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ABSTRACT: Because of the limited resources of most Latin American countries, an ecological strategy for controlling bovine rabies through elimination of vampire bats is proposed instead of attempting total eradication. The strategy is essentially a combination of one or more of the anticoagulant control techniques applied with knowledge of the epizootiology of vampire rabies. Since rabies outbreaks in vampire bats are migratory, each outbreak is studied to determine the direction and velocity of its course, then an area is selected in its path where vampires are eliminated, forming a barrier and resulting in elimination of the outbreak.

Since the publication in 1972 of two new and quite effective techniques for eliminating vampire bats through different methods of administering anticoagulant (Linhart 1972; Thompson 1972), there has existed the reasonable feasibility for controlling bovine rabies in Latin America. Both the U.S. AID and the Pan American Health Organization have sent specialists throughout South and Central America teaching the techniques. Yet today bovine rabies remains an important adverse factor impeding development of the cattle industry from Mexico to Argentina. The reason is the impracticality of attempting widespread elimination of the species. In most countries where vampire control teams exist, efforts are scattered and sporadic, tending to respond to alarm situations. Likewise where teams attend to outbreaks of bovine rabies, their efforts are mistakenly directed to those ranches where cattle have died. This report outlines an ecological strategy for controlling bovine rabies which is economically feasible for most countries. The method has been successfully applied in Venezuela and Brazil.

Understanding the ecological strategy suggested here requires a comprehension of the epidemiology of rabies in vampire bats as well as some knowledge of the social behavior of this species.

Bovine rabies is caused by the same virus causing rabies in dogs and other animals. The principal vector of bovine rabies in Latin America is the common vampire bat (Desmodus rotundus). The disease has been known since the Spanish Conquest, when men and horses were bitten by vampires and contracted rabies. There is little relationship between bovine and canine rabies since the ecology of the virus differs greatly within different hosts. Clearly, when a rabid dog, fox or skunk bites a cow, it may later succumb to rabies; but the theme of this paper is the control of the disease produced by rabid vampire bats.

The name of the disease varies from country to country, and bovine rabies has long been known as "rabia paralitica bovina" (bovine paralytic rabies), or frequently "rabia paresiante" (paralytic rabies), while in other countries it is known as "derriengue", "mal de caderas", "tumbi baba", etc. The symptoms of this disease in cattle may be confused with other diseases, such as Aujesky's disease, tick bite paralysis, encephalitis, and others. The only accepted diagnostic tests are those made with tissues; that is, fluorescent antibody technique, mouse innoculation, and Seller's test, all with cerebral material from suspect animals. Today the disease is found throughout the distribution of the vampire bat, that is from central Mexico in the north, throughout Central and South America to northern Argentina.

From the ecological viewpoint, those regions where vampires are found have suffered many changes since the arrival of Europeans to the Americas. Many of these changes have favored the vampires. Today there are many large domestic animals where previously there were few or none. Likewise of importance is the increase of sites which can serve as roosts such as mines, tunnels, wells, barns, etc. Today there are probably many more vampires than previously and their concentrations favor the spread of disease. With the opening of new virgin lands for cattle future losses will increase.

In the past, with the exception of one technique (Greenhall 1964), in order to apply control methods, such as the use of fire, dynamite, insecticides, etc. the principal problem lay in the difficulty of finding most of the vampire roosts. Thus control of bovine rabies through controlling the vector, the vampire bat, was not feasible. Consequently, effective programs were based on cattle vaccination. The vaccine is effective in respect to saving the life of the vaccinated cow, but since cattle play no role in the epizootiology of rabies in vampires, outbreaks continued as a potential danger to non-vaccinated animals and man himself.

In recent years advances in the field of control of hematophagous bats and also in knowledge of the epizootiology of rabies in these vectors, offer together hope for the effective control of bovine rabies through strategic elimination of these vectors. Linhart et al. (1972) have demonstrated a new method of control of vampires utilizing topical treatment with an anticoagulant. The treated bats return to their roosts where they contaminate others of the colony, frequently eliminating all. In the first tests, chlorophacinone was used at 50 mg per 1.5 ml of vaseline; later others have used various anticoagulants with success: diphacinone at 15 mg/ml, and warfarin at 50 mg/ml. The latter two substances are most frequently used now.

EPIDEMIOLOGY OF RABIES IN VAMPIRE BATS

Until the publication by Lopez et al. (1969) there was no observable pattern in the epizootiology of bovine rabies. These authors by means of examination of voluminous data from northern Argentina, demonstrated that bovine rabies entered this country from the north and spread gradually southward. They studied an outbreak discovered in the Province of Salta on the frontier with Bolivia and followed its progress to the south. It was estimated that the average distance traveled annually by this outbreak was 40 km. This pattern of movement of rabies virus was observed previously by Johnson (1971) and termed a mirgratory epizootic.

Delpietro et al. (1972) in Argentina, reported on different patterns of neutralizing antibody and rabies virus isolation found in vampires in zones classified as epizootic areas, uninfected areas, and enzootic areas (in recess). In the area in recess rabies virus was not found in saliva or tissues, but an antibody rate of 24% was found. In the epizootic area rabies virus was isolated from 24% of the vampires, but antibody was not found in their sera. And finally, in the uninfected area, neither virus nor antibody was detected.

Lord et al. (1975) reported a study of the epizootiology of rabies in vampire bats in northern Argentina. Vampire populations were studied opportunistically, before, during and at varying intervals after outbreaks of bovine rabies. A total of 1,024 vampires were examined for detection of antibody and virus, and an additional 83 were examined for virus only.

Only rarely did neutralizing antibody appear in those sera samples taken before outbreaks of bovine rabies. Of those vampires captured during outbreaks, a low proportion of samples were positive for antibody. However, variable proportions of positive samples (including some high rates) were obtained from vampires taken at varying intervals after outbreaks. In this study eleven virus isolations were made; in all cases they came from vampires captured during or very shortly prior to outbreaks of bovine rabies.

It was suggested that rabies virus acts in vampire populations in the same manner as several other viruses act in other hosts. That is, the virus infects many individuals, of which some die and others survive, demonstrating their exposure to virus by means of antibody. With time, the virus disappears from the population of vampires because removal by death and immunity lowers the density of susceptibles to below the threshold of contagion and does not return until the incorporation of an adequate number of new susceptibles (either by birth or through immigration).

The results of these studies indicate that epizootics of rabies in vampire bats are migratory, always moving in a given direction. Likewise they tend to have a periodicity of four or more years between outbreaks.

These conclusions have been confirmed through observations on the migratory nature of bovine rabies outbreaks. A well documented outbreak in northwestern Argentina has already been described (Lopez 1969). Another outbreak of bovine rabies was first observed in May, 1970 on Apipé Island, in the Paraná River, Province of Corrientes, situated in northeastern Argentina (Delpietro 1972). This outbreak followed a complex trajectory. On reaching the mainland, the outbreak separated in two, the part traveling west following the river terminated near the town of Ita Ibaté in March, 1971. The part moving east divided also with one extension terminating near the town of Eldorado, Province of Misiones, the other part moved southward following the course of the Aguapey river to its confluence with the Uruguay river. Here the outbreak extended south stopping spontaneously near the city of Alvear. Another part crossed the Uruguay river and divided into three parts following different trajectories in the State of Rio Grande Do Sul, Brazil, where competent specialists eliminated the problem in 1973, following the strategy outlined in this paper.

Although they remain unpublished, migratory epizootics of bovine rabies have been observed in Trinidad, Surinam, Brazil (near Recife) and Venezuela. An outbreak of bovine rabies was investigated near Guasipati, State of Bolivar, Venezuela in November, 1975. The information collected indicated that this outbreak had been following the course of the Miamo river for three years, at an average speed of 20 km per year. This outbreak was also eliminated by the technique described here.

The tendency for outbreaks of bovine rabies to follow the course of rivers during their migrations is explicable through the great number of roosts found on their margins, especially large hollow trees. Besides, some rivers form cliffs, which frequently have natural caves. Other topographical features may provide many roosts for vampires, such as foothills of mountain chains which frequently also have cliffs with caves. Geological areas often providing caves useful to vampires are those where limestone outcrops occur. In the Gran Chaco there are zones where the presence of underground water permits digging of numerous wells. These wells, lined with wood beams or bricks, provide excellent roosts for vampires. Where these wells abound dense populations of vampires develop, which were involved in outbreaks already mentioned in northwestern Argentina (Lopez 1969; Johnson 1971; Lord 1975).

When the epizootiology and history of bovine rabies outbreaks is studied, in most cases it is possible to understand why each outbreak is following a given course. Usually it is due to a combination of ecological, topographical and geological features which provide the necessary roosts, but more important, this determination allows prediction of the future course of the outbreak with a certain degree of security. With this knowledge it is possible to interrupt the outbreak by means of removal of the vampires from an area in its path.

The seasonal aspect of the epizootiology of bovine rabies, first reported by Johnson (1948) in Mexico, has been given little attention. In Venezuela an analysis of the relation of bovine rabies and precipitation showed a postive correlation ($r = 0.83$) which was statistically significant at the

95% level. In Argentina and Mexico bovine rabies also appears to be seasonal, although the relation to precipitation appears to be inverse. The relation between bovine rabies and rainfall is not thought to be cause and effect, but rather that both are seasonal and the correlation is only coincidental. What may possibly be found to be related to the seasonal periodicity of bovine rabies is the seasonal variation in vampire reproduction. Until recently (Turner 1975), publications did not recognize seasonal changes in vampire reproduction since pregnant females may be found in all months. A study made in Argentina of 1,498 female vampires showed a notable variation in prevalence of pregnancy during the year (Lord, ms.). While pregnant females were found in all months, the proportion varied from 10% to 70%. This seasonal reproduction results in an annual periodicity of the entry of young vampires (susceptible to rabies) into the population. Conceivably the seasonal variation of bovine rabies may be linked to the periodic increment of new susceptibles to the vampire population. Nevertheless, the existent information is scarce and should be amplified to verify this hypothesis.

BEHAVIOR OF VAMPIRES

Knowledge of the behayior of vampire bats is of importance in understanding the epizootiology of rabies in this species, which bears on the correct application of the control method. That is, interest in the behavior of vampires provides the knowledge necessary to accomplish the most efficient and practical control of their populations, with the goal of eliminating rabies outbreaks and thus terminating cattle losses.

The author, together with colleagues, has studied the behavior of vampires both in special cages under controlled light conditions, and also in their natural caves. The studies were begun in Argentina and continued in Venezuela (Lord, in press).

Observations of vampires resting in their roosts revealed the many opportunities that rabies virus has for transmission between these bats. Besides selecting dark, humid and poorly ventilated roosts, all conditions which facilitate virus transmission by aerosol, vampires participate in communal grooming which can result in direct transmission of virus in saliva of infected individuals to the wounds of others, or mouth to fur to mouth transmission (rabies virus can penetrate the buccal mucosa, but not the mucosa of the stomach) (Baer 1970).

Hanging by one leg, the vampire wets the claws of the free foot it its mouth, then proceeds in combing itself. It is common to observe social licking between colony mates, especially under the wings and on the neck near the ears. Thus the ease with which saliva containing rabies virus may be transferred between colony members should be apparent.

The social organization of vampire bats, besides being interesting, likewise is importantly related to the epizootiology of rabies. Vampire colonies are organized into principal colonies comprising all the females plus a few males, and satellite colonies made up of bachelor males. In the principal colony one of the males is dominant and the only other males permitted are immatures accompanying their mothers. Around the principal colony, which usually occupies the preferred niche in the cave, occupying niches of lesser category are the satellite colonies of males. When roosts are in trees or smaller caves, the principal colony occupies the better roost and the satellite colonies may be scattered about in trees or caves of lesser desirability. Each evening some of the males from these satellite colonies try to enter the principal colony. The dominant male immediately opposes their entry and expels them. Although these fights may be vigorous, sometimes incurring bites, more frequently the encounters are bluff and intimidation. Usually the dominant male is victorious.

In the satellite colonies of bachelor males a greater intensity of fighting is observed with real bites, as manifested by the numerous scars and wounds on these males and drops of fresh blood scattered on the walls of their roosts. Recapture studies of vampires marked with numbered bands indicate that the males of the satellite colonies travel farther, even moving up to 100 km, although most recaptures indicate a home range of less than 15 km. The females may visit satellite colonies briefly, and the males of these colonies may enter the principal colony when the dominant male leaves to feed. Visits between neighboring colonies of vampires are common. This tendency results in an indirect communication between nearly all colonies in an area in the form of a chain or network. It is, thus, easy to comprehend the manner in which rabies virus may spread from one colony to another.

SURVEILLANCE

Surveillance is a requisite for the control of all diseases and bovine rabies is no exception. Many countries already have good surveillance systems, if not for bovine rabies, then for other diseases which can be utilized. The majority of these systems have as their goal indication of the magnitude and geographical location of diseases as well as their periodicity, etc.

With the goal of controlling bovine rabies, the information required is somewhat more specific than normally needed for other purposes, but the difference is small and generally it is sufficient to include one or two more questions in the routine questionnaires.

The size of bovine rabies outbreaks varies between 1 or 2 km in width to perhaps a maximum of 75 km, with the majority being about 5 to 10 km wide. This size indicates that the usual collection of data by means of political divisions such as municipalities, districts, etc. is not sufficiently detailed to show the location of an outbreak of bovine rabies. Thus it becomes necessary to indicate the location of properties, ranches, farms, estancias, etc. where cases have occurred. Since the majority of maps do not include such divisions, it usually is necessary to record the direction and distance to the nearest town.

Another matter of importance for control of the bovine rabies outbreak is to determine its direction of movement. Knowledge of the history of the outbreak, obtained through interviews with affected cattlemen, for two years is sufficient to realize where it came from and in all probability, where it should go. Likewise this same information provides an idea of the annual velocity of the outbreak. Most outbreaks travel from 20 to 50 km per year.

Of prime importance in the investigation of an outbreak is obtaining cerebral material from one or more of the most recently dead animals. This material should be preserved in ice or frozen for delivery to the diagnostic laboratory. Only after laboratory confirmation can one assume that most cases in the outbreak are rabies.

DETERMINATION OF THE CONTROL AREA

The control area is not located where cases of bovine rabies have already occurred. Where cattle are dying the outbreak in the vampire population has already passed its peak and is in recess, however beyond the bovine outbreak new susceptible vampires have already been infected (Lord 1975). Thus, the control area must be located in the path of the epizootic, anticipating its direction of movement.

A rectangular area is designated where vampires will be eliminated thus forming a barrier in the path of the on-coming outbreak. The border of the control area closest to the outbreak should be about 20 km in front of the latest bovine case if the speed of displacement is about 40 km per year. If the velocity of the outbreak is less, for example 20 km per year, then the control area may be located 10 km in front of the latest cases. The width of the control area should exceed the width of the outbreak by 15 km on each side (except if some topographical feature indicates otherwise) and the depth of the area should be also 15 km. For example, if an outbreak is 5 km wide then the control area should be 35 km wide by 15 km deep.

Using a detailed map of the area, it is convenient to mark off the area selected for vampire control. The cattlemen of the area should be contacted and advised of the plan of the campaign, requesting their collaboration. Usually it is not necessary to utilize all properties to obtain complete coverage. The area should be blocked off in squares of 25 km^2 (that is 5 by 5 km) with the ideal distance between control sites being 5 km.

Cattlemen are requested to keep all or at least 50 cattle in a corral each night for a week prior to the night of control activities on their property. Habitual maintenance of cattle in a corral entrains vampires to come to that corral and significantly increases the capture rate.

WORK PLAN FOR CONTROL OPERATIONS

It is obvious that the size of the outbreak will determine the size of the control area and thus affect the effort required. Usually it is convenient to schedule the work so that two adjacent properties may be worked on the same night.

Control operations should begin with those properties most centrally located in the control area and farthest from the outbreak. The control progress should be systematic, proceeding toward the outbreak and laterally. Because vampire bats avoid flying on bright moon-lit nights (Flores Crespo 1972), control operations should he planned to coincide with the new moon. Thus, monthly, there are two weeks which are superior for vampire capture, the week before and the week after the night of the new moon.

The following procedure has been found to be suitable for control operations on each property. At 4:00 PM (1600 hours) the control team begins placing the nylon mist nets around the corral where the cattle will sleep. The nets should cover all approaches to the corral, but be sufficiently distant (at least one meter) to keep from becoming tangled with the corral if a wind comes up. Until dark the nets should be closed high on the poles to avoid capturing birds and to allow cattle to pass beneath. Just before dark, after the cattle have entered the corral, the nets are opened. Periodically, every half hour or so during the night, the nets are checked and vampires removed and placed in a holding cage (other bat species are released). Normally work can be terminated at midnight because by that time more than 75% of an entire night's capture has been taken. The nets are taken down and the vampires treated with anticoagulant and released. Approximately one gram of the anticoagulant mixture is applied to the back of each vampire.

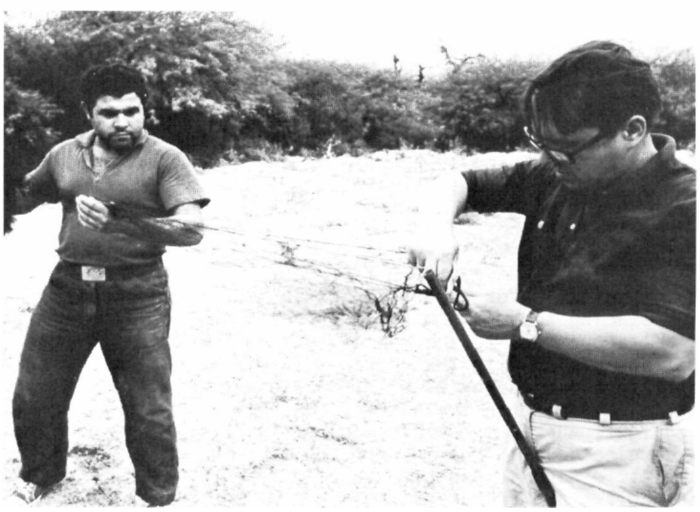
Details for the placement of nets for the capture of bats are given in English in the publication by Greenhall and Paradiso (1968) and in Spanish by Mitchell and Burns (1973).

DISCUSSION

When Linhart et al. (1972) published the new technique for controlling vampire bats by topical application of an anticoagulant, others of the same team revealed another new method which also utilizes anticoagulant. This other method, published by Thompson et al. (1972) consists of applying the anticoagulant into the rumen of the cattle. The anticoagulant then circulates in the cattle's blood, killing any vampire which feeds on them for up to 3 or 4 days afterwards. Studies have shown that anticoagulant residues in meat and milk pose no hazard to human health (Bullard 1977). Later Flores Crespo et al. (1974) reported another system of vampire control through application of anti-coagulant to the roost niches of vampires.

Face of a vampire bat (Desmodus rotundus]

Application of anticoagulant to a vampire bat.



Setting a mist net for capturing vampire bats.

Removing a vampire bat from a net.

The most recent control method developed is, in fact, an improvement of the systemic method (Thompson 1972). In this method, also published by Flores Crespo et al. (1979), the anticoagulant is inoculated intramuscularly into the cattle, which is considerably more practical.

Still another method of controlling vampires is a slight modification of the technique reported by Greenhall (1964), in which anticoagulant in vaseline is substituted for strychnine syrup, which is applied to fresh bite wounds on cattle. Because vampires habitually re-open wounds, they thus ingest the poison.

The method of treating the walls of the roost (Flores Crespo 1974) has the disadvantage that after causing the death of the vampires, the anticoagulant remains as a potential danger to other bat species which may use the niche. Delpietro (personal communication) has reported that some anticoagulants may persist actively for more than a year following application in this manner. The systemic methods (Thompson 1972; Flores Crespo 1979) have many advantages since they do not require working at night with nets, nor is it necessary to be able to identify bats. The Greenhall (1964) method with or without its modification, also has the same advantages as the systemic methods and is even easier to apply since no inoculation equipment is involved. But it is the opinion of the author that these methods are not as potent as the direct application of anticoagulant to captured vampires, since this latter method has been shown to result in the death by contamination of from 20 to 40 colony members for each treated bat.

The ecological strategy proposed here combines the anticoagulant methods (Linhart 1972; Thompson 1972; Flores Crespo 1979) with the technique of Fornes et al. (1974) to control outbreaks of bovine rabies. It is suggested that directing control efforts toward elimination of active outbreaks of bovine rabies better fits the resources of most countries, than attempting total elimination of vampire bats from extensive areas.

LITERATURE CITED

BAER, G.M., ABELSETH, M.K. and DEBBIE, J.G. 1970. Oral vaccination of foxes against rabies. Am. J. Epid. 93:487-490.

BULLARD, R.W. and THOMPSON, R.D. 1977. Efficacy and safety of the systemic method of vampire bat control. Interciencia 2:149-152.

DELPIETRO, H., DIAZ, A.M.O., FUENZALIDA, E. and BELL, J.F. 1972. Determinación de la tasa de ataque de rabia en murcielagos. Bol. Of. San. Pan. 63:222-230.

FLORES CRESPO, R., LINHART, S.B., BURNS, R.J. and MITCHELL, G.C. 1972. Foraging behavior of the common vampire bat related to moonlight. J. Mamm. 53:366-368.

________________ , BURNS, R.J. and FERNANDEZ, S.S. 1974. Evaluación de una técnica para combatir los vampiros en sus refugios. Bol. Of. San. Pan. 76:427-432.

________________ , FERNANDEZ, S.S., DE ANDA LOPEZ, D., IBARRA VALARDE, F., and ANAYA, R.M. 1979. Intramuscular inoculation of cattle with warfarin: a new technique for control of vampire bats. Bull. Pan. Am. Health Org. 13:147-161.

FORNES, A., LORD, R.D., KUNS, M.L., LARGHI, O.P., FUENZALIDA, E. and LAZARO, L. 1974. Control of bovine rabies through vampire bat control. J. Wildl. Dis. 10:310-316.

GREENHALL, A.M. and PARADISO, J.L. 1968. Bats and bat handling. U.S. Fish & Wildlife Serv. Rec. Publ. 72, 47 pp.

______________ . 1964. Bats: Their public health importance and control with special reference to Trinidad. Proc. 2nd Pest Control Conf., p. 108-116.

JOHNSON, H.N. 1948. Derriengue: vampire bat rabies in Mexico. Am. J. Hyg. 47:189-204.

___________. 1971. General epizootiology of rabies. In: Rabies. Ed. Y. Nagano and F.M. Davenport. Univ. Park Press, Baltimore, p. 237.

LINHART, S.B., FLORES CRESPO, R. and MITCHELL, G.C. 1972. Control de murciélagos vampiros por medio de un anticoagulante. Bol. Of. San. Pan. 73:100-109.

LÓPEZ ADAROS, H., SILVA, M. and LA MATA, M. 1969. Rabia paralitica en el norte argentino In: Seminario sobre rabia para los paises de la Zona IV, Bolivia, Colombia, Ecuador. Peru, Lima. Of. San. Pan., Wash. D.C. pp. 161-203.

LORD, R.D., FUENZALIDA, E., DELPIETRO, H., LARGHI, O.P., DIAZ, A.M.O. and LAZARO, L. 1975. Observations on the epizootiology of vampire bat rabies. Bull. Pan. Am. Health Org. 9:189-195.

___________ , MURADALI, F. and LAZARO, L. 1976 (In press). Behavior of captive vampire bats.

___________ and LAZARO, L. (In press). Activity patterns of captive vampire bats.

___________, MURADALI, F. and LAZARO, L. 1976. Age composition of vampire bats (*Desmodus rotundus*) in northern Argentina and southern Brazil. J. Mamm. 57:573-575.

___________, KUNS, M.L., DELPIETRO, H. and LAZARO, L. Seasonal variation in the prevalence of pregnancy of vampire bats. (ms. in preparation).

_________. 1976. Importancia de los murcielagos en la epidemiologia de las zoonosis, con enfasis en la rabia bovina. Salud Animal, Org. Pan. Am. de la Salud. Pub. Cien. N°334:89-97.

MITCHELL, G.C. and BURNS, R.J. 1973. Combate quimico de los murcielagos vampiros. U.S. Fish & Wildlife Serv. Denver, Co. 40 pp.

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

TURNER, D.C. 1975. The vampire bat: a field study in behavior and ecology. Johns Hopkins Univ. Press, Baltimore. 145 pp.