AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
BATCH #14

1. SUBJECT CLASSIFICATION

A. PRIMARY
Serials Y-AL72-0000-G302

B. SECONDARY
Agriculture--Pests of animals--Latin America

2. TITLE AND SUBTITLE
Vampire bats: rabies transmission and livestock production in Latin America; Palo Alto,Mex.Field Station annual progress report,calendar year 1969

3. AUTHOR(S)
(101) Denver Wildlife Research Ctr.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1970	25p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Interior

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*
(English only)
(Research summary)

9. ABSTRACT

10. CONTROL NUMBER
PN-RAA-694

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Bats,vampire
Latin America
Pest control

13. PROJECT NUMBER

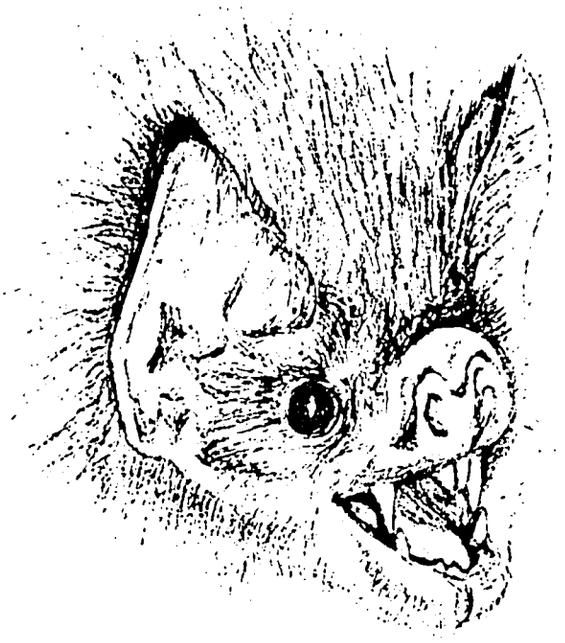
14. CONTRACT NUMBER
PASA RA(ID)1-67 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

VAMPIRE BATS:

RABIES TRANSMISSION AND LIVESTOCK PRODUCTION IN LATIN AMERICA



1969 ANNUAL REPORT

PALO ALTO, MEXICO, FIELD STATION

DENVER WILDLIFE RESEARCH CENTER
U.S. BUREAU OF SPORT FISHERIES AND WILDLIFE

in cooperation with

INSTITUTO NACIONAL DE
INVESTIGACIONES PECUARIAS

SECRETARIA DE AGRICULTURA
Y GANADERIA

GOBIERNO DE MEXICO

OFFICE OF AGRICULTURE
AND FISHERIES

BUREAU OF TECHNICAL ASSISTANCE

U.S. AGENCY FOR
INTERNATIONAL DEVELOPMENT

Results Incomplete and Not for Publication,
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Director, Denver Wildlife Research Center

ANNUAL PROGRESS REPORT
WILDLIFE RESEARCH WORK UNIT
DENVER WILDLIFE RESEARCH CENTER

Calendar Year 1969

WORK UNIT DF-103.3: Mammal Damage Control Research--Vampire Bats*

PRINCIPAL INVESTIGATORS: Samuel B. Linhart, Raul Flores Crespo, Richard J. Burns, G. Clay Mitchell, and James R. Tigner

ABSTRACT: Physiologist G. Clay Mitchell and Srita. Clorinda Sarabia were employed during 1969. The remaining unfilled authorized positions include a veterinarian and two field assistants.

An international agreement between the U.S. and Mexican Governments was drafted and signed, providing a means for reimbursement of salaries and expenses of Mexican personnel assigned to the project. Land at the Palo Alto facility was staked and graded for construction of a cattle corral and bat observation room.

Safety procedures were updated and revised and all personnel received X-rays, rabies boosters, Histoplasmosis skin tests, and instruction on safety precautions.

Data was compiled on feeding activity, attack patterns, and grooming behavior of captive vampires. Vampires commonly fed upon cattle without climbing upon their victims, resulting in some questions as to whether or not control agents applied directly to cattle is the most feasible approach. TV observations of vampire grooming behavior indicate that grooming is intense and thorough and that control agents made to adhere to the appendages and hair of vampires would be ingested during grooming activity.

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*This research was conducted with funds provided to the Bureau of Sport Fisheries and Wildlife by the Agency for International Development under the project "Control of Vertebrate Pests: Rats, Bats and Noxious Birds," PASA RA(ID) 1-67.

The study to recover fluorescent particles (FP) from the gastro-intestinal tract of vampires was transferred to the Denver Center.

Collection of vampire growth data continued and two possible methods of determining age were selected for further study.

A satisfactory technique for attaching radio transmitters to vampires was developed, and the use of fluorescent or reflective materials to follow vampire movement within corralled cattle was investigated.

Considerable time was devoted to study of repopulation rates of vampire bats following reduction in roosts by mist netting. In one Gulf Coast study area, it was found that populations returned to former density levels within a month or less, whereas populations located in the interior, south of Oaxaca and near Cuernavaca, had not recovered after 6 months and 1 year, respectively.

Two potential vampire repellents were tested in the laboratory. One, Tributyltin sulfide, showed some degree of repellency at the .006 level of concentration.

Vampire toxicity levels for 1080, strychnine, and diphacinone (an anticoagulant) were determined. Problems with gavaging were experienced due to the peculiar structure of the vampire gastro-intestinal tract.

Two publications were submitted to the Journal of Mammalogy.

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INTRODUCTION

Annual bovine losses resulting from vampire bat-transmitted rabies are estimated at 100,000 head in Mexico and approximately 1,000,000 head throughout Latin America. Additional mortality of other livestock species, debilitating daily loss of blood, and secondary infection through bite wounds, further aggravate the problem.

Research under this Work Unit, the objective of which is to develop techniques for controlling vampire bats, was begun in June 1968. It is funded by the Agency for International Development under a PASA agreement with the U.S. Department of the Interior. Basic investigations are carried out by the Bureau of Sport Fisheries and Wildlife at the Denver Wildlife Research Center in Denver, Colorado. More advanced studies and field investigations are conducted at the Bureau's Vampire Bat Research Station located at the Instituto Nacional de Investigaciones Pecuarias in Mexico City, Mexico.

Personnel

Dr. Clay Mitchell, physiologist, was employed and worked at the Denver Center for approximately 6 months. His reassignment to the Mexico field station is anticipated in early 1970. Miss Clorinda Sarabia was employed in October 1969 as a laboratory technician at the Mexico field station.

Further recruitment of Mexican personnel was delayed during the first 6 months of 1969 due to lack of a means by which to effect international reimbursement to the Government of Mexico for salaries and travel expenses of Mexican personnel assigned by the Instituto to the field station. No additional personnel were hired during the second half of 1969 because the PASA agreement remained unsigned. It is anticipated that the remaining authorized field station personnel, a veterinarian and two field assistants, will be employed early in 1970. Recruitments of these positions will considerably advance the rate of progress.

Several discussions were held with the Director of the Instituto and with Dr. Bernardo Villa, the latter a world authority on bats and a professor at the National Autonomous University of Mexico. It is hoped that arrangements can soon be completed so that Dr. Villa can serve as consultant to the project.

Biologists Linhart and Burns each completed 50 lessons of Spanish at the Berlitz School of Languages.

Facilities and Equipment

Discussions were held with the Instituto administration and with engineers of the Secretaria de Agricultura y Ganaderia regarding construction of a corral and observation room, and modification or construction of additional offices for new project personnel. Land has now been staked and graded for the corral facility and detailed plans should be completed shortly.

The bat chamber in the temporary observation corral was modified to insure a constant source of temperature and humidity.

Closed-circuit television equipment was received and its use demonstrated by a company representative from Denver. This equipment has proved very satisfactory for observing vampire bat grooming behavior.

The total station complement of three vehicles was picked up in San Antonio, Texas.

The station's file of technical publications was expanded with the acquisition of additional reprints. Arrangements were made to reproduce all vampire reprints in the library of Dr. Bernardo Villa not presently in the station files.

Planning

Four new study plans were drafted, submitted to Denver, and approved.

Discussions were held with Unit Leader Tigner, both in Mexico and in Denver, regarding administrative problems and the status of present and future studies at the Mexican field station.

Arrangements were made for a trip to South America by Samuel Linhart in March 1970 and letters were sent to 13 individuals in Colombia, Argentina, Brazil, Venezuela, and Trinidad requesting information and/or assistance. Purpose of the trip is to coordinate and review research and vampire bat control programs underway throughout Latin America.

Discussions were held as to possible future studies dealing with repellents, with "Vampirol" (a commercially available strychnine solution for vampire control), and testing of chemical carriers or vehicles for application of control agents.

Samuel Linhart spent 2 days in Washington, D.C., where he received training in the use of the night vision equipment presently on loan from the Army Electronic Command.

Coordination and Cooperation

An international agreement between the U.S. Government and the Government of Mexico was drafted and revised a number of times to satisfy all parties concerned. This agreement, signed in July, formalizes and spells out the details of the work in Mexico and the relationship between the Instituto, the BSFW, and AID. Most important, it provides a means by which international reimbursement can be made to the Instituto for salaries and expenses of Mexican personnel on the project and for those facility modifications necessary to conduct vampire investigations.

The station was visited by Division Chief Robinson and Drs. Mack and Konnerup, WOH, ARDS, at which time meetings were held with the Director of the Instituto and AID Embassy personnel to resolve financial problems, to finalize our international agreement, and to brief them on station activities.

Mr. Favell, Economic Counselor and AID Coordinator for Mexico, and Mr. Peer, AID Controller, both of the American Embassy, visited the station. A summary of objectives, studies, and progress was presented, followed by a discussion with Dr. Pedro Solana, Director of the Palo Alto Instituto.

Talks were held with the UNDP FAO staff at Palo Alto, also working on vampire-transmitted rabies, regarding collection and standardization of ecological data so that such information could be shared by both groups. A letter was sent to the FAO ecologist suggesting a cooperative study dealing with development of indices to measure vampire populations. This proposal was later discussed in detail, as were other subjects of mutual interest.

The USIS at the American Embassy was provided with information and photos of the activities at the Palo Alto Station for use in a future news release.

Biologist Flores Crespo accompanied DWRC biologists Besser and De Grazio on a field trip to the Lake Chapala area, south of Guadalajara, where observations of bird damage and bird concentrations were made.

Dr. William Wimsatt, Department of Zoology, Cornell University, visited the laboratory and was given a resume of our activities. Dr. Wimsatt is an authority on the physiology of the vampire bat and was consulted by the Station Leader prior to activation of the station.

Laboratory

Specific laboratory studies undertaken during 1969 will be discussed in detail under "Results and Discussions." Briefly, the following was accomplished:

(1) Data on growth, behavior, and aging criteria of captive juvenile vampire bats was recorded. Work was initiated to determine if eye lens weights or tooth cementum layers would serve as age criteria for adults.

(2) Observations on feeding, attack patterns, and grooming of captive vampires were continued. Corral observations were terminated.

(3) Laboratory tests of two potential vampire repellents were initiated in October and terminated in December.

(4) Considerable time was spent attempting to devise a technique for attaching radio transmitters. Radio transmitters will be used in a future study to learn about the movement and feeding patterns of vampires under natural conditions.

(5) Pilot studies were made to determine if fluorescent or reflective markers or tags could be used to follow vampire movement within a corral of cattle.

(6) Bat skins were prepared as museum specimens for the station's collection of study skins.

(7) Work was carried out to determine the cause(s) of high mortality of captive vampires, both in transit and in the laboratory colony. Overcrowding is believed to have been the cause of considerable mortality.

(8) Work on a technique to quantitate and standardize the amounts of a fluorescent compound (FP) recovered from the gastro-intestinal tracts of vampires was transferred to Denver. It is hoped that FP will serve as a tracer to determine the efficacy of selected control techniques.

Field

Twenty-nine field trips, totaling 101 days in the field (297 man-days) were taken to the States of Morelos, Veracruz, San Luis Potosi, Puebla, Oaxaca, and Jalisco. The majority of these trips served to:

(1) Search for vampire caves and collect bats for shipment to Denver or for use in the laboratory studies at the Instituto.

(2) Search for new study areas, or periodically check known vampire caves for rates of repopulation.

(3) Field test radio-telemetry equipment, or other experimental field apparatus.

A total of 121 visits to 65 different caves was made by project personnel during the year.

Safety

An air extractor and ultra-violet light were installed in the animal colony to reduce possible exposure to aerosol-borne rabies virus. Unfortunately, the rapid extraction of air makes maintenance of required temperature and humidity very difficult.

Safety regulations were revised and periodic safety meetings were held to explain certain health hazards.

All personnel received X-rays, rabies boosters, and Histoplasmosis skin tests. Burns, Tigner, and Linhart converted their histoplasmin tests from negative to positive, indicating exposure and infection. Three bat bites (one from a rabid bat) were experienced. The necessary booster shots were given and the required accident forms prepared. As a result of these exposures, additional safety precautions were proposed and incorporated into the station's safety regulations.

RESULTS AND DISCUSSION

Work was carried out on the following eight studies:

(1) Feeding behavior of captive *Desmodus rotundus* and extent of body grooming after feeding.

This study was initiated in 1968 and consists of two segments:

A. Movement of captive vampires upon their prey, feeding behavior, and location of bite wounds: Data from this segment serve to determine the feasibility of applying control agents directly to cattle. Quantitative information on the subject is not available in the literature.

This segment is now completed. Procedures and results are summarized below:

An indoor cattle corral (3 x 2.5 x 2 meters) was made bat-proof and a glass partition erected to house two observers. A 30-cm-square vampire cage with heat and humidity sources, and with a door that could be opened from the observation booth, was placed inside the corral.

Five male bovines and 11 vampires (8 males and 3 females) were used. The cattle were a criollo-cebu cross about 15 months old varying in color from white to brownish-black. Vampires that had not yet lost the ability to fly were conditioned to live under constant light and to feed daily at 10:00 AM.

One bovine was placed in the corral and two vampires were placed in the cage the day before the first observation period. The wing band of one vampire was painted to distinguish it from the second. The day observations were begun when the cage door was opened at 10:00 AM and the vampires were permitted to enter the corral. Two observers were present, one to observe and record the behavior of each bat. Bat behavior was divided into 13 categories and each was timed with a chronometer.

A single observation period consisted of 3 continuous hours. Five observations were made of each bovine with its associated pair of bats. It was necessary to replace one bat, hence a total of 11 were used.

Forty-four of the 50 observations obtained were considered valid. A total of 49 bites was observed (in several cases a single bat made more than one bite). Location of bite and position of both bovine and bat is shown in the following table:

TABLE 1. Feeding activity of captive vampires

Bite location	No. bites observed	Position of bovine	Position of feeding bat
Neck	1	Standing	Neck of bovine
Coronet and hoof area	27	Standing	On floor of corral
Neck	1	Lying down	On floor of corral
Chest	13	Lying down	On floor of corral
Lower shoulder	1	Lying down	On floor of corral
Mid-foreleg	1	Lying down	On floor of corral
Mid-hindleg	1	Lying down	On floor of corral
Lower-hindleg	2	Lying down	On floor of corral
Rump	2	Lying down	On floor of corral
Total	49	-	-

Of particular interest was that only one of the 49 bites was inflicted while the bat was located up upon the bovine. All other bites were inflicted from the ground. However, under field conditions vampires have frequently been observed climbing and feeding upon their victims and it is suspected that under artificial light and captive conditions the above behavior was not completely normal. The extent of this aberrant behavior will only be known after extensive field observations have been completed.

Time spent feeding varied from a few minutes to more than 1 hour, the mean being 36.5 minutes. Feeding time appeared to depend somewhat on the rapidity of blood flow.

A walking or hopping gait was used to pursue victims. The mean time spent in such activity was about 24 minutes (n = 34). Under field conditions it is probable that less time would be required as corralled cattle were probably more restless. Feeding was generally intermediate, taking place when cattle movement ceased or was at a minimum. Old bite wounds were frequently reopened.

Movement upon the prey was observed in only 10 of the 44 observations and usually lasted only a few seconds, although one bat climbed about for approximately 10 minutes. However, in only one instance was a bite actually inflicted; all other bats subsequently dropped to the floor to bite and to feed.

The mean time spent grooming was not considered valid as many observations were terminated before grooming took place.

The captive conditions described above probably resulted in a certain amount of aberrant behavior. Nevertheless, it was demonstrated that vampires are able to bit and feed, without difficulty, from the coronet or hoof region of standing cattle without touching their victim, excepting teeth, tongue, and possibly mouth. This behavior was observed in 27 of 49 cases. They frequently fed from lying cattle, inflicting bites on nearly all parts of the body without climbing upon or otherwise touching their victim. This was observed in 21 of the 49 bites. In no case did bats bite or feed upon the coronet or hoof region of lying cattle. It was also noted that vampires were reluctant to fly after feeding and preferred to rest for a period of time.

Extensive nocturnal observations in the field in representative areas of Mexico will be made in 1970 to gain a better idea of vampire bat feeding behavior. Such data are necessary to determine the most feasible method of applying control agents.

B. Grooming behavior of captive vampire bats: The application of certain control methods is dependent on the use of a technique whereby vampires are exposed to a control agent, a quantity of which is deposited on the fur or appendages, and it is subsequently ingested by the bat while grooming. The quantity of material ingested is dependent, in part, on the degree and extent of grooming. Repellency of potential control agents may also be determined by differences in grooming behavior of treated and control animals.

This study is now at the midway point. Five vampires, three males and two females, have each been observed for five observation periods for a total of 25 observations. Each bat was placed in a small, wire cage placed inside a portable refrigerator box and observed by closed circuit TV. Each observation period consisted of 6 hours (a total of

150 hours of observation). Twenty milliliters of blood were placed in the cage at the beginning of each observation period and the time spent feeding, resting or sleeping, moving about the cage, and grooming, was timed with a chronometer. The number of mouth-body contacts that occurred during grooming were counted. A summary of these data is shown in the following table.

TABLE 2. Activity of five captive vampires during 6 hours of daily observations for 5 days

Activity	$\bar{X}$ Time of each activity	Range and $\bar{X}$ time, in percent, for all five vampires	
Sleeping or resting	4 hr 58 min	75.4 - 87.1%	82.6%
Moving about cage	9 min	0.3 - 5.8%	2.1%
Feeding	18 min	3.9 - 6.3%	5.0%
Grooming	34 min	5.0 - 19.4%	9.5%
Total	5 hr 59 min		99.2%

$\bar{X}$ number of mouth-body contacts = 260

The observations indicate that vampires spend considerable time grooming. The hind legs are used to clean or scratch nearly all parts of the body and head. Grooming with the hind legs normally consists of rapid scratching for 3-5 seconds and immediate cleaning of the foot and claws with the mouth. The hind legs, genital region, and wings are also cleaned with the mouth. The mean time spent grooming during the 6-hour observation period was 34 minutes, or 9.5%. Extrapolating these data to 24 hours, the mean time would be 2 hours and 16 minutes, with a mean of 1040 mouth-body contacts.

The second phase of the study will consist of an equal number of observations made 6 hours before feeding.

While varying ectoparasites loads and grooming behavior of wild vampires under natural conditions may differ from that of captive bats, the data thus far are encouraging. It suggests that control agents made to adhere to the fur and appendages of vampires would be thoroughly groomed off and ingested.

(2) Recovery of fluorescent particles (FP) from the gastro-intestinal tract of vampire bats (Desmodus rotundus).

This study was initiated in 1968 to determine if FP ("Tracerite") could be used as a quantitative chemical tracer or indicator to determine: (a) weather resistancy of control agents and carriers applied to livestock, and (b) the amounts of a control agent picked up by bats while feeding and subsequently ingested while grooming.

Nearly all results from this study were reported in the 1968 Annual Progress Report. Responsibility for this study has been shifted to the Section of Basic Studies at the Denver Center and results obtained in 1969 will be reported elsewhere.

(3) Growth and age determination of vampire bats.

This study seeks to determine a method for aging vampire bats. Such data will be necessary for future studies of vampire population dynamics and mortality rates. The first phase deals with growth and age determination of juvenile vampires born in captivity.

A. Growth: Weight and standard measurement data were recorded from captive, known-age, juvenile vampires born in the colony. Weight and total length generally increased rapidly until the young were about 3 months old and then leveled off. Length of left forearm increased rapidly until the young were 2 months old, and thereafter continued at a slower rate until they were 5 months old. Thumb, ear, and foot length generally increased until the young were from 2 to 3 months old and then leveled off. There is evidence that juvenile vampires within the colony are not growing normally, due to diet, captivity, etc., and that the data thus far obtained may represent sub-optimal growth patterns. It is suggested that these growth data be verified by banding and periodic recapture of wild vampires within a suitable cave.

B. Dentition: Dentition of juvenile vampires was checked at regular, periodic intervals to record eruption and loss of deciduous teeth and replacement by permanent teeth. The data obtained are shown in the following table (I=Incisor, C=Canine, CT=Cheek Teeth):

TABLE 3. Age of captive vampires at time of major changes in tooth complement

Teeth	Age at time of eruption	Sample size[1]
Deciduous upper I	Present at birth	7
Permanent upper I	From 2 to 5 weeks	4
Permanent lower I	Present at birth	7
Permanent upper C	From birth to 2 weeks	6
Permanent lower C	From birth to 3 weeks	6
Permanent upper CT	From 4 to 9 weeks	4
Permanent lower CT	From 3 to 9 weeks	3
	Age at time of loss	
1st deciduous upper I	From 11 to 18 weeks	2
2nd deciduous upper I	From 15 to 21 weeks	2

[1]Sample size varies because of difficulties encountered in raising young vampires in captivity. Young died periodically throughout the study.

The dental formula for the normal complement of adult teeth is:

$$\frac{1\ I \quad 1\ C \quad 2\ CT}{2\ I \quad 1\ C \quad 3\ CT} \times 2 = 20$$

C. Age of weaning: Age of weaning of juvenile vampires may occur at about 4 months. However, in two cases our observations indicated that females with suckling young partially or completely ceased lactating and then resumed several weeks later. In the intervening period at

least one of the young began consuming blood from cage feeders, but subsequently returned to suckling the female. The suggestion is advanced that a possible pseudopregnancy may have resulted in continuation of lactation.

D. Vaginal spot: A dark spot resembling a small but severe bruise appears on the external genitalia of gravid female vampires. After parturition occurs the spot gradually becomes lighter and smaller and finally disappears. In two females from our colony, this spot disappeared at 15 and 18 weeks after parturition.

E. Age determination of adult vampires: Sections of vampire bat teeth were received from Denver and checked for the presence of annuli in the tooth cementum. Annuli remarkably similar to those observed in the teeth of coyotes and other species were found to be present, suggesting the possibility of a study to determine if this technique could be used to determine vampire age.

Over 100 vampire eye lenses were collected in the field to determine if a frequency distribution of their dried weights would reveal differences in lens weights with respect to age. This work will be continued in 1970.

(4) Methods of instrumenting and marking vampire bats.

During 1969 work carried out under this study plan consisted of two segments:

A. Attachment of radio transmitters to vampire bats: This problem was initially investigated at the Mexican field station and later at the Denver Center. In Mexico, models were constructed to approximate the size, shape, and weight of transmitters to be used in the field. Attachment techniques tried included glue, suturing directly through the skin, and loops of string placed about the hind legs. One or two of these proved successful for a few days, but a permanent attachment method, causing no damage to the bat, was not developed. Following laboratory tests and observations, a 1-day field trip to a cave near Cuautla, State of Morelos, was taken to determine flight characteristics of instrumented bats. Five nongravid vampires were netted within a cave, model transmitters affixed by glue and suture, and the bats then released approximately 300 meters from the cave. Bats were released in a field affording a clear view from point of release to the cave entrance, situated above the valley floor in a cliff. All bats flew normally but either entered a dark narrow arroyo between the point of release and the cave, or else flew to nearby trees, presumably to hide until darkness.

Subsequent work at the Denver Center, trying various combinations of glue, nylon pads, suture clips, collars, and sutures, resulted in a satisfactory technique. A collar of shim brass covered with shrink tubing is placed around the neck of the bat. A small piece of shim brass extends from the collar posteriorly to a nylon pad on top of which the transmitter is glued with Plas-T-Pair. This pad is then sutured to the skin on the back. Such an attachment device was retained by two captive bats for 3 weeks without apparent damage or sloughing of the skin. Sloughing of the skin has been the major problem encountered with nearly all attachment techniques tried to date. However, the method described above places most of the weight on the neck and the sutures on the back serve only to stabilize the unit.

B. Use of fluorescent or reflective materials to follow vampire bat movement: A pilot study was initiated to determine if ultra-violet light could be used to follow vampire bat activity within a herd of corralled cattle. Initial attempts to apply fluorescent dyes and paint pigments to the fur and wings of vampires proved successful; however, most of the pigment had fallen off or was groomed off after a few days. The use of fluorescent paint pigment mixed with Plas-T-Pair and applied to wing bands proved more successful, as did fluorescent and reflective tapes glued to the back of the bat. The reflective tape technique may prove useful when used in conjuction with the night vision equipment ("Starlite") on loan from the Army Electronic Command.

(5) Repopulation rates of vampire bats.

This study was undertaken to determine how rapidly vampire populations returned to their original numbers after population reduction by mist netting. Such information will obviously have considerable bearing on the frequency of control needed to maintain vampire populations at low levels of abundance.

Seven vampire roosts located in caves and abandoned mines in three different physiographic regions in Mexico have now been studied for varying lengths of time. Unless otherwise mentioned, the vampire population in each roost was estimated, a reduction (by mist nets) was carried out, and subsequent, periodic population estimates were made. Temperature and humidity were recorded both at the entrance and within the roost at the time of each visit. A summary of the data obtained, by geographic location, from each of the seven roosts is as follows:

A. Tuxpan, State of Veracruz: Vampire roosts were located in two caves on the coastal plain near Tuxpan at about 20 meters above sea level. Inasmuch as the two caves were located within 25-40 meters of each other, vampires present in both were considered as one population. The area is humid and without a well-defined dry season. The temperature is hot with no well-defined cold season.

On the first visit, September 8-12, 1969, the total population of the two caves was initially estimated at 85-110 vampires ("La Gruta I" with 60-80 bats and "La Gruta III" with 25-30 bats). During 2 nights of intensive trapping, 140 vampires were taken from the caves and the untrapped remaining population of vampires was estimated at 50-70. Thus, the last estimate of approximately 60 vampires plus the 140 bats previously removed equals a total of 200, differing by approximately 100 individuals from our original estimate of 85-110 present within the two caves. It seems very unlikely that our original estimate was in error to such an extent as there were few places within the caves where vampires could escape detection.

The second visit to these caves was made on October 13, 1969. It was found that the population had increased from the 50-70 bats estimated present a month earlier to 105-135, resulting in an increase of about 55 vampires. Such increase could only come from rapid repopulation by immigration into the caves.

B. San Jose el Viejo, State of Oaxaca: The two roosts under study are located in two abandoned mines in the mountains about 115 kilometers south of Oaxaca, State of Oaxaca, at 950 and 1090 meters above sea level. The area is semi-arid with a dry winter period. It has moderate temperatures without a well-defined cold season.

The mine "Tiro de la Mina del Aire" was visited for the first time by Dr. William Wimsatt, Cornell University, on about April 1, 1969. At that time he estimated the vampire population at about 100 individuals. Prior to his second visit on May 15, 1969, attempted control efforts by local residents reduced the population to about 60 bats, as estimated by Wimsatt. On May 15 he mist-netted 50-51 vampires, leaving an estimated 6 bats in the roosts.

We visited the mine on November 6 and December 4, 1969, approximately 6 months later, and estimated the population present at 20-30 and 17-20 vampires, respectively. Thus, the mine showed an increase from 6 to about 20-25 vampires over a period of about 6 months (May 15 to December 4, 1969), and to date population in this roost is far below the number of vampires originally present.

The mine "Veta Nueva" was visited for the first time on November 5, 1969. The population was estimated at 145-150 vampires and 103 were removed the same day, leaving about 45 untrapped bats. On November 7, 2 days later, the population was estimated at about 40 vampires. On December 4, 1969, the cave was again visited and the population was estimated at about 60 vampires, or an increase of about 20 individuals in a month.

C. Cuernavaca, State of Morelos: The three roosts under study are located in caves in barrancas near Cuernavaca, Morelos, at about 1500 meters above sea level. The area is humid to semi-arid with a well-defined dry season. It has moderate temperatures with no well-defined cold period, but is the coolest of the three areas studied.

The three caves, "Ocho de Julio," "Palmira III," and "Del Rio Palmira, were periodically visited 10 times between January 23 and November 27, 1969. The populations in all three caves had previously been reduced by project personnel during several visits over a period of about 6 months and vampire populations were already very low at the time the study was formally initiated.

The original estimate of 300 vampires present in "Ocho de Julio" was made on July 8, 1968. However, as this constituted our first attempt at estimating populations, the above figure may have been exaggerated. On July 8, 52 vampires were collected and on August 23 the population was found to be considerably reduced, a substantial proportion of the population apparently having permanently left the cave. At that time 11-20 vampires were estimated to be present, 14 of which were trapped. During subsequent visits to this cave the vampire population climbed from 5-10 in January 1969 to a high of 40-50 in July and then declined to 10-12 by November. There was evidence of frequent human disturbanc at this cave.

The initial estimate of the vampire population in "Palmira III," made on September 26, 1968, was about 51-100 bats. This estimate may also have been somewhat high. The cave was trapped three times between September 26, 1968, and January 3, 1969, and a total of 41 bats was removed. Periodic data from this cave subsequently showed that vampir numbers climbed from 1-5 in January 1969 to a high of about 20 during June and July, then dropped to 5-10 in November.

The cave "Del Rio Palmira" was intially trapped on September 26, 1968, at which time the population was estimated at about 11-20 vampires. A total of 17 bats was collected from September to November 26, 1968, when there was an estimated 5-10 bats present. The vampire population subsequently declined from 1-5 in January to 0 from April to August; then increased to 6-8 in October and November. This cave, at times, showed evidence of human disturbance.

In all three caves discussed above, populations have not returned to original levels of abundance within a year after reduction. The minor fluctuations of population densities in these caves during the year of periodic inspection may possibly be related to temperature. From August through November temperatures in the caves "Ocho de Julio" and "Palmira III" decreased, as did the vampire population, while during the same months the temperature in the cave "Del Rio Palmira" increased and so did the number of vampires. Data from two other caves in the Cuernavaca area, "Del Amate" and "De los Muñecos," have indicated a relationship between local movement, or changes in principal roost sites within the caves, and seasonal temperature fluctuations.

The data thus far obtained indicate that repopulation rates may vary according to geographic location. The differing rates may be a result of differences in climatic factors and/or available habitat, since food supply does not seem to be a limiting factor in any of the three areas.

Movement of Tuxpan vampires from suboptimal habitat, available to a lesser extent in Cuernavaca or Oaxaca, may be the reason for the rapid repopulation observed in that study area.

(6) Blood as an attractant to vampire bats.

Attracting vampire bats to specific bait animals that have been treated with a control agent may offer promise as a control technique. Such a technique has the advantage of requiring treatment of fewer animals and thus minimizing possible hazards of systemic or dermal toxicants and contamination of animal products. However, its use is contingent on the availability of a suitable attractant. An effective attractant might also serve to concentrate vampires at a specific site within a cave or at a corral where control could be applied, thus eliminating the necessity of placing control agents on cattle.

This study, designed to test bovine blood as an attractant to vampire bats, was not initiated in 1969 due to incomplete staffing of the station and priorities given to other studies.

(7) Efficacy of selected chemical compounds as vampire bat repellents.

The exclusive use of repellents is not considered a feasible approach to control since its use would probably cause vampires to feed on alternate, untreated hosts in adjacent areas. However, one possibility is the use of a repellent on all cattle within a herd, excepting one or two individuals which would serve as "bait" animals.

Laboratory evaluation of two potential vampire repellents was completed in December 1969. One, suggested by the Communicable Disease Center, PHS, Atlanta, Georgia, is currently recommended for use in attics or buildings where insectivorous bats are a problem. The second compound, provided by the Denver Wildlife Research Center, was Tributyltin sulfide, previously found to effectively repel certain rodent species.

The CDC solution as formulated, was as follows:

Water (110°F)	99 ml
Sponto 221 (emulsifying agent)	3 ml
Oil of Mustard	1 ml
Oil of Sassafras	1 ml
Water (65°F)	192 ml
	296 ml

One cc of the above solution contains .0067 cc of active compound.

The DRC Tributyltin sulfide was provided in a spray can and 1 cc of this formulation contained .006 cc active material.

The two compounds were evaluated in the laboratory by means of tubular cardboard cylinders measuring 15 cm by 71 cm. Each cylinder was divided into three chambers by means of removable sliding doors. The central chamber served as a holding area for a single vampire. A blood feeder containing 20 cc of defibrinated bovine blood was placed at either end of the left and right feeding chambers. Immediately after each day's test was completed the quantity of unconsumed blood remaining in each feeder was measured. Each day a known quantity of the test repellent was placed in front of one blood feeder. The following day the repellent was placed in front of the feeder in the opposite feeding chamber. This pattern of evaluation was continued daily for 6 days, thus providing the bat a choice of treated or untreated feeder and chamber. Alternating the repellent daily from left to right eliminated any feeding preference with respect to conditioning or learned behavior.

All test animals were conditioned for 2 weeks to feed for 1 hour daily before the above tests were begun. They were also conditioned to feed from alternate chambers for 6 days before a repellent was introduced into the test apparatus.

A minimum of six bats was used to test each repellent. Several died during the course of the study, thus the variation in number of test animals. Each bat was tested daily for 6 days for a minimum of 36 observations of each repellent at a given concentration. Both repellents were tested at two concentrations, the second concentration being 10 times more active by volume.

Degree of repellency was determined by two means:

A. The total quantity of blood consumed by all test animals (during the 6-day period) from treated versus control feeders.

B. The total number of times bats fed from treated or control feeders.

A summary of the results are indicated below:

TABLE 4. Tributyltin sulfide: Summary of results over 6-day period

Repellent concentration	No. bats	Total blood consumed		No. times fed from feeder	
		Control	Treated	Control	Treated
.0006[1]	7	348.0	298.5	26	28
.006[2]	6	420.0	136.0	26	10

[1] 1/10 of 1 cc of stock solution containing .0006 cc of active compound was placed in front of the feeder in the treated chamber.
[2] 1 cc of stock solution containing .006 cc active compound was placed in front of the feeder in the treated chamber.

TABLE 5. CDC formulation: Summary of results over a 6-day period

Repellent concentration	No. bats	Total blood consumed		No. times fed from feeder	
		Control	Treated	Control	Treated
.00067[1]	6	315.0	215.0	24	18
.0067[2]	8	372.0	343.0	30	27

[1]1/10 of 1 cc of stock solution containing .00067 cc of active compound was placed in front of the feeder in the treated chamber.

[2]1 cc of stock solution containing .0067 cc active compound was placed in front of the feeder in the treated chamber.

It can be seen that no marked differences in consumption rates were apparent with the CDC formulation although consumption rates and frequency of feeding was somewhat higher at control feeders using the .00067 level. The results with Tributyltin sulfide at the .006 level of concentration were somewhat more encouraging in that over three times as much blood was taken from control feeders than from those treated with this repellent. Future work should include a test of Tributyltin sulfide at the .06 level, although a 6% solution might not be practical either from the standpoint of cost, or considering the possibilities of dermal irritation or absorption by treated cattle.

(8) Pharmacological evaluation of chemical agents for controlling vampire bats.

These investigations seek to determine the effect of potential control agents on captive vampire bats. All work during 1969 was carried out at the Denver Wildlife Research Center.

One problem encountered at the onset was difficulty in administering compounds by gavage of canulation due to the peculiar structure of the gastro-intestinal tract of the vampire. Instead of having the common mammalian (bat) esophagus-stomach-intestine arrangement, the vampire has a T-type junction with the stomach being a blind pouch. This type of junction is producing some problems in the route taken by gavaged material (entering only the stomach, entering only the intestine,

entering both). A series of bats was used in a barium sulfate-fluoroscopy tests before toxicity studies were attempted. The test was to determine the fate of material: (a) introduced by cannula into the esophagus, (b) placed in the mouth and voluntarily swallowed by the bat, and (c) added to the liquid blood meal. From these tests it was learned that barium sulfate introduced into the esophagus or placed in the mouth and swallowed all goes into the intestine, bypassing the stomach. When added to the blood meal and voluntarily consumed by the bat, the barium sulfate entered the intestine, then overflowed filling the stomach.

These data complicate running an LD_{50}, in that, results may vary if the toxicant bypasses the stomach (in esophageal gavage) as compared to the animal receiving the toxicant in a blood meal in a more dilute concentration with part of the toxicant entering the intestine and part the stomach.

LD_{50} concentrations of several standard toxicants were run to obtain baseline data for later comparison with newer, and hopefully, more species-specific control agents. The results of these tests are as follows:

A. 1080: For sodium fluoracetate (DRC-4008) formulated in saline, the vampire LD_{50} (introduced by cannula into the esophagus) is .495 mg/kg (.743-.330, 95% confidence limits). However, when 1080 was added to the blood meal, the results varied greatly. Vampires were allowed to feed on a mixture of 1080 and blood for one night:

Dead	Not Affected
147 M = ate 1.97 mg/kg	103 F = ate 0.90 mg/kg
149 M = ate 2.50 mg/kg	94 F = ate 2.34 mg/kg
157 M = ate 0.89 mg/kg	90 F = ate 3.17 mg/kg
136 M = ate 0.62 mg/kg	
112 F = ate 1.36 mg/kg	

From these data, it was thought males might be more susceptible to 1080 than females so another group was tested and none died, the males eating up to 2.74 mg/kg and females eating up to 2.56 mg/kg. Since 1080 is water soluble, and most of the water is presumably removed from the blood meal in the stomach, one would expect it to be more toxic when passing the normal digestive route, but this was not shown.

Gavage by means of a curved cannula passed into the bat's stomach, if possible, will hopefully result in less variable results.

B. Strychnine sulfate: For strychnine sulfate (DRC-4007) formulated in saline, the vampire LD_{50} (introduced into esophagus) is .404 mg/kg (.717-.228, 95% confidence limits).

C. Diphacinone: One of the anticoagulants, diphacinone, was tested by adding it to the blood meal. The chronic LD_{50} for albino rats is approximately 0.2 mg/kg/day for 4-5 days. The LD_{100} for Desmodus is approximately 0.2 mg/kg/day for 5 days, although animals which ate 0.144 mg/kg and 0.137 mg/kg for 5 days showed some free blood around the arm areas and may have succumbed in their natural environment. Of interest is that there was no aversion to diphacinone fed in the blood meal, while for 1080 (tasteless to humans?) there was some aversion, possibly due to the bats consuming a sublethal dose and becoming sick. Rats characteristically show some aversion to diphacinone added to their diet.

It is undecided as yet if future pharmacological investigations will be undertaken at the Denver Center or at the Mexico field station.

PUBLICATIONS

Two publications were submitted to the Journal of Mammalogy after review and editing by BSFW and AID:

Burns, R.J. Twin vampire bats born in captivity.

Flores Crespo, R., R.J. Burns, and S.B. Linhart. Load lifting capacity of the common vampire (Desmodus rotundus murinus Wagner).