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BATS: THEIR PUBLIC HEALTH IMPORTANCE AND CONTROL WITH SPECIAL REFERENCE TO TRINIDAD

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This brief review of the public health importance and control of bats is oriented to Trinidad, where, during the past ten years I investigated their zoomedical importance (1). Trinidad is noted for Pawan's classic epidemiological studies of bat rabies (2,3) as well as its bat control program with which I have been associated since its inception in 1934 (4). Further, Trinidad has bat problems, in addition to rabies, which occur in other countries of the world. Although various methods of bat control have been developed in Trinidad, the field is virtually unexplored. Increasingly, bat control is a matter of paramount importance to Trinidad and other countries in Central and South America striving for self-sufficiency in meat and dairy production to feed their expanding populations.

Trinidad is a very bat conscious country. For its size it supports one of the largest, most varied bat populations in the world within a compact area, about the size of Delaware, separated from Venezuela by about six miles of water. Since the early settlement of Trinidad in the 1770's, a variety of bats have invaded homes, damaged fruit crops, and bats have attacked livestock, poultry, and even people. There is in the folklore a supernatural character, the "Soucouyant", which in illiterate rural areas is believed to attack people, although it is conceded that a bat attacks their animals. And each year during the Pre-Lenten Carnival, masqueraders wear bat costumes so detailed that it is possible to identify the bat species portrayed (1).

Actually very little is known about tropical bats, especially the ubiquitous vampires, and their distribution, life history and ecological role have yet to be studied. In a general way it is known that fruit-eating bats disseminate the seeds of economically important trees; that nectar-and pollen-feeding bats pollinate certain trees; that insect-eating bats daily consume more than their body weight in insects; that flesh-eating bats feed upon a variety of vertebrates; and that vampires subsist solely on blood. All these bats are normally found in a wide variety of secluded habitats such as caves, hollow trees, and under foliage. They are competent fliers and many travel great distances in a short time--a significant consideration in the transmission of disease between the mainland and Trinidad.

Bats were in Trinidad before people. With the advent of man, his buildings, livestock and crops, certain bats changed their normal feeding and roosting habits. These adaptable species benefitted and their numbers increased in some instances to alarming proportions. Some bats which have taken advantage of man's presence are the fruit bats (Artibeus and Carollia) which left their cave roosts to hang in trees or about houses, and changed their diets from indigenous to introduced fruits and fruit crops; the free-tailed bats (Molossus) which prefer hot attics to breezy palm fronds; and finally, the vampires which find domestic animals, poultry and man, a more easily accessible, plentiful source of blood than was afforded by the wild mammals and birds of the forest, savannah and swamp. Thus it is these adaptable species which create a public health problem requiring control.

Bat problems of public health importance which require control may be listed as: 1) Bat Associated Diseases; 2) Vampire Bats 3) House Bats:

1. BAT ASSOCIATED DISEASES

a) Virus Diseases: In Trinidad and throughout Latin America, vampire bats are the most important vectors of rabies although any kind of bat may become infected and transmit the disease. Since 1953 rabies in insectivorous bats has been reported from the United States, Canada, Germany, Yugoslavia, Turkey, and India where no vampires occur (5). Recorded human deaths have occurred in Trinidad, British Guiana, Mexico and the United States. Despite vaccination, cattle losses have been staggering numerically and economically. The cattle industry in Venezuela is reported to have dropped about 50% since World War II from about 20. million head to 10 - 12 million -- attributed directly to vampire bats transmitting rabies (6). In Mexico, the annual loss of cattle is said to be 130 million pesos (7). There is still much to be learned about the epidemiology of bat rabies. In Trinidad it is endemic and apparently cyclic and I have accurately predicted rabies outbreaks twice by careful study of bat behavior and proper interpretation of other factors in-. cluding the incidence of rabies on the adjoining South American mainland (I. p. 197). A most significant advance in the understanding of bat rabies was made by Constantine who reported (8) that bat rabies might be transmitted through an airborne medium instead of a direct bite.

In recent years viruses other than rabies have been isolated from the salivary glands of bats in California, Africa and Trinidad. These viruses have been identified as arthropod borne and may be possible causes of encephalitis. In California, Johnson isolated from the salivary glands of Mexican free-tailed bats (Tadarida mexicana) the Rio Bravo virus which is serologically related to St. Louis virus (9). The Trinidad Regional Virus Laboratory isolated, from the salivary glands of Artibeus and of mosquitoes, Tacaribe virus which is related to the virus of Argentinian hemorrhagic fever (Junm virus) (10), Under investigation is the possible association of bats with an outbreak of hemorrhagic fever in Bolivia and bat bands for this study were sent there as recently as January 31, 1964, by the Division of Wildlife Research, U. S. Fish and Wildlife Service. The hosts of such mosquito-borne viruses as Eastern, Western, and Venezuelan equine encephalitis are not completely known and bats may be involved. There is also reason to suspect that bats might provide an overwintering mechanism of Japanese "B" Encephalitis virus (11). The possibility that bats might be involved with jungle yellow fever was tested in Brazil with negative results (12).

Important consideration is being given to the fact that bats may spread these viruses and other pathogenic organisms during either local travels or extended migrations with the possible involvement of mosquitoes and ectoparasites.

At least four orders of arthropods are included among bat ectoparasites, namely: Diptera, Hemiptera, Siphonaptera and Dermaptera. At least 50 different Dipteran and Hemipteran ectoparasites have been reported Trinidad bats (I.pp 204-205). Direct contact with man could occur from a heavy house infestation by bats or during bat collecting and cave exploration.

b) Spirochetal Diseases: Leptospirosis is spread by contact with in fected urine through wounds, mucous membranes, and ingestion. The disease affects man and livestock. Since bats (Cynopterus) were found infected with strains of Leptospira in Indonesia around 1938 (13), it was decided to select certain Trinidad bats for investigation: the fruit bats, Artibeus and Carollia, as they might contaminate fruit with their urine during feeding; vampires as they excrete quantities of urine while flying about their victims and feeding on them; and free-tailed bats as they urinate in rain nutters and water barrels used for collecting drinking water. Unfortunately, this investigation in collaboration with the Trinidad Regional Virus Laboratory was terminated when I left Trinidad.

Another spirochetal disease which would warrant investigation in Trinidad would be relapsing fever carried by the ticks Ornithodoros which may be infected with the spirochete Borrelia. In Trinidad three species of Ornithodoros have been taken from the common bats, Desmodus, Molossus and Noctilio, as well as the rarer leaf-chinned bats, Chilonycteris, Mormoops, and Pteronotus (I, pp. 204-205).

c) Fungus Diseases: Among the fungus diseases associated with 'bats and bat caves is acute pulmonary histoplasmosis which has been fatal to humans in the United States, Mexico, South America and Africa. Although ho cases of histoplasmosis have been reported from Trinidad, we have made, in collabora tion with the Communicable Disease Center and National Institutes of Health, numerous isolations of Histoplasma capsulatum from caves and hollow trees in habited by a variety of bats as well as from soil contaminated by house dwelling bats (14,15). In Panama, the fungus has been isolated from the greater moustache bat, Chilonycteris, a species found also in Trinidad (16).

In Trinidad further isolations were made of the pathogenic fungi, Allescheria boydii, Cryptococcus neoformans, and Microsporum gypsum,causitive agents of mycetomas, cryptococcosis and ringworm, from bat contaminated soil around hollow trees, in flower beds and around houses (14,15). Bats are not known to be infected by any dermatophyte and a survey conducted with the Communicable Disease Center failed to isolate ringworm fungi from the hair of 242 Trinidad bats of 26 species (14, p. 252).

d) Bacterial Diseases: Not much is known about bacterial diseases in bats but pseudotuberculosis caused by the microorganism, Pasteurella pseudotuberculosis. which is capable of producing infections in birds, mammals, and man has been found infecting some bats in England (17, p. 611).

e) Protozoan Diseases: American trypenosomiasis or Chagas Disease has not been reported in Trinidad but warrants further investigation. Elsewhere in the American tropics bats are considered to be reservoir hosts for Trypanosoma cruzi which is transmitted by Triatomid bugs (17, p. 923). In 1963 from the State of Sab Paulo, Brazil a strain of T. cruzi belonging to immunological Type A, which includes virulent human strains, was isolated from a free-tailed bat, Eumops abrasus, caught in an area endemic for the disease (18). |n Trinidad, bats and bugs have been found in the same caves and hollow trees. Unidentified trypanosomes have been observed in Trinidad bats. "Murrina", the trypanosome disease transmitted by vampires solely to horses in Panama and possibly elsewhere in the American tropics, is not of

public health importance. Virtually nothing is known about bat malaria even though it is common among Old World insectivorous and frugivorous bats. It has never been reported From the Western Hemisphere. The life histories of the various plasmodia in their hosts is completely unknown. However, it is thought that bat malaria is not of public health importance (19).

f) Parasitic worms: Very little is known about the public health importance of the various parasitic worms in bats. Since numerous nematodes, cestodes, and trematodes have been found in Trinidad fish bats, Noctilio, and the phylloston-id bats, this field warrants further investigation (I, p. 204).

2. VAMPIRE BATS

Three genera of vampire bats, Desmodus, Diaemus and Diphylla, comprise the family Desmodidae which is restricted to i ;v Western Hemisphere, and presents a unique American problem of major public health and economic importance from northern Mexico to Argentina. Desmodus and Diaemus occur in Trinidad and the presence of Diphyll1a is suspected. Excluding the disease factor, repeated vampire predation is debilitating to livestock and humans, for a single Desmodus can consume as much as two ounces of blood at a single feeding and leave a wound oozinq and seeping for as long as twenty minutes. These open bleeding wounds are an attraction for the myiasis-causing larvae of such flies as the screwworm (Calliphoridae) which *arc* obligatory parasites attacking mammals and also create avenues for other blood-sucking arthropods which may carry viral, parasitic and bacterial infections. Nursing sows are frequently bitten on their teats with such intensity that milk cannot flow through the scarified tissue and the young are unable to suckle. Since 500 or more vampires may congregate in roosts, predation in a single area can be intense. The weakening cachexia in livestock caused by repeated vampire attacks with possible resultant disease or parasitism, assumes gigantic proportions in any country trying to achieve self-sufficiency in livestock production, whether it be on the large rattle holdings of Mexico and South America or in small but densely populated Trinidad, largely dependent on small peasant farming.

It is interesting that vampire predation in Trinidad is still intense despite urbanization of once rural areas; and vampires are even found in the larger cities. We have been investigating the host preferences of Trinidad vampires in collaboration with the Lister Institute of Preventive Medicine in England, which uses the precipitin test to analyze the stomach and fecal contents of freshly caught vampires. One Desmodus had traces of human and cattle blood in the stomach while a trace of horse blood was found in the feces of the same bat. Evidence shows that Desmodus is still seeking the blood of wild mammals while Diaemus may be changing its previously preferred avian diet to bovine blood. Despite the damage caused by vampires, there have been relatively few field studies made. The answer to vampire control will be found in further study of its biology. A few interesting challenges are: How does the vampire find its prey? Why does the vampire repeatedly return to a specific victim in preference to other equally accessible animals or humans sleeping in the same enclosure or dwelling? In Trinidad certain hunters and woodcutters sleeping in the forest have been regularly bitten through burlap sacks used as sleeping bags. Do these victims have a substance in their blood or body odor attractive to vampires? Conversely, do unmolested animals and humans have repellent factors? Perhaps the answers to these questions

will be found in physiological studies of selected victims. Fortunately, vampires can be easily observed under certain field conditions and make ideal laboratory animals. I maintained a breeding colony of approximately *40* Desmodus for six years in the Trinidad Regional Virus Laboratory. During the same period of time I also had under observation in the field a Desmodus roost containing a comparable number of bats.

3. HOUSE BATS

House bat infestation constitutes a serious public health and nuisance problem. The bats involved *are* primarily insectivorous species of the worldwide families, Vespertilionidae and Molossidae, the common smooth-faced bats and free-tailed bats, respectively. In addition to the above bats which constitute the problem in the temperate sub-tropics and tropics, tropical fruit bats may regularly enter unscreened houses on their nightly food flights, either attracted by exposed ripe fruit or to find a temporary resting place. In so doing, they defile food, walls and floors with their urine and droppings. In Trinidad, the free-tailed bats, Molossus of two species, usually occupy roof spaces by the hundreds (20). They prefer houses that have hipped or shed roofs covered by corrugated metal or asbestos sheets. Great damage is caused to ceilings due to the accumulation of guano and urine. Besides the psychological unpleasantness caused to human occupants, there is the noise of restless, scurrying bats, offensive odors and attraction of coprophagous insects. Potential health hazards include the possibility that chitinous remains of finely chewed insects, which largely constitute the guano, might be inhaled as they sift from the attic flooring to the rooms below; the possibility that bat ectoparasites might attack man; the contamination of drinking water by urine and feces from flying bats being caught in the guttering and water tanks and finally the known association of bats and histoplasmosis (20, *14,* 15). It. would be interesting to study the physiology of a bat which can roost with its body touching a metal roof having a heat of 135°F. and whose live body feels cool to the human touch immediately on being collected!

BAT CONTROL

Experience over some thirty years in Trinidad has established methods of bat capture and control, mainly of vampires, which though limited have proved to be effective and constitute a valuable foundation upon which future research may be built. The most satisfactory control of the house bat problem is bat proofing of houses and stalls during initial construction, since bat proofing later may be difficult, costly or virtually impossible. In Trinidad there is a trend toward poured concrete roofs that leave no spaces in which bats may roost, so in time this problem may diminish. However, after infestation, chemical control properly applied has been successful up to four years in our experimental houses (20). The materials used in this work, as far as we know, acted only upon the bats, their parasites and the coprophagous insects. Repellents *are* preferred under ordinary circumstances where bats are not diseased, and it was found that one pound of BHC 50% wettable powder to a gallon of water was adequate. However, future studies should be directed toward substances harmless to user, householder and bats, such as non-toxic repellents, either harmless chemicals, ultrasonic devices or other means since the bats involved are ordinarily beneficial, insectivorous species. The fruit bats which frequently enter homes through open windows and louvers may easily be excluded by proper screening. If this cannot be done, it is possible to

interrupt their flight pattern or disturb their temporary roosts by closing certain windows and louvers for about ten days, which frequently discourages their visits. Temporary roosts, such as picture moulding, may be covered with paper, aluminum foil, or any material which will prevent the bats from alighting or, in certain instances, by a poisoning method to be discussed later.

Unfortunately, many of the animals which feed upon bats in Trinidad are themselves being rapidly diminished by man and cannot be considered today as natural control. Boa constrictors and other snakes are feared and therefore killed on sight. Owls and hawks are shot in Trinidad as they are in other parts of the world while, among the mammals, opossums, raccoons, ocelots and the tayra (a tree weasel) are hunted for sport and food. On the other hand, the carnivorous spear-nosed bats such as Vampyrum and Phyllostomus, perhaps others, feed upon other bats, negating the value of wholesale bat eradication.

Current methods of bat collecting and vampire control in Trinidad include the use of firearms, various types of nets and seines, Constantine-type automatic traps (22), and a poisoning technique. Knowledge of bat habits and habitats is essential to obtain satisfactory results.

Mist nets set along bat flyways, around thatch huts, houses, animal enclosures, and around pasturing livestock have caught many species of bats in a single night, especially vampires which tend to fly in waves (23). One night we mist-netted 35 Desmodus within a few minutes. Seines and traps set in front of caves, mine shafts, abandoned concrete buildings and hollow trees have caught up to 500 Desmodus from a single roost.

Certain caves and hollow trees in Trinidad provide ideal conditions of temperature and humidity for vampire bats. These roosts *are* inspected at regular intervals by the bat collecting crews who have been instructed to disturb them as little as possible when removing bats from these roosts.

Strychnine syrup applied to vampire bites as a means of control was first developed in Trinidad and works on the premise that vampires will return to feed on wounds made the previous night (4). One drop of sweetened strychnine syrup (stock solution is 7.2 g. strychnine sulphate to 174 ml water and 174 ml sugar syrup), when properly applied to a fresh wound, will kill a vampire within two seconds after the bat's tongue has touched the bite thus treated. In one instance 12 vampires were poisoned and recovered in a single night from a cow and a calf. There were 49 fresh bites on the calf and the cow was also heavily bitten. The milk yield dropped drastically, the cow lost blood and weight during the attack period, of about two weeks. The attacks ceased after the dozen vampires were poisoned with the result that the cow gained weight and the milk yield returned to normal. Fortunately, these animals had been immunized against rabies, but this indicates the possible extent of damage to livestock whether the threat of rabies is present or not. When a single animal is attacked by so many vampires at one time it usually indicates that the vampires are either pregnant females or females carrying young bats and that their roost is nearby. Although the poisoning technique is specific for vampires and the treated animals suffer no ill effects, the chief hazards lie in its accidental or improper use and therefore it is issued to livestock owners under strict control. This method may also be used to control fruit bats (which have become house bat nuisances) by impregnating with syrup a partially peeled banana which is then hung up out of the way of children and pets in some place frequented by the bats.

FUTURE CONTROL

It is doubtful that vampires can be completely eradicated but I believe that they may be controlled biologically. It is necessary to study the habits and ecology of the vampires as well as other bats found in association with them to discover something which might make effective control possible. Our studies have indicated that clues point toward chemosterilants which may be used in roosts, attractants in the form of sonics and ultrasonics, and chemical lures to bring bats from their inaccessible roosts, while useful suggestions may also be found in the methods used for mosquito and screw worm control.

All possible avenues of control should be investigated, including bat epidemics such as occurred in Mexico where Villa (24) reported hundreds of thousands of Mormoops found dead of some unknown cause. Suggested control methods must be tested and evaluated in the laboratory and under field conditions. Fortunately, the vampire, Desmodus, is an ideal animal to study in the field and, as has been mentioned, we have had a breeding colony under laboratory observation for over six years. As a locale for field study, Trinidad is a natural laboratory in which it is possible to observe and study a great number of bat problems as well as bat behavior and ecology. Within this compact island area assessment can more easily be made of the value of various new and experimental control techniques than would be possible on the South American mainland.

ABSTRACT

This review of the public health importance and control of bats is oriented to Trinidad since this country is well known for its studies of bat problems, especially rabies, and its bat control program. Bat problems which require control are: Bat Associated Diseases (viral, spirochetal, fungal, bacterial, and protozoan), Vampire Bats and House Bats. Present methods of bat control and possibilities for future control are discussed since this is a matter of importance to Trinidad and other countries in Central and South America.

Because of its large variety of bats and location, the small island of Trinidad is a natural laboratory to study bat ecology and evaluate control measures.

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