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FINAL REPORT

CHAD RODENT CONTROL RESEARCH PROJECT

October 1989 - December 1992

April 23, 1993

A Cooperative Program

of

Government of Chad/Ministry of Agriculture and Forest Development

U.S. Agency for International Development

and

U.S. Department of Agriculture/Animal and Plant Health Inspection Service

Animal Damage Control/Denver Wildlife Research Center

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EXECUTIVE SUMMARY

A rodent control research project was carried out with funding provided by the U.S. Agency for International Development (USAID) and technical assistance furnished by the Denver Wildlife Research Center (DWRC) at three sites in Chad (N'Djamena, N'Gouri, and Karal) from October 1989 until December 1992. A resident biologist served as DWRC Project Leader from July to December 1990 and from March until December 1991. DWRC provided four consultancies to Chad between August 1992 and the close of the Project in December 1992. Project objectives were as follows: (1) begin to determine the life cycles of the major rodent pests of the Chadian Sahel, (2) evaluate the efficacy and appropriateness of control methods, and (3) prepare training materials on rodent biology and control for use by the Ministry of Agriculture's (MOA) crop protection personnel.

Six rodent species were identified as important pests of dune-grown millet and winter-grown vegetables at N'Gouri and Karal: the lesser hairy-footed gerbil (*Gerbillus gerbillus*), slender gerbil (*Taterillus* sp.), robust gerbil (*Tatera robusta*), Egyptian jerboa (*Jaculus jaculus*), Nile or unstriped grass rat (*Arvicanthis niloticus*), and multimammate rat (*Mastomys [Praomys] natalensis*). The unstriped grass rat and the multimammate rat are the primary pest rodents living in irrigated and recessional crop areas. The primary pests on dunes are the lesser hairy-footed gerbil and the Egyptian jerboa, which dig up, eat, and store millet and sorghum seeds at the time of planting. All species respond to the greening and maturation of weeds and grasses during and following the rainy seasons by intense breeding. Rodent population peaks are reached from October until December, depending upon the length of the breeding season. Populations then decline until July or August when the next breeding season begins.

Food preference studies disclosed that most Chadian rodents preferred millet over four other cereal grains, with rice and wheat as good alternatives for baits. Zinc phosphide at 1% concentration gave excellent results against wadi rodents and fair results against rodents on dunes. Chlorophacinone and bromadiolone at 0.005% would be good alternative toxicants for field use.

Training and training materials were developed for crop protection personnel, and two seminars/workshops were presented in-country. A training manual was developed in both English and French text and will be distributed to Sahelian Ministries of Agriculture. Fourteen issues of "Rat Facts," a one-page informational sheet in both English and French, were prepared and distributed to Chad/MOA, AID/N'Djamena, and DWRC personnel.

DWRC technical assistance consisted of 4 TDY (temporary duty) visits before the Project was initiated and 11 TDY visits after the Project began, a total of over 12 man-months of in-country assistance besides the presence of a resident biologist serving as Project Leader for 14 months. DWRC made numerous literature searches, procured equipment and supplies, and assisted with the production of four technical reports and a progress report.

INTRODUCTION

The Sahelian region encompasses about 20 percent of Africa and includes portions of nine African nations with a population of about 30 million people. The Sahel previously was a major food-producing area for northern Africa. But, because of droughts and crop depredations by birds, rodents, and insects, the Sahel now is a food-deficit region.

Lack of Knowledge of Rodent Outbreaks

In 1986 several Sahelian countries declared national disasters due to massive outbreaks of rodents. USAID was hampered in providing assistance due to a lack of knowledge of the rodent species concerned, their population dynamics, and effective control measures. Short-term technical assistance was provided by the USDA/APHIS/DWRC in the form of eight TDY's to the Sahel between April 1 and November 10, 1987. The in-country crisis response was inadequate due to poor organization in crop protection and lack of trained personnel, lack of materials, transportation, and lack of time in which to implement needed control measures. To ensure the implementation of effective crop protection measures in the future, it was felt essential to conduct research into rodent biology and control methods; therefore research was initiated in Chad to monitor rodent populations, evaluate control techniques, and train crop protection personnel to effectively address future recurring rodent population irruptions, as occurred in 1962, 1975-76, and 1986-87 in the Sahel.

The Chad Rodent Control Research Project (RCRP) is a cooperative program between the Chad MOA/Direction de la Protection des Vegetaux (DPV), USAID, and the USDA/APHIS/DWRC. Funding was provided by the USAID/Africa Bureau under the Africa Emergency Locust and Grasshopper Assistance (AELGA) Project.

Project History

Two research sites were selected for detailed studies: a recessional crop area near Karal and a dune and wadi agricultural area around N'Gouri. Field work at N'Gouri was begun during the October 1989 visits of Mr. G. Keith LaVoie and Dr. John Wilson. Monitoring of rodent populations was then carried out monthly by the Project Assistant and DPV technicians by snap trapping on transects in the N'Gouri area. The resident Project Leader, Dr. J. Juan Spillett, arrived in N'Djamena in July 1990. Dr. Spillett added the Karal area as a study site in August 1990. Dr. Spillett and his family were evacuated to the United States in December 1990 due to a coup d'etat in Chad. Dr. Spillett returned in mid-March 1991 to resume field work, but in December 1991, he resigned his position and returned home. No field work was completed from December 1991 until August 1992. Between August and December 1992, DWRC provided four 1-month consultancies to Chad. DWRC also provided training at two seminars/workshops. Dr. Spillett and counterpart staff trained 18 MOA/Crop Protection Service technicians in rodent research and control at a 2-day Pest Management Workshop held in N'Djamena during November 1990; and DWRC Consultants (Dr. Richard Dolbeer and Mr. Joe Brooks) and the Project Assistant (Dr. Maho Angaya) presented a 1-week seminar during September 1992 to 15 participants from the MOA and nongovernmental and private voluntary

organizations. The Project was closed out in December 1992, and Project equipment and the Project vehicle were turned over to the MOA/DPV for their use in continuing rodent control research work.

OBJECTIVES

The following Project objectives were stated in the PASA:

(1) Begin to determine the life cycles of the major rodent pests of the Sahel.

(2) Evaluate the efficacy and appropriateness of control methods.

(3) Prepare training materials on rodent biology and control for use by the MOA's crop protection personnel.

EXPECTED INPUTS

(1) Funding of $615,000 from USAID for a 2-year project period.

(2) A resident Project Leader for at least 2 years of the Project life.

(3) Qualified and experienced counterpart personnel appointed by the MOA/DPV who could be trained to assume the responsibilities of the rodent research Project when USAID funding ends.

(4) A qualified USAID Personal Service Contract (PSC) Project Assistant with a degree in biology.

(5) A reasonably well-equipped office/laboratory facility in which to conduct laboratory research of the Project.

EXPECTED OUTPUTS

(1) A prioritized list of preharvest rodent problems in Chad, according to their nature, extent, and importance.

(2) An initial methodology to assess crop loss due to rodents in vegetable and recession crops.

(3) A report in French and English on comparative, replicated laboratory and/or field trials of rodenticides or control techniques.

(4) A draft training manual on rodent biology and management.

(5) A regional training workshop for at least 15 participants.

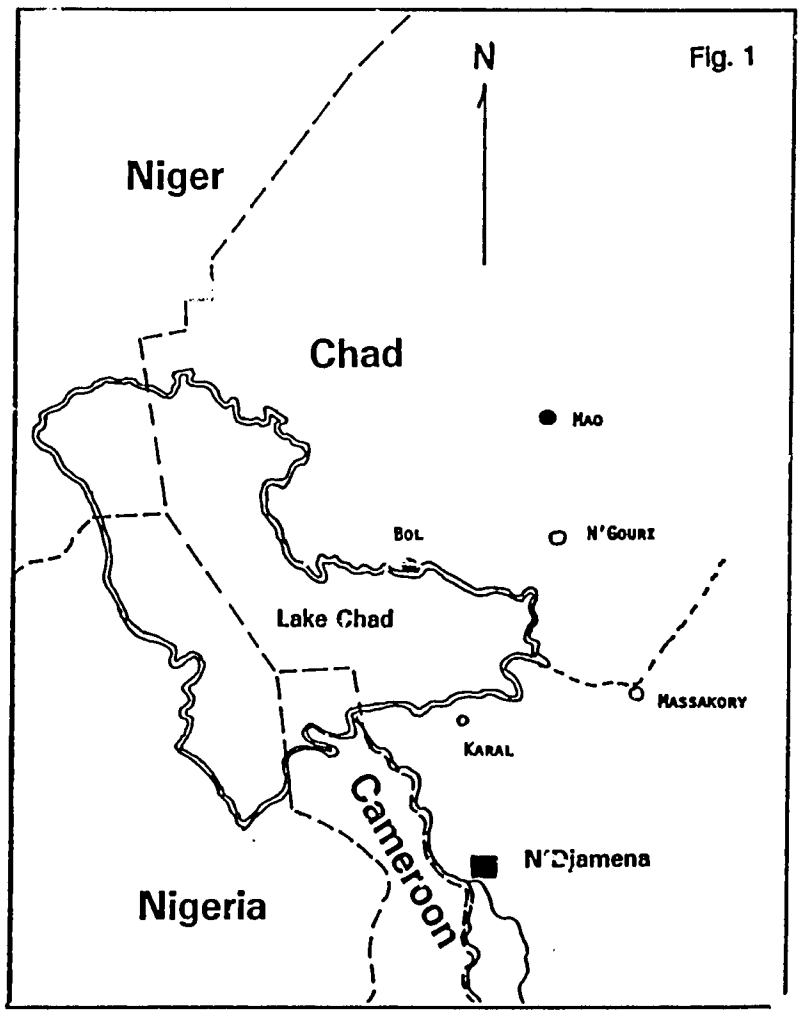
(6) Monthly progress reports submitted to the Agricultural Development Officer/AID/N'Djamena and USDA/OICD.

RESEARCH METHODS AND RESULTS

Methods

N'Gouri area

Rodent sampling sites were selected in late 1989 in typical wadi and dune cultivations in the N'Gouri area, approximately 230 km northeast of N'Djamena (Fig. 1). Wadi cultivation involves labor-intensive irrigation and cultivation of onions, tomatoes, peppers, okra, manioc, sorghum, and millet in scattered, small (< 5 ha) oases in the interdunal depressions. Dune cultivation is extensive dryland farming of millet on dunes or sandy hills surrounding the wadis. Both cultivations are done entirely by hand.



Rodent sampling was initiated in October 1989, and trapping was done approximately monthly thereafter. One wadi site was added in June 1990 and two others in July 1990. If a wadi was not in production at the time of field sampling, it was not sampled for rodents. Animals were trapped in linear transects with 25 stations (one rat snap trap at each station) at 10-m intervals. Six transects were set at each wadi. One transect was set in the noncultivated margin of the wadi, one transect in the noncultivated interior, another in the cultivated margin, another in the cultivated interior, and two in the noncultivated exterior. Figure 2 shows typical locations for the six transects at N'Gouri. Transects exterior to the wadis differed from transects interior to the wadis by having one rat snap trap and one mouse snap trap at each of the 25 stations. Small (15-20 mm^2) pieces of cardboard impregnated with peanut oil were used for baits, following the suggestion of Dr. Wilson after his 1989 visit (Wilson 1989). Traps were set in late afternoon, left overnight, and collected the next morning.

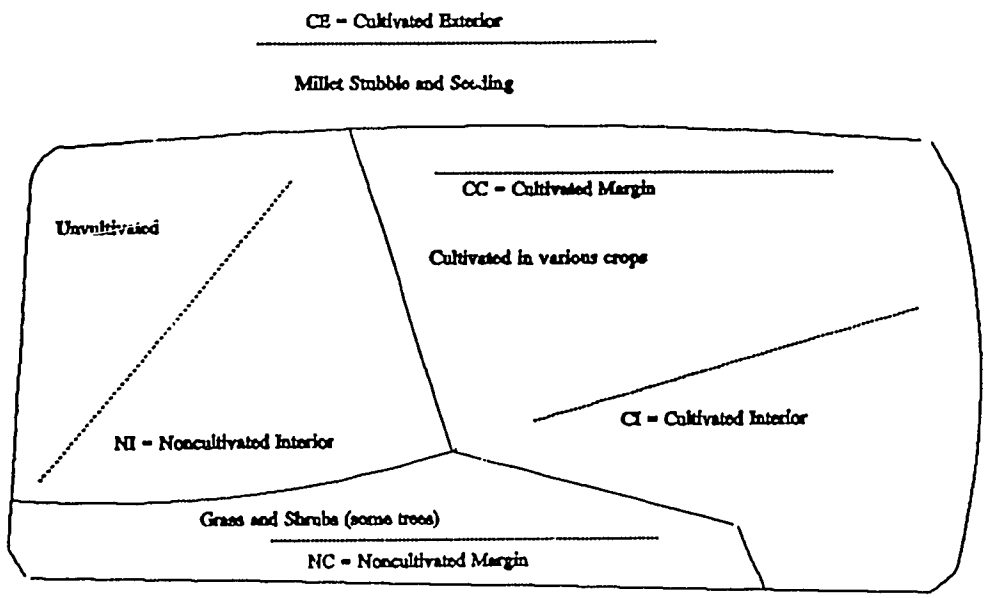


Fig. 2. Wadi traplines at N'Gouri.

Three dune sites were sampled monthly beginning in November 1989; one more dune was added in July 1990. Two linear transects of 25 stations (using one mouse snap trap and one rat snap trap at each station) were set at 10-m intervals.

Trapped rodents were identified to species, and data were recorded for sex, weight (BW), head and body length (HBL), tail length (T), age class (immature or adult), and reproductive condition of each animal. Beginning in late 1991, the hind foot (HF) and ear (E) length were recorded for each animal.

Karal area

Rodent population sampling was initiated in August 1990 on recessional agricultural crops or in adjacent vegetative types in the Karal area, south of Lake Chad and approximately 100 km north of N'Djamena. Recessional agriculture is the planting of crops on lands that are flooded each year by the waters of Lake Chad as a result of the rainy season. As the waters recede and the lands dry, rice, corn, sorghum, millet, cowpeas, peanuts, manioc, okra, sweet potatoes, watermelons, cantaloupe, gourds, and tomatoes are planted.

Rodent populations were sampled in a wide variety of crop types and in adjacent vegetation types with linear transects of 25 stations (one rat and one mouse snap trap at each station) spaced 10-m apart. Fields at Karal regularly were taken out of production as part of the customary farming process. Fields not in production at the time of a sampling trip were not trapped. The same data as recorded in the N'Gouri area were recorded for rodents trapped in the Karal area.

Rodent Species

Chadian-collected skins and skulls of gerbil specimens (*Gerbillus* and *Taterillus*) were compared with identified specimens in the collection of the Smithsonian Institution's National Museum of Natural History, Washington, D.C., in an attempt to identify the species from the research study areas. We followed the taxonomy presented for *Gerbillus* by Schlitter (1976) and for *Taterillus* from Robbins (1977). We are indebted to Dr. Thomas H. Fritts, Chief, Biological Survey, Dr. C. Brian Robbins, and Mrs. Linda Gordon for permission to use the mammal collection.

The *Gerbillus* specimens were identified as the lesser hairy-footed gerbil (*Gerbillus gerbillus*), based on comparisons with material collected in northeastern Nigeria, Niger, and Chad. Happold (1987) refers to the Nigerian *Gerbillus* as *G. agag*, although Rosevear (1969) places *agag* as a subspecies of *G. gerbillus*. Earlier reports of the Chad RCRP incorrectly referred to *G. gerbillus* as Anderson's gerbil (*G. andersoni*).

We were unable to place the *Taterillus* as to species due to the paucity of Chadian specimens. It appears that three species of *Taterillus* (*lacustris*, *arenarius*, and *gracilis*) may be expected to occur in the Lake Chad area. Only the collection and comparison of additional Chadian specimens can resolve the question of species' identity.

The robust gerbil (*Tatera robusta*) follows the description and name as suggested by Kingdon (1974).

Lesser hairy-footed gerbil (*Gerbillus gerbillus*)

The lesser hairy-footed gerbil is small (15 to 34 g), with sandy dorsal pelage and a pure white ventral pelage (Fig. 3). The sandy color extends in a broad stripe down to the tip of the nose. This gerbil's eyes are large and surrounded by white. A white patch occurs behind the ear. Its tail is long, sandy above, white below, with an elongated tuft of long hairs, often with blackish tips at the end. The soles of the hind feet are covered with short white hairs.

These gerbils typically live on sandy dunes, where they construct burrows to escape the daytime high temperatures. They are entirely nocturnal. They feed on grass seeds, grass stems and roots, and insects. They are found at both the N'Gouri and Karal areas.

Slender gerbil (*Taterillus* sp.)

The slender gerbil is medium-sized, ranging in weight from 30 to 68 g. Its dorsal pelage is sandy-orange, and its ventral pelage is pure white (Fig. 4). There is a sharp line of demarcation between the white and sandy colors. The hands and feet of the slender gerbil are white, its head is slender with a slightly pointed nose as compared with the robust gerbil, its eyes are particularly large, and the tail is usually well-tufted and darkest near the tip. The soles of the hind feet are sometimes partially haired and pigmented, as in the robust gerbil, and the upper incisors are grooved. Externally, this genus is similar to, but usually smaller than, the robust gerbil.

Fig. 3. Lesser hairy-footed gerbil.

Fig. 4. Slender gerbil.

Slender gerbils live in burrows which are about 50 cm deep, situated in well-drained soils, and resemble those of robust gerbils. Near N'Gouri, slender gerbils appear in the thorny fencerows surrounding the cultivated wadis, along with robust gerbils, unstriped grass rats, and multimammate rats. Slender gerbils are strictly nocturnal. They are essentially seed-eaters, but consume some insects. These gerbils are found at both the N'Gouri and Karal areas.

Robust gerbil (*Tatera robusta*)

Fig. 5. Robust gerbil.

The robust gerbil is large, heavily built, and weighs between 80 to 120 g (Fig. 5). This gerbil's dorsal pelage is sandy-gray to sandy-brown, the ventral pelage is white, and its tail is sparsely haired, dark above, gray-white below, with the terminal third covered with blackish hairs. Its head is rounded in shape, and it has rather large eyes. The soles of the hind feet are naked and darkly pigmented.

Robust gerbils appear on dry, sandy soils where there is a good cover of grasses or dense shrubs or in thorny fencerows around irrigated, cultivated wadis near N'Gouri. Like other gerbils, they dig deep burrows, often with many chambers and tunnels. These burrows are used for resting during the day, rearing the young, and storing food. Robust gerbils are mainly granivorous, but they will eat fruits, some leaves and roots, and insects. They are nocturnal. Robust gerbils are found at both the N'Gouri and Karal areas.

Nile rat or unstriped grass rat (*Arvicanthis niloticus*)

The unstriped grass rat is heavily built, shaggy-coated, and weighs from 115 to 160 g (Fig. 6). Its dorsal pelage is grayish-brown to dark brown, and its ventral pelage is light-brown to medium-brown with white tips. The aspect of the dorsal pelage is best described as speckled with yellow and black. The head is rounded with a blunt nasal region. The tail is dark above, paler below, and shorter than the head and body length. The tail is also covered with small hairs.

Unstriped grass rats are common in the fencerows surrounding wadis near N'Gouri and occasionally are trapped in recessional crops near Karal, Beltram, and Guité, near Lake Chad. They are localized in their distribution because of their large water requirements, needing some form of irrigation or high residual soil moisture. Their runways can be seen along the interiors of the thorny fencerows. Surface nests as well as burrows are located in thick grasses or thorny growth. They are gregarious, but the number of rats within each burrow system tends to be regulated into small groups. Unstriped grass rats are primarily diurnal, feeding and moving about from dawn until mid-morning and again from mid-afternoon until dusk. They feed mainly on the seeds, leaves, and shoots of grasses. They also attack crops, mainly grains, cassavas, sweet potatoes, tomatoes, and eggplant.

Egyptian jerboa (*Jaculus jaculus*)

The Egyptian jerboa is medium-sized and averages about 50 to 60 g in weight. Its head and body measures from 92 to 119 mm, and its tail is from 166 to 195 mm (Fig. 7). The jerboa's head is large and rounded, and its snout is rather blunt. Its dorsal fur is long and silky, pale sandy to sandy-red in color, while the belly fur is pure white. The basal two-thirds of the tail is covered with short sandy hairs, while the terminal third is covered with long hairs forming a brush. Jerboa hind legs are extremely long, an adaptation for hopping and leaping, while the forelegs are rather short and held close to the chest. The long tail is used as a counterbalance and rudder when leaping. Jerboas feed mainly on seeds, roots, and bulbs.

Jerboas are common around N'Gouri, but were not recorded at Karal. They are rarely captured in snap traps. While they are crossing the roads around N'Gouri on dark nights, jerboas are easily seen in the beams from vehicle headlights. Counts of jerboas in September and October 1992 showed 4 to 5 animals per kilometer of road. Jerboas occur in sandy habitats which, for most of the year, have little ground cover except for scattered shrubs. Jerboas are nocturnal, and during the day they live in burrows where they are sheltered from high temperatures.

Multimammate rat (*Mastomys [Praomys] natalensis*)

The multimammate rat is a medium-sized (60 to 110 g) animal that is easily confused with the roof rat, except for its tail, which is shorter than the head and body (Fig. 8). The dorsal fur of the multimammate rat is brownish-gray and its ventral fur is light gray. The female may have as many as 12 pairs of mammaries (ranging from 8 to 12 pairs). Its tail is naked and unicolored.

Fig. 6. Unstriped grass rat.

Fig. 7. Egyptian jerboa.

Multimammate rats are found in both the N'Gouri and Karal areas, although they were rarely trapped in the N'Gouri wadis until after the excellent rains of 1992. This rat is one of the common species found in cultivated crops near Karal; and it is known as the village rat in Beltram, Karal, and Guité, where it lives in houses and grain storage facilities.

Multimammate rats are nocturnal and basically omnivorous in food habits. In better habitats, they tend to feed as much on animal matter, particularly insects, as on vegetable matter. When their diet is restricted, they may feed exclusively on a single item, such as cassava, rice, or maize. They live in burrows in the fields, but occupy houses and stores just as easily.

Fig. 8. Multimammate rat.

Multimammate rats are capable of reaching high densities in agricultural habitats because of their high reproductive potential. This makes them formidable pests of crops. Breeding activities are strongly correlated with rainfall. A few weeks after the onset of rains, breeding begins. Multimammate rats can have litters averaging 11 young, sometimes increasing to 12 or 13 in times of favorable nutrition.

Important Pest Species

Of the above six rodent species, the important pest species in the N'Gouri area are lesser hairy-footed gerbils on sand dunes and unstriped grass rats

in wadis. The gerbils can be important predators on dune millet crops at the time of sowing, since they dig up the newly planted seeds and store them in their burrows. This means the farmers may have to replant their crops several times. An increase in the number of unstriped grass rats, following the normal seasonal breeding, multiplies damage to vegetable crops and can cause serious losses during the winter months. In the Karal area, the important pest species is the multimammate rat, which is found in abundance in the vegetable crops in the winter months; it can damage tomatoes and sweet potatoes. This species also is a pest of stored foods in villages.

In years of deficient rainfall, these species are of chronic concern to farmers, causing some replanting of millet and minor damage to irrigated winter crops. However, when rains are normal or above--especially for several years successively--these rodents respond to better nutrition by increased breeding and with better survival of young. The resulting high densities can lead to massive rodent outbreaks in the Sahel, such as seen in past decades.

Species Proportions

A total of 1,108 rodents were captured: 677 from wadis and 276 from dunes near N'Gouri and 155 from cultivated and noncultivated sites in the Karal area.

The proportions of the several species trapped from the wadis and dunes near N'Gouri are given in Figures 9 and 10. Unstriped grass rats comprised over 55% of the wadi rodents, with the several gerbil species comprising most of the rest. Multimammate rats accounted only for 3% of the collection. The high proportion of the lesser hairy-footed gerbil in the wadi collection was from trapping on the dune slopes adjacent to the wadis, where they were captured almost exclusively.

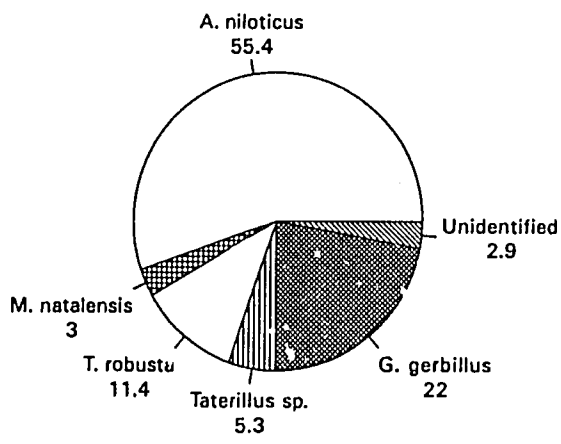


Fig. 9. Wadi rodent species.

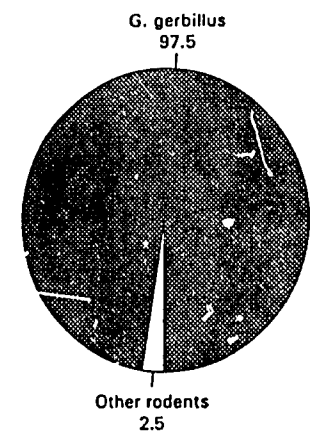


Fig. 10. Dune rodent species.

On the dunes proper, the lesser hairy-footed gerbil accounted for over 97% of rodents captured. Only three the Egyptian jerboa were trapped on dunes during the 3 years of the Project, although later investigations disclosed they were an important component of the dune fauna.

The species proportions at Karal are given in Figure 11. All species found at N'Gouri were caught at Karal, but the *Mus* sp. was found only at Karal. Slender gerbils and multimammate rats predominated at Karal, while the *Mus* sp., robust gerbils, and lesser hairy-footed gerbils comprised most of the rest. Unstriped grass rats were rare at Karal, showing up only in the last trapping during November 1992.

The *Mus* species was never precisely identified. They were thought to be *M. musculus*, but since *M. haussa* (the *Hausa* mouse) and *M. minutoides* (the pygmy mouse) may occur in the same area, we were unable to determine the species.

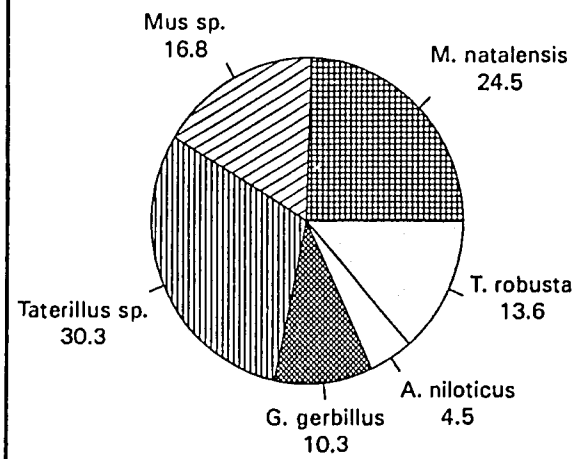


Fig. 11. Rodent species at Karal.

Habitat Use

Use of habitats by the several Sahelian rodent species was somewhat compartmented. Figure 12 shows the distribution of several rodent species in habitats studied at N'Gouri. The wadi rodent populations were made up of the unstriped grass rat, robust gerbil, and slender gerbil. These three species comprised 92% of all animals captured from traplines set in fencerows or fields in the wadis. When traplines were set on the sides of the surrounding dunes, cultivated or not, lesser hairy-footed gerbils also were captured.

On the dunes proper, almost 97.5% of all captures were lesser hairy-footed gerbils, while only a small proportion of jerboas and slender gerbils were caught.

In the villages, we found multimammate rats in the markets and grain storage structures. Occasionally some of these rats may have dispersed from the villages and rare individuals were captured in wadis. However, they were common in the recessional agricultural areas.

Rodent Breeding and Population Structure

All of the rodent species begin breeding shortly following the onset of the annual rains (Table 1). In addition, females of the unstriped grass rats and the lesser hairy-footed gerbil were found pregnant in the dry season months of February, March, and May. This may be normal for unstriped grass rats since they live in the fencerows surrounding irrigated crop fields and undoubtedly take advantage of this moister environment during the dry season. The gerbils bred during these dry season months in 1990, which followed only a fair rainy season in 1989.

Fig. 12. RODENT SPECIES UTILIZATION OF THE SEVERAL HABITATS AT N'GOURI, CHAD

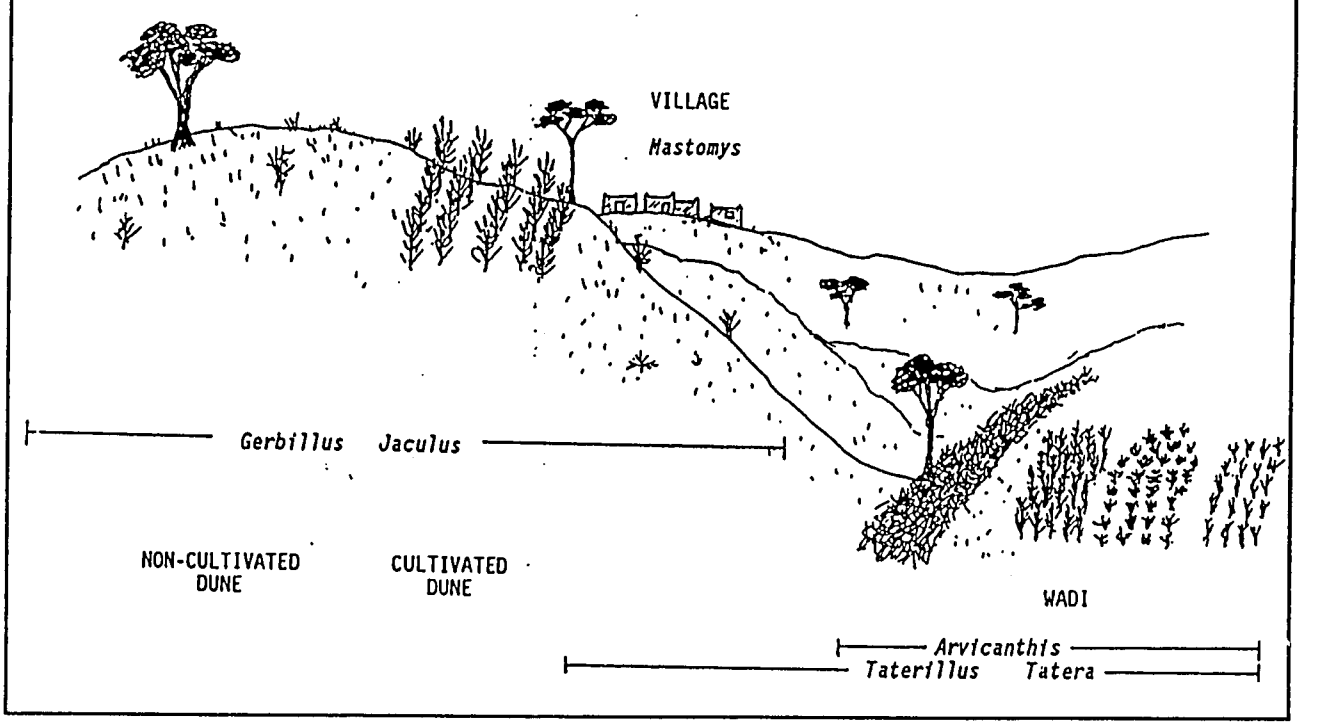


Table 1. Breeding seasons of several Sahelian rodents from N'Gouri and Karal.

Rodent species	RAINY SEASON						DRY SEASON					
	J	A	S	O	N	D	J	F	M	A	M	J
Unstriped grass rat	▒	▒	▒	▒	▒	▒	▒		▒		▒	
Multimammate rat		▒	▒	▒	▒							
Lesser hairy-footed gerbil		▒	▒	▒		▒		▒	▒		▒	
Slender gerbil	▒	▒	▒	▒	▒							
Robust gerbil			▒	▒								

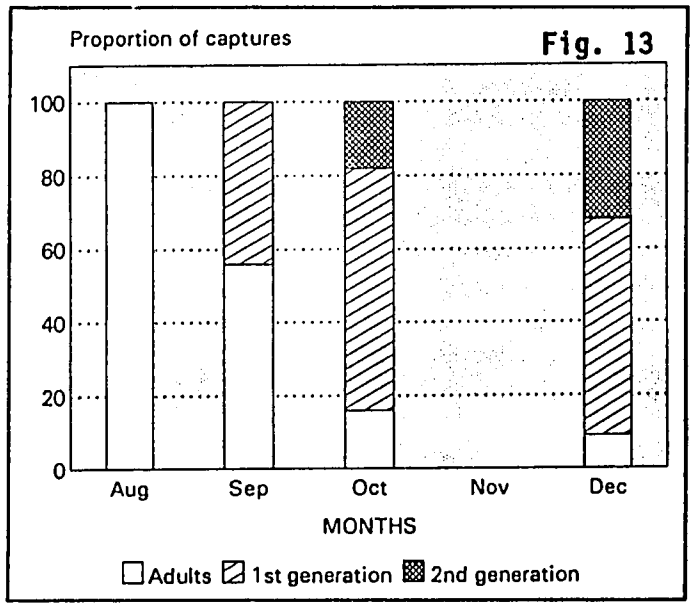
▒ = Months in which females were seen visibly pregnant.

The average litter size for the several rodents is given in Table 2. The multimammate rat and the unstriped grass rat have the largest litters, which is characteristic of their pest status.

Table 2. Litter size in several Sahelian rodents.

Species	No. examined	Mean litter size ± S.D.	Range
Unstriped grass rat	33	6.9 ± 3.1	3-17
Multimammate rat	9	9.3 ± 4.4	4-18
Lesser hairy-footed gerbil	38	4.2 ± 1.4	2- 7
Slender gerbil	12	5.7 ± 2.0	2- 9
Robust gerbil	4	6.0 ± 3.6	3-11

Immatures were seen in the months of September through December. In October 1992, immatures comprised 16% of the unstriped grass rats collected, 71% of the robust gerbils, 69% of the multimammate rats, and 18% of lesser hairy-footed gerbils. Near Karal, immatures were 50% of the unstriped grass rats collected, 29% of the robust gerbils, 35% of the slender gerbils, and 50% of the multimammate rats.



The changes in age structure of the lesser hairy-footed gerbil populations at N'Gouri from August until mid-December 1992 are shown in Figure 13. In mid-August, female gerbils were found pregnant, following the onset of the seasonal rains. In mid-September, the offspring of these dry-season survivors first appeared in Dolbeer's trapping results (Dolbeer 1992). In late October, McConnell (1992) found these first-generation animals and the dry-season survivors were breeding, and immatures of the second generation were present as 18% of the collection. By mid-December, Brooks (1992) found that 32% of the collection was second generation, while the survivors and first generation (born in August/September) were still breeding, but at a slackening pace.

These findings illustrate how rodents may respond to a season of good rainfall and excellent growth of vegetation by prolonged breeding and an outpouring of several generations within a short time. By mid-December, densities of 200 gerbils/ha were estimated based upon burrow counts on dune transects and trapping at burrows.

Rodent Population Fluctuations

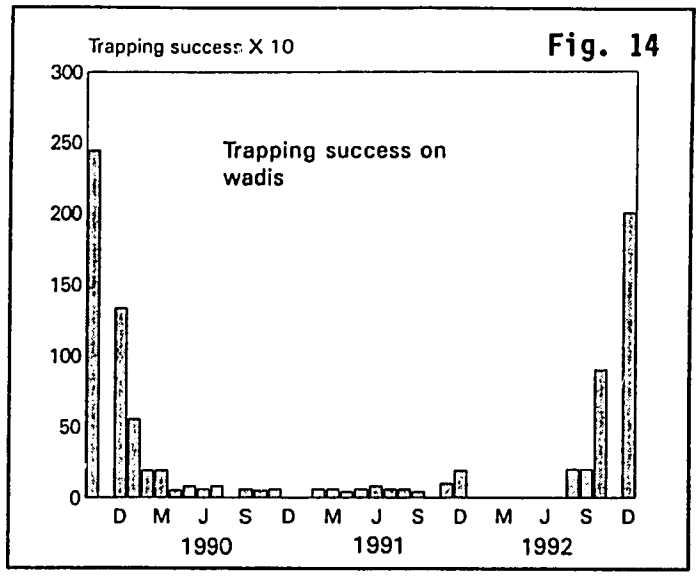
Rodent population densities fluctuated greatly from the start of the Project in October 1989. The observed trapping success on wadis at N'Gouri for the period from October 1989 to December 1992 is given in Figure 14. From October 1989 until March 1990, trapping success progressively declined, indicating

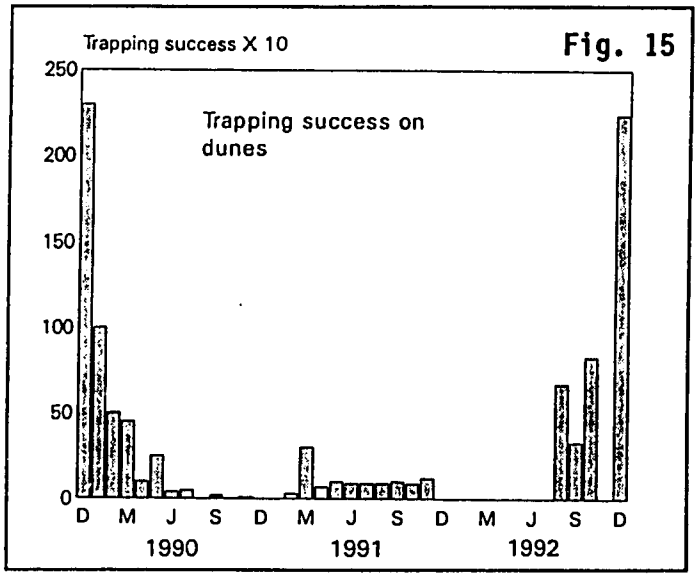
decreasing rodent populations in the wadis. By April 1990, trapping success reached its low. This trend continued for another 2 years, with no evidence of any significant increase in rodent numbers. Not until the excellent rainfall of July/September 1992 did rodent populations again increase to good levels. The trapping from October/December 1992 documented rapidly increasing populations in contrast to those seen in October/December 1989 when populations were declining.

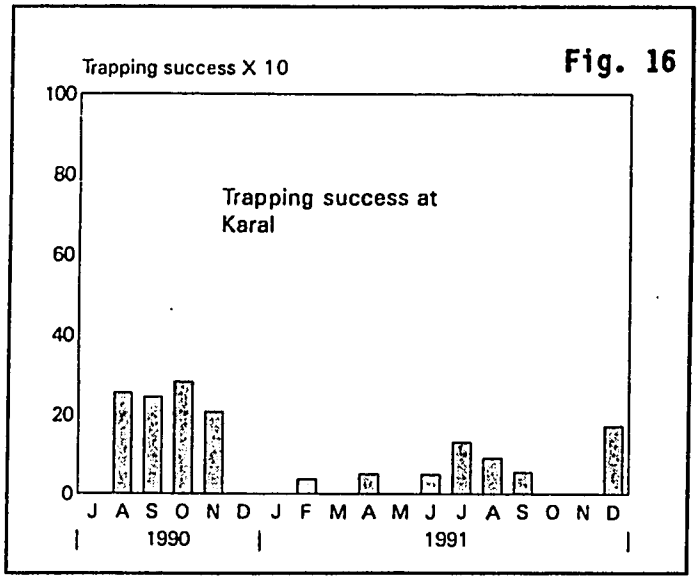
This same trend was seen in trapping success on dunes during the 3-year period (Fig. 15). Dune rodent populations declined abruptly from December 1989 until a low was reached in June 1990. A minor peak in trapping success was seen in March 1991, but essentially trap success remained low until August 1992 when a rapid increase in gerbils was seen on the dunes.

Trapping at Karal was carried out basically in the period August 1990 until December 1991 (Fig. 16). Fairly good trap success was recorded in the initial months of trapping at Karal; but thereafter, except for July and December 1991, it remained low. The reasons for these low rodent population levels are discussed in the next section.

We believe that rodent populations remained at low levels throughout 1990 and 1991 because of deficient rainfall, poor timing and distribution of the rains, and a lack of green vegetative growth during this period (see discussion in next section on rainfall and Normalized Difference Vegetation Index, NDVI).







Rainfall and NDVI Data

The rainfall and Normalized Difference Vegetation Index (NDVI) for N'Gouri are given for each rainy season from 1985 to 1992 in Figure 17. The data were supplied by the USAID/Famine Early Warning System (FEWS) Project in N'Djamena, Chad, and Arlington, Virginia. Data are reported in dekads by dividing the months into three 10-day periods (the final period may have 8 to 11 days, depending on the month). The NDVI images are obtained from the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting series of satellites, which remotely sense the entire Earth and its atmosphere once each day and once each night. Since chlorophyll reflects more in the infrared band than in the red band, higher NDVI values indicate the presence of more chlorophyll and, by inference, more live vegetation. A composite of daily NDVI images is created for each 10-day period, using the highest NDVI value for each pixel during this period. This minimizes the effects of clouds and other interference that tend to reduce NDVI values. NDVI is often referred to as a measure of "greenness" or "vegetative vigor."

NDVI is an index without units. NDVI ranges from -1 to 1. A value less than 0.1 indicates dry conditions. Values between 0.1 and 0.2 indicate emergence of vegetation. Values between 0.2 and 0.25 indicate generalized pastures, and a value above 0.25 indicates increasingly heavy vegetative vigor.

The rainfall amount and pattern in 1985 was not enough to result in a vigorous growth of vegetation, the NDVI never having attained 0.20 in the entire season. The patterns of rains and consequent development of vegetation in 1986 were excellent, resulting in 8 continuous dekads ≥ 0.20 NDVI. This was an outbreak year for rodent populations. The rainy season was weakly developed in 1987, resulting in very little development of vegetation, which was drying by the first 10 days in October. The rainfall pattern in 1988 was strongly developed and well-distributed over a 2-month period; consequently, 8 dekads scored ≥ 0.20 NDVI, but were divided into an early peak in late July and another peak from late August through late September. This probably resulted in better than normal seed production by weeds and grasses in wadis and dunes and an increase in rodent populations that was still apparent by late 1989.

The 1989 rainy season started with heavy rains in early June, but there was no apparent influence on the development of vegetation. The final rains in June did stimulate plant growth, but vegetation did not really "green up" until the first part of August. However, only 4 dekads of NDVI ≥ 0.20 were seen, and vegetation was drying back by mid-September. The pattern in 1990 was one of moderate rains spaced about a month apart until early August. The NDVI was ≥ 0.20 in only 4 dekads, and vegetation was drying by early September. In 1991, heavy rains during late July resulted in only 2 dekads ≥ 0.20 NDVI.

In 1992 the rains came early in July, and vegetation had greened by late July. After the vegetation dried out a little, heavy rains in August, continuing into mid-September, led to a vigorous growth of weeds, grasses, and the millet crop.

It appears that at least 6 to 8 dekads (60 to 80 days) of vegetative growth are necessary for the development of a nutritious diet and abundant seed production to which rodent populations might respond adequately. The rain patterns necessary for potential rodent outbreaks are those where vegetation has developed by the first week in August, which gives rodent populations enough time to breed for at least 4 to 5 months.

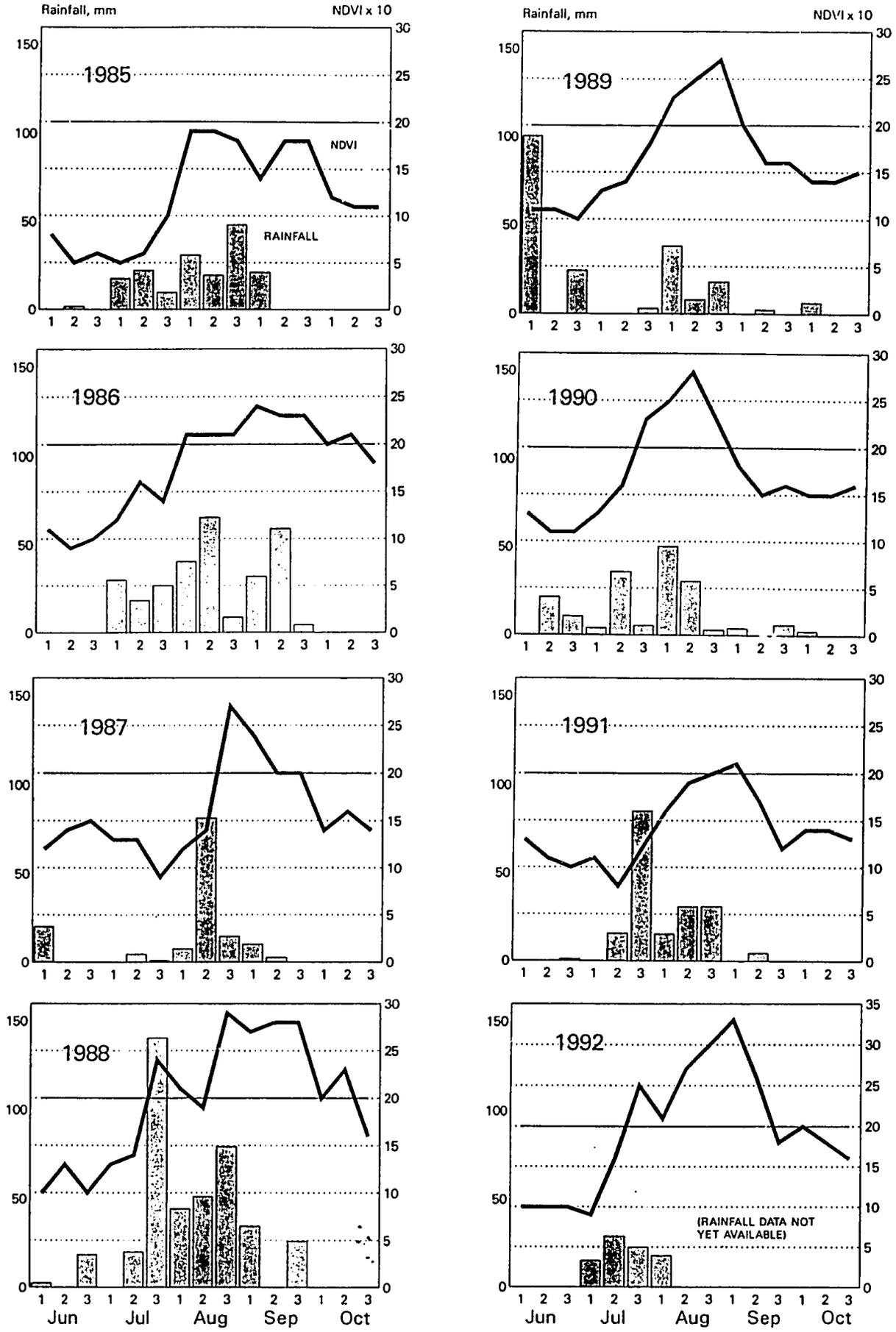


Fig. 17. Seasonal rainfall and Normalized Difference Vegetation Index (NDVI) by dekads each month for N'Gouri, Chad (data from USAID/FEWS Project).

Monitoring Methods and Comparisons

Trapping rodents with snap traps set on traplines in wadis, on dunes, and in cultivated fields in recessional agricultural areas was the method used for monitoring populations during this Project. In the last months of the Project, snap trapping was compared in efficacy with live trapping, tracking tiles, and food stations. Other measures of rodent activity were also used: burrow counts on transects and vehicle headlight counts of rodents crossing roads at night. We found that for grass rats and gerbils living in wadi fencerows, live traps, tracking tiles and food stations were more effective at measuring rodent activity than were snap traps (Table 3). For gerbils living on dunes, tracking tiles were twice as effective as snap traps, and food stations were five times more effective for measuring activity. Burrow count transects were used in December 1992 to estimate the density of lesser hairy-footed gerbils on dunes near N'Gouri (Table 4). A count of gerbil burrows is made along a transect 4-m wide and 250-m long (= 1,000 m^2 or 0.1 ha). In December there was an average of 725 gerbil burrows/ha (Table 4). Trapping at gerbil burrows revealed that 29% produced captures. This indicated there were over 200 gerbils/ha (0.29 x 725 = 210). Burrow counts of gerbils on sand dunes, combined with snap traps placed at burrow entrances, could give an excellent idea of gerbil density.

Table 3. Comparison of several rodent population monitoring methods in wadis and on dunes during 1992.

		% Positive			
Location	Month	Live traps	Snap traps	Tracking tiles	Food Piles
Wadis	Sep	10.0	4.0	25.6	50.0
"	Oct	41.0	10.0	46.0	44.0
Dunes	Oct	-	8.0	21.0	41.0

Table 4. Mean numbers of lesser hairy-footed gerbil burrows counted on 4- x 250-m transects on dunes near N'Gouri.

Dune	Transects counted	Mean No. burrows/transect
Oumar	3	65.0
JEB	3	75.7
Kiri Kala	4	71.0
Ghoural	3	70.7
Ygra	2	85.0
Total/Means	15	72.5

During our 3 years of trapping at N'Gouri, only 3 jerboas were captured. However, during 1 night in September 1992, while taking headlight surveys on roads near N'Gouri, 5 jerboas were counted per kilometer of road (Table 5), and Project staff captured 10 jerboas by hand. Jerboas do not go to traps; consequently, using snap traps almost completely overlooks their presence.

McDonald and McDonald (1992) were able to derive a model for predicting the (square root of) trap success 2 months in advance, based on rainfall measured 2 months in the past and the current value of trap success for three cases: all rodent species combined, unstriped grass rats, and gerbils. Because no trapping and data collections were done during an actual rodent outbreak, they were unable to derive a predictive model for a rodent outbreak.

No one method is suitable for all rodents. Snap trapping is necessary for gathering data on breeding and population age structure. This method, combined with tracking tiles, would be best for grass rats, multimammate rats, and gerbils living in wadis and in fields in cultivated recessional areas. Burrow counts, combined with snap traps at burrow entrances, would be best for gerbils living on dunes. Vehicle headlight surveys would be best for jerboas and could well be suitable for all rodent species where roads pass near or through agricultural areas.

Table 5. Road counts of rodents at night near N'Gouri during 1992.

Date	Distance covered (km)	Rodents counted	Rodents/km
Sep	20	100	5.0
Oct	15	53	3.5
Dec	20	10	0.5*

* A full moon had risen 2 hours before the road counts were made. The effect of moonlight in depressing activity of desert rodents has been documented by Lockard and Owings (1974).

Food Preference Studies

The feeding preferences of several Chadian rodent species for common cereal grains was investigated in the laboratory. Groups of 3 to 8 rodents were offered a nightly choice between 2 cereal grains for 3 to 4 nights. The grain chosen most often, along with the most consumption, was considered the preferred choice (Table 6). Aside from the Egyptian jerboa, which had feeding preferences markedly different from the other rodents, most rodents preferred millet, with rice as their second choice. Overall, millet would be the grain of choice for use with toxicants against these Sahelian rodent species, with rice and wheat as good alternatives.

Table 6. Preferred cereal grains by several species of Chadian rodents (first choice = **, second choice = *).

Rodent Species	Cereal Grains Preferred			
	Millet	Wheat	Rice	Sorghum
Unstriped grass rat	**		*	
Multimammate rat	*		**	
Lesser hairy-footed gerbil	**		*	
Robust gerbil	**	*		
Egyptian jerboa			**	*

Toxicity Studies in Laboratory and Field

We ran toxicity tests in the laboratory and tested baits and toxicants in the field. The toxicity of zinc phosphide, chlorophacinone, and bromadiolone were determined against multimammate rats and unstriped grass rats in the laboratory. When 1% zinc phosphide baits were offered to multimammate rats, 7 of 10 died. All rats eating 69 mg/kg or more were killed. Unstriped grass rats were killed by intakes of 49 mg/kg or more of zinc phosphide.

Zinc phosphide at 1% concentration was tested against rodents living in wadis and gerbils living on dunes in several field trials by Dolbeer (1992) and McConnell (1992). Dolbeer recorded 79 and 95% reduction in rodent activity after 3 nights' exposure of 1% zinc phosphide in wadis near N'Gouri. McConnell used 1% zinc phosphide baits against lesser hairy-footed gerbils living on sand dunes at N'Gouri and found 15 to 73% reduction in rodent activity when baits were exposed for 3 or 4 nights. Bait (millet with peanut oil) acceptance was excellent on the dunes.

Chlorophacinone and bromadiolone at 0.005% gave complete kills of group-caged multimammate rats with 3 nights' feeding. Chlorophacinone and warfarin gave 91 and 94% reduction in rodent activity measures when used against rodents living in wadis in one trial, but results were inconclusive in another trial. The approximate 3-day LD_{50} of chlorophacinone for unstriped grass rats, based upon results from stomach gavage, was less than 0.7 mg/kg for the 3 doses.

TRAINING

Seminars/Workshops

A 2-day workshop was given by the resident Project Leader in November 1990 to 18 MOA personnel. This workshop included presentations on rodent identification, biology, ecology, data collection, and population monitoring. A 1-week seminar was presented by Dr. Richard Dolbeer, Dr. Maho Angaya, and Mr. Joe Brooks in September 1992 for 15 persons from throughout Chad. A draft training manual with French text and many visuals were specially prepared for this training.

Training Manual

A 90-page draft training manual dealing with rodent research and methods of rodent control was prepared for the seminar/workshop held during September 1992. This manual was translated into French by personnel in Chad, most notably Dr. Angaya, and this version was used for training purposes. Subsequently, the French version has been rechecked and placed on a computer disk, and a final version is being prepared for printing.

REPORTS

Progress Report

A summary of progress on the Project was issued in October 1991 as a Progress Report, 1989-1991. This report summarized the findings and activities of the Project from its beginning in October 1989 until the end of October 1991.

Quarterly Reports

Spillett, J. J. Quarterly Report. Chad Rodent Control Research Project. (AID-USDA Pasa No.-AFR-0517-P-AG-9042-01), AELGA Project 698-0517. A cooperative program of Government of Chad/Ministry of Agriculture/Crop Protection Service, U.S. Agency for International Development/Agriculture Development Office, and U.S. Department of Agriculture/Animal and Plant Health Inspection Service/Denver Wildlife Research Center; Denver, Colorado. July 1-September 30, 1990. 10 pp.

Angaya, M. Rapport Trimestriel. Projet de Recherche sur les Rongeurs au TChad. Projet 698-0517 de Aelga. Securite et Autosuffisance Alimentaire Victoire sur les Calamites Naturelles au Sahel. Un Programme de cooperation entre Le Ministere de Developpement Rural, Service de Protection des Vegetaux et L'USAID-USDA-DWRC. 11 Novembre 1991-17 Février 1992. Février 1992. 9 pp.

Angaya, M. Rapport Trimestriel. Projet de Recherche sur les Rongeurs au TChad. Projet 698-0517 de Aelga. Securite et Autosuffisance Alimentaire Victoire sur les Calamites Naturelles au Sahel. Un Programme de cooperation entre Le Ministere de Developpement Rural, Service de Protection des Vegetaux et L'USAID-USDA-DWRC. 1er Mars au 30 Mai 1992. Juin 1992. 6 pp. and 1 annex.

Technical Reports

Four Technical Reports have been prepared and submitted:

LaVoie, G. K., L. A. Fiedler, J. E. Brooks, and J. J. Spillett. A preliminary research bibliography of rodent pests of the Sahel, Africa. Chad Rodent Control Research Project, Technical Report No. 1. A cooperative program of Government of Chad/Ministry of Agriculture, U.S. Agency for International Development, and U.S. Department of Agriculture/Animal and Plant Health Inspection Service/Science and Technology/Denver Wildlife Research Center; Denver, Colorado; November 1991. 18 pp.

Spillett, J. J., D. Koulangar, and J. E. Brooks. Preference by the Nile rat (*Arvicanthis niloticus*) for five cereal grains and two oil additives. Chad Rodent Control Research Project, Technical Report No. 2. A cooperative program of Government of Chad/Ministry of Agriculture, U.S. Agency for International Development, and U.S. Department of Agriculture/Animal and Plant Health Inspection Service/Animal Damage Control/Denver Wildlife Research Center; Denver, Colorado; February 1992. 8 pp.

Brooks, J. E., R. A. Dolbeer, M. Angaya, J. E. McConnell, and G. K. LaVoie. The toxicity and efficacy of several rodenticides to Sahelian rodent species in Chad. Chad Rodent Control Research Project, Technical Report No. 3. A cooperative program of the Government of Chad/Ministry of Agriculture, U.S. Agency for International Development, and U.S. Department of Agriculture/Animal and Plant Health Inspection Service/Animal Damage Control/Denver Wildlife Research Center; Denver, Colorado; November 1992. 12 pp.

McDonald, T. L. and L. L. McDonald. Prediction and monitoring of rodent abundance in agricultural areas of Chad, Africa. Chad Rodent Control Research Project, Technical Report No. 4. A report prepared for the Denver Wildlife Research Center; Denver, Colorado; December 1992. 36 pp.

Rat Facts

Fourteen issues of "Rat Facts," a 1-page fact sheet of rodent information, written in English and French, were prepared and distributed to the Chad Ministry of Agriculture, USAID, and DWRC from September 1990 until February 1992. The titles are:

1. The Sahel and rodents. September 1990.
2. Rodent pests in the Sahel. November 1990.
3. Rodent population dynamics. March 1991.
4. Assessing crop losses to rodents. April 1991.
5. Rodent pests in Africa. May 1991.
6. Rodents and disease. June 1991.
7. The unstriped grass rat. July 1991.
8. Cricetid rodents and the genus *Gerbillus*. August 1991.
9. Rodent control. September 1991.
10. The "sand" gerbil (*Gerbillus andersoni*) of Sahelian Chad. October 1991.
11. The multimammate rat--Africa's most common rodent pest. November 1991.
12. Bait preference by the Nile rat. December 1991.
13. Prevention is better than cure. January 1992.
14. Habitat and food habits of the unstriped grass rat and gerbil. February 1992.

Trip Reports from DWRC Consultancies

DWRC provided eight consultancies to Chad following the rodent outbreak of 1986-87 until the DWRC resident biologist arrived in N'Djamena during July 1990 to serve as Project Leader for the Rodent Control Research Project. The biologists providing technical assistance and their visits are summarized as follows:

LaVoie, G. K. May 1987. Chad--Trip Report. 10 pp. plus 6 attachments.

Confirmed reported high rodent densities and crop losses. Tentatively identified the major rodent species damaging various agricultural crops. Assessed present situation, predicted trends on rodent damage to agricultural products, and suggested possible short- and long-term control measures.

Mitchell, G. C. October-November 1987. Chad--Trip Report. 10 pp. plus appendix.

Assessed rodent problems in Chad, conducted experimental field evaluations of warfarin grain baits, trained 9 extension agents in bait formulation, trained 29 extension agents in methods of applying prepared baits and in evaluating experiments, and made recommendations for rodent control measures.

LaVoie, G. K. March-April 1988. Chad--Trip Report. 12 pp. plus 5 attachments.

Identified rodent pest species in irrigated and dryland agricultural areas, conducted cage and small plot rodenticide evaluations in irrigated wadis in the N'Gouri area, and trained 17 agricultural extension personnel in rodent control measures in the Bongor area.

Fiedler, L. A. April-May 1989. Planning for the establishment of the proposed Rodent Control Project in Chad. 9 pp. plus 4 appendices.

Suggested scheduling and procedures for implementing a rodent control project, as well as discussed project-related concerns, including housing, transportation, and logistical support.

LaVoie, G. K. October-November 1989. Chad and Guinea-Bissau. 10 pp.

Provided field assistance to Dr. John Wilson in initiating a rodent population monitoring program near N'Gouri, Chad, and helped develop plans for the Chad Rodent Control Research Project.

Wilson, J. October-November 1989. Chad--Trip Report. 57 pp. including 4 appendices.

Selected study sites in the N'Gouri and Abeche areas, initiated long-term monitoring studies on rodent populations in wadi cultivations around N'Gouri, conducted bait acceptability trials, and trained counterpart scientists in rodent identification, trapping, autopsy, and data collection methods.

Bruggers, R. L. November-December 1989. Chad, Rome, and Morocco. 7 pp.

Discussed implementation activities and worked out budget considerations with AID/Chad for the Chad Rodent Control Research Project PASA.

LaVoie, G. K. April 1990. Chad--Trip Report. 7 pp. plus 3 figures and 1 appendix.

Continued rodent population sampling and monitoring in the N'Gouri area with the Project Assistant and technicians from the Crop Protection Service. Briefly reviewed Chad Rodent Control Research Project activities and concerns.

Seven TDY visits were made by DWRC biologists to the Project after it was implemented to provide technical assistance to the resident biologist and counterpart personnel and to provide training to Chadian crop protection staff and personnel of nongovernmental organizations (NGO's) and private voluntary organizations (PVO's). The biologists and their times of visits are given as follows, along with the titles of their trip reports.

Savarie, P. J. October 1990. Rodent control research and training activities in Chad. 7 pp and 1 appendix.

Limited closed/open burrow trials on the field efficacy of zinc phosphide (Zn_3P_2) baits indicated that 1% Zn_3P_2 baits effectively controlled rodents. Limited feeding trials of caged rats with 1% Zn_3P_2 also were conducted, but results were inconclusive. No supplies of Zn_3P_2 rodenticides were found in the N'Djamena area, although brodifacoum, chlorophacinone, alphachlorophacinone, and aluminum phosphide were available. Training and technology transfer in toxicology of rodenticides was conducted with the Chad Department of Agriculture/Crop Protection Service personnel.

Brooks, J. E. April 1991. Rodent control research and damage assessment activities in Chad. 12 pp.

With rodent densities very low due to a prolonged drought, there was no visible damage to vegetables; however, a guide for damage assessment methods in vegetable and grain crops was compiled. Two food preference trials were run in the laboratory, and a protocol for food and bait preference testing was prepared.

LaVoie, G. K. August 1991. Chad rodent control research. 14 pp. and 3 attachments.

Data from monitoring rodent populations at two agricultural sites near N'Djamena suggested that populations of all the main agriculturally important rodent species were increasing due to improved habitat conditions resulting from the first good rains in over 2 years; this population increase should provide animals needed for bait preference, rodenticide toxicity, and small, comparative field control trials.

Brooks, J. E. August-September 1992. Chad Rodent Project: administration, research, and training. 11 pp and 4 attachments.

Project activities were reviewed at the two research sites. Toxicity tests in the laboratory were carried out with chlorophacinone, bromadiolone, and zinc phosphide on unstriped grass rats and multimammate rats. Training materials were prepared and, with the help of R. A. Dolbeer and M. Angaya, a 5-day seminar on rodent biology and control was presented to 15 Chadian participants.

Dolbeer, R. A. August-September 1992. Rodent control training and rodenticide field trials in Chad. 19 pp and 1 appendix.

Assisted in the preparation of training materials and the presentation of a 5-day seminar on rodent biology and control to 15 Chadian participants; estimated bird damage to maize, millet, and sorghum crops; conducted field trials of 1% zinc phosphide and 0.005% chlorophacinone baits against rodent species living in and around wadis near N'Gouri; and collected data on the biology and status of rodent populations in the Sahelian region of Chad.

McConnell, J. E. October-November 1992. Chad rodent research and rodenticide field trials. 12 pp and 3 annexes.

Evaluated the efficacy and appropriateness of alternative control methods (pit traps), conducted rodenticide field trials of 1% zinc phosphide against gerbils on sand dunes near N'Gouri, evaluated and compared rodent population monitoring methods on sand dunes, and collected data on the status of rodent populations in the Sahelian region of Chad.

Brooks, J. E. November-December 1992. Trip Report--Chad rodent control research and closeout of the Project. 5 pp. plus 4 annexes and attachment.

Inventoried and transferred Project equipment and supplies to the Chad Ministry of Agriculture (MOA), prepared and submitted a Project Assistance Completion Report to USAID, and completed any remaining field and laboratory work of the Project.

CHAD COUNTERPART PERSONNEL

Maho Angaya[1]	Project Assistant
Mornan Kounade[2]	Project Assistant
Abdelwahib Yacoub[3]	Project Assistant
Djibo Koulangar[4]	Project Technician
Dourbaga Maila[5]	Project Technician
N'Doubakoi Tatoloum[6]	Project Technician
Delassoum Richard[7]	Chauffeur
Mahamat El-Hadji N'Gaba[8]	Chauffeur
Dilemko Louis[9]	Janitor/Animal Keeper

[1] Dr. Angaya was Project Assistant between November 1991 and December 1992.
[2] Dr. Kounade worked with the Project from May 1990 to June 1991.
[3] Mr. Yacoub worked with the Project between October 1989 and June 1990.
[4] Mr. Koulangar joined the Project in March 1990.
[5] Mr. Maila began working with the Project during its initial stages in October 1989; he left the Project in January 1991.
[6] Mr. Tatoloum began working with the Project in October 1990; he was transferred from the Project in June 1991 to serve as "Chef de Base phytosanitaire du LAC" in Bol, Chad.
[7] Mr. Richard worked for the Project from July 1990 until December 1991.
[8] Mr. N'Gaba was Project chauffeur between August 1992 and December 1992.
[9] Mr. Louis worked for the Project from July 1990 until December 1992.

DISCUSSION AND CONCLUSIONS

The important pest rodents in the Chadian Sahel were defined, and significant observations on rodent biology and breeding were observed. Rainfall--not just the total annual amount but, more importantly, its pattern during the rainy season--bears a close relationship with the breeding, survival, and population densities of both the arid-tolerant and arid-intolerant rodent species. If the rainfall comes in a sporadic pattern after July 1 with periods of dryness, then vegetation (both crops and native plants) may not develop to the point of maturation. This will lead to very little breeding among the rodents. If, however, the rains provide sufficient residual moisture in the sandy soils to maintain vegetation throughout the growing season, crop harvests and plant seed production will be good, leading to prolonged breeding and a population increase among the rodents. The NDVI is the best indicator of plant production.

The arid-intolerant rodent species (the unstriped grass rat and the multimammate rat) live in situations where they are sustained by irrigation of crops or by recessional crops on the shores of Lake Chad.

Food preference studies of five rodent species studied disclosed that millet was the grain of choice for three species, while rice was preferred by the remaining two. This finding was borne out by field trials using millet with 1-2% added peanut oil, which was well-accepted by rodents both in wadi and dune habitats. Rice-based baits would be a good alternative.

Of the several toxicants tested, zinc phosphide at 1% concentration, and the anticoagulants warfarin (0.025% concentrate), chlorophacinone (0.005%), and bromadiolone (0.005% concentrate) all proved acceptable as rodenticides against the several Sahelian species tested.

Due to the short Project life, we did not have time to develop a technology package for transfer to Chadian farmers. This would have been done if the next phase of the Project had been continued. Farmers need to be educated to the need for dealing with rodent populations because of chronic crop losses caused by rodents. Being aware of the methods of rodent control, the farmers would then be in a much better position to deal with outbreaking rodent populations.

This Sahelian Rodent Control Research Project has provided new knowledge and experience that should enable us to better predict and circumvent the next Sahelian rodent outbreak. The training manual, which is to be printed in both English and French and widely distributed, outlines the steps to be taken to set up a routine rodent control program within the Crop Protection Services in west African countries. It outlines the emergency response that is necessary to head off crop losses. The identification of the major Sahelian rodent pest species and the role they play in crop damage and crop losses is much better understood than it was during the last outbreak. Methods to monitor rodent populations have been developed and now need only to be implemented in west African countries. A predictive model for rodent outbreaks has not been developed as yet; but close attention to weather patterns, especially rainfall patterns following period of drought, rodent population responses to vegetation development when good rains do appear, and NDVI values above 0.20 for 6 dekads or more may give us the clue to the next outbreak long before it develops. We can now recommend the toxicants and bait materials to be used for emergency rodent population reduction.

The Project fulfilled almost all of its objectives as defined in the PASA. This was accomplished despite in-country political unrest, the resignation of the resident biologist, and a long hiatus before Project activities were resumed in mid-1992. The experiences gained in Chad have significant application elsewhere in the Sahel.

RECOMMENDATIONS

(1) Field baits for use in poisoning Sahelian rodents should consist of either millet or rice, along with the addition of 1-2% peanut oil.

(2) Toxicants and concentrations recommended for use against Sahelian rodent species are zinc phosphide at 1%, warfarin at 0.025%, chlorophacinone at 0.005%, and bromadiolone at 0.005%. Zinc phosphide baits need to be exposed for up to 3 nights only, then withdrawn. The three anticoagulants should be exposed for at least 10 days or until bait takes cease. Care should be taken to expose any toxic baits only in protected sites, i.e., on rodent pathways in fencerows, bait containers, or inside burrow entrances. Any dead rodents should be picked up daily and disposed of by deep burial. All unused baits should be retrieved at the end of a poisoning period.

(3) In the future, local language proficiency should be required for any resident Project Leader. Neither reading nor speaking the local language, French, was a serious disadvantage for the resident Project Leader. Even for short-term assignments, proficiency in the local language would prove beneficial.

(4) The Project relied mainly upon snap trapping on transects as the method of rodent population monitoring. Later experience indicated that several methods should be used in conjunction with each other. Burrow counts on dune transects, along with snap trapping, are probably the best for monitoring *Gerbillus* populations. Road counts at night are best for monitoring *Jaculus* populations since these rodents rarely come into traps. Tracking tiles and snap or live trapping are best for monitoring *Arvicanthis*, *Mastomys*, *Tatera*, and *Taterillus* populations.

(5) McDonald and McDonald (1992) were unable to derive a predictive model for rodent outbreaks based upon trapping data from the Project because no trapping was conducted during an actual rodent outbreak. Trapping and data collection should be done whenever the next outbreak occurs.

(6) The MOA/DPV has presented a work plan for the period after USAID funding and DWRC technical assistance ends. A short-term visit to evaluate the effectiveness of the MOA/DPV should be made in June or July 1993. At the same time, a visit to the study site at N'Gouri to trap and monitor rodent populations would be appropriate. Since the populations approach their lowest levels of the year at this time, the findings could be compared to the high levels seen in December 1992.

A final visit in September 1993 to carry out the same project evaluations and rodent population monitoring at study sites should give a good estimate of the anticipated rodent population levels to be expected by December 1993.

(7) Crop Protection Divisions and Ministries of Agriculture in Sahelian countries should prepare contingency plans for dealing with the next potential rodent outbreak.

(8) DWRC should offer a French-language training course to crop protection personnel and other interested parties in the other Sahelian countries concerned: Mali, Burkina Faso, and Niger. An English-language version of the training could be used in the Sudan.

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