March 1970

VAMPIRE BAT CONTROL: A REVIEW AND PROPOSED RESEARCH PROGRAMME FOR LATIN AMERICA

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ABSTRACT: In Latin America paralytic rabies transmitted by vampire bats is a major cause of death in cattle. This problem becomes more acute as countries attempt to increase livestock production to feed rapidly expanding human populations. Vaccination has been the principal weapon against rabies, however this offers no protection to domestic animals and poultry against daily predation of vampire bats. Established methods of vampire bat control, though limited, have proved effective and should be continued while more effective methods are being developed and tested. Existing methods are discussed in some detail. Of the approximately 200 kinds of bats found in Latin America all could be potential vectors of rabies. The 12 species most frequently found infected with rabies (including the three types of vampires) should receive close ecological study for possible control. They have certain attributes in common: they have been reported rabid; are found in association with vampires; are widely distributed; are found in buildings near domestic animals and people; live in groups; have sharp teeth; fly considerable distances; frequently change their roosts; do not hibernate and are biologically or economically important.

Improved vampire bat control must be based on an ecological approach in which all available techniques are combined into an integrated control which will not affect other species of bats. Such an approach could use biological, chemical, physical and regulatory techniques. These cannot be fully developed until basic information is available on two points. First, there must be a thorough understanding of the ecosystem in which the bats live, including population dynamics. Second, the population levels which cause damage must be determined. This information Is lacking for vampire bats. Two other questions must also be answered: first, what are the host preferences of vampire bats throughout their range from Mexico to Argentina? And second, how many vampires inhabit any given area? A precise technique for measuring these numbers is essential to evaluate any control measure.

All the countries in Latin America are discussed on a regional rather than a political basis listing special problems to be solved.

The vampire bat problems throughout Latin America should be defined. FAO could, if requested, assist these countries in carrying out presently known methods of vampire bat control which could provide immediate relief in limited areas. It could also help to establish priorities of research based on the financial and manpower capabilities of these countries to conduct such research.

Introduction

The Food and Agriculture Organization (FAO) has stated that it is in Latin America that population has been growing faster than in any other region of the world in the last 30 years and it is likely to do so in the next 30. An increase in livestock is one of the highest priorities in the world agricultural scene today. An analysis of the past trends of the agricultural development in Latin America shows clearly that animal production, especially cattle production, has remained practically stagnant in most countries. It was pointed out during the First International Conference on Rabies in the Americas in 1967 that the vampire bats of tropical America are perhaps the most important reservoirs of rabies and that this disease must be considered as the most serious animal health problem in Latin America (23). This is further confirmed by the Pan American Health Organization adding that the estimated annual losses are a million head of cattle valued at over 100 million dollars (1). Associated indirect causes such as malnutrition, myiasis and blood loss raise this figure to 250 million dollars. It is obviously a major obstacle to the expansion of the regions agricultural economy according to the World Health Organization Expert Committee on Rabies in their Fifth and most recent report (25).

The problem will become more acute since, as countries attempt to raise more cattle, pigs, sheep, goats and poultry, increased vampire bat populations are inevitable. This has been the basic pattern from the time that domestic animals were first introduced into Latin America.

*FAO/UNDP/SF Research on Paralytic Rabies Project, Instituto Nacional de Investigaciones Pecuarias, Palo Alto, Mexico. Project Contribution No. 19.

As a result of the recommendations of an FAO/WHO Mission to Latin America in 1966 the "FAO Research on Paralytic Rabies Project", financed jointly by the United Nations Development Programme (Special Fund) and the Government of Mexico, became operational in July 1968 at the Ministry of Agriculture's Instituto Nacional de Investigaciones Pecuarias near Mexico City to assist Mexico and provide advice and training to other Latin American countries *(24)*. The Project has begun a programme of applied research to investigate all aspects of vampire bat rabies and the ecology of vampire bats. FAO experts in virology, epizootiology and ecology work with Mexican counterparts in the laboratory and the field.

Vaccination has been the principal weapon in rabies control. However, the daily biting of cattle and other livestock by vampire bats, whether infected with rabies or not constitutes a substantial blood drain on individual animals. Vaccine will not protect the livestock from the bites of vampire bats, and therefore integrated control is essential.

The Ecology Section of the Project is concerned with the development and evaluation of vampire bat control with emphasis on the feasibility of biological control. It cooperates with other agencies having similar interests, particularly the US-AID Vampire Bat Control Program in Mexico, the Zoonoses Center of the Pan American Health Organization in Argentina, and the Ministry of Agriculture of the Government of Trinidad and Tobago.

While new methods of vampire bat control are being sought and tested, the livestock owner, particularly the small farmer, should have immediate assistance to protect his livestock. Established methods of vampire bat control, though limited, have proven effective. However, the success of these measures depends upon their intelligent application. Unfortunately the staff of some control programmes cannot correctly identify vampire bats or their roosts and have used non-selective methods (such as dynamiting or indiscriminately fumigating caves) which result in the needless destruction of thousands of useful insect, fruit and nectar feeding bats along with the vampires. . .

As the vampire bat problem intensifies, as it will, affected countries may want to conduct their own investigations of control. They should be encouraged to do so according to their technical ability and financial means. They should be able to seek and receive the advice and assistance of FAO which should serve as a clearing house for data and should periodically visit these countries to assess their problems or to advise the national services on methods of vampire bat control. In addition FAO should conduct seminars and training programmes for local services; suggest priorities of study, explain basic ecological principles; provide a data sheet which may be useful for all countries; provide a general outline of bat ecology and natural history for study, and if possible prepare a newsletter at regular intervals. The purpose of this paper is to suggest the basis for such a programme.

Vampire Bat Problem

Restricted to the Western Hemisphere, vampire bats are the cause of a unique disease problem. Since these bats must subsist exclusively on the blood of mammals (including man) and birds, infected vampires transmit paralytic rabies as part of their normal feeding habits. Under investigation are other methods by which rabies transmission may occur, i.e., through urine, faeces, milk, placenta, aerosol, etc. The vampire bat family Desmodontidae is comprised of three genera Desmodus, Diaemus, and Diphylla all of which are known to be infected over a great part of their ranges. The most important transmitter is the abundant Desmodus rotundus, one of the most common of all tropical American bats. It is found from northern Mexico to Central Argentina, from sea level into high mountains inhabiting forests, savannahs, deserts and swamps.

The repeated nightly attacks by vampire bats debilitates livestock and poultry, not infrequently exsanguinating the latter. The open wounds caused by their bites continue to ooze blood for many hours and may attract the screwworm (Callíphorldae). Other pathogens may be transmitted such as Trypanosoma hippicum which causes trypanosomiasis or "murrina" in equines. A single bat can consume a daily average of 20 ml of blood (7.3 liters=15 pints a year). Since several hundred Desmodus may occupy a single roost, their predation in a single area can be intense.

Milk yield of severely bitten cows markedly drops, while sows bitten on their teats are unable to nurse their young.

When Latin America was being settled by Europeans, the indigenous vampire bats found the introduced domestic animals a more easily accessible, plentiful source of blood than was the native wildlife. Man-made roosts such as mines, wells, culverts, and buildings added to the

vampires natural roosts (caves and trees). The adaptable vampire bats, especially Desmodus, have benefited, and their great population increases have given them pest status.

Vampire Bat Control and Conservation

The thought that the destruction of vampire bats might upset the balance of nature should not be disturbing to conservationists since the balance has been upset already, in favor of the vampire, by the introduction of domestic animals. A biological equilibrium between the vampire and its environment undoubtedly existed prior to the introduction of this new and ever increasing (domestic animal) blood supply. This new food supply and new roosts have permitted the vampire to invade new territory. Vampires have noticeably moved northward in Mexico closer to the United States and southward in Argentina from tropics to subtropics and in some cases into a temperate zone habitat of Cordoba, Argentina. Balanced populations of vampire bats probably exist today only in those ecosystems such as remote virgin rain forests in the Amazon and the bird guano islands off the coast of Peru, where domestic livestock is absent and the bats still feed upon the indigenous fauna.

Since the eradication of all vampire bats appears impossible (whether desirable or not) due to their wide distribution, abundance and frequently inaccessible roosts, it is more practical at present to think in terms of integrated control, especially of local bat populations, giving priority to areas where there is a high incidence of rabies and/or intense vampire predation, both situations making the raising of domestic animals difficult.

Recognizing that the control of vampire bats is closely linked with the survival of other types of bats which pollinate certain plants, disseminate seeds or feed upon noxious insects, the International Union for the Conservation of Nature and Natural Resources, at its Latin American Regional Conference, at San Carlos Bariloche, Argentina, on 2 May I968, pointed out (among other things=inter alia), that many species of bats either found roosting with or misidentified as vampires, play an important role in nature and therefore passed a resolution recommending that the necessary control of vampire bats be based on sound biological and ecological studies (21). In addition it was also pointed out that "personnel charged with the application of control measures be properly trained to identify vampires and their roosts (underline mine) and to avoid indiscriminate and mass destruction....of caves and roosts sheltering large numbers of bats and other animal and plant species beneficial to man or of great scientific interest."

Non-Vampire Bats and Conservation

Elsewhere in this discussion I have mentioned the needless though well-intentioned killing of bats other than vampires during vampire bat control campaigns. It is important to mention briefly the biological and economic importance of the Chiroptera-bats. The bats constitute about 281 of all mammal species and are a complex zoological group whose role in nature is not yet fully understood. During the Second Vertebrate Pest Control Conference in 1964, I mentioned the public health importance and control of bats (8). Under normal circumstances bats are useful and beneficial and their feeding habits should be carefully considered before a destruction campaign against any species is contemplated. Diets vary according to species. In Trinidad, Desmodus has been found roosting in association with 17 other bat species comprised of 8 insectivorous, 1 piscivorous, 1 omnivorous, 2 carnivorous, 2 frugivorous, 2 nectarivorous, and 1 sanguivorous. Thus, indiscriminate bat extermination may bring about a possible upsurge in insect-borne disease and the non-pollination of such flora as Agave. Alea. Ceiba. Crescentia. Hymaneae. Musa, Parkia and Parmentina. (9) and the failure to distribute widely the seeds of cacti, palms, sapucaia nuts as well as others.

Priority of Bat Control

Taking into account ecological considerations, the control of vampire bats as mentioned earlier is closely tied to the survival of other bat species. While any of the 200 species of New World bats could be a potential vector of rabies, there are certain species (in addition to the vampires) which have benefited by changing their normal food and roosting habits with man's colonization of the Western Hemisphere. Many bats, for example, have abandoned caves and hollow trees to live in buildings occupied by man and domestic animals, thus increasing the possibility of the transmission of pathogens. The 12 species most frequently found infected with rabies (including the three types of vampires) should receive close ecological study for possible control. They have certain attributes in common: they are found in association with vampires; they are widely distributed; they may be found in buildings near domestic animals and people; they live in groups or colonies; they have sharp teeth; they can fly considerable distances; they frequently change their roosts; they do not

hibernate; and, they are biologically or economically important (11). The list of these bats follows:

1. Noctilio leporinus - Fisheating bat. Piscivorous and insectivorous. Found from Mexico, West Indies to southern Brazil.
2. Phyllostomus hastatus - Greater spear-nosed bat. Omnivorous. Found from Honduras to Bolivia and Trinidad. Second largest bat in Latin America.
3. Glossophaga soricina - Long-tongued nectar bat. Nectarivorous, frugivorous, and insectivorous. Found from Mexico to northern Argentina and the West Indies.
4. Carollia perspicillata - Short-tailed fruit bat. Frugivorous. Found from Mexico to Paraguay. Undoubtedly the most abundant fruit bat in tropical America.
5. Artibeus jamaicensis - Jamaican fruit bat. Frugivorous. Found from Mexico to Brazil and the West Indies. Frequently found rabid and common in urban areas.
6. Artibeus lituratus - Trinidadian fruit bat. Frugivorous. Found from Mexico to Argentina and the West Indies. Frequently found rabid and common in urban areas.
7. Desmodus rotundus - Common vampire bat. Sanguivorous. Found from northern Mexico to central Argentina, southern Uruguay and Trinidad. Rabid over entire area.
8. Diphylla ecaudata - Hairy-legged vampire bat. Sanguivorous. Found from northern Mexico to southern Brazil. Not reported from Trinidad but suspect. Rabid over area.
9. Diaemus youngi - White-winged vampire bat. Sanguivorous. Found from northern Mexico to southern Brazil and Trinidad. Becoming more important with rabies.
10. Tadarida brasiliensis - Brazilian free-tailed or guano bat. Insectivorous. Found from central United States to central Argentina and the West Indies. Often found in the millions in Carlsbad Caverns. Associated with aerosol transmission of rabies.
11. Molossus ater - Large free-tailed house bat. Insectivorous. Found from Mexico to Argentina. Most common of house bats living in roof spaces.
12. Molossus molossus - Small free-tailed house bat. Insectivorous. Found from Mexico to Argentina and West Indies. Common and often found with Molossus ater.

Cost of Vampire Bat Control

Cost should not be the primary factor upon which a policy of vampire bat control is based. Vaccination cannot prevent vampire bats from biting. A vampire control programme in a rabies area is a valuable and necessary adjunct to rabies vaccination to protect the essential cattle industry. In areas of peasant farming where vampire bats are a serious threat to dairy cattle, draft animals, pigs, goats and poultry, a vampire control programme is of great value and can be carried out by the livestock owner in cooperation with the national agricultural authorities.

Vampire Bat Control

General Considerations; Trinidad was the first country to establish a government programme to control vampire bats, following a severe outbreak of paralytic rabies that killed thousands of cattle and 89 people between the years 1925-1935. In 1934, I assisted in organizing this programme, but did not direct it until 1954. This programme has continued uninterrupted since its inception. Methods were improved during the mid-1950's. The annual average catch of 2000 Desmodus represents a savings of about 14,880 liters (3,720 gallons) of blood which otherwise would have been drained from Trinidad livestock.

While new control methods are being sought and tested, established methods may well be employed to alleviate distress. Thus livestock owners will have immediate relief, provided the known methods are intelligently applied.

Present Methods

Dynamite and Poison Gas

The use of dynamite and poison gas was discontinued in Trinidad due to their ineffectiveness as well as the human risk. These indiscriminate measures resulted in the killing of thousands of bats of various species with little or no affect on the vampire populations (12). Brazil has reported the destruction of bats in caves by the use of "Rhodiatrox" (phosphorus base) employed alone or together with dynamite (3). No mention is made of the numbers of vampires killed. During an FAO assignment in Brazil, Dr. Villa reported bats having been destroyed with a gas "Phosphotoxin" and that vampires were killed along with other bat species (28) but it is not known how many vampires were killed. Villa further states that in rabies outbreak areas diurnal roosts of bats have been destroyed either by the stock raisers or agricultural department officials. Several thousand caves were destroyed in the State of Rio Grande do Sul and again it was not indicated whether the bats killed were

vampires or other bat species. Argentina has also reported the use of poison gas (cyanide) to kill vampires (2). However the use of gas, aside from the danger to the operators, might be considered as a useful method since in Argentina Desmodus is found in pure colonies and seldom in association with other species of bats.

Smoke and Fire

In Trinidad and Mexico dense smoke will often successfully dislodge vampires from hollow trees. Desmodus is an extraordinarily strong bat and some bats only respond to excessive heat when a smoldering fire bursts into flame. Smoking bunches of dried grass tied to the tips of long poles and thrust up inside the hollow tree is effective. Some hollow trees have upper openings not visible from the ground and the use of smoke will indicate these second exits which vampires will use unless they are closed off. During World War II United States armed forces used flame throwers in Trinidad in an attempt to exterminate vampires in caves. This method was discontinued as dangerous and not practical. Smoke and fire must be used with extreme caution to prevent the inside of a hollow tree from catching fire—thus completely ruining it as a natural trap (12).

Lights, Including Electric, Kerosene and Candles

Light by itself or used in conjunction with the wings of owls and hawks to cast moving shadows (placed above livestock in stables and stalls, for the most part), has been discontinued in Trinidad because the vampires soon tolerate or ignore weak light and will bite on the dark or shaded side of their victims (12). In Mexico some ranches have had excellent success by brightly illuminating and floodlighting cattle corrals yet other ranches have abandoned the practice. It may be useful to floodlight corrals by railroad sidings to protect cattle waiting to be loaded into trains. The pyschological value of light to protect sleeping humans should not be overlooked by the person who believes that a light be his bed will protect him against vampires.

Spiky Vegetation

In Trinidad lime twigs, bouganvillea, and other spiky branches hung in the house and livestock enclosures are still used in country districts. It may prevent bats from entering through holes and cracks (12). I do not know whether this method is used elsewhere.

Protective Screening

Metal or plastic screening with mesh openings no larger than a half inch will effectively prevent vampires and most other bats from entering homes and livestock enclosures provided it is carefully installed initially and kept in repair. While the average Trinidad livestock owner makes little effort to screen his animal shelters, large scale poultry and pig producers can not successfully operate unless their buildings are screened to protect livestock from vampire bats. I have noticed in many areas of Latin America that while an initial effort may be made to bat proof animal enclosures by screening, there is little effort made to replace broken or rusty screen. Great care must be taken to see that doors fit almost flush to the ground since vampires frequently search for prey by walking on the ground and can easily enter any crack which measures one inch by a half inch. Wooden louvers which cannot be closed should be screened since vampire bats have been known to enter homes with fixed louvers. Mosquito netting over beds and hammocks will protect the sleeper although vampires have been known to bite through cloth screening where the body, such as elbow or toes, come in contact with the net. In Trinidad vampire bats have been known to bite through burlap sack which forest workers sometimes use as sleeping bags to protect themselves from vampires. Yet, unexplainably, other workers sleeping in the same camp, in open hammocks without any protection whatsoever are not molested (9). The use of wire screen to cover natural wells or "cenotes" in Yucatan, Mexico will effectively close vampire roosts.

Firearms

Shooting vampire bats inside caves and hollow trees is a practical method used in Trinidad and possibly elsewhere. Smooth bore, .22 caliber pistols, revolvers, rifles and shotguns using scatter shot cartridges or .410 shotguns using the smallest size shot possible (No. 8-12 preferable) are recommended. In addition to the usual care exercised when handling firearms, when shooting, especially in close quarters, care must be taken to protect bare skin and eyes from ricocheting pellets. In Trinidad, if only large shot is available, such as No. 4, it is frequently replaced by clean coarse quartz sand, almost gravel. Often large size lead shot is replaced with the hard, round, lightweight seeds of

the plant "shack-shack", Leucaena glauca, which will kill a vampire attacking a fowl without injury to the bird (10).

Nets

Seines. Simple seine nets with half inch mesh and soft lay (such as used by fisherman) have been successfully used to trap vampires at entrances to hollow trees. Net sizes vary from 5-12 m = 15-36 feet long and from 2-4 m = 6-12 feet wide with mesh no greater than a half inch = 12 mm. Collectors simply cover the opening in the tree by wrapping the seine around the tree or nailing the net over the opening. It is necessary to plug other holes that may provide secondary escape routes. These nets have also been set across cave, tunnel, nine and well openings by bracing them with makeshift frames of wooden poles (12).

Trammels. Trammel nets have been used in Trinidad to catch vampires as they issue from caves, along flyways and around cattle. A complete unit consists of two long, large meshed nets usually of dark twine, each about 14 m by 2 m = 42 by 6 feet, mesh openings are about 40-50 mm = 1-1/2 - 2 in. A third central net of finer twine with 1/2 inch = 12 mm mesh is loosely stretched between the two outer nets. The inner net is pulled through the openings of the larger nets to form pockets. A bat striking one of the outer nets will pass through the large meshes to become trapped or pocketed in the smaller and looser meshes of the inner net (26).

Mist Nets. Japanese mist nets (originally used to catch birds) are set along known or suspected flyways traveled by vampires and also around livestock corrals, huts, dwellings or shelters in which animals or humans have been attacked by vampires. Most nets are made of a fine-gauge nylon. The netting is fitted loosely over a string frame which is considerably smaller than the net itself. Strings also pass horizontally through the net, dividing it into two or four shelves. Loops of heavy cord at the ends of each shelf string provide a means of attaching the net to supports. The most versatile nets for catching bats have four shelves, are 6 or 12 m = 18 or 36 feet long and 4 m = 12 feet wide (high), and are made of 50 or 70 denier black nylon thread In a 24 mm = 1 inch mesh. The nets are ordinarily supported by poles. Almost any sapling 3 m = 9 feet long will serve. It should be reasonably straight and stiff, with little taper, and a basal diameter of about 50 mm = 2 inches. Hard, heavy woods are best but bamboo will serve. Sometimes telescoping metal poles or sectional wooden poles with metal ferrules are convenient. The support poles may be driven directly into the ground, or if the ground is hard or rocky, steel pipes, each 4 cm - 6 cm = 18 - 24 inches long with an inside diameter of 65 mm = 2-1/2 inches and one end flattened to a wedge-shape, may be driven into the ground to serve as a receptacle for the poles. Space in this paper will not permit a discussion of the operation and proper selection of netting sites. There is a detailed description of their rigging, operation, maintenance and selection of net sites in the publication "Bats and Bat Banding" (13). They have been successfully used to net vampires in Mexico (7), in Trinidad (10) and elsewhere in Central and South America.

As a control method mist nets are effective but expensive. In Trinidad mist nets set around pastured cattle caught 57 vampires during three nights, providing complete relief for four months. During one night four nets were set capturing 29 vampires. Relief was for almost five months (10). This same method has been used by the FAO/UNDP Research on Paralytic Rabies Project in two places in Mexico. On a government ranch in the State of Puebla and on a privately owned dairy ranch in the State of Oaxaca. Between May and October 516 and 182 vampires were netted, respectively. To check the efficiency of the method, the bat bites on cattle were counted before and after capture. On the government ranch bat bites were reduced from 529 to 100 -- more than 80% reduction in bat predation. On the private ranch bat bites on dairy cattle were reduced from 98 to 24 -- approximately a 75% reduction in vampire bat attacks (22).

Hand Nets. Long handled insect nets and dip nets for fish are useful in many situations to catch bats inside caves and in other enclosures. To be effective, they should have deep bags so that the mouth of the net may be closed by turning the handle after a bat has been caught, to prevent its escape.

Traps

Traps are more practical than nets for collecting vampires from caves and certain other situations. They are not easily damaged, do not need constant attention and the bats may be left in them for sometime and easily removed at leisure. An ingenious automatic trap was devised to capture, unharmed, large numbers of the insectivorous free-tailed bats Tadarida brasiliensis *(k)*. This trap consisted of a rectangular aluminum frame, 10 by 20 feet,

supporting very fine vertically arranged extremely fine steel wire spaced one inch apart and kept taut by springs attached to the end of the wires. Bats were stopped in flight and slid down the wires through a funnel into an escape-proof cage. Smaller traps of the same design successfully caught vampire bats in Mexico. More recently the trap was redesigned to increase its efficiency and portability. The new trap is hinged to fold in transport and the cage has been replaced by a collapsible plastic receptacle (5). Over 500 vampires were captured in several evenings of trapping in Mexico. The 'Constantine' trap described has undergone numerous modifications, the most important being the use of monofilament nylon fish line with a 6 to 20 lb. test. The fish line eliminate the springs since the line contains its own tension. The fish line is easily purchased almost anywhere and light wooden frames are less expensive and more easily constructed than metal ones (13). In Brazil the staff of the Department of Agriculture of the State of Sao Paulo has installed an elaborate network for the electrocution of cave bats (28). However, not only were vampires killed but also a large number of other species.

Natural Traps

Caves, hollow trees, mines, wells, culverts and other vampire roosts can be exploited as natural traps. To be effective they should be disturbed as little as possible when the bats are being collected at regular intervals. This method is extensively used in Trinidad.

Livestock Naturally Attractive to Vampires

Certain bovines, equines, caprines, other mammals and even humans seem to be especially attractive to vampire bats for some as yet unexplained reason. Nets set around these natural attractants will capture vampires. One bull in Trinidad attracted several hundred vampires to mist nets set around it over several years. One cow having 49 bites was treated with the poisoning method to be described next and killed 12 vampires in a single night (10).

Strychnine Poison Technique

Based on the fact that vampires return to feed at wounds made the previous night a sugar syrup containing a supersaturated solution of strychnine sulphate is applied to a fresh wound. One drop of this mixture, properly applied, will kill a vampire within seconds after its tongue touches the treated bite. This technique, developed in Trinidad, has been successfully used in Mexico and Brazil on bovines, equines, swine, sheep, goats and poultry (10). It is not used on water buffalo bitten inside their nostrils, dogs, or nursing sows, unless the sucklings are restrained from nursing. The poison is not absorbed and does not injure the treated animal. Therefore, it is possible to treat a number of wounds on a single animal. Care must be taken not to apply it where an animal could lick the treated wounds. The thickish syrup is applied to the center of a bite or under a scab which may be lifted and then replaced. Simple applicators are a crushed toothpick, matchstick or a small brush (such as is used to apply nail polish). If too generously applied it will serve as a repellant and will cause a bat to seek a new biting spot on the same animal or find a new victim. For the best results the poison should be applied in the late afternoon for if applied too early in the day, the treated animal might roll in the dirt, mud, or the syrup might be diluted or washed away by a heavy rain. Poisoned vampires are usually found on the ground nearby the treated animal but recoveries may be difficult due to bats falling into deep brush or being trampled beyond recognition in a crowded corral. Dead bats left overnight may be eaten by ants or other animals. This technique is useful for individual animals which may be touched or handled without difficulty. There are several products available in Mexico and are variously called "Vampirol", "Melito Veneno Vampiro" and "Unguento Anti-Vampiro" which have been used with good results in Yucatan, Veracruz and Oaxaca. Extreme care must be taken to prevent this dangerous poison from being handled by unauthorized persons, children or pet animals.

Vampire Bat Control Research

General Considerations: Improved vampire bat control must be based on an ecological approach in which all available techniques are consolidated into a unified programme of integrated control. Every known method, to control vampires should be used and will be limited only by the convenience of application and cost. Such an approach can use biological, chemical, physical and regulatory techniques. These cannot be fully developed until basic information is available on two points. First, there must be a thorough understanding of the ecosystem in which the bats live, including population dynamics. Second, the population levels which cause damage must be determined. Such information, including the life history, is either scanty or entirely lacking for vampire bats.

Integrated Control

This is based on the following principles:

1. The ecosystem as a whole is considered as one unit. The major interactions of its components must be understood to successfully manage vampire bat populations.
2. The population level at which vampire bats cause damage or become a nuisance varies from one area to another. Control measures should be applied to keep local vampire populations below tolerated levels in high risk areas, rather than attempting to eliminate them (which is probably impossible).
3. No single technique should be relied upon to provide a satisfactory solution for any given situation.

k. The application of a method, such as a broad spectrum pesticide, may have undesirable side effects.

Approaches to Vampire Bat Control Research

There are a number of possibilities which may, in time, yield satisfactory results. All require both laboratory and field studies. Priority should be given to those methods which will destroy vampire bats on or about their victims since this is a highly selective approach and should prevent vampire bat attacks on livestock. The destruction of vampire bats within their roosts may yield long term results but will be more difficult due to the inaccessibility of bat roosts and the association of vampire bats with other bat species.

There are two general approaches to the reduction of troublesome populations, in this case, vampire bats: 1) Conventional Methods of Control. 2) Biological Control.

Conventional Methods of Control

a) Chemical control such as attractant, repellents, toxicants, anesthetics, stupefacients.
b) Physical control to improve traps, nets, devices to use motion, shape, color, light, odor.
c) Electronic control using sonic and ultra sonic devices.
d) Bounty payments seldom work and should not be considered.

Biological Control

I have followed Howard's definition of biological control which is an attempt to reduce the population density of vampire bats (by increased mortality, reduced natality, causing a significant emigration) either by increasing predation, habitat manipulation, the introduction or stimulation of epizootics, or by the application of antifertility agents (19).

Biological Control Versus Chemical and Physical Control

At the present state of knowledge there is no immediate prospect for the development of an effective biological control of the tremendous vampire bat population. It is possible that certain chemical or physical means may be effective. However, if a bioenvironmental control can be found, it will undoubtedly be a more satisfactory weapon certainly than chemical control since it will be effective for a longer period of time and be less likely to have adverse side effects.

Biological control is applied ecology and aims at the regulation of population levels rather than the destruction of individuals. It will intentionally modify, If possible, biotic elements in the vampire bat's environment (18, 19). The present possibilities for biological control are: a) Predators - natural and introduced; b) Habitat or environmental manipulation; c) Disease; d) Parasites; e) Chemosterilants or Genetic Manipulation.

a) Predators

Natural predators should be sought, although it is highly doubtful whether they could be considered effective control. Unfortunately, natural predators, such as owls, opossums, snakes, which are known to feed upon bats (vampires not reported) are themselves hunted by man. It should not be overlooked that man is the most important predator of vampires and up to now has made only the progress mentioned in this paper. It has been pointed out to me, in semi-jest, that since man has had a direct impact on wild animal populations (primarily by using animals as a source of food)—that if man could be induced to feed upon vampire bats this would reduce their populations. In New Guinea and Australia, the large fruit bats called "Flying Foxes" are frequently eaten and are said to be very tasty. These fruit bats

unfortunately are not eaten where they damage fruit crops, so this type of control has not been tested. In Latin America where blood-sausage is relished by many people, it has been suggested that a blood-drinking bat could be added to the diet!

Howard cautions that the intentional introduction of predators to control troublesome vertebrates, obviously should not be undertaken until after all potential ecological consequences have been carefully considered (19).

b) Habitat or Environmental Manipulation

After the various vampire ecosystems are studied and the major interactions of its parts are understood; it may be possible to manage vampire populations successfully. I believe that the microclimate of the vampire bats[1] roosts, especially temperature and relative humidity, are two major factors. The recently observed northward movement of Desmodus, Diphylla and Diaemus in northern Mexico toward subtropical and temperate United States and the southward extension of the range of Desmodus in Argentina (6) may best be explained by the bats finding suitable daytime roosts which permit them to forage at night in temperatures from 0° to -10°C where ponds are covered with ice and the bats observed attacking livestock during a snowstorm at temperatures which would normally be fatal to vampires without roosts in which they can keep warm. Any habitat manipulation, according to Howard, that effectively reduces the pest will very likely alter the entire ecosystem (19). However, if vampire roosts could be effectively manipulated to be unattractive to vampires (without dynamiting or gassing the roost) this might also affect other species of bats found in association with them.

c) Disease

In recent years some thought has been given to the introduction of some specific pathogen or disease which could start an epizootic among vampire bats similar to myxomytosis used against the rabbit in Australia. New Castle Virus fatal to poultry also has been suggested. However, disease as vampire control deserves close study. Before any disease causing organism can be an important control of these bats, more information is needed on the complete ecology of the agent; further, epizootics are usually only temporary. Herman has pointed out some basic rules which must be carefully considered concerning the use of disease in vertebrate control (15): applied to vampires--

1) The pathogen must be demonstrated to be highly pathogenic to vampire bats. Herman points out that usually a disease which occurs normally on the subject species is not a potential applicant, or it would already be doing an adequate job. While rabies is considered to be a disease of overpopulation and invariably fatal, vampire bats have developed an unusual tolerance to the virus. Thus, the sought for pathogen is more likely to be an organism exotic to vampire bats.

2) The potential killing power, residual duration and ultimate resistance must be anticipated. Therefore one should strive for as complete knowledge as possible concerning the long range consequences to the total population and survival of vampire bats.

3) The pathogen must be host-specific, for a disease introduced into vampire bats must not be a threat to other bats, livestock or man.

4) The pathogen must be available. There must be a sufficient supply of the infective material for the first implant, but the natural environment must be favorable for its perpetuation if the desired result is to be achieved. If a vector or intermediate host is essential, it must be present in the environment.

5) Finally, if initiated, the control program should be monitored in every detail to ensure its progress in the direction anticipated without adverse detrimental side events not anticipated.

d) Parasites

While the ectoparasites of Desmodus have been collected and studied to some degree no intensive collection of the endoparasites have been collected or studied. This is virtually an unexplored field, the results of which might be the desired control.

e) Chemosterilants and Genetic Manipulation

Antifertility agents may be an excellent approach to vampire bat control. If the bats could be induced to take "the pill" in some manner (perhaps introduced into the bloodstream of their hosts to be ingested by the bats) this would be a safe method to artificially reduce their reproductive rates. If these rates could be suppressed by the use of some economically efficient material, the need for toxic chemicals would be lessened, thus reducing

the contamination of the ecosystem. Lethal genes, male producing genes and genes which control the number of generations should deserve more study. Hormones which when introduced into the vampire are lethal or may influence behavioral and physiological changes.

Suggested Areas of Research

Vampire bats are powerful fliers and their range spans two hemispheres covering a wide diversity of habitats. The bats should be studied within natural regions without respect to political boundaries. Some investigators tend to avoid duplication of efforts. However, this field has so many possible variables that duplicate studies should be encouraged since in different areas different results may be obtained, indicating that bats respond differently under various conditions.

Studies such as taxonomical, physiological and parasitological may be undertaken in temperate zone and high altitude laboratories. Behavioral studies undertaken in zones where vampire bats do not naturally occur must when interpreting their results take into consideration such limiting factors of stress, altitude, space, temperature, humidity, as well as the difficulties encountered in transporting the bats, which may elicit abnormal or unusual behavior.

Despite the tremendous damage to livestock caused by vampires, surprisingly little is known of their life history and ecology. Through increased study vital links may be broken to control the bat or the disease through effective measures. Teamwork between zoologists and ecologists, in conjunction with the epizootiologists and virologists (with the assistance of other disciplines) acting as a team is the only satisfactory method to achieve this goal.

With regard to ecological studies of vampire bats, funds, space, time and manpower limit any programme. A basic programme should include:

a) The capture and identification of the bats to define the problem.
b) The determination of population structure and numbers involved.
c) The initiation of a banding programme, if feasible, to study movements.
d) The recording of mortality and predation where possible.

Expanded programmes should include studies of: a) distribution of bats, b) habitat, c) roosts, d) food, e) behavior, f) reproduction, g) population dynamics, h) parasites, i) predation, j) diseases.

Specific Ecological and Behavioral Questions

Contained within but not specified in, the life history and ecology outline are such questions as these which require answers:

a) At what age do young vampires seek live animals on their own?
b) Care and training of young vampires. Does the mother teach the young?
c) How do vampire bats locate their prey?
d) What are their flight patterns and travel routes?
e) What are the determining factors of digesting places, i.e., transient nocturnal roosts?
f) What other species of bats roost in association with vampires?
g) Host preferences of vampire bats?
h) How to census vampire bat populations?

Space does not permit a detailed discussion of these studies. However, two require emphasis: g) and h).

g) Vampire Bat Host Preferences

If the vampire bat's wild and domestic host preferences were known, this knowledge could assist in their control and might also indicate unknown animals involved with the epizootiology of paralytic rabies. Field observations of bat bitten animals have been the primary method used to determine host preferences. Now, by using a precipitin test, it is possible to determine from ingested blood removed from the bats' gastro-intestinal tract what animals and birds have been preyed upon in any area. My studies in Trinidad have indicated that Desmodus and Diaemus have fed upon a wide variety of domestic animals, cattle preferred, in addition to a number of unidentifiable wild animals. In contrast, our studies in Mexico, thus far, suggest that vampires feed almost exclusively upon cattle, although horses, donkeys, pigs and poultry are also attacked. Studies have yet to be made in areas where domestic animals have not yet been added to the original natural hosts.

h) Census of Vampire Populations

Before any control programme can be evaluated it is essential to determine the numbers of vampire bats in any given area. At present there is no technique which will indicate what comprises a vampire population. Unless there is some means to measure the number of bats, present control will have to be assessed subjectively by recording the degree of reduction in the number of vampire bites on livestock.

Special Studies by Country and Region

Not included in the outline of life history and ecology are some studies which are peculiar to each specific region. While ideally the vampire problem should be studied regionally, since the bats live in specialized environments which cross geographic boundaries. Unless these studies receive support from an international agency, they must be carried out separately by the countries concerned. FAO could assist these countries in establishing priorities of investigation.

The incidence of paralytic rabies closely follows the range and distribution of vampire bats, particularly Desmodus rotundus. The disease has been recorded from all countries, from Mexico to Argentina, including Trinidad (but not the West Indies) with the exception of Uruguay, Chile and Peru. Countries which have reported vampire bat control programmes are: Mexico, Guatemala, El Salvador, Venezuela, Trinidad, Colombia, Brazil and Bolivia. The types of control used have already been mentioned. All countries could profit by having well-trained teams of government bat control officers, patterned after Trinidad. In large countries where it is impractical for bat control teams to cover the entire country, the team or individual officer, could instruct interested livestock owners and associations such as the cattlemen's associations in the various techniques currently used successfully and advise on the method that would be most successful in their particular area.

Mexico

1) Should determine the northernmost existence of vampire colonies on both coasts. A constant surveillance should be maintained for any northward movement. The finding of a single vampire north of its known range may only indicate a migrant wandering off course.
2) Should determine the highest elevations at which vampires occur and the factors which influence this.
3) Should determine whether there is a seasonal migration between the higher and lower elevations at the change from dry to wet season and whether this correlates with weather coming from the United States of America.
4) Should determine the vertical distribution of vampires in the steep canyons where the tops are cold and the bottoms are either sub-tropical or tropical. Would any movement of cattle, up or down, show a difference in vampire attacks?
5) Should determine the effect on vampire bats of the "northers" which cross the Gulf of Mexico, particularly during the dry season.
6) Should study the ecology of the vampire bats in Yucatan or the Yucatan Peninsula. It is important to find out the exact factors which determine vampire roosts and to what extent the natural wells or "cenotes" harbor vampire populations.
7) Should determine the microclimate of such man-made roosts as mines, culverts, tunnels, wells, buildings and archeological ruins.
8) Should investigate the possibility that the Pre-Colombian people were well acquainted with vampire bats as is indicated by the panteon of gods. Perhaps, methods of control were used.

Yucatan Peninsula, British Honduras, Northern Guatemala (Peten)

1) In Yucatan, especially, determine vampire roost preferences.
2) Determine the effect of "northers" and other extremes of weather such as hurricanes.

Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama

1) Few studies have been made concerning the vampire bats of Central America with the exception of as yet unpublished data in Costa Rica. Priority should be given to the cattle raising areas and where small animal production, such as pig and poultry production is being encouraged in the mountainous areas.
2) In Nicaragua, determine whether a study of the islands of Lake Nicaragua would be of value.
3) In Costa Rica, determine whether a vampire bat study would be of value in the Peninsula de Nicoya and other cattle raising areas.

4) In Panama, determine whether a study between western and eastern Panama would be of value, including the Peninsula de Azuero.
5) Determine whether a vampire study would be of value in the area decided upon for a new canal.

Colombia

1) The following areas would be of value to study: Western or Pacific side of the Andes; Amazon forests; Atlantic coast from Santa Marta to the Venezuela border.
2) Ecological study of the Sierra Nevada de Santa Marta.

Venezuela

1) The following areas would be of value to study: Zulia region around Lake Maracaibo and the Andies; a collaborative study with Colombia on the western side of the Gulf of Venezuela; the Llanos; Isla Margarita (said to have a large population of Diaemus youngi); a collaborative study with Trinidad and Tobago of the Paria Peninsula and the land bordering the gulf.
2) A collaborative study with Trinidad and Tobago to include an extensive vampire bat banding programme to determine the extent of migration between the two countries.
3) A special study to determine whether there is a east-west annual migration of Desmodus dependant on the wet and dry seasons, from southeastern Venezuela to the State of Lara. This migration is said to start at the onset of the rainy season by November while the eastward return starts in December. If true, this movement may have bearing on the suspected inter-change of vampires between Colombia, Venezuela and Trinidad. If this exists determine whether this migration correlates in time with the northwestward spread of paralytic rabies.

Trinidad and Tobago

1) The long history of vampire bat research in this country should continue. Because of its location, any control programme could be easily assessed and basic studies pursued.
2) Continue search for the third vampire bat Diphylla ecaudata found on the mainland.
3) See item 1 and 2 Venezuela.
4) Surveillance of the increased cattle (dairy and meat) programme to determine the extent of vampire predation.
5) Surveillance of vampire populations. With the rapid development of Trinidad, it will be important to observe the behavior of vampire populations while their roosts are destroyed and their food supply increases. A similar situation may not develop within the rest of Latin America for many, many years.
6) Use the bat control teams to train other teams either in Trinidad or other countries.
7) Surveillance of Tobago for vampires. A food supply is present, roosts are available and vampires are now known to be able to fly the less than 20 miles distance between the two islands.

Guyana, Surinam, French Guiana and Adjoining Brazil and Venezuela

1) Ecological studies should be made in the following areas: Islands of the Essequibo River, Guyana.
2) Studies of the Guiana savannahs (Rupununi) between Venezuela, Brazil and Guyana, including the Intermediate Savannah, Guyana. These are the cattle raising areas.
3) Ecological studies in Surinam and French Guiana to compare with Guyana and Brazil.

Brazil

1) Ecological studies could be made collaboratively with the 11 countries bordering Brazil.
2) Ecological study of the four major morphoclimatic regions (27) as follows:
   a) Amazonian (and Guianan) hylaea (rainforest);
   b) Atlantic Forest (eastern Brazil);
   c) Central Brazilian cerrados (States of Minas Gerais, Goias and Mato Grosso);
   d) Northeastern Brazil caatingas (dry areas between the two forests and cerrados).
3) Study of northeastern State of Ceara where cattle raising is difficult due to bats.
4) Study of the gallery forest along the rivers of the cerrados which enter the Amazon.
5) Vampire bat host preference studies should be made in those areas where domestic animals have not yet been introduced. Since vampires are found widely over Brazil, suggested areas are the hylaea and the gallery forests.

Uruguay

1) Since paralytic rabies has not yet been reported from Uruguay, an interesting study would be to determine why. There does not seem to be any ecological barrier between Brazil and Uruguay. The Uruguay River between Argentina is no barrier. The Brazilian states of Rio Grande do Sul, Santa Catarina and Parana are famous in the history of vampire bats and paralytic rabies. Why the disease has not jumped a non-ecological barrier is of interest.
2) Surveillance should be maintained on the southernmost vampire populations now reported from Minas, a short distance northeast of Montevideo--this city being south of Buenos Aires.

Argentina, Paraguay

1) Argentina should determine the southernmost existence of vampire populations, now thought to be at Cordoba (32° 4O'LS).
2) An interesting physiological study would be to understand how Desmodus populations can tolerate cold. Crespo reported a mule bitten by a vampire in May 1953 at an elevation of 2,600 m at a temperature of -6°C. He also reports cattle bitten by vampires all during the winter when nights have intense frosts and snowstorms (6). This is important in light of data reported that cold in Mexico limits the northern range of Desmodus rotundus, the same species found in Argentina (20). These studies showed that vampires died below 20°C. The investigators conclude "that the determination of the lowest ambient temperature (which Desmodus tolerates) seems pointless." I believe otherwise.

3) A study should be made of the vampires in the Gran Chaco of Argentina and Paraguay.

Chile

1) Paralytic rabies has not been reported from Chile. Desmodus rotundus is confined to a transition zone between the temperate and subtropics which is a narrow strip of desert coast in the north adjoining Peru and extending to the Provinces of Tacna and Tarapaca south to the Rio Loa. Desmodus is also found from Coquimbo to near Valparaiso. Surveillance should be kept on any recently introduced livestock. A blood meal host preference study would be of interest to determine what these bats are feeding upon. Any domestic animals within the range of the vampire could well be attacked. The Andes are an ecological barrier between Argentina and Chile so that Chile may remain free of paralytic rabies.

Bolivia, Peru and Ecuador

1) Ecological studies should be made of the vampire populations on both the Pacific and Amazon side of the Andes in Ecuador and Peru. This is important since Peru has not yet reported paralytic rabies. An effort is being made to clear the Amazon forest and introduce cattle which may then be rapidly subject to vampire predation.
2) Host preference studies should be made in the forest areas prior to the introduction of livestock.
3) Host preference studies should be made on the bird guano islands off the coast of Peru where the vampires feed upon sea birds and sealions (6).
4) Vampire bat studies should be made in the cattle areas of Bolivia to determine whether the largest rodent in the world, the Capybara, Hydrochoerus hydrochoerus is attacked.

Conclusion

The vampire bat problem extends from northern Mexico to central Argentina. Over this area it transmits, paralytic rabies, one of the major obstacles to the raising of livestock in the area. The entire problem requires definition. Present control measures could prevent the loss of many animals and should be continued until such time as newer methods are placed into operation. FAO, could if requested, assist these countries.

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