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VAMPIRE BATS

and their effect on cattle production in Latin America

The common vampire bat (Desmodus rotundus)

The interaction between vampire bats and man predates the arrival of Europeans in the new world. The Mayas and Aztecs considered vampire bats important enough to rank them as deities. Villa (1969) attributed this importance to the vampire's role in disease transmission — probably rabies. He pointed out that the Spanish conquistadors lost numerous cavalry horses to bat-transmitted rabies, and early missionaries suffered heavy livestock losses. The vampire bat continues to this day to be an economic pest and a rabies vector in tropical America.

This article summarizes some of the interesting and unique natural history of the vampire bat, its importance as a rabies transmitter and economic pest, and past methods used to control it, as an introduction to a report on the recent efforts of the Denver Wildlife Research Centre (Colorado, United States) at vampire control.

by Nelson B. Kverno and G. Clay Mitchell

Strictly speaking, the term "vampire" actually refers to three haematophagous (blood-eating) bat species in the family Phyllostomatidae. However, only one, the common vampire *Desmodus rotundus*, is economically damaging to man. This species has less specialized feeding habits than the other two and has exploited the opportunities made available by man's introduction and husbandry of livestock. The common vampire is the species referred to throughout this article.

The common vampire extends from tropical Mexico to northern Argentina. Its current range and distribution within this boundary depend on food supply, acceptable roost sites and climatic tolerance (McNab, 1973). Its density within the range, however, appears to be simply a function of food supply (Villa, 1969). Man has, in general, increased both the distribution and density of the vampire within its range. He has allowed it to spread by creating new roost sites — for example, mines, wells and aqueducts. More important, he has increased both its spread and its density by making available more food in the form of livestock (Dalquist, 1955).

The vampire bat is colonial, although its colonies are small (50-200 members). Throughout most of its range, it roosts in such shelters as caves, hollow trees and mine shafts. Vampire colonies are always clearly segregated from other bat species in the

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Fresh vampire bat bite on a horse

same roost, but vampires within the colony are quite gregarious. They roost close together and spend considerable time in contact with each other.

Vampires have low fecundity, presumably giving birth to only one young a year (Wimsatt and Trapido, 1952), but are long living. Linhart (1973) found that the age of wild-trapped vampires averaged 2.6 years and ranged up to 13 and 14 years. Also, their nocturnal habits and secluded roosts protect them from predation. Thus, the vampire's low natality is compensated by its longevity and by low predation. The contribution of the cattle industry as an additional food source has resulted in an imbalance where natality exceeds mortality, and so the population has expanded. Neither man nor nature has effectively reversed this trend.

The vampire feeds exclusively on blood. Its teeth are designed for cutting through the skin; the lower incisors are separated to permit the tongue to lap the blood escaping from the wound (Pawan, 1936). It is this unique feeding specialization that accounts for the vampire's notoriety as an economic pest and rabies vector. It is also this feature that has facilitated the development of an ecologically sound means of managing the species.

Calf with multiple vampire bat bites on face, ears and neck

Economic significance

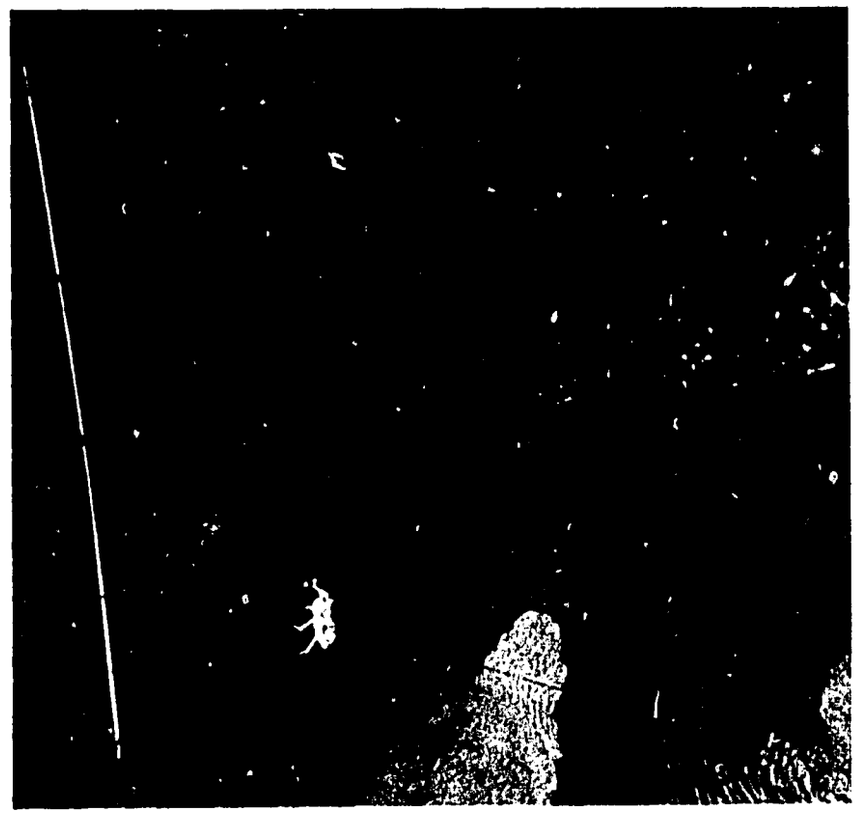
Vampires were clinically shown to carry rabies in 1911 (Pawan, 1936). Bat-borne rabies is the paralytic type, which is highly virulent to most animals, but vampires possess a degree of tolerance or reservoir ability (Pawan, 1936). In fact, an infected bat, capable of transmitting rabies, may appear healthy and not even exhibit symptoms of the disease (unpublished data, Denver Wildlife Research Centre). The virus, found in the saliva, is conveyed to other members of the colony primarily through biting (Villa, 1969). Unlike insectivorous or fruit-eating bats, the vampire is an ideal vector to host species because it inflicts a wound when feeding.

The most obvious loss attributable to the vampire is the direct loss of its livestock host to rabies. The economics of bat-transmitted rabies in cattle has not been well documented. The accuracy of reporting varies appreciably among countries, as do diagnostic procedures. However, since verification of the disease requires laboratory examination of fresh brain tissue, most deaths are diagnosed only when there are clear external signs. Even so, the estimates of bovine mortality to bat-transmitted rabies in Latin America are staggering: Acha (1967) estimated annual losses of half a million head

of cattle; Malaga-Alba (1959) estimated 1 million head; and Constantine (1970) quoted Steele's estimate of 2 million head, which he translated as a direct loss of $100 million a year. Mortality estimates are unavailable for livestock other than cattle.

Estimates of secondary losses are even more vague. Constantine (1970), again quoting Steele, reported that indirect losses approach $250 million a year. This figure is not as excessive as it may first appear, since the number of cattle bitten daily adds up to millions and the resulting blood loss amounts to several thousands of litres. The average adult vampire bat weighs 30 g and consumes approximately its weight in blood daily. With an estimated additional 20 ml of blood lost through bleeding of the wound, each bite represents a loss of about 50 ml of blood. Recently, in Nicaragua, an average of 400 fresh bites a day on a herd of 100 cattle was recorded. At 50 ml per bite, the blood loss in this herd was about 20 litres a day. The effect of bloodletting on weight gain in beef cattle and on milk production in dairy cattle has not been determined, but it will probably prove to be a major protein loss. Secondary infections and reduced hide quality due to bite wounds add further to this list of losses.

Aggregate economic losses are important statistics, for they reflect the impact on a nation's gross national product. But only when the losses are expressed in terms that the individual can relate to, is there a real appreciation of the problem and an understanding of the human anguish involved. An example is provided by the impact on the owner, his family and the employees of a moderately large ranch in Bolivia, from the following losses in 1972 to vampire bat-transmitted rabies: 200 of their 1 400 cattle, 9 of their 70 horses, 18 of their 20 pigs, and 25 of their 70 goats. Even more traumatic were the losses sustained by a smaller rancher in Nicaragua: in 1 month (January 1974), 50 of his 60 cattle died of rabies.



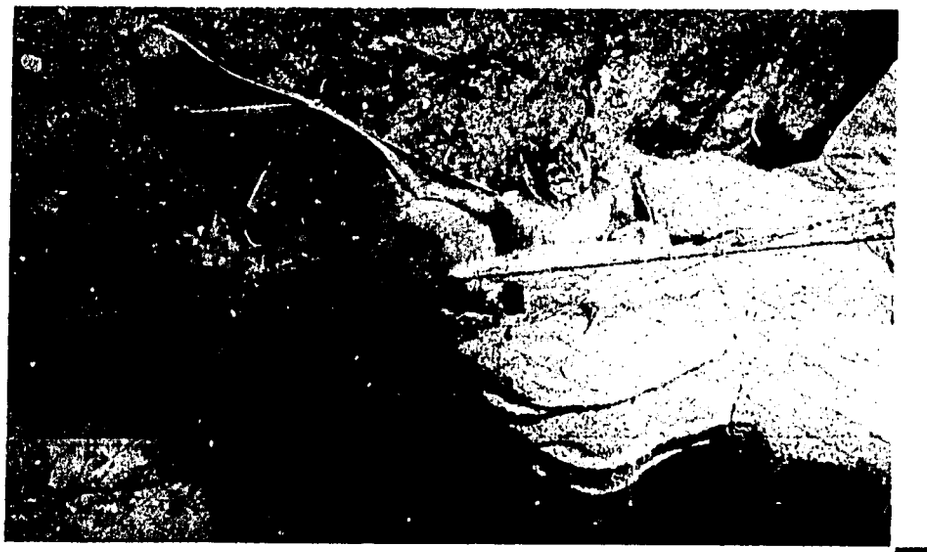
Vampire bats captured in a mist net

Deaths of single animals are often regarded as unimportant, but when one considers the innumerable cases where rural families have lost their only milk cow — often their most valuable possession — they assume real significance.

Numerous attempts to reduce vampire populations have been employed over the years. Destruction of roosts with explosives and fumigation of caves are two procedures that have proved partly effective, but their application is limited to known roosts. Moreover, these methods are not selective and have resulted in the death of large numbers of beneficial bats (Villa, 1969). Their use is therefore strongly discouraged. Poisoning vampires by applying a strychnine-syrup mixture to bite wounds on cattle has also been suggested (Greenhall, 1963). Since this method relies on the bats rebiting the old wounds, and can only be used with docile cattle, it is moderately effective at best. Greenhall (1963) also reported some success in capturing bats with mist nets placed around tethered cattle.

Other methods of control that have been attempted include electrocution (Villa, 1969), traps (Constantine, 1958) and shooting (Greenhall, 1970). None of these procedures have been really effective in solving the vampire problem.

Vaccinating against rabies is effective in combating the disease in cattle. Vaccines are available that will provide protection for as long as four years. In most Latin American countries reliable vaccines must be imported, and cost as much as US$2.50 per dose. Also, for satisfactory results the vaccines require special care in handling and applying, which they have not always received. Because of the high cost and a history of frequent failure, most ranchers do not vaccinate until they experience a rabies outbreak. Thus, as Constantine (1970) concluded, even though effective rabies vaccines are available, better protection can probably be achieved by controlling the vampire bats. It might also be noted in this connection that vaccination cannot be a total alternative to bat control,



Left: *Removing a vampire bat from a mist net*

Right: *Vampire bats roost in caves in tightly packed groups. This close body contact helps to pass the topically applied control compound from one carrier to many others.*

Below: *Treating a vampire bat with diphenadione paste prior to its release*

although modern vaccines provide a high degree of protection against bat-transmitted rabies. If bat predation remains frequent, economic losses will continue to be important even with vaccinated animals, due to blood loss and wound contamination.

Some recent efforts

Under the authority of the Foreign Assistance Act, the United States Agency for International Development (AID) requested assistance in 1967 from the U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, to conduct research on the vampire bat problem in Latin America. In June 1968 a programme was initiated through the Bureau's Wildlife Research Centre in Denver, Colorado, under the auspices of AID. The objective was to develop safe and selective methods for reducing damage to cattle by vampire bats in Latin America. The programme consisted of two elements: a laboratory team at the Denver Centre and a field team in Palo Alto, Mexico. Mexico's Secretaría de Agricultura y Ganadería, Instituto Nacional de Investigaciones Pecuarias, cooperated in the field project.[1]

This programme was the first major research effort directed toward the development of management procedures for vampire bats. The first two years were devoted mainly to exploratory studies. Laboratory investigations concentrated on the species' unique physiology and its toxicological tolerances to some potential control chemicals. Field investigations were more concerned with the species' general biology and behaviour.

Research findings

During these initial studies it became apparent that the only practical locations where the bats could be attacked were the two places where they congregated — the roost and the feeding site. It was also determined that roosting vampires spend nearly 10 percent of their time grooming themselves and each other (Flores Crespo *et al.*, 1972). Toxicology studies showed that vampires were highly sensitive to anticoagulants — drugs that interfere with blood clotting (Thompson *et al.*, 1972).

The difference between success or failure in achieving research objectives often depends upon the ability of the investigators to assimilate and utilize bits of seemingly unrelated information. Such was the case with S.B. Linhart, who conceived the idea of placing an anticoagulant, in some sticky substance, on the backs of captured bats and releasing them to carry the chemical back to the roost and contaminate other members of the colony. Although vampires feed exclusively on blood, he concluded that the colony members would ingest toxic levels through mutual grooming. To test this idea, he removed a single vampire bat from a 20-bat laboratory colony, treated it with 1.5 ml of petroleum jelly containing 50 mg of an anticoagulant drug, and then returned it to the colony. The treated bat was dead the following morning, and 18 of the remaining 19 bats died within 14 days (Linhart *et al.*, 1972).

Encouraged by the laboratory results, the team tested this procedure under field conditions in Mexico. On two ranches cattle were corralled and

[1] This cooperative research was conducted with funds provided to the Bureau of Sport Fisheries and Wildlife by the United States Agency for International Development, under the project entitled The Control of Vertebrate Pests, USDI/PASA RA(ID) 1-67.

mist nets were placed around the corrals. All vampire bats captured during the night were treated topically with petroleum jelly containing an anticoagulant and then released. When the ranches were revisited two weeks later, the number of fresh vampire bites on the cattle had been reduced by 94 and 97 percent respectively, and 95 and 97 percent fewer vampires were netted that night.

Several tests were also conducted on vampire colonies in caves, to confirm the effectiveness of treating only a few colony members and also to determine the effect on beneficial bats using the same roost. Actual counts of vampires in these caves showed that as many as 22 untreated colony members could be killed for every vampire treated. Of several other bat species in the caves, none were found dead (Linhart *et al.*, 1972).

After these initial field trials, laboratory studies were conducted to select the best anticoagulant and establish the minimum effective levels required. The final recommendation for topical treatment of each vampire was 25 mg of diphenadione.

About the same time that the topical treatment was being developed, other investigators, under the direction of R.D. Thompson at Denver, were evaluating systemic treatments of livestock with anticoagulants. This method capitalizes on the daily requirement of vampire bats for blood and the different sensitivity of cattle and bats to anticoagulants. These studies showed that the LD_{50} (dose lethal to 50 percent of the population) of a single oral dose of diphenadione to vampires was 0.91 mg/kg of body weight, but that a single oral dose of 5 mg/kg in cattle produced only a moderate, temporary increase in the clotting time of plasma prothrombin. The tendency for the anticoagulant to bind to the blood protein of cattle for several days, the sensitivity of vampire bats to the drug, and the concentrating effect in the bats due to the relatively large amounts of blood they consume in relation to their own blood supply, proved to be a lethal combination.

When cattle were injected in the rumen with 1 mg/kg of diphenadione, single feedings of the cattle blood, at 24, 48 and 72 hours after injection, killed all the vampires in the test. Field studies in Mexico confirmed the effectiveness of this systemic approach. Cattle at three ranches were

corralled and injected with 1 mg/kg diphenadione. After two weeks fresh vampire bites had been reduced 93 percent (Thompson *et al.*, 1972).

When livestock are treated systemically, chemical residues in the animals' meat and milk must be low enough for safe consumption. The workers at Denver therefore conducted preliminary tests to ensure that vampire control treatments with diphenadione would not produce toxic residues. Laboratory rats fed nothing but liver from treated cattle showed no effects (Thompson *et al.*, 1972). Likewise, calves showed no effects and no change in prothrombin clotting time when they fed exclusively on milk from cows treated at 2.75 mg/kg, nearly three times the recommended dose. More recently, sensitive procedures have been developed to analyse diphenadione residues chemically; these confirm that only traces of the drug are present in milk or body tissues of treated cattle (R.W. Bullard and R.D. Thompson, unpublished). Since diphenadione is a standard anticoagulant used in human therapy, with daily doses ranging between 2.5 and 30 mg (Martin, 1970), the systemic treatment appears to be quite safe.

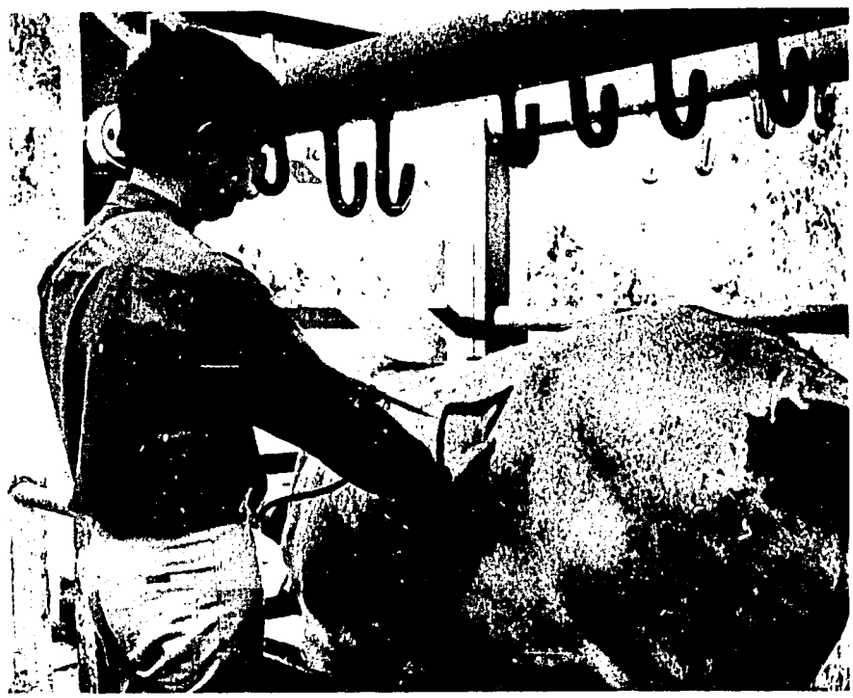
Field test results

With the excellent results from the preliminary trials, the research team began the process of field testing the topical and systemic methods and demonstrating their use to nationals in countries throughout Latin America. The results continued to be excellent. Initial reductions were almost always 90 percent or better, and vampire populations generally remained low for long periods after treatment.

How often control will have to be repeated depends, of course, on how quickly vampire bat populations recover in the area. Although vampires have a low reproductive potential, the gap may be filled by new bats moving in from surrounding areas. Homogeneous, favourable habitats, where there has been little control and where vampire populations are relatively high and uniform, will undoubtedly repopulate more rapidly than areas where vampires occur only in isolated pockets. It has generally been found that the more arid the region, the better are the chances that populations will be small and scattered, and therefore that control will be effective for long periods. But this can also happen in humid regions.

An example of this is provided by three field demonstrations of the topical method conducted in January 1972 at ranches in northeastern Brazil, in the state of Pernambuco. Two were in the humid coastal region near Cabo and the third in the arid region to the east near Aguas Belas. These ranches were revisited one year after treatment; those near Cabo were also reevaluated after 18 months. The results of these investigations are summarized in the table.

The isolated vampire bat colony at the ranch near Aguas Belas was practically eliminated; repeat control will probably not be required there for many years. The colonies at the two ranches near Cabo will probably also be slow to recover. Although the coastal climate near Cabo is more favourable for vampires, the region is extensively devoted to sugarcane growing and probably supports a low overall vampire bat population. The isolated cattle herds at the two test ranches doubtless provided the opportunity for equally isolated vampire colonies to become established and survive. Thus, fresh bites were still down 92 and 80 percent respectively 27 months after treatment.



Injecting diphenadione into rumen compartment of a cow's stomach. Note injection should be made in the area of the triangle drawn on the cow.

Safety and selectivity

The welfare of nontarget species should always be of paramount importance in the development of any control procedures. In past programmes, selectivity has often become secondary to the control of vampire bats. The two methods developed in our programme are both quite safe for nontarget species of bats. In fact, the selective removal of vampires could actually benefit other bat species in some areas by reducing competition for roosting space.

The topical method gets high marks

Results of topical application of diphenadione to vampire bats at three cattle ranches in two areas of Brazil

Ranch	Habitat	Time checked, in relation to treatment	No. of cattle checked	No. of fresh bites	No. of vampires treated	Reduction in bites after control - %
Engenho Santo Estavao, near Cabo	Coastal, humid	Before	44	73	33	
		14 days after	44	0		100.0
		1 year after	45	4		94.5
		18 months after	45	4		94.5
		27 months after	42	14		80.8
Engenho Velho, near Cabo	Coastal, humid	Before	60	67	54	
		14 days after	60	3		95.5
		1 year after	60	6		91.0
		18 months after	60	6		91.0
		27 months after	67	5		92.5
Fazenda Barra Nova, near Aguas Belas	Inland, arid	Before	195	74	80	
		11 days after	195	0		100.0
		1 year after	260	0		100.0

for selectivity, since vampires are gregarious only with other vampires. However, this method does require special training to ensure its proper application. Since the nets may catch other species of bat, it is essential that the operators receive instruction in how to identify and handle vampires (Greenhall, 1972), and that they develop sincere concern for the welfare of beneficial bats. Inherent in the method is the possibility that predators will locate and consume an occasional treated bat that has fallen from the roost. Control programmes will be too infrequent, however, to adversely affect predator populations. For selectivity, the systemic approach appears virtually flawless. This method is not only species specific, but affects only those vampires in the population that feed on treated cattle. This aspect may account for the slightly lower kills than those recorded with the topical method; all bats within a colony do not necessarily feed on the same host animals every night. The systemic procedure has the additional advantage of requiring that only the cattle be handled, and giving them injections is already a common procedure at most ranches. The chemical costs somewhat more than for the topical method but is still inexpensive. Based on current prices, treating cattle costs about $15 per hundred doses, or 15 cents a head.

Conclusions

In the brief period of five years, a team of biologists, starting with only the most basic information, developed a solution to a problem that has plagued man for centuries. During the next two years, as we move from the glow of research success into the realities of application, we will test the limits of the procedures that have been developed. No wildlife problem that covers approximately one eighth of the earth's land surface can be thought of as a single problem. The unique features in each new situation will require a programme of adaptive research to refine the procedures and correct deficiencies.

No species of vertebrate should be considered pests *per se*. Only individuals of the species are involved in pest situations. The objective of control programmes should therefore be to provide relief from the damage, not just to kill animals. Vampire bats are no exception, for they are fascinating and unique creatures. Because they have an extensive range and feed on a variety of vertebrate hosts, there is no need for concern that our control methods will eliminate the species. Nevertheless, control programmes, even those as selective as ours, should be confined to those areas where livestock values or human health are in jeopardy.

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TICK-BORNE LIVESTOCK DISEASES AND THEIR VECTORS

2. Epizootiology of tick-borne diseases

This article is concerned with aspects of the epizootiology of the more important tick-borne diseases of cattle: babesioses, theilerioses, anaplasmoses and cowdriosis. These are considered in the order in which the causal agents were discovered and described. Some of the opinions expressed are not necessarily accepted by all workers, and some statements, especially on parasites of the family Theilerlidae, are based on unpublished work.

by Gerrit Uilenberg

A knowledge of the epizootiology of tick-borne diseases is of fundamental importance for their effective control. It is only by understanding how the different pathogens are transmitted, what factors influence transmission, and in what ways the animal defends itself against the clinical effects of infection that one can hope to devise successful methods of disease control. This is especially true in areas where complete eradication of the tick vectors is not feasible due to acaricide resistance, or human problems such as poor dip management, irregular attendance of herds at dips or sprays, etc., or because wild animals serve as reservoirs for tick populations.

Anaplasma and *Cowdria* are not protozoa like *Babesia* and *Theileria*, but belong to the order Rickettsiales. Nevertheless, all these infections share a few common points in their epizootiology. The simplest epizootiological model is provided by bovine babesiosis, caused by *Babesia argentina* and *Babesia bigemina* in Madagascar and Australia where the only vector is the one host tick, *Boophilus microplus*. In practically the whole of Madagascar and in much of the tropical north of Australia the climate is favourable for this tick. Wild animals do not serve as reservoirs for either the tick or the babesial parasites. Cattle, after recovery from their first infection, remain carriers for a considerable period, and the opportunity for a proportion of the tick population to be infected is excellent at all times. Because of favourable climatic conditions, the tick population remains at a high enough level to infest all calves shortly after birth, and as a result all young calves become infected with both species of *Babesia*. However, since young calves up to the age of about nine months are more resistant to the clinical effects of the infections than older animals, and since protective antibodies from the dam are transmitted to the calf via the colostrum, there is no mortality and no apparent signs of disease. Immunity among the adult cattle is maintained and reinforced by frequent reinfection. This situation in which *Babesia* infection is widespread but does not constitute a disease problem is described as enzootic; there is no apparent babesiosis, but all animals are infected and are resistant to clinical illness. The whole of Madagascar can be considered as enzootic for these babesial parasites of cattle, but in Australia the climate becomes less and less favourable for the tick as one goes south toward the drier interior and toward the cooler subtropical coastal regions, where the tick population falls to a level so low that not all calves acquire the *Babesia* infections. Here the proportion of susceptible adults is variable, and these animals will show clinical disease when exposed to infected ticks, often resulting in mortality. This situation may be described as epizootic when the disease is apparent, and may lead to outbreaks.

Where seasonal climatological factors favour a temporary increase in the tick population, or where a herd with many susceptible animals is moved into a region with more ticks, the epizootic situation becomes unstable. However, as one moves farther away from the enzootic areas, the tick population density becomes lower until only sporadic cases of babesiosis are seen; one finally reaches the tick-free area where the vector cannot survive and the whole cattle population is susceptible.

Movement of cattle from free areas into epizootic and enzootic areas, and from epizootic into enzootic areas, will result in disease, as will,

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