, 7:254-257.

Guerrero, R. D. III. 1970. The yield reduction of rice caused by mechanical and actual rat damage. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 47 pp.

Guerrero, R. D. III. 1971. The effect of simulated rat tiller cutting on the yield of rice. Philipp. Agric. 54:439-447.

Hamza, M. 1980. The potential of vegetable tannin as a bird repellent. Unpublished M.S. Thesis, Bowling Green State University, Bowling Green, Ohio. 58 pp.

Hamza, M., B. Ali, I. El Haig, W. Bohl, J. Besser, J. De Grazio, and R. L. Bruggers. 1982. Evaluating the bird repellency of methiocarb. Malimbus 4(1):33-41.

Hoque, M. M. 1972-1973. Notes on rodent pest affecting coconut. Philipp. Agric. 56(7&8):280-289.

Hoque, M. M. 1973. The toxicity of four anticoagulant rodenticides to Rattus rattus mindanensis Mearns. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 27 pp.

Hoque, M. M. 1979. Development of an anticoagulant resistance monitoring program for Philippine rats. Unpublished Ph.D. Thesis, University of the Philippines at Los Baños. 63 pp.

Hoque, M. M., and M. V. Garrison. 1982. Interim rat control measures for Leucaena. Leucaena Forum International: PCARR, Los Baños, Philippines, 2(1):3-4.

Hoque, M. M., and R. F. Reidinger. 1980. Relationships of costs to oral toxicities in five rodenticides available commercially in the Philippines. Pages 205-209 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

Hoque, M. M., R. F. Reidinger, and J. L. Libay. 1976. Crown-baiting in coconut trees using anticoagulant rodenticide to reduce rat damage. Proc. 7th Natl. Pest Control Counc. Conf. 7:148-149.

Johns, B. E., and H. P. Pan. 1981. Analytical techniques for fluorescent chemicals used as systemic or external wildlife markers. Vertebrate Pest Control and Management Materials, ASTM STP 752, E. W. Schafer, Jr. and C. R. Walker, eds., American Society for Testing and Materials, pp. 86-93.

Johns, B. E., and R. D. Thompson. 1979. Acute toxicant identification in whole bodies and baits without chemical analysis. Avian and Mammalian Wildlife Toxicology, ASTM STP 693, E. E. Kenaga, ed., American Society for Testing and Materials, pp. 80-88.

Kennelly, J. J., M. V. Garrison, and B. E. Johns. 1970. Laboratory studies of the effect of U-5897 on the reproduction of wild male rats. J. Wildl. Manage. 34:508-513.

Kennelly, J. J., B. E. Johns, and M. V. Garrison. 1972. Influence of sterile males on fecundity of a rat colony. J. Wildl. Manage. 36:161-165.

Kolz, A. L. 1975. Mortality-sensing wildlife transmitters. Proc. 12th Annu. Rocky Mountain Bioengineering Symp. Vol. II:57-60.

Kolz, A. L., and D. S. Balser. 1972. Wildlife research priorities. The Wildl. Soc. News 139:13-14.

Kolz, A. L., and G. W. Corner. 1975. A 164-megahertz telemetry transmitter for birds and bats. West. Bird Bander 50(2):38-40.

Kolz, A. L., G. W. Corner, and R. E. Johnson. 1973. A multiple-use wildlife transmitter. U.S. Bur. Sport Fish. Wildl. Spec. Sci. Rep. Wildl. 163. 11 pp.

Kolz, A. L., G. W. Corner, and H. P. Tietjen. 1972. A radio-frequency beacon transmitter for small mammals. J. Wildl. Manage. 36:177-179.

Kolz, A. L., and R. E. Johnson. 1975. An elevating mechanism for mobile receiving antennas. J. Wildl. Manage. 39(4):819-820.

Kolz, A. L., and R. E. Johnson. 1976. Coulometric recorder for timing and counting events in the field. J. Wildl. Manage. 40(2):278-282.

Kverno, N. B. 1970. Standardization of procedures for developing vertebrate control agents. Proc. 4th Vertebr. Pest Conf., Davis, California, 4:138-139.

Kverno, N. B., and G. C. Mitchell. 1976. Vampire bats and their relationship to cattle production in Latin America. World Anim. Rev. 17:1-7.

LaVoie, G. K., G. C. Atwell, F. N. Swink, J. P. Sumangil, and J. L. Libay. 1971. Movement of the ricefield rat, Rattus rattus mindanensis, in response to flooding and plowing as shown by fluorescent bone labeling. Philipp. Agric. 54:325-330.

LaVoie, G. K., F. N. Swink, and J. P. Sumangil. 1971. Destruction of rice tillers by rats in relation to stages of rice development in Luzon. Philipp. Agric. 54:175-181.

LaVoie, G. K., H. P. Tietjen, and M. W. Fall. 1971. Albinism in Thomomys talpoides from Colorado. Great Basin Nat. 31(3):181.

Libay, J. L., and M. W. Fall. 1976. Observations on an exceptionally dense population of wild rats in marshland. Kalikasan (Philipp. J. Biol.) 5:207-212.

Linhart, S. B. 1971. A partial bibliography of the vampire bats (Desmodus, Diphylla, Diaemus). U.S. Dep. Inter. Bur. Sport Fish Wildl. 53 pp. (mimeo)

Linhart, S. B. 1973. Age determination and occurrence of incremental growth lines in the dental cementum of the common vampire bat (Desmodus rotundus). J. Mammal. 54(2):493-496.

Linhart, S. B. 1975. Vampire bat control. Pages 221-241 in G. Baer, ed., The Natural History of Rabies. Academic Press, N.Y., N.Y.

Linhart, S. B., R. Flores Crespo, and G. C. Mitchell. 1972. Control of vampire bats by topical application of an anticoagulant, chlorophacinone. Bol. Ofic. Sanit. Panamer (English edition) 6(2):31-38.

Linhart, S. B., R. Flores Crespo, and G. C. Mitchell. 1972. Control de murcielagos vampiros por medio de un anticoagulante. Bol. Ofic. Sanit. Panamer (Spanish edition) 73:100-109.

Llaguno, G. V. 1973. The effects of feeding different doses of an organophosphate compound (Guthion) on red blood cell and plasma cholinesterase in the horse. Unpublished M.S. Thesis, University of California, Davis. 39 pp.

Londoño V., J. F. 1971. Murcielagos, ratas, pajaros y hambre. Revista ESSO Agricola No. 3, May-June 1971. (Spanish translation of Bats, Rats, Birds, and Hunger, by C. L. Cadieux.)

Londoño V., J. F. 1972. Las torcazas, problemas en su cultivo. Algunos metodos de control. Instituto Colombiano Agropecuario. NOTISOYA 2. 1 p.

Londoño V., J. F., D. J. Elias, D. Valencia G., and P. P. Woronecki. 1971. Informe preliminar sobre la incidencia de torcaza naguiblanca (Zenaida auriculata) y su relacion con problemas de dano a algunos cultivos en el Valle del Cauca, Colombia. Instituto Colombia Agropecuario, Region 5. 5 pp. (mimeo)

Marges, B. E. 1972. Reproduction and seasonal abundance of the ricefield rat (Rattus rattus mindanensis Mearns) at Siniloan, Laguna. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 43 pp.

Marges, B. E., E. A. Benigno, and P. J. Alfonso. 1972. Studies on reproduction and movement of the ricefield rat (Rattus rattus mindanensis) at Siniloan, Laguna. Proc. Pest Control Counc. Philipp. 3:62-63.

Mian, Y. 1982. Ecology and control of sympatric rodents on islands adjacent to deep-water rice in Bangladesh. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 111 pp.

Mitchell, G. C. 1971. Nuevas tecnicas de control de poblaciones de vampiros. Procedimiento de V° Congresso Latinoamericano de Microbiologia, Punta del Este, Uruguay 5:357-358.

Mitchell, G. C. 1978. Management programs for vampire bat populations in Latin America--an assessment. Bat Res. News 19(1):27. (Abstr.)

Mitchell, G. C. 1979. Plagas de vertebrados y la agricultura en America Latina. Pages 200-206 in Control integrado de plagas en sistemas de produccion de cultivos para pequenos agricultores, Volumen I; CATIE-UC/USAID-OIRSA; Turrialba, Costa Rica; August 27-September 21, 1979.

Mitchell, G. C., and R. J. Burns. 1973. Chemical control of vampire bats. U.S. Dep. Inter. Bur. Sport Fish Wildl. 37 pp. (mimeo)

Mitchell, G. C., and R. J. Burns. 1973. Combate quimico de los murcielagos vampiros. RTAC/U.S. Embassy, Mexico City, Mexico. 40 pp.

Mitchell, G. C., and R. J. Burns. 1978. Combate quimico aos morcegos hematofagos. Coronel Pacheco, Brasil, EMBRAPA, CNPGL. 31 pp.

Mitchell, G. C., R. J. Burns, and A. L. Kolz. 1973. Rastreo del comportamiento nocturno de los murcielagos vampiros por radio-telemetria. Tecnica Pecuaria en Mexico 24:47-56.

Mitchell, G. C., N. B. Kverno, G. F. de Queiroz, O. R. de Alencar, P. J. da Silva, A. S. da Silva, J.E.M. Couceiro, R. Gueiros, and M. M. de Arruda. 1972. Avaliacao a campo de metodo para controle de morcegos hematofagos em Pernambuco, Brasil. Bol. Def. Sanit. Anim. 6(2-2):39-40.

Mitchell, G. C., and J. R. Tigner. 1970. The route of ingested blood in the vampire bat (Desmodus rotundus). J. Mammal. 51:814-817.

Mott, D. F. 1973. Monk parakeet damage to crops in Uruguay and its control. Proc. 6th Bird Control Semin., Bowling Green, Ohio, 6:79-81.

Ndege, J. O. 1982. Evaluation of methiocarb efficacy in reducing bird damage to ripening wheat in Arusha-Tanzania. Unpublished M.S. Thesis, Bowling Green State University, Bowling Green, Ohio. 59 pp.

Pan, H. P., R. W. Bullard, and I. Okuno. 1980. "Bitter" taste in sorghum. Sorghum Newsletter 23:116.

Piccinini, R. S., C. G. Araujo, and G. C. Mitchell. 1974. Experimentos realizados com o anticoagulante diphenadiona, para o combate ao vampiro comum, Desmodus rotundus, nos Estados de Pernambuco e Paraiba, Brazil. Proc. 14th Congresso Brasileiro de Medicina Veterinaria, Sao Paulo, Brasil, Veterinarias 3(3):58-59.

Poché, R. M. 1980. Range extension of Rattus exulans in South Asia. Mammalia 44(2):272.

Poché, R. M., M. E. Haque, M. Y. Mian, P. Sultana, and M. A. Karim. 1981. Rice yield reduction by simulated rat damage in Bangladesh. Trop. Pest Manage. 27(2):242-246.

Poché, R. M., Md. A. Karim, and Md. E. Haque. 1980. Bird damage control in sprouting wheat. Bangladesh J. Agric. Res. 5(2):41-46.

Poché, R. M., Md. Y. Mian, Md. E. Haque, and P. Sultana. 1982. Rodent damage and burrowing characteristics in Bangladesh wheat fields. J. Wildl. Manage. 46(1):139-147.

Poché, R. M., P. Sultana, S. R. Evans, M. E. Haque, M. A. Karim, and M. A. Siddique. 1982. Nesokia indica from Bangladesh. Mammalia 46(4):547-549.

Poché, R. M., P. Sultana, Md. Y. Mian, and Md. E. Haque. 1979. Studies with zinc phosphide on Bandicota bengalensis (Gray) and Rattus rattus (Linnaeus) in Bangladesh. Bangladesh J. Zool. 7(2):117-123.

Reidinger, R. F. 1976. Organochlorine residues in adults of six southwestern bat species. J. Wildl. Manage. 40(4):677-680.

Reidinger, R. F. 1978. The status of vertebrate research and control in Bangladesh and recommendations. AATC Monograph No. 3. (mimeo) 25 pp.

Reidinger, R. F., Jr., and J. L. Libay. 1979. Perches coated with glue reduce bird damage in ricefield plots. Proc. 8th Bird Control Semin., Bowling Green, Ohio, 8:201-206.

Reidinger, R. F., and J. L. Libay. 1980. Crown-baiting in coconut trees with anticoagulant rodenticides to reduce rat damage. Pages 211-222 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

Reidinger, R. F., Jr., and J. L. Libay. 1981. Size and weight of coconuts damaged by rats. Philipp. Agric. 64(3):281-286.

Rubio, R. P. 1977. Food and feeding habits of the house bat, Scotophilus temminckii (Horsfield), Chiroptera: Vespertilionidae. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 42 pp.

Ruelle, P., and R. L. Bruggers. 1982. Traditional approaches for protecting cereal crops from birds in Africa. Proc. 10th Vertebr. Pest Conf., Monterey, California, 10:80-86.

Sanchez, D. C. 1972. Acceptance of some common foods by the ricefield rats (Rattus rattus mindanensis and Rattus argentiventer) and its relation to selection of bait carriers. Proc. Pest Control Counc. Philipp. 3:60.

Sanchez, D. C. 1977. Population patterns of sympatric rodents: Rattus r. mindanensis (Mearns) and R. argentiventer (Robinson and Kloss) associated with the rice crop in Oriental Mindoro, Philippines (1973). Unpublished M.S. Thesis, University of the Philippines at Los Baños.

Sanchez, F. F. 1973. The Philippine Rodent Research Center. The Rat Fighter (Bureau of Plant Industry, Manila) 7:29.

Sanchez, F. F. 1976. Rodents affecting food supplies in developing countries: problems and needs. FAO Plant Prot. Bull. 23(3/4): 96-102.

Sanchez, F. F. 1976. Knowledge that the pest management specialist will need. Presented at the Workshop on the Consolidation of Crop Protection Courses, sponsored by the East-West Food Institute and the College of Tropical Agriculture of the University of Hawaii; Honolulu, Hawaii; January 5-9, 1976.

Sanchez, F. F. 1976. The current status of rice pest management in the Philippines. Keynote address at the 1976 Annual Meeting of the Entomological Society of America; Honolulu, Hawaii; November 29-December 3, 1976.

Sanchez, F. F., and E. A. Benigno. 1981. Trends in rodent pest management. Symp. on Pest Ecology and Pest Management. BIOTROP; Bogor, Indonesia; December 3-4, 1981. 77 pp. (mimeo)

Sanchez, F. F., and R. F. Reidinger. 1980. Control of agricultural rodents through the sustained baiting method. Pages 183-186 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

Savarie, P. J. 1980. Problems and recent advances in the development of rodenticides. Pages 187-204 in F. F. Sanchez (ed.) Proc. Symp. on Small Mammals: Problems and Control. BIOTROP Spec. Publ. 12; Los Baños, Philippines; December 6-8, 1977.

Savarie, P. J., and D. J. Hayes. 1980. Markers for toxic grease formulations. Rodent Newsletter 4(2):14.

Savarie, P. J., G. H. Matschke, E. W. Schafer, Jr., and G. J. Dasch. 1973. UK-786 possible species-specific toxicant for Norway rats. Nature 241(5391):551-552.

Savarie, P. J., J. R. Tigner, D. J. Elias, and D. J. Hayes. 1980. Development of a simple two-ingredient pyrotechnic fumigant. Proc. 9th Vertebr. Pest Conf., Fresno, California, 9:215-221.

Schafer, E. W., Jr., R. B. Brunton, and D. J. Cunningham. 1973. A summary of the acute toxicology of 4-aminopyridine to birds and mammals. Toxicol. Appl. Pharmacol. 26:532-538.

Schafer, E. W., Jr., R. B. Brunton, and N. F. Lockyer. 1974. Hazards to animals feeding on blackbirds killed with 4 aminopyridine baits. J. Wildl. Manage. 38(3):424-426.

Schafer, E. W., Jr., R. B. Brunton, and N. F. Lockyer. 1975. The effects of subacute and chronic exposure to 4-aminopyridine on reproduction of coturnix quail. Bull. Environ. Contam. Toxicol. 13(6):758-764.

Schafer, E. W., Jr., R. B. Brunton, and N. F. Lockyer. 1976. Evaluation of 45 chemicals as chemosterilants in adult male quail (*Coturnix coturnix*). J. Reprod. Fertil. 48:371-375.

Schafer, E. W., Jr., R. B. Brunton, N. F. Lockyer, and D. J. Cunningham. 1975. The chronic toxicity of methiocarb to grackles, doves, and quail and reproductive effects in quail. Bull. Environ. Contam. Toxicol. 14(6):641-647.

Schafer, E. W., Jr., R. B. Brunton, N. F. Lockyer, and J. W. De Grazio. 1973. Comparative toxicity of 17 pesticides to the quelea, house sparrow, and red-winged blackbird. Toxicol. Appl. Pharmacol. 26:154-157.

Schafer, E. W., Jr., and L. L. Marking. 1975. Long-term effects of 4-aminopyridine exposure to birds and fish. J. Wildl. Manage. 39(4):807-811.

Schneider, E. E., and M. W. Fall. 1970. The role of bird management in fire protection. Proc. 5th Bird Control Semin., Bowling Green, Ohio, 5:53-55.

Shefte, N., R. Bruggers, and E. W. Schafer, Jr. 1982. Repellency and toxicity of three bird control chemicals to four species of African grain-eating birds. J. Wildl. Manage. 46(2):453-457.

Shumake, S. A. 1977. The search for applications of chemical signals in wildlife management. Pages 357-376 in D. Muller-Schwarze, ed., Chemical Signals in Vertebrates. Plenum Publishing Corp., New York.

Shumake, S. A. 1978. Food preference behavior in birds and mammals. Pages 21-42 in R. W. Bullard, ed., Flavor Chemistry of Animal Foods. American Chemical Society, Washington, D.C.

Shumake, S. A., and C. J. Caudill. 1974. Operant conditioning of licking in vampire bats, Desmodus rotundus. Behav. Res. Methods Instrum. 6(5):467-470.

Shumake, S. A., and K. A. Crane. 1980. Laboratory tests of the repellent activity of selected chemicals for protecting corn from damage by cotton rats (Sigmodon hispidus). Rodent Newsletter 4(2):12.

Shumake, S. A., S. E. Gaddis, and E. W. Schafer, Jr. 1976. Behavioral response of quelea to methiocarb (Mesurol^{R}). Proc. 7th Bird Control Semin., Bowling Green, Ohio, 7:250-254.

Shumake, S. A., A. L. Kolz, K. A. Crane, and R. E. Johnson. 1982. Variables affecting ultrasound repellency in Philippine rats. J. Wildl. Manage. 46(1):148-155.

Shumake, S. A., A. L. Kolz, R. F. Reidinger, and M. W. Fall. 1979. Evaluation of nonlethal electrical barriers for crop protection against rodent damage. Vertebrate Pest Control and Management Materials, ASTM STP 680, J. R. Beck, ed., American Society for Testing and Materials, pp. 29-38.

Shumake, S. A., R. T. Sterner, S. E. Gaddis, and K. A. Crane. 1982. Conditioned taste aversion in Philippine rice rats (R. r. mindanensis): comparisons among drugs, dosages, modes of administration, and sexes. Anim. Learn. Behav. 10(4):499-504.

Shumake, S. A., R. D. Thompson, and R. W. Bullard. 1973. An automated odor test for rats. Behav. Res. Methods Instrum. 5(3):279-282.

Shumake, S. A., R. D. Thompson, and C. J. Caudill. 1971. Taste preference behavior of laboratory versus wild Norway rats. J. Comp. Physiol. Psychol. 77:489-494.

Shumake, S. A., R. D. Thompson, and C. J. Caudill. 1977. A technique for visual threshold measurement in vampire bats. Physiol. Behav. 18:325-327.

Sterner, R. T. 1982. A microcomputer-based system for continuous measurement of rodent food intake. Behav. Res. Methods Instrum. 14(6):526-531.

Suliman, S. M. 1980. The feeding behavior of the Nile rat (Arvicanthis niloticus). Unpublished M.S. Thesis, Bowling Green State University, Bowling Green, Ohio. 111 pp.

Sultan, Z. M. 1978. Behavioral studies of rats in relation to coconut damage. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 45 pp.

Sultana, P. 1981. Comparing food preference evaluation techniques for lesser bandicoot rats (Bandicota bengalensis Gray). Bangladesh J. Agric. Res. 6(2):51-57.

Sultana, P., and R. M. Poché. 1982. Food intake in three Asian Muridae. Mammalia 46(3):403-405.

Sumangil, J. P. 1969. The biology and control of field rats in the Philippines. Pages 204-211 in Production of Protein-rich Foods from Local Sources. RDC, Centro Escolar University, Manila.

Sumangil, J. P. 1971. Burrows and breeding of ricefield rats in Cotabato, Philippines. Unpublished M.S. Thesis, Colorado State University, Fort Collins, Colorado. 38 pp.

Sumangil, J. P. 1972. Burrows and breeding of ricefield rats in Cotabato, Philippines. Proc. Pest Control Counc. Philipp. 3:61.

Sumangil, J. P. 1972-1973. The effects of rain and shower in the feeding activity of Cotabato field ratas. Philipp. Agric. 56(7&8):267-273.

Sumangil, J. P. 1976. The national rat control program. Proc. 7th Natl. Pest Control Counc. Conf. 7:95-97.

Sumangil, J. P., P. J. Alfonso, and F. N. Swink. 1969. Rat control recommendations for rice. Page 26 in The Philippines Recommends for Rice-1969. University of the Philippines, College of Agriculture.

Sumangil, J. P., P. J. Alfonso, F. N. Swink, and J. Morales. 1970. More effective control of rats. Pages 32-33 in The Philippines Recommends for Rice-1970. Natl. Food Agric. Counc., Manila, Philippines.

Swink, F. N., G. K. LaVoie, G. C. Atwell, J. P. Sumangil, and A. M. dela Paz. 1973. Preliminary comparisons of three baiting methods for Philippine ricefield rats. Philipp. Agric. 56:251-257.

Thompson, R. D., D. J. Elias, and G. C. Mitchell. 1977. Effects of vampire bat control on bovine milk production. J. Wildl. Manage. 41(4):736-739.

Thompson, R. D., D. J. Elias, and G. C. Mitchell. 1979. A multi-disciplinary approach to development of appropriate vertebrate control technology. Proc. Int. Symp. Eng. San Salvador, El Salvador.

Thompson, R. D., D. J. Elias, S. A. Shumake, and S. E. Gaddis. 1982. Taste preferences of the common vampire bat (Desmodus rotundus). J. Chem. Ecol. 8(4):715-721.

Thompson, R. D., and S. E. Gaddis. 1972. Preference response of vampire bats to basic taste stimuli. Proc. 3rd Annu. N. Am. Symp. Bat Res., San Diego, California. (Abstr.)

Thompson, R. D., and C. V. Grant. 1971. Automated preference testing apparatus for rating palatability of foods. J. Exp. Anal. Behav. 15:215-220.

Thompson, R. D., C. V. Grant, and B. E. Johns. 1979. Cardiac and operant behavior response of starlings (Sturnus vulgaris) to distress and alarm sounds. Proc. 8th Bird Control Semin., Bowling Green, Ohio, 8:119-124.

Thompson, R. D., G. C. Mitchell, and R. J. Burns. 1972. Vampire bat control by systemic treatment of livestock with an anticoagulant. Science 177:806-808.

Thompson, R. D., S. A. Shumake, and R. W. Bullard. 1972. Methodology for measuring taste and odor preference of rodents. Proc. 5th Vertebr. Pest Conf., Fresno, California, 5:36-42.

Tigner, J. R. 1972. Seasonal food habits of Rattus rattus mindanensis (the Philippine ricefield rat) in Central Luzon. U.S. Dep. Inter. Bur. Sport Fish. Wildl. 66 pp. (mimeo)

Tovar, I. 1982. Movements of Rattus rattus mindanensis (Mearns) in a rice cropland and freshwater marsh revealed by radio-tracking. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 81 pp.

Tuazon, E. D. 1979. The yield loss of rice at different stages of growth and intensities of damage. Unpublished M.S. Thesis, University of the Philippines at Los Baños. 24 pp.

Valencia, G., Danilo, and D. J. Elias. 1975. Control de ratas y ratones domesticos. ICA Informa No. 1. Instituto Colombiano Agropecuario, Bogota, Colombia. 4 pp.

West, R. R., and M. W. Fall. 1973. Some approaches for reducing rodent damage to growing rice. Pest Control Counc. Philipp. 4:18.

West, R. R., M. W. Fall, and E. A. Benigno. 1976. Comparison of tracking tiles and snap traps for obtaining population indices of Rattus rattus mindanensis in the Philippines. Philipp. Agric. 59(9,10):379-386.

West, R. R., M. W. Fall, and J. L. Libay. 1972. Field trial of multiple baiting with zinc phosphide to protect growing rice from damage by rats (Rattus rattus mindanensis). Proc. Crop. Sci. Soc. (Philipp.) 3:143-147.

West, R. R., M. W. Fall, and J. L. Libay. 1975. Reducing interactions among rats to improve bait acceptance. Philipp. Agric. 59(1&2):31-36.

West, R. R., M. W. Fall, and J. L. Libay. 1975. Tiller cutting behavior of rats in growing rice. Philipp. Agric. 59(1&2):27-30.

West, R. R., W. H. Robison, A. M. dela Paz. 1973. Weatherability of zinc phosphide-treated rice baits. Philipp. Agric. 56:258-262.

West, R. R., D. C. Tolentino, and D. C. Sanchez. 1972. Evaluation of aerial dispersal of zinc phosphide baits for rodent damage control. Proc. Pest Control Counc. Philipp. 3:62.

Wilkens, H., and R. J. Burns. 1972. A new Anoptichthys cave population (Characidae, Pisces). Ann. Speleol. 27:263-270.

Woronecki, P. P. 1973. Rodent problems in the Darien of Colombia. Biol. Conserv. 5:3.

Wurster, D. H., and G. C. Atwell. 1973. A comparative chromosome study of Rattus rattus mindanensis and Rattus argentiventer. Philipp. Agric. 56:243-250.

APPENDIX C: OUTREACH ACTIVITIES FROM DWRC.

Project Countries

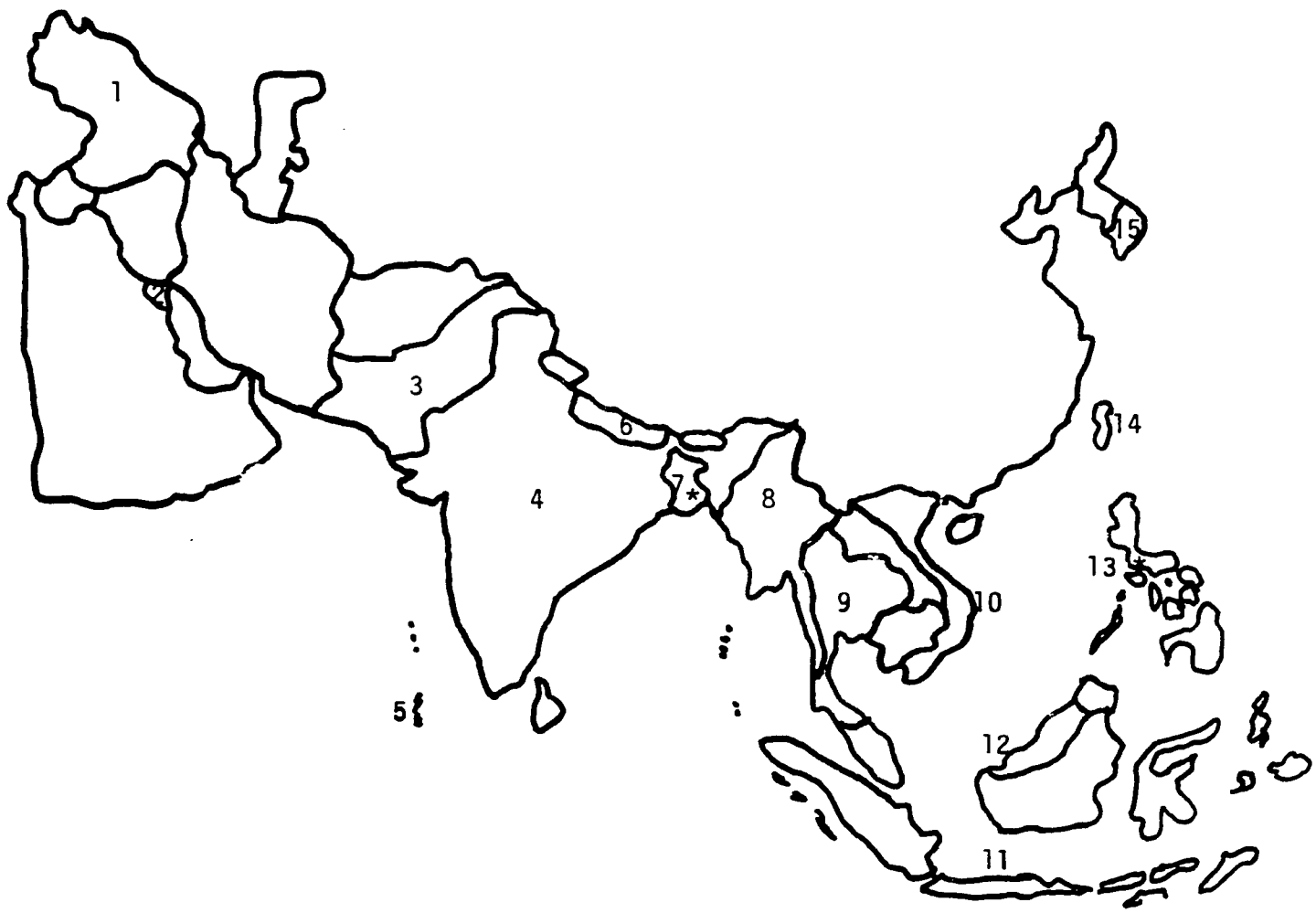
Philippines	1968-
Mexico	1968-1973
Colombia	1970-1974
Tanzania	1976-1977
Sudan	1977-1981
Bangladesh	1978-
Haiti	1980-

Nonproject Countries

Argentina	Ecuador	Kuwait	Philippines*
Barbados	Egypt	Liberia	Senegal
Bangladesh*	El Salvador	Maldive Islands	Somalia
Belize	Ethiopia	Malaysia	South Korea
Bolivia	Ghana	Mexico*	Sudan*
Brazil	Guatemala	Morocco	Tanzania*
Burma	Guyana	Nepal	Taiwan
Cameroon	Haiti*	Nicaragua	Thailand
Chad	Honduras	Nigeria	Trinidad
Colombia*	India	Pakistan	Turkey
Comoro Islands	Indonesia	Panama	Uruguay
Costa Rica	Jamaica	Paraguay	Venezuela
Dominican Republic	Kenya	Peru	Vietnam

*Nonproject country at time of visit.

ASIA



1 Turkey
2 Kuwait
3 Pakistan
4 India
5 Maldives
6 Nepal
*7 Bangladesh
8 Burma
9 Thailand
10 Vietnam
11 Indonesia
12 Malaysia
*13 Philippines
14 Taiwan
15 South Korea

* USAID/DWRC Field Station

MEXICO, CENTRAL AMERICA, CARIBBEAN

*1 Mexico
2 Guatemala
3 Belize
4 El Salvador
5 Honduras
6 Nicaragua
7 Costa Rica
8 Panama
9 Jamaica
*10 Haiti
11 Dominican Republic
12 Barbados

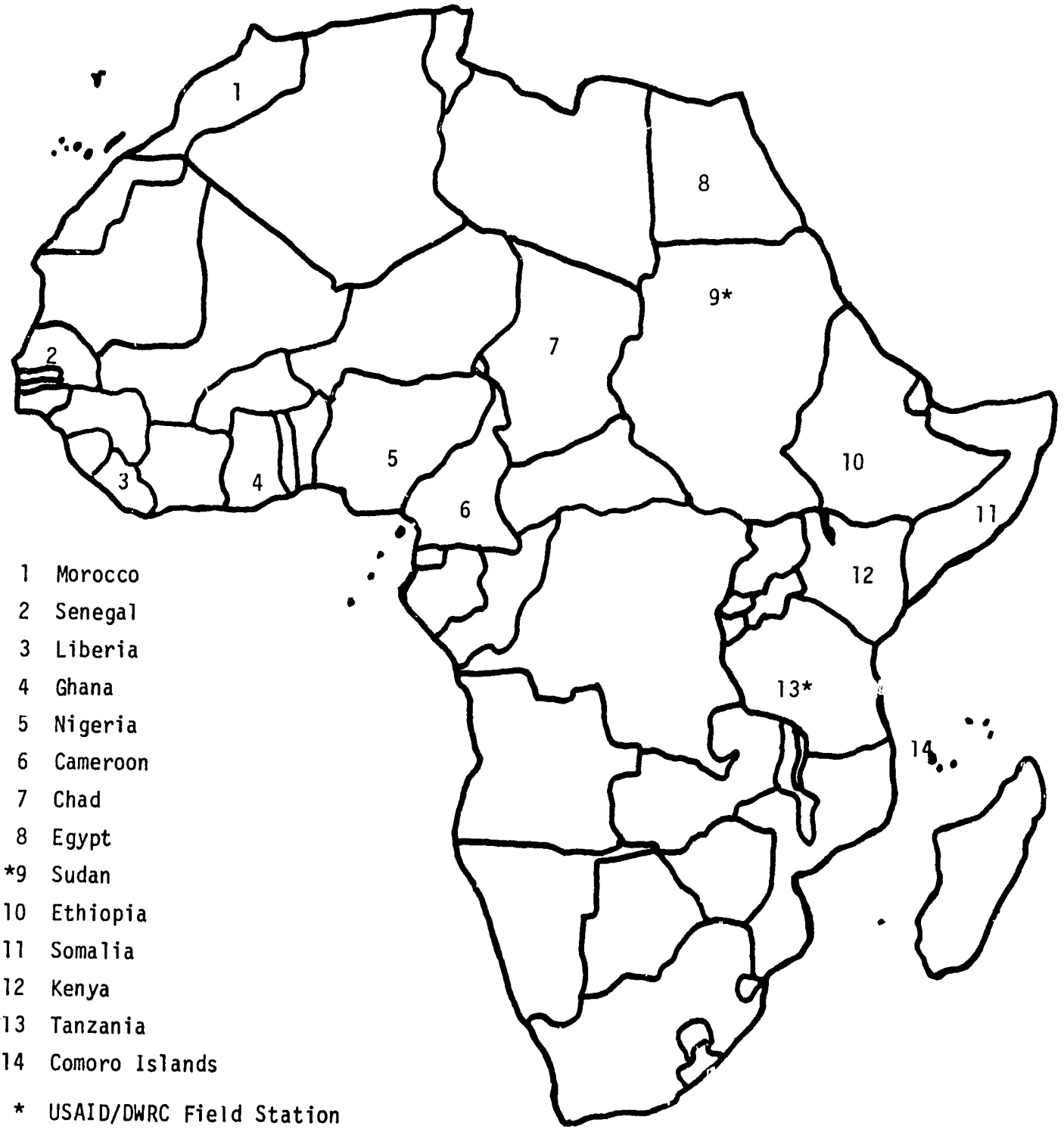
* USAID/DWRC Field Station

SOUTH AMERICA

*1 Colombia
2 Venezuela
3 Guyana
4 Ecuador
5 Peru
6 Brazil
7 Bolivia
8 Paraguay
9 Argentina
10 Uruguay

* USAID/DWRC Field Station

AFRICA



1 Morocco
2 Senegal
3 Liberia
4 Ghana
5 Nigeria
6 Cameroon
7 Chad
8 Egypt
*9 Sudan
10 Ethiopia
11 Somalia
12 Kenya
*13 Tanzania
14 Comoro Islands

* USAID/DWRC Field Station

APPENDIX D: OUTREACH ACTIVITIES FROM THE PHILIPPINES, 1968-1982.

Staff contact at international workshops and seminars	Short-term training at Los Banos (1-6 months)	Graduate training at Los Banos	Working visits or temporary assignments of Philippine-based staff	Workshops conducted in host countries by Philippine-based staff
Bangladesh	Bangladesh	Bangladesh	Bangladesh	Indonesia
Burma	Comoro Islands	Burma	Germany	South Korea
Costa Rica	Indonesia	Indonesia	Great Britain	Thailand
Dominican Republic	Maldive Islands	Pakistan	Indonesia	Vietnam
El Salvador	Nepal	Venezuela	Malaysia	
Fiji	Nigeria		Maldive Islands	
Finland	Pakistan		Nepal	
France	South Korea		Pakistan	
Germany	Sri Lanka		South Korea	
Great Britain	United States (Peace Corps)		Sudan	
Guatemala	Venezuela		Thailand	
Haiti	Vietnam		United States	
Honduras			Vietnam	
India				
Indonesia				
Jamaica				
Japan				
Laos				
Malaysia				
Mexico				
Nepal				
Nicaragua				
Pakistan				
Singapore				
South Korea				
Sri Lanka				
Taiwan				
Thailand				
United States				
Venezuela				
Vietnam				

APPENDIX E: FOREIGN GRADUATE PROGRAMS IN VERTEBRATE PEST MANAGEMENT ASSOCIATED WITH USAID/DWRC PROJECTS.

Country	Individual	Program	Research training	Institution*	Sponsors	Completion date
Philippines	R. Guerrero	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1970
Philippines	J. Sumangil	M.S.	Rodents	CSU	USAID; Phil. Govt.	1971
Philippines	B. Marges	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1972
Philippines	E. Benigno	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1972
Philippines	L. Ferrer	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1973
Philippines	M. Hoque	M.S.	Rodenticides	UPLB	USAID; Phil. Govt.	1973
Philippines	G. Llaguno	M.S.	Pesticides	UCD	USAID; Phil. Govt.	1973
Colombia	F. Londono	M.S.	Vertebr. Pests	UCD	USAID; Colombian Govt.	1973
Philippines	B. Rubio	M.S.	Bats	UPLB	Univ. Phil.; individual	1977
Philippines	P. Alviola	M.S.	Birds	UPLB	Univ. Phil.; individual	1977
Brazil	R. Piccinini	Ph.D.	Bats	UCD	Brazilian Govt.	1977
Philippines	R. Tucay	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1978
Philippines	Z. Sultan	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1978
Philippines	D. Sanchez	M.S.	Rodents	UPLB	USAID; individual	1978
Philippines	R. Dizon	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1977
Philippines	E. Tuazon	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1979
Philippines	F. Castro	M.S.	Rodents	UPLB	USAID; Phil. Govt.	1978
Sudan	M.H.Z. Elabdin	M.A.	Birds	BGSU	USAID; Sudan Govt.	1980
Sudan	M.S. Suliman	M.A.	Birds	BGSU	USAID; Sudan Govt.	1980
Philippines	E. Benigno	Ph.D.	Damage Assess.	UPLB-OSU	Phil. Govt.; USAID; indiv.	1979
Philippines	A. Dela Paz	M.S.	Damage Assess.	UPLB-BGSU	USAID; Phil. Govt.	1979
Philippines	M. Hoque	Ph.D.	Rodenticides	UPLB	Univ. Phil.; individual	1979
Philippines	B. Estioko	Ph.D.	Rodents	UPLB	Phil. Govt.	1978
Philippines	M.V. Dalmacio	M.S.	Rodents	UPLB	Phil. Govt.	1974
Pakistan	A.A. Khan	M.S.	Rodents	UWGB	FAO	1977
Bangladesh	M.S. Ahmed	M.S.	Rodents	UPLB	IRRI	1982
Bangladesh	M.A. Karim	Ph.D.**	Rodents	BGSU	USAID; Bangl. Govt.	--
Venezuela	I. Tovar	M.S.	Rodents	UPLB	Venez. Govt.	1982
Philippines	D. Sanchez	Ph.D.**	Rodents	BGSU	USAID; Phil. Govt.	--
Philippines	R. Dizon	Ph.D.**	Vertebr. Pests	BGSU	USAID; Phil. Govt.	--
Tanzania	J. Ndege	M.S.	Birds	BGSU	FAO	1982

APPENDIX E (cont'd)

Country	Individual	Program	Research training	Institution*	Sponsors	Completion date
Sudan	M. Safi	M.S.	Birds	BGSU	FAO	1982
Indonesia	Rochman	M.S.**	Rodents	UPLB	IRRI	--
Korea	W.S. Cho	M.S.**	Vertebr. Pests	CSU	USAID; Korea Govt.	--
Bangladesh	P. Sultana	Ph.D.**	Vertebr. Pests	CSU	USAID; Bangl. Govt.	--
Ethiopia	A. Damena	M.S.**	Birds	BGSU	FAO	--
Bangladesh	Y. Mian	M.S.	Vertebr. Pests	UPLB	USAID; Bangl. Govt.	1982
Bangladesh	E. Haque	M.S.	Vertebr. Pests	UPLB	USAID; Bangl. Govt.	1982
Philippines	P. Ocampo	Ph.D.**	Vertebr. Pests	NCSU	USAID; Phil. Govt.	--
Philippines	P. Milan	Ph.D.**	Vertebr. Pests	BGSU	World Bank	--

* Institution Code: BGSU, Bowling Green State University; CSU, Colorado State University; NCSU, North Carolina State University; OSU, Oregon State University; UCB, University of California at Berkeley; UCD, University of California at Davis; UPLB, University of the Philippines at Los Banos; UWGB, University of Wisconsin--Green Bay.

** Program in progress.

APPENDIX F: PROJECT MILESTONES, 1966-1982

1966

USAID's Dr. Douglas Caton first emphasized the magnitude of worldwide damage caused by birds and mammals. Dr. Caton contacted the U.S. Department of the Interior's (USDI) Denver Wildlife Research Center to help define the problems and to explore means of reducing vertebrate pest damage in developing countries.

1967

Preliminary analyses, which indicated tremendous losses in crops and domestic animals, led to "The Control of Vertebrate Pests: Rats, Bats, and Noxious Birds," a project which culminated in a USAID/USDI PASA approved by Secretary of the Interior Stewart Udall and USAID Administrator William Gaud on 5 April 1967. USAID allotted $22,000 to DWRC for the purpose of investigating potential sites for field stations in developing countries.

DWRC personnel traveled to Mexico and several countries in Southeast Asia and made preliminary arrangements to establish field stations that would address the problem of vampire bat-transmitted rabies to livestock in Latin America and rodent damage to rice in Asia.

1968

In June, the USAID/DWRC project established stations at Palo Alto, Mexico and at Los Baños, Philippines by transferring two DWRC biologists to each station.

Mexico

Ten field trips, representing 109 man-days in the field, were made for orientation to acquire familiarity with habitat and roost preferences of vampire bats (*Desmodus rotundus*), to gain proficiency in the use of collecting equipment, and to secure bats for laboratory colonies at Palo Alto and Denver.

Philippines

Surveys indicated that rat damage occurred in all stages of growing rice but increased as the crop matured. Surveys in two municipalities of Cotabato Province showed that rats caused a 10% reduction in the rice crop.

Outreach Activities from DWRC

A DWRC biologist traveled to Latin America to document agricultural losses to birds. Forty-six scientists, mainly agronomists and ornithologists, were contacted in Colombia, Honduras, Mexico, Nicaragua, and Venezuela. The consensus of the scientists contacted was that species of five families of birds--parrots, doves, sparrows, blackbirds, and ducks--were largely responsible for attacks on corn, rice, grain sorghum, fruit, and soybeans.

1969

Mexico

Data were compiled on feeding activity, growth and age determination, attack patterns, and grooming behavior of captive vampires.

A satisfactory technique for attaching radio transmitters to vampires was developed.

Philippines

Distribution studies showed *Rattus rattus mindanensis* to be the principal agricultural rodent pest on most of the larger islands. *Rattus argentiventer* assumed this role on Mindoro and Mindanao.

Studies in Mindanao in 1969 showed rice damage by rats to be about half of 1968's average of 10%. First-year damage estimates in Central Luzon averaged 3%.

The rat population on the Central Luzon study area was estimated at 20/ha. Livetrapping data indicated an average movement of 51 m between locations.

Rats utilizing an extensive rain-fed paddy system overgrown with weeds were marked with a bone labeling chemical. Three-quarters of the marked rats trapped in these paddies stayed within 100 m of the release area.

Outreach Activities from DWRC

Field surveys were made in six Latin American countries to obtain information on bird damage problems in agriculture. Species of blackbirds, finches, parrots, parakeets, doves, and ducks caused most of the damage. Grain sorghum, corn, and rice were damaged most heavily. Bird damage problems in Latin America were found to be similar to those in the United States, involving many of the same crops and genera of birds. It was concluded that research conducted in one area should be beneficial for the other.

Field studies were conducted on parakeets in grain sorghum in Nicaragua and doves in soybeans in Colombia. Parakeets were easily netted and were found to be very responsive to broadcast distress cries. The repellent methiocarb applied to soybean seeds before planting greatly reduced damage by eared doves (*Zenaida auriculata*) to germinating seeds.

A survey of mammal damage to agricultural crops was conducted in Honduras, Nicaragua, Venezuela, Colombia, and Bolivia. Rice, corn, sugarcane, bananas, pineapple, truck crops, coconuts, and cacao were the crops most often damaged. Cotton rats (*Sigmodon hispidus*), black rats (*Rattus rattus*), pocket gophers (Geomyidae), and some smaller roden seemed to be the primary problem species.

Supporting Research at DWRC

Seven hundred and thirty-two chemical compounds were evaluated for biological activity as candidate animal damage control agents. Fifteen potential repellents and fifteen toxicants passed the screening program as active compounds.

Studies on digestion and metabolism of blood by vampire bats revealed that they were highly dependent on the protein fraction of blood as a source of energy.

An experiment was conducted to measure cardiac and respiratory responses of wild birds to methiocarb when administered on cracked and pelleted corn on an empty and full stomach. Results revealed that the chemical was markedly more effective in pellets and/or an empty stomach.

A study of the estrus cycle of Polynesian rats (*Rattus exulans*) revealed these rats definitely experienced postpartum estrus within 48 h of parturition. The mean gestation period was 22.2 days and litter size averaged 3.2 pups.

1970

Mexico

A study using night vision equipment to observe the feeding behavior of vampire bats under natural conditions indicated that 40% of vampires feeding on any given night would have sufficient contact with their prey to receive a dermally applied control compound.

Two years of observation indicated that vampire repopulation rates varied according to geographical location and were probably related to a combination of climatic factors and available habitat.

Philippines

Personnel of the Rodent Research Center (RRC) participated in a national rat damage appraisal with the Bureau of Plant Industry (BPI). Damage sampled in the 98 barrios of 16 major rice-producing provinces averaged 4.5%. Projected figures based on the damage surveys, current rice prices, and estimated 1970 production figures indicated that field losses due to rats could be more than ₱51.2 million.

Of 12 compounds tested for toxicity on ricefield rats, all were lethal at levels below 65 mg/kg. *R. argentiventer* generally seemed more susceptible to these toxicants than *R. r. mindanensis*.

A thesis study showed that 20% mechanical damage in the early growth stages of rice did not significantly affect ultimate yields because regeneration of tillers occurred.

Colombia

Two DWRC biologists were transferred to Cali, Colombia in October, and the initial phase of establishing a vertebrate damage control research center began. The center was established with the Instituto Colombiano Agropecuario (ICA) and located at the Centro Nacional de Investigaciones Agropecuarias (CIAT) at Palmira, Valle. Problem situations were surveyed. Soybean damage by eared doves was one of the most serious bird problems and received initial research emphasis.

Outreach Activities from DWRC

Tests in the United States indicated that the fright-producing chemical Avitrol, when applied to grain baits, was an effective tool for reducing blackbird damage to corn. In an initial field test in a Venezuelan sorghum field, dickcissels (*Spiza americana*) were successfully frightened from treated areas. Similar success was obtained in baiting a sorghum field in Mexico.

A biologist from the RRC in the Philippines traveled to Thailand and instructed Thai scientists in laboratory procedures for evaluating lethal rodenticides.

A biologist from the Mexico field station visited Argentina, Brazil, Trinidad, and Venezuela and discussed the vampire bat-livestock rabies problem with various specialists and agencies.

Supporting Research at DWRC

Two hundred and eighty-six compounds were evaluated for biological activity as candidate animal damage control agents. Twenty-two candidate toxicants passed the sceening program as active compounds.

Twenty vampires were placed in an artificial roost. A single bat was removed and 1.5 cm^3 of Vaseline containing 50 mg of chlorophacinone was smeared on the dorsal surface from the scapular region posteriorly to the uropatagium. The carrier bat was reintroduced into the colony and was dead the following day. Eighteen of the remaining 19 bats subsequently died. First deaths occurred in 5 days. Over 50% of the deaths took place by the 7th day and 80% by the 9th day. The last two deaths occurred on day 14. These results demonstrated the possible use of the technique for controlling vampires in the wild.

The taste preference profile was determined for vampires. Bats clearly demonstrated taste discrimination ability by significant aversion to the sour and bitter stimulus. Vampire olfactory perception of blood was tested by measuring heart and respiration rate responses and showed that the vampire is very sensitive to either the odor of fresh or putrified blood. The blood of the vampire was found to be strikingly different from that of many other mammals.

Two chemosterilants, DRC-4801 and DRC-4802, were tested for possible use in Polynesian and Norway rat (R. norvegicus) control. Female Norway rats showed a 21.3- and 20.1-day delay in the onset of pregnancy when orally dosed with 0.5 mg/kg of both compounds. The former compound delayed pregnancy in Polynesian rats for only 7.6 days.

Several chemosterilants were tested in male rats. U-5897, a chemical inducing permanent sterility following a single oral dose, was effective only in Norway rats. Polynesian, ricefield (R. r. mindanensis), and black rats showed a poor, if any, antifertility response to the chemical. The chemical also was ineffective as a chemosterilant in prairie dogs (Cynomys spp.), pocket gophers, and jackrabbits (Lepus spp.). An analog of U-5897 was tested in Norway and Polynesian rats and was found ineffective as a chemosterilant.

Two colonies of Norway rats were established to determine if a male chemosterilant could effectively limit population size. To simulate a chemosterilant's effect, 85% of the males in one colony were bilaterally vasectomized prior to the start of the study. No marked differences in productivity were noted between the two colonies after 6 months.

Instrumentation was perfected to record ultrasounds produced by vampires.

The fabrication and development of miniature (2 g or less), 30 MHz, radio-frequency (rf) beacon transmitters for pest species was completed. Improved circuit component selection, faster construction techniques, and greater product reliability were achieved.

1971

Mexico

Telemetry studies of the nocturnal behavior of vampires revealed that they normally foraged once nightly when there was total darkness. The time and distance of foraging depended on the length of the dark period. No migration was observed, but there was local movement associated with the breeding season.

Evaluations of two vampire control methods developed at Denver were field tested. Both methods showed promise for use as future control techniques.

Preliminary steps were made to train Mexican veterinarians for a national campaign against rabies spread by vampire bats.

Philippines

A national survey for rat damage to lowland rice in major rice-producing provinces during the 1970 wet season and the 1971 dry season revealed an estimated national loss of 3.4%.

A 2-year study of rat populations in rain-fed and irrigated riceland was completed. Birth rates (births/rat/year) were calculated as 10.67 for the

irrigated and 8.23 for the rain-fed areas in 1970, and 15.63 and 9.79 for the two areas in 1971. In both areas, the reproductive pattern seemed to relate to the habitat provided by the rice crop.

No major food preferences were indicated in a series of laboratory and field tests with R. argentiventer and R. r. mindanensis. Both species readily accepted most of the materials tested, suggesting that many items could be used as toxicant carriers or bait for traps.

Weathering studies indicated that bait containing 2% zinc phosphide and 1% vegetable oil would remain toxic for at least 24 h even under extremely wet field conditions.

Fieldwork was completed for a study of the food habits of R. r. mindanensis. A University of Colorado graduate student cooperating with the RRC completed the study and found that when rice seed was available, it comprised about 75% of the diet.

One Filipino staff member returned from Colorado State University after completing the requirements for a Master's degree in Wildlife Ecology.

Colombia

Efforts were made to delineate vertebrate damage problems considered serious and warranting intensive research. Those meeting this criteria included eared doves in soybeans and sorghum, dickcissels in rice and sorghum, shiny cowbirds (Molothrus bonariensis) in corn, rice, and sorghum, parrots in sorghum, and rodent damage to coconuts and rice.

Data were accumulated on food habits, breeding seasons, and other aspects of eared dove biology.

Outreach Activities from DWRC

Two trips were made to Chad under auspices of USAID and FAO. Part of the FAO-sponsored quelea project in Ft. Lamy, Chad, related to reducing hazards resulting from spraying lethal chemicals on roosting and nesting sites. DWRC personnel cooperated by searching for better and safer toxicants, and a number of compounds were suggested.

Studies in Nicaragua were initiated on cotton rats damaging rice. The density of cotton rats in ricefields was high. Rice treated with 2% zinc phosphide effectively reduced populations when applied during the dry season. Zinc phosphide bait was far more effective than the Racumin bait tested. Plowing also reduced populations.

Field tests were conducted in Venezuela on a North American migrant bird, the dickcissel, causing damage to ripening grain sorghum. Grain baits treated with Avitrol indicated effectiveness, but more field testing was required.

A biologist traveled to Taiwan to review rodent control and rice production methods and to Indonesia to provide assistance to the government in rodent control and participate in a pest control workshop.

A DWRC biologist traveled to Barbados and recommended rodent control methods to reduce the incidence of leptospirosis. The trip was funded by the Pan American Health Organization (PAHO).

Supporting Research at DWRC

Norway rats were found to be highly susceptible to the lethal effects of a new chemical, DRC-5876.

The 4,000 compounds included in a rodent repellency study were encoded and added to the chemical structure and activity publication as an appendix.

Studies with the bird-frightening agent Avitrol to gather data toward registration showed there was very little movement of the radio-labeled compound through any of the alkaline and acidic soils tested; residues were more tightly bound to acidic than alkaline soils and less available for microbial and/or chemical degradation; there were no apparent phytotoxic effects to sorghum seedlings grown in nutrient culture containing 10 and 100 ppm of the compound; and there were detectable amounts of radio-activity in the shoots and heads of 1- and 3-month plants.

A four-choice, open-field odor test maze was used to evaluate odor preference responses to over 50 compounds in ricefield rats. Several natural oils, amines, and aldehydes showed a high degree of attractant quality.

Potential vampiricides, chlorophacinone and diphenadione, could be determined in blood plasma by either UV spectrophotometry or gas-liquid chromatography and indicated that meat or milk samples might be analyzed by the same procedure.

Considerable progress was made in developing a livestock systemic technique for vampire bat control. Tests indicated that DRC-5652, an anticoagulant, had excellent potential as a livestock systemic for reductional control of vampires. It was toxic to vampires (acute LD50 = 0.90 vs. 3.75 mg/kg), had much less effect on cattle prothrombin clotting time, and was not retained in the host's body for a prolonged time after treatment.

A new transmitter was designed for use on birds and bats which operated on a 164-MHz frequency.

1972

Mexico

A study on reducing vampire populations by applying chlorophacinone to their roost was completed. Results showed treating roosts was probably a selective and effective means of controlling the population without secondary hazards for other cave-dwelling animals.

National Geographic filmed a sequence on vampire bats which appeared in the television special "World of Darkness," released in January 1973.

In a field experiment, 207 head cattle on three adjoining ranches were given single intraruminal injections of 1 mg/kg diphenadione. Fresh bites fell from 214 before treatment to 15 about 2 weeks after dosing. Chi-square analysis showed that the 93% reduction was highly significant ($P < 0.01$) and that the treatment was equally effective at the three ranches. The cattle showed no ill effects from the treatment. The technique was scheduled to be used throughout Latin America for reductional control of vampire bats.

Philippines

A national rat damage survey in lowland rice areas throughout the Philippines revealed that approximately 2.5% of the tillers had been cut by rats, and more than 90% of the paddies surveyed had rat damage.

Work on rodent census techniques continued. Comparison of snap-trap lines and similarly placed lines of inked tracking tiles suggested that, if carcasses are not required, inked tiles could be used to provide a sensitive, repeatable population index with less effort than trapping. Preliminary work also suggested that snap-trap grids (400 to 500 traps/ha) could be one of the more practical means of making actual estimates of rat populations in ricefields.

Continued observations on the reproduction of *R. r. mindanensis* confirmed that breeding was related to habitat quality rather than season. Pregnant females or newborn young were found during every month, wherever ricefields or associated habitats provided adequate food and cover.

Preliminary field tests of sustained baiting with chronic toxicants, coupled with mid-crop exposure of zinc phosphide, showed that rats readily accepted anticoagulant bait, and many rats from peripheral areas were drawn to baited areas along with resident animals. Locating bait stations within paddies showed promise as one means of improving bait acceptance.

One Filipino staff member returned from Bowling Green State University, Bowling Green, Ohio after 1 year of nondegree study in Economic Biology.

Two full-time staff biologists were added: one supported by BPI, the other by UPLB. Both completed Master's degrees in Vertebrate Biology under fellowships associated with the RRC program.

Colombia

Rodent damage surveys conducted in three coconut-producing areas of Colombia indicated that damage ranged from light to very heavy and was caused primarily by *R. rattus*.

Ground baiting with Avitrol was successful in frightening shiny cowbirds from experimental corn plantings. Black vultures (*Coragyps atratus*) were

observed causing severe damage to oil palm fruit near Turbo, but initial attempts to control the problem were unsuccessful. The effectiveness of methiocarb as a soybean seed repellent for eared doves was field tested, but results were inconclusive.

Outreach Activities from DWRC

A trip was made to further investigate bird and rodent damage problems in Senegal, Liberia, Ghana, Nigeria, Chad, and Cameroon; to accompany FAO personnel to rice damage areas in Chad and Cameroon; to discuss research findings in Africa with FAO personnel in Rome; and to develop plans for a USAID/DWRC research program in Africa.

Three 12-day workshops on Vertebrate Pest Management were conducted in Korea, Thailand, and the Philippines by DWRC biologists. Major objectives of the workshops were to present the principles and strategies involved in protecting agricultural crops. Eighty-five trainees from eight Asian countries participated.

DWRC biologists gave demonstrations on vampire bat control in Brazil, Belize, and Bolivia and evaluated vampire bat predation on livestock in Costa Rica and Nicaragua.

A DWRC biologist conducted field trials on rodent damage to coconuts in San Andres Island, Colombia and to rice in Nicaragua.

An contractor assessed the status of vertebrate pest problems in the Philippines, Malaysia, Indonesia, and Thailand and proposed a regional plan for vertebrate pest control research.

Supporting Research at DWRC

Twenty-two compounds were evaluated as male avian chemosterilants. Eight chemicals induced sterility for varying periods of time, two of which seemed to be permanent.

The comparative toxicity of 17 pesticides to three species of birds indicated that toxicity to one species can often be used to indicate toxicity to another species.

Plant and soil studies with the bird-frightening chemical Avitrol indicated that soil type, organic matter, pH, soil temperature, and moisture content influenced degradation. Plant and soil studies with the bird-repellent chemical methiocarb indicated rapid hydrolysis of the parent material in a slightly alkaline, loamy sand.

Two chemicals were tested as rat toxicants by the EPA single-dose rodenticide protocol. DRC-3992 did not pass the test; DRC-4575 passed but company approval was needed before decisions on future development could be made.

There were a total of 6,000 chemicals encoded into the computer notation system and filed in the Center's file of biologically active compounds.

The knowledge that prior sensory experience was important in food preference behavior provided the guidelines for developing a promising attractant for the ricefield rat. A volatile rice fraction was found to consistently enhance bait consumption in a series of laboratory preference tests and in a semifield evaluation.

Studies showed there was no human or environmental hazard associated with treating cattle and vampires with diphenadione.

It was determined that the Polynesian rat had an average estrous cycle of 3.9 days, a postpartum estrus, and delayed implantation if more than one nursing young was present. A study of the spermatogenic cycle and duration of epididymal sperm transport in the Polynesian rat showed that the time required for epididymal sperm transport was 18 days.

A radio-frequency transmitter containing digital integrated circuits was developed into a versatile wildlife research tool. The transmitter had an electronic printed circuit board to facilitate fabrication and to allow for a convenient means of altering the operation so that parameters of temperature, mortality, location, and diurnal activity could be monitored either individually or collectively.

1973

Mexico

The field study to determine how quickly vampire populations recovered after being reduced by control measures was continued. Eighteen months after control, vampire populations still remained low.

Recommendations were made to modify the control method of topically treating captured bats so that fewer bats could be treated with equal results.

Regional campaigns to reduce vampire populations were begun in Colima, Morelos, and Yucatan.

Vampire control workshops were conducted in Nicaragua; Panama; Colombia; Recife, Brazil; and Salvador, Brazil. In all, 245 participants from six countries received training.

Closing ceremonies for the project were held on 11 December 1973. Participants were from Washington, D.C., Denver, Colorado, and Mexico City, Mexico.

Philippines

Full- or part-time RRC staff included 10 biologists, 1 biometrician, 2 field technicians, 3 trainees from other countries, 3 graduate students, and 8 supporting staff members.

Intensive removal trapping, repeated at 2-week intervals throughout a crop season to simulate acute toxicant baitings and to provide data on rat population characteristics, resulted in rapid recovery of the population after each trapping period. Thus, small-farm control programs based on simple or periodic reduction of rat populations would be unsatisfactory in rice protection.

A study using untreated bait at stations placed in a grid within a ricefield showed rat bait consumption increased dramatically from 2 to 12 weeks after transplant, especially at perimeter stations.

Under conditions of high rat density, major increases in bait consumption were obtained by making it possible for more animals to feed without disturbance at baiting points. This was accomplished by adjusting both the number of stations and the amount of bait according to the intensity of feeding at each point. Closed circuit television monitoring showed up to 15 rats feeding simultaneously at points adjusted this way, while no more than two were observed feeding simultaneously at the same point in the reference plot. The procedure seemed to have economic and biological advantages over use of "torpedos" or distributing stations throughout the area.

Recommendations for rat control based on the suggestions of representatives from BPI, UPLB, the German Crop Protection Strengthening Programme, and the RRC were issued in conjunction with the national rice production program Masagana-99. Recommendations were based on field evaluations and data supplied by the project.

Results of a sustained baiting test with anticoagulants at the barrio level illustrated a major reduction in rat damage to rice crops and emphasized the significance of using trained field technicians in the implementation of the program.

Over 300 visitors from many countries were briefed on RRC activities and given technical assistance or advice on program planning. Numerous requests for technical information on rodent control were filled.

Staff members participated in fourteen 2-week courses for 960 extension workers and technicians. Center staff also taught in four 1-month rice production training workshops for 120 crop and livestock inspectors and participated in the training of 1,200 field technicians.

Three participatory research trainees from Nepal, Korea, and Indonesia spent a total of 15 months participating in a variety of ongoing research and control method evaluation activities and worked independently on projects or project proposals related to pest problems in their own countries.

Two students completed M.S. degree requirements in vertebrate pest management at UPLB. One student completed requirements for the M.S. degree as a USAID Participant Trainee in Pharmacology at the University of California.

Staff members taught or helped teach courses in Vertebrate Pests, Mammalogy, and Wildlife Management at UPLB.

Colombia

Major objectives on the problem of rodent damage to coconuts were completed. Excellent control was achieved with diphacinone-treated bait.

The effectiveness of methiocarb as a soybean seed repellent for eared doves was field tested and observations indicated good repellency, but a qualitative and quantitative evaluation was needed. Treating soybean seeds with methiocarb did not affect germination or production.

An aging and sexing technique for the eared dove was developed; over 60 food items were isolated and data were also gathered on parasites, diseases, and breeding season.

Outreach Activities from DWRC

DWRC biologists conducted vampire bat control seminars in Panama, Nicaragua, Colombia, and Brazil and held discussions with government officials in Guyana and Trinidad.

Bird damage problems were investigated by DWRC biologists in Uruguay, Nicaragua, Tanzania, and Ethiopia.

Work continued on the rodent problem to rice in Nicaragua and rat damage to coconut on San Andres Island, Colombia.

A vertebrate pest management workshop was conducted by a DWRC biologist in Indonesia.

DWRC biologists assisted FAO in a review of regional vertebrate pest problems and in a baiting experiment in Thailand and assisted personnel in Vietnam on rodent damage surveys on rice and sorghum.

A DWRC biologist visited Turkey and collected information on vertebrate pest problems occurring in agriculture.

A DWRC biologist conducted field experiments on quelea damage to small grains in Chad, Kenya, and Tanzania in cooperation with FAO biologists.

Supporting Research at DWRC

Five candidate fluorescent pelage markers were evaluated. DRC-6082 was selected as the fluorescent marker of choice and was successfully used on rodents by personnel at the RRC.

At the request of an FAO Fellow-Korea, rat feeding tests were conducted with two Korean zinc phosphide formulations and one red squill formulation. They were compared to formulations prepared in the United States. There were no significant differences in mortality and amount of chemical

consumed between the zinc phosphide or the red squill formulations. These bioassay data indicated that the potency of the respective formulations produced in the two countries is equal.

Laboratory and semifield preference tests were conducted with ricefield rats on four varieties of rice. In both laboratory and semifield tests, significant preference ($P < 0.01$) was shown for one variety, FK-178A.

Pilot work was initiated to demonstrate the feasibility of protecting rice-growing areas and high-value crops from damage by ricefield rats with nonlethal electric barriers. It was determined that 1,200 V at 300 μA were effective in deterring food-deprived rats from a food source. There was a 99% drop in food consumption and a 98% reduction in rat presence in a control chamber ($P < 0.05$). These tests established that a 45-cm barrier height, a 15-cm electrode spacing, and barrier angles between 45° and 90° produced the most consistent repellency.

As part of the Center's effort in developing highly palatable baits for rat control, the volatile constituents of ground California brown rice were isolated and found to be attractant to *R. r. mindanensis*.

1974

Philippines

A trapping study of an upland crops area in Batangas suggested that *Mus musculus* was found principally in houses; *R. exulans* was present in all habitats, but particularly abdundant in coconut groves; and *R. r. mindanensis* and *Suncus murinus* were common in ricefields, cornfields, ground level vegetable plots, coconut groves, and sugarcane areas. Breeding seemed continuous among all the species encountered.

Several field studies confirmed that sustained baiting with chronic toxicants provided highly beneficial damage reduction in an area where *R. argentiventer* had limited production.

A study comparing four methods of analyzing food contents of Philippine rats showed that the use of histological techniques markedly increased the accuracy in identification of minor food items in rodent stomachs; however, the technique could underestimate the volumetric proportions of the stomachs occupied by major food items.

A preliminary test of "sipaet," a variety of rice from Sumatra that was claimed by farmers to be resistant to rat damage, received significantly less damage than a common Philippine variety. These results probably indicated the ability of rats to express food preferences; it is likely that "resistant" varieties would still suffer damage under no-choice field conditions.

The effects of toxicant concentration on bait acceptance by *R. r. mindanensis* were evaluated for three acute and four chronic rodenticides. Of particular interest, encapsulated norbormide was well accepted over a

wide range of concentrations. Unencapsulated norbormide and zinc phosphide were poorly accepted, even at low concentrations.

Observations in marshland areas revealed localized breeding populations of R. r. mindanensis exceeding 1 rat/m^2, suggesting that areas bordering agricultural lands might be involved in erratic rat outbreaks that have occurred in the Philippines in the past.

Preliminary work in cooperation with the Food Science Department, UPLB, was begun to develop rat meat formulations that were acceptable and could be stored without refrigeration. A taste panel found that two sausage formulations prepared from rat meats were similar to two made from pork in general sensory characteristics, including flavor, tenderness, and juiciness, and rated one of the rat sausage formulations as having the highest general acceptability.

Cage studies, conducted on three species of Philippine weavers (Lonchura punctulata, L. malacca, and L. leucogaster), indicated that these birds have the potential of removing or destroying 7-10 g rice grain/bird/day. Acute oral toxicities of two compounds, fenthion and methiocarb, were determined for the three species, and results indicated that all three were more sensitive to fenthion than methiocarb and that L. leucogaster was least sensitive to either compound.

Over 300 visitors from many countries were given technical assistance in the form of literature on rodent control or advice on program planning. Approximately 160 requests for technical information on rodent control were filled.

Staff members participated in several 2-week courses for more than 500 extension workers and technicians, presented lectures on vertebrate pest control in seven 1-month courses for over 200 bank loan officers, and participated in the 6-month rice production and multiple cropping courses at IRRI and in the in-service training of several hundred Filipino field technicians.

Two research trainees from South Vietnam participated for 6 months in vertebrate pest research studies and worked independently on project proposals related to pest problems in Vietnam.

A small library was established to organize and maintain resource materials for staff and other users. The library included 665 books and pamphlets, 53 center publications, 648 reprints, 55 periodicals, and numerous reference materials.

Colombia

In simulation tests of doves damaging soybeans, significant losses occurred during the early plant development stage. Dove damage could be reduced by effective use of methiocarb, good cultural methods, and bird scarers. Additional data were compiled on the food habits, biology, and damage caused by eared doves.

The Government of Colombia was assisted by the project in formulating a plan for a rat control campaign in coconut on San Andres Island.

USAID/DWRC assistance to the Government of Colombia terminated October 1974. The Vertebrate Pest Center continued to function and was funded by the government.

Outreach Activities from DWRC

A study was continued in Brazil to determine the recovery rates of vampire populations after reductional control. Twenty-seven months after control, populations remained low when compared to precontrol levels.

Active vampire control campaigns were initiated in Brazil, Colombia, Guyana, Nicaragua, Panama, and Venezuela. Vampire training sessions were held in Guyana and Ecuador.

Meetings were held with Ministry of Agriculture personnel in Guatemala, Honduras, El Salvador, Paraguay, and Peru regarding vampire control and training.

Two trips to Africa were undertaken to continue gathering information on bird and rodent damage problems; to evaluate promising bird control techniques in cooperation with personnel in Kenya and Tanzania; to confer with USAID and government officials in Morocco about their bird damage problems; and to finalize plans for an USAID/DWRC cooperative research program on quelea to be headquartered at the Tropical Pesticides Research Institute (TPRI) near Arusha, Tanzania.

Field tests with the bird repellent methiocarb were conducted on ripening wheat at Nanyuki and Nakuru, Kenya and on ripening rice at Rujewa, Tanzania. Two of the three field tests showed that methiocarb, applied at a rate equivalent to 3 lb a.i./acre, was effective in reducing quelea damage to both wheat and rice by about 90%. Results from the third test were statistically inconclusive because of unseasonable rains and uneven bird pressure.

In Nicaragua, additional information was gathered on bird and rodent damage to rice in cooperation with Banco Nacional personnel.

The hypothesis that vampire bat predation, even in the absence of disease, was debilitating and resulted in lowered milk production of dairy cattle, was investigated under field conditions. Milk production and several hematological indicators were measured before and after controlling moderately severe vampire predation on 58 lactating Holstein cows near Quito, Ecuador. Single intraruminal doses (1 mg/kg) of diphenadione reduced vampire attacks by 98% from a pretreatment mean of approximately 4 bites/cow to 0.1 bites/cow posttreatment. Red blood cell count, packed cell volume, and percent butterfat increased significantly ($P < 0.05$) but milk production remained virtually unchanged from a pretreatment mean of 28 lb/cow/day.

Supporting Research at DWRC

Through a cooperative agreement with the World Health Organization (WHO), difenacoum and Kayanex rodenticides were tested on rats. Results indicated that difenacoum was a better candidate rodenticide for ricefield rats.

Female wild Norway rats were gavaged the day after littering with a single oral dose of DRC-4805 (1.0 mg/kg) to determine its effect on the young. The DRC-4805 that was transferred through the milk to the young made all but one of the treated males and all of the treated females selected for breeding trials infertile. All control males and females bred successfully.

Ricefield rats showed a significant ($P < 0.05$) preference for FK-178A flavor treated rice over California Brown flavor treated rice. Preference seemed to be based on a flavor difference rather than other factors such as texture, nutritional value, or grain size.

The Philippine ricefield rat seemed to acquire a "taste" for the flavor of rice volatiles. Consequently, knowledge of important volatile components could lead to the development of a synthetic flavor that would increase bait palatability. Rice aroma volatiles were collected and analyzed by combined gas chromatography-mass spectrometry. Seventy-five compounds were identified, 64 of which are being reported for the first time in either unprocessed or processed rice. Fifty-four of these were not previously identified in any unprocessed cereal grain. Predicted identities were obtained on an additional 31 compounds. This was the most extensive work that has been reported for any of the uncooked cereal grains.

An analytical method was developed for measuring trace residues of warfarin in plants, water, and soil. Nitrochromic acid oxidation was used to form a product that is detectable at levels equivalent to 10 nanograms of warfarin. A general cleanup procedure was also developed that could be used with the oxidation process.

Prototype delayed turn-on transmitters for migrating birds were designed and prepared for field evaluation.

A device was developed to record feeding activity data for rats. The device was unique in that it used a coulometer component as the recording medium and required only microwatts of battery power. This recording concept could be extended to many biological applications requiring the counting and timing of events.

Two barrier designs were evaluated to protect a food source from rat infestation. One design produced a 95% savings of food and a 97% reduction in rat activity.

Philippines

A baiting program using anticoagulants to protect coconuts from rat damage was evaluated where R. r. mindanensis, R. argentiventer, R. exulans, and S. murinus were found. Production in the treated plots increased twofold from pretreatment levels while it remained about the same in the reference plots. The procedure provided effective, economical protection from rat damage.

A study confirmed that current methods for quantifying bird damage to corn in the United States could be modified to provide a reliable means of predicting corn losses to rats in the Philippines. Regression equations for estimating weight loss from a known length of damage were highly correlated at all length categories and were similar to those developed to predict corn losses to birds in temperate countries.

A baiting program using anticoagulants was evaluated in a corn area where R. r. mindanensis, R. argentiventer, R. exulans, and S. murinus were found. In reference plots, rat activity increased as the season progressed, while it decreased rapidly in the treated plots. There was nearly 94% reduction of damage in the treated plots. Based on these data, treatment was economically beneficial.

A study determined the importance of farmer loan or commodity support for successful implementation of the sustained baiting procedure in rice. One barrio was given technical assistance as required for one growing season, but only limited commodity support for the first few weeks of the season, while a reference barrio was given neither commodity nor technical assistance. Farmers in the assisted barrio followed the sustained baiting technical recommendations until commodity support was terminated, then they rapidly abandoned the new technology for traditional methods. Rat activity in the assisted barrio remained lower than in the reference barrio while the sustained baiting procedure was followed, then gradually returned to reference areas levels of activity. Damage levels at harvest were similar between the two areas. From this study, it appeared that farmers of the assisted barrio required loan or commodity support in addition to technical assistance for successful implementation of the procedure.

Preliminary field surveys were conducted and discussions were held with sugarcane farmers and industry staff to determine the extent of rat damage to sugarcane in the Philippines. Based on conversations with growers, managers and researchers, rat-related losses were of less immediate importance than storage, reprocessing and export-related marketing problems, problems associated with milling allocations and capacities, development and implementation of improved cultural practices, and the development and distribution of high-yielding varieties. Based on staff observations and the comments of some farmers, however, there was justification for rat-related research on a localized basis, which should include developing means of indexing rat populations and assessing damage

levels, selection of effective toxicants and delivery systems, and evaluation of potential hazards associated with promising control programs.

In a preliminary trial of a sublethal electric barrier, four 0.25-ha plots containing IR-26 variety rice at about 10 weeks after transplant and the likelihood of heavy rat pressure were selected. Fenced areas had 0.60% and 0.78% cut tillers, while unfenced areas had 13.6% and 13.4% cut tillers.

In preliminary laboratory tests of coulometric field event recorders for measuring rat activity at bait stations, cell counts and activity times were similar to expected values determined from closed circuit TV observations. Percent error for 100 counts was always less than 5% for all operational cells and was about 1% for cell in 10-min time trials.

Sustained baiting with anticoagulants was included as a required practice for farmers participating in the Government of the Philippines national rice production program, Masagana-99, and was included in the major damage reduction method in the government's national rat control program for non-Masagana-99 areas. Implementing rat control aspects of these programs was initiated through massive in-service training programs of government technicians and rat control officers in current methodology and through reorganizing rodent control agencies.

Over 300 visitors from many countries were briefed and given technical assistance or advice. Over 250 requests for technical information on rodent control were filled. Staff members participated in several 2-week courses for more than 1,000 extension workers and technicians, presented lectures on vertebrate pest control in several 1-month courses for over 200 credit loan officers, gave lectures on rat biology and control to more than 2,000 production technicians, and assisted two research trainees from Sri Lanka.

In its second year of operation, the Center library contained 676 books and pamphlets, 59 Center publications, 704 reprints, 55 periodicals with a total of 971 volumes, 76 maps, and 500 photographs.

Africa

The Quelea Research Project, a cooperative undertaking between the East African Community (EAC), USAID, and DWRC was officially established in late December 1975. It was based at the Tropical Pesticides Research Institute (TPRI), Arusha, Tanzania.

A DWRC biologist was temporarily assigned to Tanzania until an individual could be selected for the permanent position.

Study pens were constructed, the existing aviary modified, and four laboratory studies were initiated on load-lifting capacity, food preferences, retention of leg streamers, and breeding of quelea in captivity.

Outreach Activities from DWRC

One staff member identified major bird and rodent pest species in Nepal, initiated preliminary damage surveys, and assisted in the development of plans for continuing research programs on vertebrate damage control for the country.

A staff member assisted Indonesia in determining the needs for rat control research and implementation programs for the Luwu Integrated Development Area in South Sulawesi and evaluated proposed programs.

Consulting trips on vampire bat control were made to El Salvador, Honduras, Panama, Bolivia, Colombia, Ecuador, and Guatemala. A Nicaraguan veterinarian, trained by DWRC personnel, gave field demonstrations on vampire bat control in Costa Rica. A vampire bat control program, planned with DWRC assistance, was initiated by the Ministry of Agriculture in Belize.

Nicaragua's national vampire bat campaign continued to be a model for the rest of Latin America. Two-year results showed biting was reduced 91.8% on 164,834 cattle.

The effects of vampire bat parasitism on bovine milk production were measured. In Ecuador there was no change in milk production after cessation of bat parasitism, but in Nicaragua, milk production increased 16% after control methods were applied.

Field research studies were initiated on monk parakeet (*Myiopsitta monachus*) damage to sunflowers and corn and on dove damage to wheat and sorghum in cooperation with Government of Uruguay personnel.

Cooperative fieldwork continued on rat damage to coconuts on San Andres Island, Colombia and on dickcissel damage to small grains in Nicaragua.

Supporting Research at DWRC

A bait containing 0.005% difenacoum killed 100% of all resistant and nonresistant wild Norway rats. Resistant rats consumed 6.5-14.3 mg/kg difenacoum. These same rats had previously survived after consuming 15-28 mg/kg warfarin baits.

The acute oral single-dose LD50 of bromadiolone in both male and female Norway rats was 1.4 mg/kg. Free-choice feeding tests using an oat groat bait containing 0.005% bromadiolone killed 90% of the males and 100% of the females.

Intraruminal injection of diphenadione for vampire bat control caused only negligible changes in prothrombin times in adult cattle but significantly increased clotting times in suckling calves. Although single injections of Vitamin K_3 attenuated this effect, anticoagulant treatment of calves less than 4 months old was discouraged pending further investigation.

Seven commercially available grain and vegetable oils were evaluated as additives for enhancing bait ingestion by ricefield rats. Results were compared to consumption of bait containing a rice-oil extract. The rice-oil preparation significantly enhanced consumption as compared to soybean, corn, palm kernel, and coconut oils, but was not significantly preferred over rice containing peanut, linseed, or high-oleic safflower oils. Ricefield rat preferences for oil-treated bait might be attributed to texture rather than flavor enhancement.

A continuous, automatic weighing system for measuring the continuous bait intake of rats was tested. The device monitors and records the minute-by-minute bait consumption of rats. Consumption weights were accurate to ± 0.06 g.

The first shipment of quelea was imported to DWRC in July. Various laboratory studies were planned and a few initial observations were made.

1976

Philippines

In May 1976, the NCPC was established on the campus of the UPLB by Presidential Decree No. 936. This Center and 7 affiliated regional field stations, were given primary responsibility for the research, development, and dissemination of integrated crop protection systems for the country.

A baiting program using anticoagulants to protect coconuts from rat damage was evaluated for 2 years in Mindoro Oriental on *R. r. mindanensis*, *R. argentiventer*, *R. exulans*, and *S. murinus*. Production in experimental plots during periods of treatment increased about 2.5 times over pretreatment levels. Cost:benefit averaged 1:24. It was concluded that sustained crown baiting had the potential for providing long-term reduction of coconut damage by rats.

A study was conducted in two 1-ha coconut plots to determine relative species composition and movement of rodents between tree crowns and the ground level. These studies found that *R. r. mindanensis* and *R. exulans* moved actively between tree crowns and at ground level, but relatively fewer individuals inhabited tree crowns. Movement of *R. argentiventer* from the ground level to tree canopy was either severely restricted or absent.

Ground-baiting and crown-baiting were compared for relative effectiveness and economic benefit in a coconut plantation. It was concluded that both ground- and crown-baiting reduced rat activity and damage, but that crown-baiting was more effective and cost less.

To determine if coconut trees could compensate for rat damage, the sizes, weights, and copra contents of individual nuts from an area which had received effective rodent control for 21 months were compared with nuts taken from an adjacent area which had no rodent control and which was suffering from heavy rat damage. Trees seemed to partially compensate for

heavy rat damage, but the amount of compensation was slight and inadequate to significantly decrease the economic benefits which were gained by following baiting programs.

The effectiveness of the sustained baiting method was tested to protect 100 ha of ricefields adjacent to marshes. Baiting closely followed the interagency recommendations for Masagana-99 and monthly records were maintained. The sustained baiting program effectively protected the site from serious rat damage, at low cost, and with potentially high economic return. This was particularly significant since the baited fields were the last to be harvested, adjacent to marshland, and represented one of the most severe experimental situations for protection from damage that was encountered in Philippine ricefields.

To compare the operational characteristics of lethal and nonlethal electric barriers, a field trial was conducted in cooperation with IRRI on six plots, about 0.25 ha each. Nonlethal barriers provided comparable or better protection from rat damage than lethal barriers and without logistical complications.

In a trial on the use of bird repellents, rice plots treated with methyl carbamate and fenthion averaged 6.5% and 7.0% damaged hills, respectively, while the two untreated plots averaged 22% damaged hills. Both compounds held promise as repellents, but more extensive studies would be required to verify these preliminary results.

More than 300 individuals from many countries visited the Center, and over 200 requests for technical information on rodent control were filled. Staff members participated in the training of over 3,000 government extension personnel and key farmers in vertebrate pest management methodology, and others in research methodology for vertebrate pest management.

One research trainee from Nigeria participated in a variety of ongoing research studies and worked independently on a project proposal related to vertebrate pest problems in Nigeria.

Africa

In April 1976, a Wildlife Research Biologist from DWRC entered on permanent duty in Arusha, Tanzania and prepared various research studies and reports. Research activities during 1976, as well as earlier DWRC activities in Africa from 1971 through 1975, were summarized. Previous research indicated that repellents showed potential in reducing quelea damage to small-grain crops.

Project personnel worked with USAID and Sudan Government agencies and developed project guidelines and objectives for the planned transfer of USAID/DWRC vertebrate pest research and control operations to Sudan in May 1977.

Outreach Activities from Denver

"The use of diphenadione (2-Diphenylacetyl-1,3-indandione) for vampire control in endemic rabies areas, northeastern Brazil" was the title of a graduate student thesis completed at the University of California at Davis. In the study area, the vampire population was reduced 99.4% after control was applied.

The Ministry of Agriculture in Panama was assisted in developing a vampire control program. Nicaragua's national vampire control campaign was reviewed with USAID and government officials.

A DWRC consultant assisted Ministries of Agriculture in developing vampire control programs in El Salvador, Costa Rica, Panama, Venezuela, and Colombia.

A DWRC biologist helped plan a vampire bat symposium with government officials in Brazil, Paraguay, Bolivia, Colombia, and Nicaragua. The symposium was held in Nicaragua; several DWRC personnel participated.

A DWRC biologist traveled to Senegal and assessed rodent damage problems in Sahelian agriculture, made recommendations for future needs, and helped plan USAID disaster assistance with USAID and government officials.

A preliminary assessment of rodent problems was made in Venezuela. Two or more rodent species caused damage to rice, sugarcane, sorghum, and other crops. A series of lectures was presented to farm and professional groups and the Government of Venezuela was assisted in outlining a vertebrate pest research project proposal.

Field experiments were initiated in Uruguay on monk parakeet damage to sunflowers and corn, and on eared dove damage to grain sorghum--all in cooperation with Plant Protection personnel.

Work was continued on the rodent damage problem to coconuts in cooperation with Government of Colombia personnel on San Andreas Island.

A trip was made to Uruguay, Paraguay, and Bolivia to assess and review severity of bird, rodent, and vampire bat problems.

A trip was made to Pakistan, Bangladesh, Nepal, Thailand, Philippines, and Indonesia to determine the status of rodent control research programs.

A DWRC biologist assessed bird and rodent damage problems to sugarcane, corn, rice, melons, and cotton in Honduras.

Trips were made to Bolivia, Colombia, Panama, Nicaragua, and Honduras to review vampire bat control programs, to assist in design of evaluation techniques in vampire bat control, to assess rat damage to corn, rice, and beans, and to discuss design of rodent-proof grain storage facilities.

Supporting Research at DWRC

Hulled millet treated with 2.5% or 3.0% Avitrol produced good results on caged quelea. These baits were submitted to the field station in Africa for evaluation.

A wax bait for rats, consisting of 35% wax, 64% ground rice, and 1% talc containing 0.05% warfarin, was developed for testing in the Philippines.

Preliminary laboratory tests showed that a fluorescent chemical will mark feathers of birds for up to 90 days after application.

Contract research conducted by the University of Wisconsin, Madison, with both red-winged blackbirds and quelea showed that viruses would not be feasible serological marking agents.

The R50 value (a measure of repellency analogous to LD50) for methiocarb in quelea was found to be 0.015% (0.011-0.021%). These values were low in comparison with R50 values established for many domestic bird species, indicating that methiocarb might have a high potential for alleviating quelea damage to agricultural crops in Africa. When taste and color stimuli were added to methiocarb-treated millet seeds, quelea showed conditioned repellency toward the taste cue for 2 weeks after exposure. This cue-conditioning effect could also have potential as a means of more quickly repelling birds from agricultural crops, and directing birds toward noncrop food sources.

Ultrasonic rodent repellent devices (20 kHz, 20-30 kHz, and 40 kHz) were tested under four different semifield conditions. At full intensity (118 dB), the 20 kHz device consistently produced the greatest repellent effects on food consumption and rat activity. When intensities of all devices were reduced 30 dB (simulated distance of 10.66 m from the source), no repellent effects were shown for any of the devices.

1977

Philippines

Fieldwork was completed on a 3-year study of crown baiting with anticoagulant rodenticides to protect coconut palms from rat damage. Coconut production in treated plots averaged about 2.8 times the pretreatment level. At then current prices, the estimated cost:benefit ratio for this method was 1:28. This method of monthly treatment of 25% of the palm crowns in a plantation with packets of warfarin bait clearly provided long-term reduction of rat damage with excellent economic return.

Surveys were conducted in Laguna Province to determine the awareness and acceptance of rat control methods by farmers participating in the national rice production loan program. One year after availability of the rodent control portion of the loan program, use of sustained baiting with chronic toxicants by farmers had increased from 2% to 12.5%. None of the farmers using chronic toxicants were following all procedures outlined in the

extension recommendations provided with the loan. Of 320 eligible farmers surveyed, only 60 had actually used the agricultural loan for production inputs. Of these, 67% used chronic toxicants for rodent control; rat damage was lower in the fields of farmers using chronic toxicants than in fields where farmers used other methods.

Surveys to assess rat damage to sugarcane on small farms on Negros Islands were carried out in 18 locations. Of the stalks surveyed in the fields, 7.2% had obvious rat damage. Sugar content averaged 19.2% for healthy stalks and 17.2% for damaged stalks.

A preliminary field trial of a topical repellent to reduce rice damage by Philippine munias (Lonchura spp.) was conducted. A small ricefield receiving heavy damage was treated with methiocarb (1.7 kg a.i./ha) when rice heads were at the milky dough stage. Damage continued on both treated and reference areas after spraying; however, the rate of increase was significantly higher in the untreated fields. Feeding activity by birds in the treated area seemed to shift to surrounding untreated fields.

A small-scale trial was conducted using bird glue made from local materials and placed on perches at 40 locations in and around a 0.2-ha ricefield. Activity in the field decreased 97% the first day; no birds were observed on the second day after treatment and 40 birds were caught on perches during the first day after treatment. Distress calls by entangled birds probably caused birds to leave treated fields.

A 1-year study of the food habits of bats (Scotophilus temmincki) foraging in the area of ricefields was completed. They fed on many species of pest insects including leafhoppers, planthoppers, crickets, grasshoppers, and moths, and some beneficial insects.

Training and communication activities included presentation of lectures, workshops, or demonstrations to over 3,000 extension personnel and key farmers and briefing more than 300 visitors. Numerous international requests for information on rodent control were also handled. Four agricultural technicians from Thailand and five from Bangladesh participated in training programs. Two staff members made U.S. study tours as USAID participants in conjunction with their graduate programs at UPLB. One staff member and three students participated in a regional training seminar on field rat control and research. Other staff members taught or helped teach classes in Vertebrate Pests and Crop Protection at UPLB. In the cooperative graduate program, one M.S. was completed; three Ph.D.'s and six M.S. programs were in progress.

Sudan

Research activities on bird control in East Africa were transferred from Arusha, Tanzania to Khartoum, Sudan where a new working agreement was negotiated between USAID/Khartoum and the Sudan Ministry of Agriculture, Food, and Natural Resources.

In Sudan, considerable efforts had been placed on large-scale quelea control operations over the past 30 years; much biological research and some control methods evaluation were carried out by FAO and Sudanese scientists. With the initiation of work in Sudan, project personnel reviewed and summarized this information and documented crop phenology and major bird problem areas.

In Kassala Province, field cages were used to study quelea damage to grain sorghum. Quelea were found to have the capability of destroying about 38 g of sorghum daily; at then current price levels, each quelea was capable of destroying approximately 43¢ U.S. of sorghum during the approximately 30-day nesting period. In the same area, a preliminary field test of methiocarb with an aerial application of 4 kg/ha did not reduce quelea damage to sorghum plots, however, the same concentration applied from the ground with a knapsack sprayer resulted in good protection.

Food habits studies at a nesting colony showed 80% of the quelea diet consisted of sorghum during this limited period when it was susceptible to damage. A colony of 1 million breeding quelea would have the capability of destroying more than 400 ha of sorghum.

Two staff members of the Plant Protection Department were accepted as USAID participant trainees to undertake graduate training programs at Bowling Green State University, Ohio.

Outreach Activities from DWRC

USAID/W and USAID Missions were assisted in preparing project documents for work in Bangladesh, Philippines, and Latin America.

Fourteen staff members and cooperators participated in seven professional meetings, presented eighteen professional papers or seminars, and chaired six meeting sessions.

Denver-based staff reviewed programs and discussed research progress with numerous visitors and responded to requests for technical information on vertebrate pest control from many countries. Research trainees (one from Venezuela; two from the Philippines) spent several weeks at the Center reviewing literature and learning research techniques. Three staff members participated in a 6-day training seminar on vampire bat control held in Santa Marta, Colombia.

Center biologists continued to assist Latin American countries in training control personnel and in developing programs for reduction of vampire bat depredation. Observations in Bolivia, Brazil, Colombia, Nicaragua, Panama, and Paraguay indicated considerable progress in organizing programs, although projects were in varying stages of development. Assessment work in Nicaragua, where the national bat control campaign was in its fourth year, indicated that fresh cattle bites were still being reduced by more than 80% by control treatments.

Project personnel spent 439 man-days in 18 countries at the request of USAID Missions, foreign governments, or international organizations. Activities included specific research studies, assisting field personnel in ongoing research, project review, supervision and program development, attendance at international meetings, and liaison with research organizations.

Two trips were made to Bangladesh to assess vertebrate pest problems in agriculture and to assist USAID and the government in developing a research project.

In Uruguay, cooperative evaluations of methiocarb to reduce eared dove damage to sorghum and soybeans were continued with government personnel.

A field study was conducted in Nepal on rodent damage to wheat.

In Indonesia, a Center biologist discussed progress of the CARE/USAID rodent project.

Supporting Research at DWRC

An investigation was completed of variables affecting ultrasound repellency in *R. r. mindanensis* and *R. norvegicus* using four commercial ultrasound generators with frequencies of 20 kHz, 20-30 kHz, 40 kHz, and 15-25 kHz. When sound intensities were adjusted to simulate operationally realistic levels, neither species responded to these frequencies. Although many commercial ultrasound devices were marketed for rat control, their efficacy had not been adequately assessed under operational conditions.

Six chemicals were evaluated as candidate repellents for reducing damage to sprouting corn by cotton rats, a problem species in southern U.S. and Latin America. Di-Syston and Furadan produced greater than 90% repellency in wheat seed bioassay tests, but neither chemical reduced rat damage to growing corn plants when applied in topical or soil treatment tests. Semifield tests using Di-Syston and the aversive drug lithium chloride in combination with saccharin and glucose suggested that the addition of taste cues might improve repellency.

A test system was developed to study rat feeding patterns by automatically recording food consumption at 1-min intervals over periods of several days. Initial trials with ground rice containing warfarin, zinc phosphide, or cellulose indicated that *R. r. mindanensis* readily detected toxic chemical additives and modified their feeding patterns to intermittent, brief sampling of food material from the longer meal periods observed with the cellulose control.

Analytical methods development was completed for determining warfarin residues in water, soil, and plant material. Residues in soil and plants could be detected to 0.1 ppm and those in water to 0.01 ppm. Recoveries from fortified samples averaged from 70% for plant samples to 104% for soil samples. These methods were to be used to complete work on a crop residue study in the Philippines.

Two studies were completed to determine the "no-effect" level of diphacinone consumed in food by laboratory rats. This material has been widely used in animal control as a rodenticide and also in the veterinary drug form (diphenadione) as a livestock systemic vampiricide. A discontinuity in toxicological symptoms in test animals was observed between 2- and 1-ppm concentrations in food, suggesting that there was no chronic effect in rats orally dosed below the 1-ppm level.

A preliminary investigation of the feeding behavior of quelea indicated that naive birds could learn to imitate the feeding patterns of birds conditioned to avoid colored food by treatment with the repellent chemical methiocarb. These data suggested that altering the feeding behavior of some birds in a flock through repellent treatments might provide a means to influence behavior of the entire flock without direct chemical contact with all individual birds.

An inverse correlation was established between polyphenol content and the relative preference of quelea for pelleted sorghum varieties described as "bird-resistant." Bird-resistant varieties were accepted more readily under darkened conditions than under artificial lighting, suggesting that color differences between treated and untreated pellets influenced the taste preference response of birds. Subsequent tests confirmed the inability of quelea to maintain color-conditioned responses under darkened conditions. Quelea were more responsive to the repellent effect of bird-resistant sorghums than red-winged blackbirds (*Agelaius phoeniceus*).

The concentrations of total polyphenolics were determined in eight bird-resistant sorghums at four stages of development. Data indicated that reactive phenolics were produced during the milk stage, continued to increase in the dough stages, and decreased during ripening. Preliminary evidence suggested that this decrease occurred through loss of activity associated with polymerization. A cooperative study was initiated with investigators at the University of Arkansas to find bird-resistant properties effective during the immature stages of sorghum but not nutritionally deleterious in mature grain.

Quelea showed little size preference for sorghum seeds during milk or dough stages. However, there was strong preference for small seed in mature grain, raising the possibility that treating a large, early-maturing seed might alleviate quelea damage in some situations.

1978

Philippines

Rat activity in coconuts was studied in Laguna Province. The predominant species was *R. r. mindanensis* both at the ground and tree crown levels. Trapping reduced both rat damage and activity in treated plots. As a simulated control approach, crown trapping improved yield by about 1.5 times over that of the reference plots. *R. r. mindanensis* exhibited a larger home range (963.2 m^2) than *R. exulans* (610.7 m^2) as determined

by radiotelemetry. In cage feeding trials, R. r. mindanensis preferred the developing button stage over larger test nuts.

Work continued on a study aimed at developing a simple means of detecting anticoagulant resistance in R. r. mindanensis and R. argentiventer. Baseline data were established by treating large numbers of each species with anticoagulant rodenticides and measuring prothrombin clotting times. This information could be used to quantify anticoagulant-resistant or susceptible animals. Bioassay tests of several alternate control agents were completed. These might be used as alternatives to common anticoagulants if resistant rat populations were to develop.

Studies to evaluate the efficacy of glue-treated stakes as a means of reducing bird damage to ricefields were continued. Pretreatment surveys revealed 14.5% damage in treated rice plots and 11.8% in reference plots. Posttreatment surveys revealed 19.9% in treated areas and 63.2% in reference areas. The glue lost its adhesiveness within 3 days but the birds avoided the area for a full 8 days after treatment.

A year-long study was conducted to evaluate the efficacy of wax bait blocks for controlling rodents in coconut palms. Bait placement in the palm crowns and deterioration of loose bait materials were two difficulties which needed to be overcome. Production records indicated that the wax-block bait treatment provided effective rodent control. Coconut production in the treated area was 2.2 times greater than that of the reference plot.

Field evaluation of the efficacy of nonlethal electric barriers as a means of reducing rodent damage to rice continued. Analysis of test results showed that the barrier was effective in reducing rat damage. Damage in the plot bounded by the barrier averaged 1.9% and damage in fields surrounding the test plot averaged 8.6%.

Five staff members completed requirements for advanced degrees including one Ph.D. and four M.S. degrees.

Five staff members served as resource speakers for a Short Course on Integrated Pest Control for Irrigated Rice in South and Southeast Asia. Several staff members held adjunct appointments with UPLB, acting as graduate advisers and instructors in vertebrate pest management and related fields.

Sudan

An examination of quelea reduction programs in Sudan revealed that such control efforts were, indeed, killing large numbers of birds and provided some relief from damage on a local basis. On a broader scale, however, such operations had relatively little effect either in reducing populations or eliminating damage. As then practiced, population reduction campaigns had little effect on quelea damage to crops on a nationwide basis.

For logistic and economic reasons, a field test, related to the quelea project, was conducted in Texas. A sorghum variety (TX 623), similar to the Daber sorghum of Sudan, and house sparrows (Passer domesticus) (same family as quelea) served as models in a field cage test to determine the concentrations of methiocarb and adhesive for field application. Results suggested that the acrylic resin, Rhoplex AC-33, interfered with or masked the repellent properties of methiocarb. Adhesives might be omitted from spray treatments in very dry climates. If they are needed, concentrations of no greater than 1 part adhesive and 10 parts methiocarb are suggested.

A survey of crop areas proposed for the Blue Nile Integrated Agriculture Development Project revealed a high potential for bird depredation problems in the future. The area was not then seriously affected but other observations had shown that agricultural schemes, both large and small, that were located in prime quelea habitat, had suffered heavy depredations.

Arvicanthis niloticus and Mastomys natalensis were the two most important agricultural rodent pests in Sudan. They caused significant damage to a variety of crops including cotton, sorghum, wheat, groundnuts, and vegetables.

One staff member completed requirements for an M.S. degree at Bowling Green State University and rejoined the project at Khartoum.

Bangladesh

All negotiations and administrative matters pertaining to the Bangladesh project were finalized and the project was officially started with the transfer of the project leader to his post in Dhaka.

One of the first priorities of this project was to identify the major problem areas, including crops and species involved, and evaluate the resultant economic impacts. A nationwide survey of vertebrate pest problems was initiated and focused primarily on rice, the staple food grain. A 1-week training program was held at the Bangladesh Agricultural Research Institute (BARI) in preparation for the survey. Trainees included officers and staff members from BARI, the Bangladesh Plant Protection Department (BPPD), and the Bangladesh Rice Research Institute (BRRI)

Construction of laboratory and office facilities began in Joydebpur, 20 miles north of Dhaka.

Outreach Activities from DWRC

A Project Paper for a proposed Latin American project was completed and submitted to USAID/W for review.

Nineteen staff members participated in 18 professional meetings and presented 21 professional papers.

The Denver Center hosted 26 international visitors from 16 countries and responded to numerous requests for technical information on vertebrate pest control. Two research trainees from the Sudan spent several weeks at the Center reviewing literature, and initiating their graduate research projects. Both were in graduate training programs at Bowling Green State University, Ohio, as USAID participants.

One staff member participated in a 7-day training seminar on vampire bat control in Asuncion, Paraguay. Two staff members participated in international conferences on vertebrate pests, including the OECD/FAO/WHO Expert Consultation on African rodent problems in Paris, France, and the International Discussion Conference on Rodent Control in Kuwait City, Kuwait.

One staff member participated in a joint FAO/GTZ/USAID formulation mission to five African countries to develop means to coordinate bird control research activities by national and international organizations.

A socioeconomic evaluation of the vampire bat control technology, developed by DWRC scientists, was being conducted under contract by Oklahoma State University. The study was scheduled for completion in mid-1979. In addition, a consultant made a social soundness analysis for the proposed Latin American project.

Project staff or consultants spent 435 man-days in 24 countries at the request of USAID missions, foreign governments, or international organizations. Activities included specific research studies, assisting field personnel in ongoing research, project review, supervision and program development, attendance at international meetings, and liaison with other research organizations.

Supporting Research at DWRC

Preliminary work began on the development of a toxicity profile for gliftor, a rodenticide used in the Soviet Union. A bioassay test revealed that it was unpalatable at higher concentrations; hence, bait shyness could be a potential problem.

Laboratory bioassays were conducted with commercial diphacinone rodent baits, following accelerated shelf-life tests. Results revealed that bait toxicity was not affected, however, palatability might have deteriorated.

Preliminary laboratory trials were conducted to examine the potential for using rodent glues as an alternative nontoxic control method in agricultural crops. Commercial products were tested with encouraging results. Some glues trapped and held rats even though they were wet, as would likely be the case in rice paddies.

Development of nonlethal electric barriers continued. Previous laboratory and field data demonstrated the efficacy of the concept. A major impediment to large-scale field application was the high cost of materials. Several modified designs using low-cost materials available in developing

countries were tested in the laboratory. Results indicated that less expensive and more readily available materials could be used with no loss of efficacy.

Several experiments were conducted to evaluate the potential of Microtaggants as a wildlife marking agent. These small, plastic particles seemed to be suitable for use as identifying markers in bait formulations or as topical marking agents for tagging pest birds.

1979

Philippines

Trials were completed to evaluate responses of *R. r. mindanensis* to 6 different kinds of bait containers (standard bamboo tube, coconut husk, plastic "floating" saucer, plastic oil can, nipa hut, and a plain wooden platform). Results indicated that when given a choice, *R. r. mindanensis* preferred feeding from certain bait containers; bait consumption over 7 weeks was highest in the coconut husk and lowest in the plastic saucer. Bait containers with the most open access (nipa hut, oil can, coconut husk) seemed to outperform those with more restricted feeding space.

The use of zinc phosphide in oil was investigated as a means of reducing rat damage in mature crops. Rat activity could be decreased dramatically by using 10% and 20% zinc phosphide applied to pieces of banana leaf laid across runways in the paddy. The results indicated the potential use of zinc phosphide, or other suitable rodenticides, as tracking materials for rat control in mature rice when baiting would not be feasible.

Staff members participated in vertebrate pest control training for more than 385 individuals. Individual technical training also was given to professionals and students from four southeast Asian countries. Several students from other countries began graduate degrees at the University of the Philippines and two Filipinos enrolled in Ph.D. programs in vertebrate pest management in the United States.

Sudan

Field studies indicated that effective crop protection from quelea could be achieved with relatively low levels of methiocarb. Tests evaluating head sprays, and strip or edge applications indicated potential ways to reduce application costs in small-scale operations.

A combination of wattle tannin (an astringent) and low concentrations of methiocarb was tested for bird repellency in laboratory cages and field enclosures. Results on ripening millet and sorghum also were promising. The combination costs less than methiocarb alone.

Different populations of quelea in Africa could be distinguished by subjective appraisal of the color of face masks of breeding males (FAO technique). The results obtained from an analysis of 410 males provided base-line proportions for the *Q. q. aethiopica* population in Sudan. The

data were useful in understanding regional migratory movements by comparison with the proportions of mask types observed from other parts of Sudan and the adjacent countries of Ethiopia and northern Kenya.

The daily and seasonal movements of several African bird species needed clarification. A better understanding of movement patterns would assist in the prediction of damage patterns and in locating nesting colonies during early development stages. Plastic streamers attached to the tarsi of quelea or village weavers with standard leg bands worked well under laboratory conditions and resulted in field resightings in East Africa. However, attaching the streamers with plastic rivets was not acceptable. Additional research was needed on marking techniques.

The extent of rodent damage in Sudan was undetermined at this time. The most important agricultural rodent pests in Sudan were identified as Arvicanthis spp. and Mastomys spp. They damaged sorghum, wheat, rice, groundnuts, and vegetables. In the Gezira alone, LS 2 million was spent during 1 year on rodent control activities, damage was reported as 70% on wheat and 30% on groundnuts. Both species were highly susceptible to zinc phosphide baits in preliminary laboratory tests.

Two project staff members attended an FAO training/workshop in pest bird biology and control at which DWRC personnel participated.

Bangladesh

A national survey of rat damage to wheat in 303 fields of four districts of Bangladesh indicated that the countrywide loss to mature wheat was 12.1%, or approximately 77,000 tons. Damage was attributed primarily to the lesser bandicoot rat (Bandicota bengalensis).

In a study of simulated rat damage to rice, significant yield reduction was found at all damage levels in mature crops. Significant yield reductions were not noted during tillering but were observed at booting when >10% of the stems were cut. These results suggested that baiting before booting stage in monsoon rice might be unnecessary.

The LD50's of zinc phosphide for lesser bandicoot rats were determined as 28.3 mg/kg for males and 23.8 mg/kg for females. Choice and no-choice feeding experiments with 1 and 2% zinc phosphide-treated wheat flour resulted in 90-100% mortality at both treatment levels.

Most rats, including the lesser bandicoot rat, meticulously groom dirt or foreign substances from their fur. Application of a zinc phosphide-commercial axle grease formulation, which rats ingested during grooming, resulted in mortality rates of 2/5 at 2% and 3/5 at 7% after 4 days.

The rodenticides DRC-4595, difenacoum, brodifacoum, and zinc phosphide were tested on five islands in deepwater rice. Rodent activity was reduced 90.1% with DRC-4575, 94.1% with difenacoum, 90% with brodifacoum, and 87% with zinc phosphide. The best time for baiting was within 1 to 2

months when the area became flooded and rats were confined to the island. After this period, the rice stems elongated sufficiently to provide floats on which the rats could live. Island baiting also greatly simplified field control programs.

Wheat had become an increasingly important crop in Bangladesh during the last decade and was susceptible to birds such as mynas, house sparrows, and crows. During the susceptible germination stage, methiocarb was applied as a seed dressing repellent at 1.0, 0.5, 0.25, and 0.1% by seed weight. Results showed from 13.9 to 27.8% more sprouts at the different treatment levels compared to the reference field.

A 1-week training seminar in preparation for a nationwide vertebrate pest damage survey was held.

One staff member began a Ph.D. program in vertebrate pest management in the United States, while another attended a 2-1/2-month training program in rodent ecology and control at the NCPC, Philippines.

Outreach Activities from DWRC

All negotiations and administrative matters pertaining to establishment of a regional vertebrate pest management program in the Caribbean were completed.

At the request of USAID/Jakarta, DWRC assisted the Government of Indonesia in preparing a Project Identification Document to outline requirements for accelerating vertebrate pest management programs.

DWRC staff spent 300 man-days in 11 countries at the request of USAID missions, foreign governments, or international organizations.

Twelve staff members participated in 17 professional meetings and presented 15 professional papers.

DWRC hosted 28 international visitors from 20 countries and responded to numerous requests for technical information on vertebrate pest control.

Two Sudanese M.A. candidates, under USAID sponsorship at Bowling Green State University, spent several months at the Center completing their research projects and returned to Sudan to rejoin the project. Their graduate research examined the potential of using commercial tree tannins from Africa as an inexpensive topical treatment for protecting cereal crops from bird damage, and the feeding behavior of the Nile rat with emphasis on developing baits and baiting techniques.

One staff member participated in a training course in Costa Rica sponsored by the University of California's USAID Pest Management Project. Another staff member participated in a bird control workshop in Tanzania sponsored by FAO. Two staff members participated in an international training seminar on vertebrate pests sponsored by GTZ.

Supporting Research at DWRC

An experimental compound, trichlorodiphenylamine, was tested as an aversive agent to reduce damage to seeds and seedlings by cotton rats. Treatment of corn seedlings with a 1% solution of this compound and Rhoplex adhesive seemed to reduce feeding but did not appreciably alter plant cutting by cotton rats.

The importance of size, hardness, color, and taste in seed acceptance by quelea was evaluated and tableted baits were developed for field experimentation.

Work was begun on systemic markers for use in wildlife studies. Quinacrine was detectable by thin-layer chromatography and fluorometry in rat blood. Rhodamine B, when orally ingested by several species of mammals and some birds was detectable in blood and as a band on the growing tissues of vibrissae, body hair, claws, or feathers.

Drug-induced taste aversion was examined in *R. r. mindanensis* using various combinations of lithium chloride, red squill, copper sulfate, cyclophosphamide, and saccharin-flavored water. Lithium chloride produced longer lasting aversions than the other materials tested. Results demonstrated that free ingestion of a drug could produce high levels of long-lasting taste aversion.

Work was conducted to develop an effective, economical fumigant formulation containing the active ingredients charcoal and sodium nitrate for controlling fossorial rodents. The gas cartridge, which emitted carbon monoxide when burned, will be used for rodent burrows.

1980

Philippines

Two successful tests were conducted with Avitrol-treated baits on Eurasian tree sparrows; one in a grain storage situation, the other in ripening sorghum.

Studies with three commercial bird glues produced poor results. Temperatures above 33°C and humidity above 85% adversely affected the glue.

A laboratory test to evaluate a topical application method for reducing rodent damage to rice indicated a 50:50 grease to oil formulation was more effective than either grease or oil alone.

An M.S. thesis on the biology of rodents and rice in Central Punjab, Pakistan was completed. Reproductive rates were higher and mean adult ages less in *Bandicota* sp. and *Millardia* sp. populations in Punjab compared to those in Sind. In Punjab, *Mus* sp. and *Bandicota* sp. showed sharp breeding peaks closely linked to the ripening of wheat and rice. *Nesokia indica* was much less abundant in Punjab probably due to better

weed control along field edges. Millardia meltada also was less abundant. Stomach content analysis indicated that rodent damage to wheat was probably more severe than damage to rice since Bandicota sp. and Millardia sp. ate rice less frequently.

A cooperative demonstration of sustained baiting in rice was completed with the Regional Crop Protection Center in San Mateo, Isabella. Masagana-99 recommendations for rat control in rice were followed. Five farms were selected in both the treated (5 ha) and reference areas (4 ha). Damage decreased from 20 to 4% in the treated farms and increased from 17.3 to 28% in the reference farms. Yield differences between the treated and reference farms were 120 vs. 67 cavans/ha.

Different baiting rates of crown baiting for reducing rat damage to coconuts were evaluated in four plots (reference; 1 in 20 trees baited; in 6.25 trees baited; and 1 in 40 trees baited). Excellent control was observed throughout the year in all treated plots compared to the heavily damaged reference plot. Despite periodic increases in rat activity at the ground level, the sparsely baited plots prevented significant damage from occurring in the crown. In another test, 10% crown baiting provided good damage control.

Technical assistance was provided to 7 of the 12 Regional Crop Protection Centers on vertebrate pest control problems and needs.

Project personnel participated in training 71 farmers and farm leaders in methods to control rats in agricultural crops. Technical training of 2-3 months was given to professional research personnel involved in rodent control in coconut in the Comoro Islands and the Republic of Maldives.

Eight students, including five from other countries, were enrolled at the UPLB for graduate level training in various aspects of vertebrate pest management. One Filipino attending UPLB, and two others at Bowling Green State University continued their graduate studies.

In addition to students enrolled in M.S. and Ph.D. programs, a 10-month diploma program in crop protection was established in November 1980. Seventeen graduate scholars were funded by a USAID Training Grant through NCPC.

Sudan

Project personnel located traditional millet and sorghum farming areas in western Sudan that experienced annual quelea damage. Damage estimates in 1977, 1978, and 1979 by farmers and government personnel ranged between 20 and 80%.

Treatment with 2 and 6% methiocarb sprays of edges of a sorghum field, markedly reduced the number of feeding birds (Ploceus spp. and Euplectes spp.) during the first few days. However, the technique did not protect the entire field, and after about 2 weeks, only the sprayed heads were not completely eaten.

Methiocarb was applied at the rate of 1 kg/ha to the outer edge of two fields of ripening wheat. Both treated fields were less damaged than their paired untreated fields. From 18 to 21 times more birds were counted in the untreated than treated fields.

A study was conducted to compare the effects of edge and whole-field treatments of methiocarb applied to ripening wheat. Methiocarb elicited a repellent response by house sparrows, weavers, and finches. No significant differences ($P < 0.05$, t-test) occurred between the yields of edge-sprayed and completely sprayed plots, supporting the feasibility of the less expensive edge application method.

A trial was conducted with methiocarb-treated seed to reduce bird damage to newly broadcast rice by larks (*Eremopterix leucotis* and *Galerida cristata*). Treating rice seed with an effective bird repellent would allow farmers to sow at the reduced rates and would probably also eliminate, in most situations, the necessity to resow. Evaluations showed the proportion of damaged seeds was substantially greater in the untreated plots (11% and 22.9%--avg 16.9%) than in the treated plots (2.9% and 5.8%--avg 4.4%). Seed and seedling samples for residue analysis were sent to DWRC for analysis. Residues from the dried samples were all ≤ 1 ppm after 15 days. Methiocarb is registered in the United States for several fruit and grain crops at much higher levels of 15-25 ppm.

Golden sparrows (*Passer luteus*), red bishops (*Euplectes orix*), and two species of *Ploceus* weavers were sent to DWRC to determine the R50 and LD50 for the avicide, Starlicide; the frightening agent, Avitrol; and the repellent, methiocarb.

Although methiocarb had proven effective as a bird repellent in many situations, its cost might be prohibitive to many African farmers. Wattle tannins occur naturally in Africa and are commercially available and inexpensive. A test was conducted to assess the repellency to quelea of a reduced amount of methiocarb combined with wattle tannin on wheat seed. The less expensive methiocarb-tannin combination elicited repellency to caged quelea equivalent to that elicited by the more expensive methiocarb-only formulation.

Bangladesh

A study was completed to compare two methods of monitoring rodent population abundance using snap traps and inked tracking tiles in a deepwater rice zone. One night of sampling per week was adequate in long-term studies to monitor small mammal relative abundance in the deepwater rice region. The choice between using trapping or tracking tiles depends upon the purpose of the study. If trends in small mammal numbers would be required, as in a bait efficacy trial, tracking tiles might be preferable. If data on species composition, sex ratios, and reproductive parameters are necessary, snap traps should be used.

The effects of simulated rat damage (stem cutting) on wheat yield were studied and results demonstrated that rat damage does not significantly

affect wheat yield until the late booting stage and that baiting in wheat before the booting stage might be unnecessary.

Nocturnal movements of the lesser bandicoot rat, the greater bandicoot rat (Bandicota indica), and the roof rat were monitored using radiotelemetry. Lesser bandicoot rats were the most important pests and spent most of their time in wheatfields. Roof rats were restricted primarily to villages. Greater bandicoot rats moved between fields and villages. Home range data indicated that the effectiveness of control with rodenticides would increase if baits were placed directly into or within 2 m of burrows. The mean functional period for the 5-g 164-MHz transmitters was 36.4 days (range 1-79 days).

A continuous area of flood plain wheatfields was selected for rodenticide testing. Five study plots were treated with either cyanogas, difenacoum, zinc phosphide, or brodifacoum; the fifth plot served as reference. The least amount of rat damage (0.29%) was recorded in the difenacoum plot, and the most damage (1.29%) occurred in the brodifacoum plot. Rats damaged 3.2% of the reference plot. There were no significant differences between the treated plots when examining stem density versus rat damage. Lesser bandicoot rats preferred and caused more damage in fields with high stem densities.

Periodic heavy rat infestations in flooded rice crops prompted a long-term study. Based on 31,092 trap nights, the most destructive rodent species to deepwater rice plants were the lesser and greater bandicoot rats. Other species trapped in the study area were the roof rat, house mouse, field mouse, soft-furred rat, and the little Burmese rat. Roof rats were abundant in villages but seldom captured in fields. Annual rodent population cycles were bimodal in the deepwater rice zone and were influenced primarily by flood level (up to 4 m deep), rainfall, and available food resources. Rodents seemed to have specific habitat preferences based on the location of 736 rodents captured on the islands. More than 94% of the roof rats were trapped inside or between dwellings; 62% of the bandicoot rats and 73% of the musk shrews were captured between dwellings or along island peripheries, and 96% of Mus spp. were captured inside dwellings. As in previous tests, rodenticides effectively eliminated 88-100% of most pest species.

Regular meetings were held with members of the Bangladesh GTZ rodent control project to discuss field and laboratory activities. Plans were initiated for cooperative large-scale rat damage assessments in rice and wheat crops.

A collaborative research project on rodent problems in deepwater rice was completed in cooperation with BRRI and the British Overseas Development Administration (ODA). The study involved ecological investigations of several rodent species and rodent control trials using different rodenticides.

A joint research project was continued with members of the Bangladesh Sugarcane Research Institute (SRI) in studies of jackal (Canis aureus)

ecology in agriculture and short-tailed mole rat damage to sugarcane and peanut crops.

Project personnel instructed BARI and IADS staff members in the preparation and use of zinc phosphide bait cakes used to reduce rat damage in experimental plots. Demonstrations of methiocarb seed treatments to reduce bird damage to sprouting wheat were also conducted.

Haiti and Dominican Republic

To address the problem of vertebrate pest damage to agriculture in the Caribbean Region, a regional project was established to serve the needs of Haiti, the Dominican Republic, and other regional countries with special emphasis placed on assisting traditional farmers. The project officially began on 11 May with a DWRC biologist's arrival in Port-au-Prince, Haiti. Plans for constructing laboratory and office facilities were completed and counterpart positions were filled. Fieldwork was begun to determine major farming areas and crop phenology patterns and to identify bird and rodent pests.

The main vertebrate pests on Hispaniola were *R. rattus*, *R. norvegicus*, and the village weaver or Madame Saga (*Ploceus cucullatus*), originally introduced from West Africa. Hispaniolan woodpeckers (*Melanerpes striatus*) also damaged citrus fruit and cacao in the Dominican Republic. Cropping phenologies were prepared for the region to facilitate this work.

Outreach Activities from DWRC

In the Philippines, a DWRC analytical chemist provided technical assistance to USAID and NCPC in procuring laboratory equipment and instruments for the Human and Environmental Safety Laboratory.

A DWRC biologist discussed research programs with various agencies and the University of Dakar, Senegal; reviewed cooperative research programs with UNDP/FAO personnel and University of Nairobi in Kenya; organized cooperative methiocarb bird repellent work and conducted preliminary radiotelemetry trials in Tanzania; and met with FAO Plant Protection personnel in Italy.

A DWRC electronics technician trained Haitian counterparts to conduct tests of prototype transmitters. In the Dominican Republic, he lectured and conducted field exercises on use of wildlife telemetry equipment.

A DWRC biologist clarified the status of the proposed 3-year bilateral Integrated Wildlife and Vertebrate Pest Management Research Project to begin May 1981 in Sudan. He provided assistance in research and administrative matters.

A DWRC biologist participated in USAID-sponsored Pest Management Workshop in Tapachula, Mexico.

A DWRC biologist discussed vertebrate pest control research in Kenya with FAO and World Bank personnel; participated in an FAO technical meeting on bird damage control; and assisted the Comorean Government/World Bank project in establishing rodent control programs in coconut areas upon request of the World Bank.

A DWRC statistician assisted in designing methods of assessing vertebrate pest damage to rice, corn, and sorghum in Haiti, and sorghum in the Dominican Republic.

DWRC personnel traveled to 13 countries involving 245 man-days.

The project biologist from Bangladesh visited Thailand to discuss rodent control activities with members of the Thai/German Rodent Control Program.

DWRC hosted seven FAO-sponsored fellows from Kenya, Somalia, and Sudan, and three FAO project biologists for short periods to familiarize them with the Center's activities and develop possible cooperative research in areas of mutual interest. Several cooperative projects, such as using Microtaggants in Ethiopia and a sensory cue/methiocarb combination spray to ripening crops in Senegal, were already initiated; others were foreseen. Cooperation in the international graduate training programs in Vertebrate Pest Management at Bowling Green State University continued. Assistance was provided in the development of similar programs at other institutions.

Two Sudanese graduate students completed their M.A. degree programs at Bowling Green State University and returned to the Plant Protection Department in Sudan.

A member of the Sudan Agricultural Research Center (ARC) Insecticide Residue Analysis Laboratory visited DWRC between 2 and 16 April to work with staff of the Chemical Research and Analytical Services Project. He assisted in conducting residue analyses of methiocarb and studied the analytical procedures used by DWRC.

A Bengali student continued a Ph.D. program at Bowling Green State University in Vertebrate Pest Management. His Ph.D. research was to be conducted at the DWRC station in Hilo, Hawaii.

Two Bengali students began M.S. programs in Vertebrate Pest Management at UPLB.

Two cooperators from the Dominican Republic received 2 weeks of training at DWRC.

Supporting Research at DWRC

Relatively little efficacy data under laboratory conditions were available for rodent burrow fumigants. No specific laboratory testing standards or methods had been established. A burrow system which simulated that of wild rodents was constructed which permitted obtaining data on efficacy,

different formulations or materials, observation of animals exposed, precise measurement of fumigant concentration at different points within the system, and immediate access to target animals. The physical dimensions and characteristics of the burrow system were based on data from excavation of 20 lesser bandicoot rat burrows in Bangladesh. Fourteen formulations or concentrations involving eight fumigants were tested on 258 animals in 86 trials.

Toxicological work with commercial rodenticides and bioassays were completed with Nile rats. No deaths were recorded using Norbormide, attesting to its selective toxicity to Norway rats. The sole survivor from fluoroacetamide tests continued to avoid untreated bait 1 week after exposure, indicating extreme bait shyness. All rats exposed to zinc phosphide and DRC 4575 died.

Nonaqueous gels were evaluated for rodenticide applications. Twenty materials (starches, glutens, carrageenins, gums, and silicon powders) were blended with additives and tested for their feasibility for tracking formulations for outdoor use. Tests revealed that amorphous silicon dioxide powders and gels may be useful as rodenticide carriers and may have many other management applications, such as carriers for attractants or repellents. The gels might be applied by means of a tracking formulation or by rubbing posts placed near burrow entrances.

Curb^R, synergized aluminum ammonium sulfate, is a chemical which reportedly affects gustatory, olfactory, and tactile senses of birds and mammals. Ten formulations, provided by the manufacturer (Sphere Laboratories, London), were tested on individual quelea. In two-choice tests, quelea ate significantly more untreated than treated food for five formulations. In no-choice evaluations, none of the formulations repelled quelea.

Enhancing methiocarb formulations with tactile, visual, and olfactory cues appeared to be a promising repellent technique for reducing bird damage. The repellency of several naturally occurring plant extracts were evaluated. Chemicals relying on odor cues seemed impractical for field use; cues with contrasting colors to the food source should be evaluated.

A new particle marker had potential for mass-marking birds. These markers were small, colored rectangles (440μ x 375μ x 34μ) of metalized polyester film. Many colors were available and the use of an 8-10 power magnifier allowed each color to be discriminated. A Microtaggant-metal flake combination provided a marker that could be seen under ultraviolet light or in daylight.

The metal flake particles were also mixed with ground corn and fed to wild Norway rats in an outdoor colony to evaluate their suitability as a bait marker for mammals. The marker was accepted by the rats, and could be detected in their digestive tracts and fecal pellets. A cooperative field trial was conducted with Ministry of Production personnel in the Comoro Islands. Different-colored markers were placed in bait in the crowns of coconut trees and on the ground beneath them. Rats readily found the bait stations and fed both in crowns and on the ground. Marker colors were

easily distinguished in the field, greatly simplifying the procedures for this type of study.

A cooperative field study of Microtaggants with FAO ornothologists was undertaken to mark red-billed quelea in Ethiopia. The study was to determine local movements and migration patterns of quelea populations. However, only hand spraying equipment was available and it was not possible to mark a sufficiently large number of birds to recapture them during migration. Mass-marking research was continued with these materials and with microscopic fluorescent particles which were to be tested in Africa in the future.

The computerized data-recording system continued to prove useful for analyzing rat feeding behavior. A study to compare the minute-by-minute feeding patterns among groups of Nile rats, cotton rats, and wild-caught and albino Norway rats was completed. Average food-intake patterns for each of the groups provided characteristic, yet quite different, species profiles.

The project continued to produce specialized miniature radio transmitters for use overseas. Of particular interest was the development and testing of 1.7- to 1.9-g bird transmitters designed to attach to the tail or leg of small passerine birds. Laboratory studies on quelea showed that the tail attachment was practical.

A feasibility study for an advanced statistical processing VHF receiver for wildlife telemetry was completed. This hardware development had the unique capability of fully automating wildlife telemetry receiving sites and providing data in a compatible format for computer processing. This new receiving hardware may prove useful for many domestic and international projects.

Several analyses were performed for methiocarb residues on rice seeds and seedlings from Sudan. The seeds, which were treated at 0.2%, were analyzed and residues ranged from <1 ppm to 12 ppm.

Analytical methods were developed or modified for carbofuran, warfarin, strychnine, brodifacoum, and reserpine. In addition several samples were analyzed for Compound 1080 and zinc phosphide.

By using grooming behavior, materials placed on the fur of a rodent can be delivered by accidental ingestion. Grooming apparently persisted in the presence of a noxious taste. However, the relationships between grooming and taste aversion had not been described. An investigation was designed to study such relationships with the hope of finding ways to improve methods of rodent control. The results suggested that grooming behavior might have some unique applications in rodent control. Overall results supported the hypothesis that taste, paired with postingestional illness, was sufficient to produce conditioned aversion. They did support contentions that taste aversions require object learning or that toxicity need be an important factor in the likelihood of a material being associated with postingestional illness.

1981

Philippines

Field studies with many crops, including corn, had shown that crops with weeds received more damage than crops without weeds or crops with low weed density. In one field study, weed control reduced rat activity and damage and warranted consideration in cost:benefit determinations. More data correlating weed levels with rat damage and yield needed to be collected.

Burning vegetation and fumigating or flooding burrows were methods frequently used to reduce rat damage to rice. In Philippine ricefields, only a portion of the rat population (usually nesting females) occupied burrows. Burrow treatments had not adequately been evaluated to reduce rodent populations and, ultimately, damage. The efficacy of a fumigant cartridge, developed at DWRC, was tested on *R. r. mindanensis* at IRRI. Little reduction in activity was achieved when burrows were fumigated during the flowering and mature stages. Burrow treatments during the reproductive season, in combination with baiting programs, might sufficiently reduce the population to a level that crop protection could be achieved. Due to the continual reinvasion of rats from surrounding areas, burrow treatments would need to be implemented over large areas to achieve an effect.

Four rat control techniques--baiting with coumachlor, baiting with brodifacoum, lethal electric rat barrier, and nonlethal electric rat barrier--were evaluated during the 1980 wet season and 1981 dry season on experimental farms of IRRI. Damage to rice tillers, rat activity, and costs of the control methods were evaluated. Damage (<1%) and rat activity in plots protected by the lethal electric barrier were lower than in plots protected by the other three techniques but were the most expensive. The survey also indicated that of 173 rice experiments conducted in 1980 at IRRI, research data were totally lost in 6.4% and partially lost in 60% due to rat damage. Researchers were able to collect all of their intended data in only 34% of the experiments.

Rat damage to Hawaiian giant Ipil-Ipil (*Leucaena leucocephala*) trees, which had been grown for fuel for thermo-generating plants at the Pilot Dendro Thermal Plant Project in Daclolo, Occidental Mindoro, was evaluated at 60%. A rodent control program including damage appraisal, snap-trapping, anticoagulant baiting, species composition identification, and training of project personnel was initiated. The pest species were identified as *R. r. mindanensis*, *R. exulans*, and *R. argentiventer*. The most severe damage occurred to newly planted seedlings or saplings of 1 m in height, causing numerous replantings.

Rat damage to coffee (*Coffea robusta*) trees in northern Luzon occurred between the months of October and December. Damage began during the flowering period when new growth was present. Rats cut, stripped, or girdled secondary and tertiary branches. After a few weeks, severe defoliation and loss of bean production occurred. Eighteen of 20 plantations visited had visible signs of rodent damage. During 175 trap

nights, 50 R. everetti, 12 R. exulans, and 10 R. r. mindanensis were caught. Traps set in trees caught only R. everetti. Damage was reduced with baiting programs.

Methiocarb was evaluated as a seed treatment for reducing bird (Lonchura spp.) damage to hand-sown rice seeds. Damage at the conclusion of the study showed 5.3% damage to the treated plot and a significantly ($P < 0.01$) higher damage level of 61.7% in the untreated plot and indicated the potential of 0.25% methiocarb seed treatment in reducing bird damage.

A year-long extension study to demonstrate crown baiting techniques in coconut was completed with the Regional Crop Protection Center in Pili. Treated and untreated plots were established, and monthly records were kept of rat damage, rat activity, and harvested coconuts.

Damage to commercial bananas caused by nectar-feeding bats (Rousettus amplexicaudatus) was investigated. These bats scratched young bananas in the process of feeding on the nectar of the banana flower, making the bananas unacceptable for market. Bat populations apparently were reduced by mist net collections during a 1-year period; more than twice as many females as males were captured.

Training continued to be an important component of the project. Two manuals were prepared in cooperation with IRRI for use in pest management training courses and for publication and distribution.

Six individuals, including five international students, were enrolled at UPLB for graduate level training in vertebrate pest management. Four Filipino students, pursuing doctoral degrees in vertebrate pest management, enrolled in the United States at Michigan State University, East Lansing, Michigan; Bowling Green State University, Bowling Green, Ohio; and at North Carolina State University, Raleigh, North Carolina.

Seventeen individuals were graduated from the 10-month diploma course for crop protection specialists. The course was again offered in June 1981 to 25 students, including one Indonesian. The course was funded by a USAID Training Grant through NCPC. Several Southeast Asian countries had expressed interest in participating in future courses.

Africa

The USAID/DWRC-sponsored Vertebrate Pest Project in Sudan closed during 1981. Consequently, all DWRC quelea research activities in Africa were conducted during TDY's from DWRC.

Bangladesh

Assessments were made of rodent damage to barley, wheat, and deepwater and transplanted rice. Damage fluctuated annually, depending upon distribution and amount of rainfall and varied from 3.2% to 13.0%. Deepwater rice losses were assessed by digging up the burrow systems of lesser bandicoot rats. Rats cut and stored an average of 1.8% of the yield during a 2-week

period. Losses were sufficiently substantial that farmers frequently retrieved this rice from the burrow systems. Fields of transplanted rice were assessed by sampling 55,404 rice tillers in 102 fields. Cut tillers (323) were found in nine fields, a damage level of 0.6%.

Anticoagulant toxicities to lesser bandicoot rats were compared by recording mortality during a no-choice 4-day feeding test. Results indicated that brodifacoum and coumatetralyl could be recommended for control.

A study of rodent ecology in sugarcane was initiated in collaboration with the Australia-Bangladesh Sugar Industry Project farm. Fields were sampled for rodents every other month for 10 months by snap-trapping. During 1,122 trap nights, 12 rats were captured (10 *Millardia meltada*, 1 *Rattus rattus*, 1 *Nesokia indica*). Analysis of stomach contents revealed that *M. meltada* was feeding mainly on weed seeds, stems, and insects. No cane was found in the alimentary canal of *R. rattus*. However, *N. indica* had eaten roots of cane plants beginning 4 months after planting, resulting in the loss of about 2%.

During the monsoon season, rodents temporarily desert flooded agricultural fields and move close to, or actually into, human dwellings. Resident household rodents were the roof rat and the house mouse. An insectivore (Soricidae), the musk shrew also occurred around housing areas. The efficacy of zinc phosphide (2%) and brodifacoum baits (0.005%), when applied at weekly intervals, was compared in housing clusters. The overall reduction was 97% for brodifacoum and 86% for zinc phosphide, and reference houses showed a 39% increase in activity. The results suggested that a large-scale baiting program during the monsoon season should be able to reduce rodent populations to nondestructive levels by the onset of the dry-season cropping period.

Damage to sweet corn by rose-ringed parakeets (*Psittacula krameri*) and jungle crows (*Corvus macrorhynchos*) was quantified. Damage was heaviest along the border rows and varied from 10.3% to 21.9%.

Bird pests of sprouting wheat included common myna (*Acridotheres tristis*), Asian pied starling (*Sturnus contra*), rock dove (*Columba livia*), collared dove (*Streptopelia decaocto*), house sparrow (*Passer domesticus*), jungle crow, and house crow (*C. splendens*). Field trials, using the chemicals methiocarb, applied at 0.25% and 0.5%, and copper oxychloride (a registered fungicide in Bangladesh), applied at 1.2%, as seed dressings, were carried out in wheat multiplication fields. Both methiocarb and copper oxychloride were potentially effective bird repellents to wheat seed.

Counterpart personnel presented a training lecture to 24 participants in the Rice Production Specialist Training Course on the biology and control of rodents that damaged food crops. Bangladesh TV filmed a 30-min program in Bengali language on rodent control and research activities of the Vertebrate Pest Section; the film was shown nationwide.

Three counterparts were in the process of completing graduate degree programs.

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

Haiti

The village weaver, a species introduced from Africa, caused damage to rice, sorghum, corn, and other crops in Haiti and the Dominican Republic. Long-term observations were made at colonies to document their reproductive biology. During the breeding season birds seldom foraged in cultivated crops but their numbers increased in cultivated areas as colonies dispersed. The intensity of damage and its impact on individual farmers was highest in small plots of upland rice bordered by native vegetation. The effects of village weavers on rice production seemed to be minimal. However, their impact on individual subsistence farmers, who could least afford losses, could be critical.

An initial survey of rat damage to field corn was completed and damage represented a 15% yield loss. Fifty-four percent of the ears sustained some damage.

Because sustained baiting was effective in reducing preharvest rice losses to rodents in the Philippines, a preliminary investigation of the sustained baiting technique was evaluated in Haiti at a rice scheme using 0.05% warfarin-corn meal. The cost of the baiting program was approximately $9.20/ha, and damage averaged between 0.4% and 1.7%.

In the Dominican Republic, U.S. Peace Corps worked with the Division of Plant Protection, Secretary of Agriculture. The project cooperated whenever possible to facilitate the research activities of these organizations on vertebrate pests. One cooperative study involved evaluating woodpecker damage to cacao. The 1980 government estimate of damage caused by woodpeckers was 4%, representing 86,843 kg, valued at $2,031,380. Another cooperative study revealed that rat damage to coconuts ranged from 0.3% to 11.0%.

Outreach Activities from DWRC

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

towers in the nesting colony. Useful data were obtained and had important crop protection implications.

The usefulness of colored leg streamers and radio transmitters to determine movements and behavior of village weavers and masked weavers (P. intermedius) that were nesting together was evaluated in Ethiopia. Nesting and movement information was particularly scarce for both of these species, and neither had been studied using marked birds. A total of 135 birds of both species were marked with plastic leg streamers, and four village weavers, weighing 35 g, were equipped with 1.8-g radio transmitters. Radios were glued to the tail. The nesting chronology of these colonies was determined and mapped. The movements of radio-equipped and streamered birds were regularly monitored from the ground and helicopter. The study demonstrated the usefulness of both leg streamers and radio transmitters for locating individual ploceid weavers.

Knowledge was needed of the pattern and timing of migratory movements of quelea in the Ethiopian Rift Valley. More than 1.2 million nesting quelea were marked in three colonies in southern Ethiopia with aerially applied fluorescent particles. Thirteen marked birds from five nesting colonies or roosts were captured during August, September, and October in the Upper and Middle Awash River Valley, up to 100 days after spraying operations and between 500 and 700 km from the original marking locations. These captures confirmed the hypothesized migration route in the Rift Valley and were the first observations of the phenomenon of itinerant breeding of quelea in Africa. This knowledge of the temporal and spatial distribution of quelea in relationship to susceptible sorghum in the Rift Valley had important implications in developing an effective crop protection strategy for Ethiopia and other African countries.

A DWRC biologist worked with FAO and the Kenya, Sudan, and Tanzania Ministries of Agriculture to partially survey quelea breeding colonies in the northern frontier of Kenya. Historical evidence suggested that quelea bred along the Ethiopian border where much suitable habitat existed, but no systematic surveys had been conducted. Colonies were located wherever suitable habitat (low Acacia trees, lush grass stands, and open water) was present. Between Lake Turkana and Moyale, 10 breeding colonies of quelea were located.

DWRC biologists initiated a study to evaluate the chemical composition of feathers from quelea throughout Africa. Because the chemical composition of soils differs between areas, accumulations of trace elements in plants, seeds, and birds tend to be unique. If the composition of trace elements in feathers of quelea actually provided a physiological marker by which populations could be recognized, it would greatly assist in management of the species. Feathers from birds of different ages and sexes were collected, both in breeding colonies and in agricultural areas in Ethiopia, Tanzania, Sudan, Kenya, and Senegal. Analyses were to be made at DWRC to test the ability of chemicals to differentiate between the major subspecies of quelea in Africa.

For the fourth consecutive year, the repellent methiocarb was tested against quelea in Ethiopia in cooperation with the Ethiopian Sorghum Improvement Project. The 12-ha experimental plot contained several thousand breeding lines and varieties of sorghum with different maturing dates. Methiocarb was applied to individual heads in alternate bands and covered approximately 50% of the area. Two applications were made, and excellent protection was provided for almost 2 weeks. At harvest, only 14.1% of the sorghum had been lost to the birds. The efficacy of methiocarb in protecting sorghum was similar to that obtained in trials during the previous 3 years. In 1976, without the use of methiocarb an estimated 42% of the crop was destroyed.

DWRC, through USAID, assisted the Ministry of Agriculture of the Arab Republic of Egypt and the Ministry of Agricultural Development and Agrarian Reform of the Government of Nicaragua in examining the extent of vertebrate problems and formulating recommendations.

In Egypt, most fields and all temporary storage sites visited showed signs of rodent problems. Rats damaged sugarcane, maize, beans, vegetables, wheat, rice, fruits, cotton, and many other crops. The major rodent pests responsible for grain loss were the Nile rat and roof rat. Birds, mainly house sparrows (*Passer domesticus*), Spanish sparrows (*Passer hispaniolensis*), common starlings (*Sturnus vulgaris*), and doves (*Streptopelia* spp.) consumed enormous amounts of cereal crops each year, both in storage and in fields. Fruit bats (*Rousettus* spp.) reportedly contributed to heavy losses in annual fruit crop production.

Nicaragua suffered chronic in-field losses to rodents in all major crops, including rice, corn, beans, sorghum, sugarcane, melons, vegetables, and cotton. The cotton rat was reported most frequently as the major agricultural pest.

Recognizing the need for graduate training in the newly emerging field of Vertebrate Pest Management, the Department of Fishery and Wildlife Biology, Colorado State University, developed a cooperative program with DWRC for individuals seeking advanced education in Vertebrate Pest Management. A special effort was made to address the individual needs of international participants in managing vertebrate pest problems in their home countries.

DWRC personnel spent 385 man-days on outreach activities in 13 developing countries.

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

Supporting Research at DWRC

A formulation of white latex paint, calcium carbonate ($CaCO_3$) pigment, and a methiocarb-wattle tannin (tactile cue) was tested on wheat, rice,

and sorghum against quelea. Both formulations enhanced the effect of 0.008% methiocarb on wheat.

Dry leaves and a steam distillate of wild ginger showed repellency against several species of mammals. Both preparations also were highly repellent to quelea, apparently causing a "numbing" sensation when ingested.

Silicon dioxide gels had potential application as rodenticide carriers. In 1981, 15 additional silicon dioxides, a clay product, and aluminum stearate were similarly evaluated. Tack was the most desirable property for most gel formulation uses and, consequently, the primary ranking factor for the silicon dioxide products. Gels could be formulated with desirable odor, flavor, and water-resistant properties, and their physical properties of viscosity and tack could be manipulated to meet particular use conditions. They had potential use in both food storage and field damage situations.

A method of applying control agents using the quelea's natural nest-weaving behavior as a means of delivering the chemicals was investigated. Testing with potential avicides (fenthion, parathion, Dasanit^R, and Volaton^R) involved presenting vicide-treated nest material (13-cm long strands of cotton string) to male-female pairs of quelea, observing changes in weaving patterns, and assessing mortality. Dasanit seemed to hold the most potential as an avicide for quelea control when applied to nesting material. The method could also have application to control of the village weaver which caused crop losses in both Africa and several Caribbean countries.

Although methiocarb had proven to be an effective bird repellent when applied to crops at 2-3 kg/ha, the cost of the chemical often limited its use. Preference tests indicated that quelea were repelled to a greater degree by 0.05% methiocarb on millet heads (13.9%) than on millet seed (5.1%), suggesting that learned methiocarb repellency was easily transferred from the seed bait to millet heads. Combinations of taste and color cues might sufficiently enhance methiocarb repellency so that normal field application rates could be reduced.

The computerized data recording system, established in 1980, continued to provide useful information on the feeding patterns of wild rats. Data analyses of comparative, minute-by-minute feeding patterns of groups of Nile rats, cotton rats, and Norway rats continued. A pilot study to assess the feeding responses of rats fed lithium chloride (an illness-causing drug used to induce learned taste aversion) was completed. The rapid cessation of feeding on lithium-treated rice, and the quick development of a learned taste aversion response suggested that the learned aversion responses should be evaluated for protecting crops and stored food.

The commercial bait Vizon (0.021% warfarin) was evaluated on wild Norway rats and ricefield rats according to EPA test protocol. Vizon caused mortality if consumed, but for both species it did not meet the EPA test standards of 33% bait acceptance and 90% mortality.

Learned aversion by laboratory Norway rats was assessed for the rodenticides strychnine, thiosemicarbazide, scilliroside, arsenic, and warfarin in relation to the tastants sucrose, sodium chloride, sucrose octaacetate, quinine sulfate, and hydrochloric acid. Results suggested that strychnine was principally bitter; thiosemicarbazide was principally bitter and sweet; and scilliroside was sour and bitter. Results of tests pairing warfarin and arsenic with LiCl were less clear and required additional studies. Sodium bicarbonate also seemed ineffective as an agent for masking the bitter taste of strychnine for rats.

The increased use of methiocarb as a crop protection chemical necessitated further study to develop a reliable analytical method for determining low residue levels. Two procedures were developed and were available for measuring methiocarb by gas chromatography.

Analyses were conducted on methiocarb wheat samples in support of bird control studies in Tanzania, and on zinc phosphide bait samples in support of rodent control studies in Bangladesh.

Although zinc phosphide was the most widely used acute rodenticide, there was a paucity of information about its metabolism and distribution in tissues of animals poisoned by it. Residues from the analysis for the gas phosphine in tissues of rats poisoned with an acute dose of zinc phosphide were evaluated. High concentrations in the stomach and intestines were expected, but its absence in the blood and other tissues was not. In the intestinal tract, phosphine was produced from zinc phosphide and was probably transported by the blood. However, phosphine might bind proteins in the blood and other tissues so that was is not extracted by the methods used.

Wildlife transmitters which weigh approximately 1 g were needed for small birds and rodents. The battery and quartz frequency crystal generally exceeded this 1-g design goal. Because there was little chance of finding an improved lightweight battery, a smaller crystal (3 x 6 mm and 0.147 g) was developed, but with marginal electrical characteristics. This was the smallest crystal ever used in the construction of wildlife transmitters.

1982

Philippines

DWRC personnel supervised research and academic programs of four international M.S. candidates. Two Bangladeshi students completed research on topics that had practical application to rodent ecology and management in Bangladesh. A Venezuelan studied the movements of rats in marshes adjacent to cropland. A Filipino student surveyed the rodent species in Philippine port zones.

A trial was conducted to determine if feeding space on a bait container affects consumption rates. Three different sizes of plastic tube, cut to simulate the traditionally used bamboo tube bait container, were compared. *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.

A study was completed with fruit bats to determine their relative population levels and frequency of return to a banana grove. R. amplexicaudatus, a nectar-feeder, that, in the process of feeding during the flowering stage, punctured and scratched commercial bananas and, thereby, reduced quality and exportability. Very little was known about this species and much less about how to reduce damage. Nectar-feeding bats seemingly did not frequent specific areas. They seemed to move throughout wide areas and visit the most attractive nectar-producing plants.

Two sites with ripening sorghum were selected for comparing the repellency of methiocarb and methiocarb/wattle tannin to Eurasian tree sparrows and spotted munias (Lonchura punctulata). Both methiocarb and methiocarb/wattle tannin gave comparable protection to undamaged sorghum and prevented additional bird damage to previously damaged sorghum.

Cooperative research was initiated with the Philippine Bureau of Forest Development. The study area had a history of rodent damage to transplanted seedlings of Hawaiian giant ipil-ipil trees. The Vexar plastic mesh tube, which was successful in reducing mammal damage to pine seedlings in the United States, was ineffective in reducing this damage. Baiting with rodenticides still seemed to be the most cost-effective method available.

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 to NCPC for training. These individuals were involved with agricultural extension services in rodent control and high-yielding rice varieties.

Cooperative studies were begun with a Burmese Department of Agriculture Junior Research Officer, as part of a 1-year special nondegree training program in rodent control with IRRI. Assistance was provided to a Ph.D. candidate at Bowling Green State University conducting field research in Leyte to evaluate rodent control methods in coconuts.

Information was exchanged on project activities and areas for cooperative sponsorship in crop protection training with GTZ.

The Project, through NCPC, cooperated with the Bureau of Plant Industry and the Philippine Coconut Authority by contributing to a series "Philippine Recommends for Rodent Control" which was to be published by the Philippine Council for Agriculture and Resources Research and Development. This publication would provide administrators, research personnel, and students with a concise summary of current rodent control

technology available for planning or teaching/training throughout the Philippines.

Eighty-one individuals representing many Asian countries received vertebrate pest training during 1982.

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

Bangladesh

Rat damage to wheat was assessed on a national scale in various districts since 1979. Surveys were carried out in six districts in 1982. Data from 237 fields indicated 8.4% damage and represented about 81,000 tons of the 962,000 tons of wheat produced for the year. About 67.5% of all fields had detectable rat damage.

The efficacy of two rodenticides, 2% zinc phosphide and 0.005% brodifacoum, as bait cakes to reduce bandicoot rat damage to maturing wheat was compared in farmers' fields. Brodifacoum gave better results than zinc phosphide, apparently because it did not induce bait shyness upon repeated exposure. 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.

A cooperative field trial comparing two rodenticides on island villages in deepwater rice was completed. 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. This was the third comparative field trial in which brodifacoum had proven superior to zinc phosphide when used in the same baiting schedule. It was thought that brodifacoum should be considered for registration in Bangladesh.

Methods of assessing rat damage in deepwater rice still needed to be developed. Much damage occurred after floods receded. Tillers damaged by rats during flood periods often responded with compensatory growth in new tiller output and panicle development. This compensatory growth did not seem to contribute significantly to yield at harvest. In general, damage in the field varied depending on when it occurred; damage during the monsoon period was randomly distributed; and fresh-cut stems were associated with the presence and proximity of the burrow openings and rat runways.

Previous studies indicated that rat damage to wheat could be reduced by using zinc phosphide bait cakes. Premixed 2% zinc phosphide bait packets were prepared and made available to farmers to test their acceptance of bait packets, the effectiveness of the bait, and to compare it to the other rat poisons farmers are using. 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. Most encouraging was the approximately 70% reduction in damage that was achieved with very little supervision. This study demonstrated the feasibility of providing an effective, inexpensive rodenticidal bait material to Bangladesh wheat farmers for reducing rat damage. A larger scale demonstration was planned.

Transplanted aman rice was planted during the monsoon season and harvested in October and November after the monsoon. When the fields were drained and the rice was ripening, bandicoot rats invaded the fields from nearby higher ground where they had lived during the flood period. Damage lasted only a short time, but could be intense. There was considerable opportunity for extension of rodent control techniques into these areas.

Vegetable oils commonly were added to rodent baits to increase their attractiveness and palatability. Because many oils were available at different costs in Bangladesh, an experiment was carried out to determine those oils preferred by lesser bandicoot rats. Because of its preference by bandicoot rats and lower price, soybean oil was recommended as a bait additive.

Avitrol (4-Aminopyridine) is a distress-producing chemical used to deter birds from feeding in certain food crops in the United States. In Bangladesh it may have application in certain situations, especially crops in high value, experimental plots. The LD50 in rose-ringed parakeets (*Psittacula krameri*) was 3.1 mg/kg and the effective dose (the dose producing a distress reaction) was 10-15 mg/kg. The effective dose in munias (*Lonchura* spp.) was between 5 mg/kg and 10 mg/kg.

Maize was a relatively new food crop in Bangladesh. Wherever planted, it almost invariably was attacked at the milk stage by flocks of rose-ringed parakeets, jungle crows, and other birds. A replicated trial evaluating Avitrol to protect maize from parakeets was conducted. Five ears were exposed and sprayed with either 3 or 4% Avitrol. The results indicated that both treatments provided excellent protection.

The R50 of copper oxychloride and methiocarb to individually caged pigeons was determined. Preliminary R50 values were 0.28% for copper oxychloride and 0.12% for methiocarb.

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. Replicated trials evaluating copper oxychloride (0.5%), methiocarb (0.25%), and trimethacarb (1.0%) as seed dressing repellents were initiated. Observations of bird damage during and after sowing showed that pied mynas, common mynas, pigeons, jungle crows, and house sparrows were the main pests to the seeds and sprouts. The results of this work were encouraging for using methiocarb at 0.25% and copper oxychloride at 0.5% as bird repellents on wheat seed. However, it seemed that future use of trimethacarb as a wheat seed treatment should be confined to concentrations of $\leq$0.5%.

Staff personnel continued to cooperate with the Bangladesh-German Plant Protection Rodent Control Programme in field, laboratory, and extension and training activities. A collaborative proposal for a study of squirrel biology and ecology was presented to the Coordinating Committee on Vertebrate Pests at the Bangladesh Agricultural Research Council (BARC). Collaborative work continued with the Christian Reformed World Relief Committee 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 was established with the Agricultural Extension Services for disseminating training and extension information. BRRI worked collaboratively with the Project staff on studies of postharvest food losses, rodent control in deepwater rice, and damage assessments in deepwater ricefields.

Haiti

Corn was the major crop grown in Haiti. Production area 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 cornfields in two regions. Preharvest losses in one area were 5.6% to Norway rats; 6.4% to Hispaniolan conures (*Aratinga chloroptera*) and village weavers; and 1.7% to Hispaniolan woodpeckers. In the other area, 2,380 ears were sampled and 0.8% had Norway rat damage, 15.1% had conure and weaver damage, and 39.9% had woodpecker damage.

A cooperative study with the Texas A&M project was initiated to compare bird damage among 12 different varieties of corn. Problem species were village weavers, Hispaniolan woodpeckers, Hispaniolan conures, and a suspect species, shiny cowbirds. Although preharvest damage to the varieties ranged between 5 and 12%, statistical analysis indicated that there were no significant differences among the varieties.

Information was gathered on the nature and intensity of crop damage by village weavers in relation to their habits, ecology, and distribution.

High-value experimental plantings of corn and sorghum at the Damien Experiment Station suffered damage from rats and birds. The situation was ideal for evaluating methods for reducing crop losses to vertebrate pests in small fields. Rat damage to corn and sorghum was greatly reduced by using a warfarin/ground corn in bait containers placed around field edges.

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 adopted the program throughout this area.

Outreach Activities from DWRC

DWRC staff traveled in Asia, Caribbean, and Latin America in conjunction with ongoing field research activities and at the request of foreign governments through USAID Missions or USAID/W, to participate in international meetings, assess vertebrate pest problems, or to review, evaluate, and coordinate present and future research programs. TDY activities from DWRC became an increasingly important part of the project. Many types of short-term evaluations and cooperative studies with host-country scientists could be carried out expeditiously in this manner. This travel involved 174 man-days in 10 countries.

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 (CICP). 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.

DWRC fieldwork in Pakistan included observations on parakeet damage in sunflower fields and the use of traps and Avitrol. No really effective crop protection technique had been developed. Avitrol, a chemical frightening agent, was the only chemical that had proved useful in combating bird damage to ripening sunflowers in the United States.

DWRC continued to assist graduate research in Vertebrate Pest Management at Bowling Green State University and at Colorado State University.

Supporting Research at DWRC

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 birds from sunflowers and grapes, but did not seem to prevent damage to corn.

The lethality of four avicides to quelea (fenthion, parathion, Dasanit, Volaton) was tested using the nest material delivery method on groups of male-female pairs in individual cages. Dasanit was found to be the most effective with an optimal concentration of 0.8% applied 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. This sex difference was not totally unexpected because males construct nests. However, the technique probably had limited applicability to quelea because of their migratory habits and the difficulty of predicting exact nesting locations. The technique might be more applicable to village weavers, bird pests in Africa and the Caribbean region.

Although a number of control methods were available for lesser bandicoot rats, another means of control could involve rodenticide-treated nest material. In a pilot test, two pairs of B. bengalensis established burrows in enclosures. The rats readily accepted straw and burlap as nest material; cotton was less preferred. Tests were underway using 1.0% zinc phosphide and 0.02% brodifacoum-treated straw/burlap to assess lethality.

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

Fluorescein disodium salt (acid yellow 73, C.I. 45350, uranine), a freely soluble fluorescent dye that is used to trace water flow, was evaluated and showed potential as a physiological marker in rats. 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.

The DWRC chemistry laboratory performed hundreds of chemical analyses in support of crop protection studies in the field. Methiocarb-treated sorghum samples from the Philippines were analyzed for methiocarb and its sulfoxide and sulfone metabolites. Organochlorine analyses were performed on an assortment of bird eggs in support of studies in Haiti. Methiocarb residue analyses were conducted on ripening wheat and on rice seed in support of two FAO-sponsored studies in Tanzania. Rice samples from an FAO study conducted in the People's Republic of Benin were analyzed for Avitrol.

Efforts continued to evaluate candidate rodenticides. An acute oral, single-dose chemical having delayed mortality in rodents was evaluated. The LD50 of M&B 36,892A in male and female wild Norway rats was 50-100 mg/kg and in lesser bandicoot rats about 150 mg/kg for both sexes. The manufacturer planned to develop it as a commensal rodenticide in the United States and the United Kingdom.

Postharvest Studies

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

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

A pilot study was begun in Bangladesh 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 species captured inside and around farm structures. Data were collected on the types and quantities of foods stored, the length of storage, and the kinds of storage containers used.

APPENDIX G: BUDGET SUMMARY, 1967-1982

FY	S&T FUNDS	BANGLADESH FUNDS	UTILIZATION FUNDS	LAC FUNDS	TOTAL
1967	22,000				22,000
1968	251,617				251,617
1969	409,509				409,509
1970	449,594				449,594
1971	558,000				558,000
1972	550,000				550,000
1973	478,641		71,359		550,000
1974	373,813		76,187		450,000
1975	411,578		60,000		471,578
1976[a]	485,000		100,000		585,000
1977	439,850		84,000		523,850
1978	480,000	24,356	95,000	10,000	609,356
1979	543,668	164,944		13,000	721,612
1980	613,566	116,000		247,400	976,966
1981	607,434	154,650		175,000	937,084
1982	462,217	167,781		297,937	927,935
TOTAL	$7,136,487	$627,731	$486,546	$743,337	$8,994,101

[a] Includes 5th quarter.

APPENDIX H: COMMON AND SCIENTIFIC NAMES OF VERTEBRATES

Rodents

Black or Roof Rat	*Rattus rattus*
Ricefield Rat	*Rattus rattus mindanensis*
Rat	*Rattus argentiventer*
Norway or Brown Rat	*Rattus norvegicus*
Little Burmese or Polynesian Rat	*Rattus exulans*
Cotton Rat	*Sigmodon hispidus*
Nile Rat	*Arvicanthis niloticus*
Multimammate Rat	*Mastomys natalensis*
Lesser Bandicoot Rat	*Bandicota bengalensis*
Soft-furred Field Rat	*Millardia meltada*
Short-tailed Mole Rat	*Nesokia indica*
House Mouse	*Mus musculus*
House or Musk Shrew	*Suncus murinus*
Pocket Gophers	Geomyidae
Prairie Dogs	*Cynomys* spp.
Jackrabbits	*Lepus* spp.
Jackal	*Canis aurens*

Bats

Vampire Bat	*Desmodus rotundus*
Rousette Fruit Bat	*Rousettus amplexicaudatus*
Yellow Bat	*Scotophilus temmincki*

Birds

White-faced Tree-Duck	*Dendrocygna viduata*
Speckled Teal	*Anas flavirostris*
Rose-billed Pochard	*Netta peposaca*
Black Vulture	*Coragyps atratus*
Ring-necked Pheasant	*Phasianus colchicus*
Doves and Pigeons	Columbidae
Rock Dove	*Columba livia*
Collared Dove	*Streptopelia decaocto*
Eared Dove	*Zenaida auriculata*
Rose-ringed Parakeet	*Psittacula krameri*
Hispaniolan Parakeet	*Aratinga chloptera*
Monk Parakeet	*Myiopsitta monachus*
Hispaniolan Woodpecker	*Melanerpes striatus*
Chestnut-backed Sparrow-Lark	*Eremopterix leucotis*
Crested Lark	*Galerida cristata*
House Crow	*Corvus splendens*
Jungle Crow	*Corvus macrorhynchos*
European Starling	*Sturnus vulgaris*
Asian Pied Starling	*Sturnus contra*

Birds (cont'd)

Blackbirds	Icteridae
Common Myna	*Acridotheres tristis*
Shiny Cowbird	*Molothrus bonariensis*
House Sparrow	*Passer domesticus*
Spanish Sparrow	*Passer hispaniolensis*
Eurasian Tree Sparrow	*Passer montanus*
Golden Sparrow	*Passer luteus*
Masked Weaver	*Ploceus intermedius*
Black-headed Weaver or Village Weaver	*Ploceus cucullatus*
Red-billed Quelea	*Quelea quelea*
Red Bishop	*Euplectes orix*
Spotted Munia	*Lonchura punctulata*
White-bellied Munia	*Lonchura leucogaster*
Chestnut Munia	*Lonchura malacca*
Dickcissel	*Spiza americana*