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Source: Journal of Wildlife Diseases, 36(1) : 56-63

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-36.1.56

Journal of Wildlife Diseases, 36(1), 2000, pp. 56–63

MANGE EPIZOOTIC IN WHITE-NOSED COATIS IN WESTERN MEXICO

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ABSTRACT: From November of 1994 to June of 1996 an epizootic of mange, probably caused by the mite *Notoedres cati,* occurred in white-nosed coatis (*Nasua narica*) in the tropical dry forests of the Chamela-Cuixmala Biosphere Reserve in western Mexico. A monitoring scheme to determine the extent and severity of the epizootic within coatis was implemented. Trapping periods and transects were conducted for 2 yr. To control the spread of the disease, all captured infected coatis were either euthanized or treated with acaricides such as Butox® and Ivomec-F®, depending on the severity of their infection. Four other species of wild mammals and feral cats had skin conditions resembling mange. A more severe problem with the disease was predicted and later confirmed in the less isolated areas of the reserve, with a higher density of coatis. Our results indicate that epizootics may be more prone to occur in areas with greater fragmentation and less isolation from anthropogenic influence. Interestingly, although there was an apparently severe impact of the mange epizootic in the coati population, the long-term impact of the disease is unknown but appears to be negligible. So in order to understand the role of diseases in wildlife populations, long-term experimental studies are required.

Key words: Conservation of biological diversity, *Nasua narica,* notoendric mange, *Notoendres cati,* reserve management, survey, tropical dry forest.

INTRODUCTION

A controversial area of research is the impact of diseases in populations of wildlife and hence in the long-term conservation of biological diversity (MacKinnon et al., 1986; May, 1988; McCallum and Dobson, 1995). Infectious agents are components of natural communities and probably play important roles in the structure and function of natural populations and communities (McCallum and Dobson, 1995; Caughley and Gunn, 1996). By differentially affecting individuals and species, diseases could change the genetic composition, density, and distribution of wild populations, and shape the community structure and composition (Scott, 1988). In some circumstances diseases may cause severe problems when they are accidentally introduced into new regions or where environmental conditions have been changed by human activities (Simberloff, 1986; Holmes, 1996). Such problems are particularly relevant for management and conservation of endangered species and nature reserves (Aguirre and Starkey, 1994; Holmes, 1996). There is evidence, however, that for mammal species like coyotes (*Canis latrans*), epizootics of some diseases can have negligible long-term effects (Pence and Windberg, 1994). The contrasting effects of diseases, should not be surprising especially when considering the wide array of wildlife species and environmental conditions present in any particular region.

In this paper we present information on an epizootic of mange in white-nosed coatis (*Nasua narica*; Procyonidae) at the Chamela-Cuixmala Biosphere Reserve (CCBR) in western Mexico, and the strategy that we implemented to limit the spread of the disease. While conducting research on the ecology of the coati in the CCBR in 1994, we detected an increasing number of individuals in poor condition, with extensive fur loss and flaky skin. We designed a management strategy to evaluate and control this epizootic that involved the identification of the disease and the assessment of specificity and severity of infection in the population of coatis. We also evaluated the relationship between the prevalence of the disease, host density, and site isolation. We expected higher prevalence in Cuixmala, which was the area of the reserve with a higher coati density and more anthropogenic perturbation.

MATERIAL AND METHODS

The Chamela-Cuixmala Biosphere Reserve (CCBR) was created in December 1993. It comprises 13, 142 ha and it is located along the coast of the state of Jalisco (Mexico; 19°22′03″ to 19°35′11″N, 104°56′13″ to 105°03′25″W). The physical and biotic characteristics of the region are described in detail elsewhere (Bullock, 1986; Ceballos and Garcia, 1995). The tropical climate is classified as hot and humid, characterized by a strong seasonality in rainfall and an annual mean temperature of 24.9 C. Rainfall is concentrated from July to October, followed by a pronounced dry season from November to June. Average annual precipitation varies from 748 to 1,000 mm. The CCBR is included in one of the most extensive remnants of dry forest in Mexico and Central America. There are approximately 429 species of vertebrates and over 1,200 species of vascular plants in the reserve; many of these species are endemic to Mexico and/or considered at risk of extinction (Ceballos and Garcia, 1995). Plant species composition has a high degree of heterogeneity associated with soil depth, soil type, and exposure. Physiognomically, dry forests are characterized by trees 5 to 15 m height, with a relatively even canopy and a few emergent trees.

The reserve is divided into two zones (Fig. 1). The Cuixmala zone comprises nearly 900 ha along the flood plain of the Cuixmala River, where there are nine vegetation communities including dry forests, and abundant permanent water bodies. This zone is in contact with perturbed areas used for agriculture and cattle ranching; a relatively small town (1,000 people) is located 2 km to the south. In contrast, the Cumbres zone, which comprises around 12,200 ha, presents a complex topography in which tropical dry forests are the dominant vegetation; there are no permanent water sources and no human activities. The coati is the most abundant carnivore in the CCBR (Ceballos and Miranda, 1986), and is the only social carnivore present in neotropical forests (Gompper, 1995), living in cohesive groups of up to 20 individuals, and adult males living as solitary individuals. Besides, home ranges of neighboring band and males overlap extensively (i.e., 30–40%; D. Valenzuela, unpubl. data). In the reserve, coatis have a higher density in Cuixmala than in Cumbres (Valenzuela, 1999).

To determine the cause of the disease we captured four infected coatis. All were thin and weak in appearance and had diffuse alopecia (partial to complete), thickened skin, covered with gray-yellowish crusts, and excoriations. Skin lesions in these animals were mainly found in the ears, supraorbital arcs and top of the head, posterior legs, basal part of the tail, and posterior portions of the flanks. Infected coatis were very pruritic and two of them also had diarrhea. Diagnosis of the disease was obtained by examination of scrapings from areas of crusted skin and fecal parasite analysis. The analyses of the skin scrapings, fecal samples, and the identification of mites was carried out by a regional laboratory of the Department of Animal Health from the National Ministry of Agriculture (El Alamo, Tlaquepaque, Jalisco, Mexico). To evaluate the prevalence of the infection and to monitor the spread of the disease across the reserve, we carried out surveys and an intensive trapping of live animals. Prevalence was calculated as the percentage of diseased coatis. Finally, to score disease severity, each captured animal was inspected by dividing the body in 10 sections, and by scoring five points to each section with partial loss of hair and 10 points to each section having complete loss of hair and skin crusts (Fig. 2). Individual disease severity scores (0–100%) were averaged for trapping period. Surveys were made by walking through roads and trails within the reserve and registering all observed coatis, considering as in-

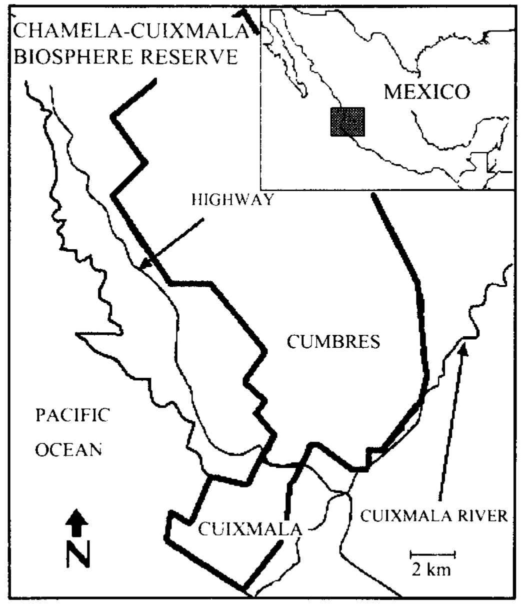

FIGURE 1. Location of the Chamela-Cuixmala Biosphere Reserve in western Mexico, and of the Cuixmala and Cumbres zones inside the reserve.

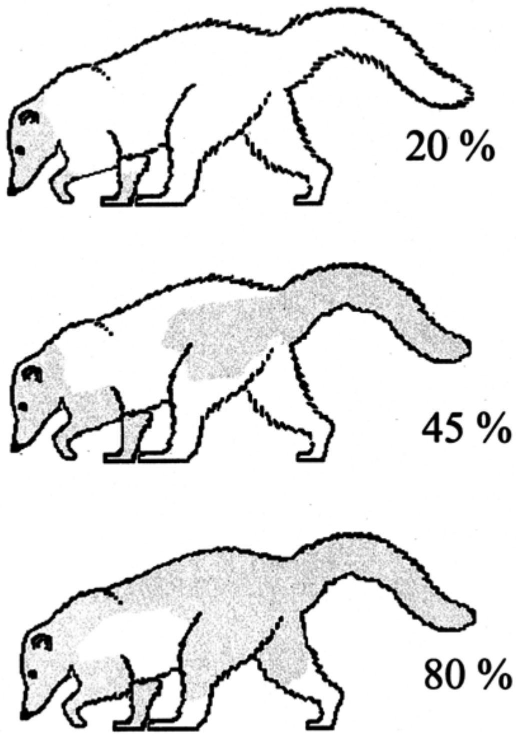

FIGURE 2. Relative degree of mange involvement in coatis. Shaded areas indicate fur loss and dermal lesions.

FIGURE 3. Representative cases of notoedric mange in coatis. All individuals with >30% of the body surface affected by the disease were euthanized.

fected all individuals showing clearly a portion of the body surface without hair. (Fig. 3) Our predictions were that there would be a higher prevalence and disease severity score in Cuixmala which has a two times higher coati density, than in Cumbres (Valenzuela, 1998) and where there was a greater exposure of wildlife to domestic animals. We used *G*-tests (Zar, 1984) to compare prevalence and severity scores between Cuixmala and Cumbres. A total of 20 surveys were conducted, covering 54 km, from November 1994 to January 1996. Based on the data from the surveys, an intensive and systematic trapping program was initiated in both Cuixmala and Cumbres, using Tomahawk Live Traps baited with sardines. Parallel with the trapping program for coatis, personnel from the health department of the Cuixmala Ecological Foundation (Melaque, Jalisco, México) conducted a trapping program of feral cats in areas adjacent to the reserve. Trapping periods were distributed in four periods of approximately 3 mo from November 1994 to January 1995, late March to early June 1995, October to December 1995, and late March to early June 1996. In Cuixmala, trapping was initiated in 17 different sites where diseased animals had been observed. In Cumbres, trapping was not conducted in the first period; however, in the following periods trapping was carried out at 24 different sites. Traps were set at each site until no diseased animals were captured for 3 consecutive days.

All captured coatis that were healthy or had <30% of the body surface affected by mange were treated with a subcutaneous injection of Ivermectine and Clorsulon (0.03 ml/kg; IVOMEC—F®; Merck; México D.F., Mexico) and an immersion in a solution of Deltametrine (1 ml/lt; BUTOX®; Rousell; México D.F., Mexico). The application of acaricides is recommended for animals infected with mange (Muller et al., 1990). Altogether, 25 healthy coatis were given preventative treatment since they were captured in addition to infected individuals. In contrast, all coatis with >30% of the body surface infected were euthanized with an intramuscular injection of Ketamine (IMALGEN® 1000; Rhone Merieux, Villa Corregidora, Querétaro, Mexico) at a dosage of 16 mg/kg, followed after induction time, by an in-

TABLE 1. Prevalence and severity score of mange in coatis (*Nasua narica*) in two locations (Cuixmala/Cumbres) at Cuixmala-Chamela biosphere reserve in western Mexico.

Trimester	Sites[a]							
	TD	TC	TS	TE	TT	CS	DP	SS
First	176/—[b]	48/—	11/—	10/—	1/—	27.2/—	22.9/—	54/—
Second	255/569	42/14	32/6	21/0	11/6	16.5/2.5	76.1/43	40/20
Third	210/293	14/4	8/0	0/0	8/0	6.7/1.4	57.1/0	16/0
Fourth	251/1,380	10/9	8/1	6/0	2/1	4.0/0.6	80.0/10	50/10
TOTAL	892/2,242	114/27	59/7	37/0	22/7	13.6/1.5	51.7/25.9	40/10

[a] TD = trap days; TC = total captures; TS = total sick animals; TE = total euthanized animals; TT = total treated animals; CS = capture success (TC/TD by 100); DP = disease prevalence (TS/TC by 100); SS = disease severity score (i.e., average percent area of body surface infected).
[b] —Indicates missing data.

tracardiac injection of Sodium pentobarbital (ANESTESAL®; Smithkline Beechman®; México D.F., Mexico) using a dosage of 0.8 ml/kg.

RESULTS

The diagnosis showed that infected coatis had adults and ova of *Notoedres cati,* a mite responsible for notoedric mange. The two coatis with diarrhea had coccidiasis and high levels of *Escherichia coli.* Based on this diagnosis we subsequently considered a coati as infected if it presented fur loss and skin lesions similar to those shown by the coatis analyzed in the lab.

Mange was very specific to coatis. Other researchers working in the same region at the same time, found that of 39 species of mammals and >1,400 captured individuals, only one raccoon (*Procyon lotor*), two ocelots (*Leopardus pardalis*), one gray squirrel (*Sciurus colliaei*), and six feral cats presented skin conditions similar to those of coatis on which mange was confirmed.

The overall prevalence of the disease in coatis was 47% (66 diseased animals/141 captured animals), and the average severity score was 35.4 ± 5.8% ($\bar{x} \pm 95\%$ confidence interval; $n = 66$). As expected, mange was more prevalent and more severe in the reserve's section less isolated and with a higher coati density. Comparing the last three trapping periods, prevalence and severity were statistically higher in Cuixmala than Cumbres (Table 1; G-test$_{(0.05)}$ df = 2, $G = -93.2$; $P < 0.000$; $G = -59.9$; $P < 0.000$, respectively). All those euthanized and 20 treated coatis came from Cuixmala; in contrast, only seven coatis required treatment in Cumbres. Treated coatis that were recaptured showed signs of recuperation, indicated by a lower proportion of body surfaces without both hair and skin crusts. Of the 66 diseased coatis, 27 were treated and 39 were euthanized and the carcasses burned (Table 1).

The overall prevalence of the disease was 52% in Cuixmala and 26% in Cumbres (Table 1). In Cuixmala it remained high during the study period, but in Cumbres it was relatively low at the end of the observations. Within both zones, there were areas where infected coatis were concentrated. In Cuixmala, the highest capture rate occurred at one site, with 39% of total captures, 36% of the diseased animals, and 36% of all euthanized animals. In Cumbres almost half of the total captures (44%) occurred at two sites, and six of seven infected coatis were captured at those sites. The remaining captures were evenly distributed among nine additional sites and there were no captures in the other 13 trapping sites. Based on observations and trapping data, a pattern of mange spread in the reserve was established and a distribution map of the disease in Cuixmala was obtained (Fig. 4a–d). Initially, mange was present at a few points (Fig. 4a); however, its dispersion increased rapidly, particularly in the areas closer to the town where the six infected feral cats were captured. During the second trapping period, the disease was more widely spread (i.e., infected coatis were observed and captured in more sites), and many more infected animals were captured (Fig. 4b). This period of high severity coincided when most of the infected coatis were captured in Cumbres. Culling the animals in worst condition at Cuixmala helped to reduce the disease's dispersion and to maintain it at a relatively low level (i.e., few sites where sick animals were observed); prevalence in those sites remained relatively constant (Table 1; Fig. 4c, d). In Cumbres, only one infected animal was captured during the last trapping period.

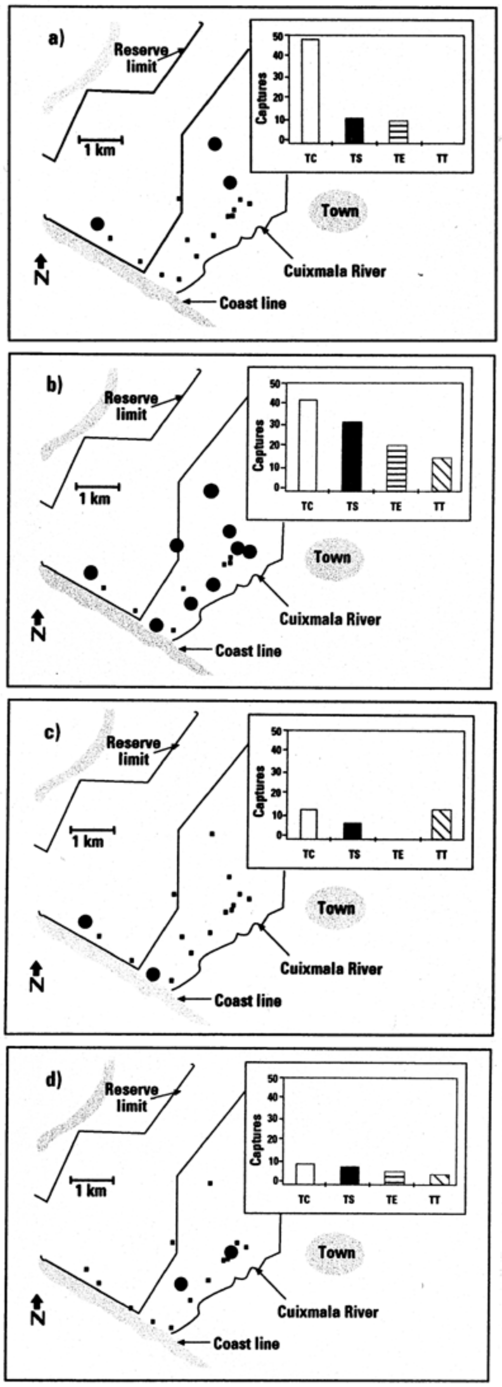

FIGURE 4. Spatial distribution of cases of notoedric mange in coatis in Cuixmala site by trimester. a. November 1994 to January 1995. b. March to early June 1995. c. October to December 1995. d. late March to early June 1996. Dark dots are trapping sites and shaded circles are trapping sites where sick animals were captured. Each histogram shows total ← number of coati individuals captured (TC), and the total number of sick (TS), euthanized (TE) and treated (TT) individuals on each trapping period.

DISCUSSION

This is the first report of a mange epizootic in a wild population of coatis. Previous reports of mange in this species have been caused by *Sarcoptes scabei,* and have been reported in individuals in captivity (Conroy, 1964; Meier, 1976). Mange can severely weaken the affected animals. The mite burrows beneath the skin to reach the dermis where the mite feeds and lays its eggs (Sweatman, 1973; Muller et al., 1990). This causes an intense reaction in the skin which thickens, forms folds, and becomes covered with gray or yellow crusts resulting in hair loss. The infected animal suffers intense itching, and the lacerations caused by scratching become secondarily infected. Crusts around the eyelids create difficulties in vision and loss of foraging ability. At an advanced stage, the infection can produce weight loss and general weakness that sometimes result in death due to secondary complications. Mange epizootics can threaten wildlife in general, but its effects can be severe in endangered species, such as Mountain gorillas (*Gorilla gorilla beringei*; Kalema, 1997) or ocelots (*Leopardus pardalis*; Pence et al., 1995).

Notoedric mange is a highly contagious disease that is mainly present in felines, but also affects many other species including members of the orders Rodentia, Carnivora, Lagomorpha, Didelphimorphia, and Chiroptera. Notoedric mange occurs in epizootic events and in some cases has been argued to temporarily reduce numbers in wild populations such as the Californian grey squirrel (*Sciurus griseus griseus*) in northern California (USA) during the 1920's (Sweatman, 1973; Muller et al., 1990). However, any claim that a disease is having a significant impact in a wildlife population must be based on experimental studies testing this hypothesis, comparing results with reference areas (Pence et al., 1994; Schubert et al., 1998).

In the present case, the gregarious nature of coatis probably favored contagion of individuals and spread of the disease. Notoedric mites are obligate parasites that live only for a few days off the host and are transmitted among hosts primarily by direct contact (Muller et al., 1990). Contact with bedding sites or recently visited sites by an infected individual, might also result in spread of the disease (Muller et al., 1990). In general, the prevalence of parasites and diseases depends on the susceptibility of an individual to the disease agent, which is determined by genotype, physical condition, and the individuals response to natural or human-induced environmental changes (Caughley and Gunn, 1996). At a population level, the dispersion of disease is related to density, number of infected individuals, number of parasites per host, and the rate of contact between hosts (Holmes, 1996). The increased dispersion of disease in wildlife populations may be compounded by a combination of factors, including habitat perturbation, presence of domestic animals acting as carriers, and unnaturally high densities of wild populations in fragmented protected areas (Primack, 1993; Aguirre and Starkey, 1994).

We suspect that the mange epizootic started in Cuixmala because there were few infected coatis in Cumbres. This may be related to the higher density of coatis and greater contact with domestic animals in Cuixmala. The higher density of coatis in Cuixmala may be attributed to more water and food availability in this site than in Cumbres. Also, before the reserve was established, it was a common practice in Cuixmala to supplement food for the coati groups in order to observe them (Valenzuela, 1998). There were reports of congregations of 70 to 80 coatis at the sites in which supplemental food was provided. Such abnormal densities may have played an important role in facilitating the start of the mange epizootic. Interestingly, the disease was initially detected at sites were food supplementation was carried out for a longer period and where the larger groups were observed.

In order to minimize the negative impacts of the disease in the reserve, a strategy was designed to optimize the use of limited resources in the control of the disease. Although the reserve covers >13,000 ha, infected coatis were initially detected in few localized areas. Therefore, we decided to concentrate our trapping efforts in those sites where infected coatis were detected, and to halt the spread of mange while minimizing the negative impact of the control strategy on the coati population. We tried to do this by culling intensely infected individuals, and by treating all individuals showing no symptoms or a low disease severity. We expected that by decreasing the number of infested hosts we could limit the spread of the disease to other species and areas of the reserve. Our strategy was successful because the epizootic was restricted to a few sites inside Cuixmala.

We found that the control of the outbreak was justified for several reasons. On the one hand, although the disease primarily affected coatis, there was a potential risk of infecting other species, particularly endangered ones, such as jaguars (*Phantera onca*). Coatis are a major prey of jaguars in the reserve (Nuñez, 1999) so the disease could pose a serious threat to these key predators that have very low densities in the area. Endangered species with small populations are unlikely to sustain diseases caused by virulent pathogens or macroparasites; they tend to acquire virulent diseases only after exposure to infected hosts of another more abundant and widespread species (McCallum and Dobson, 1995).

Mange epizootic events are more prone to occur during the dry season in tropical regions (Sweatmann, 1973). In the CCBR, water and food resources become limited during the dry season and affects coatis and many other species of animals and plants (Ceballos, 1995). Such effects were quite pronounced during the 1994–95 dry season, which was particularly severe due to an atypical low precipitation, in comparison with an 8 year average data (Bullock, 1986). Precipitation was 30% lower and, during the 2 mo of higher precipitation, it rained three times less. Many species of animals, including coatis, concentrated around the few available waterholes at a dry season like that. In these circumstances an infected animal could become an effective source of mites for other wildlife species.

We believe that the mange epizootic increased the effect of other natural mortality factors for coatis. Although we expected a higher mortality of coatis in Cumbres during the dry season due to the lack of permanent sources of water, we found a 40% decline in coati density in both Cumbres and Cuixmala (Valenzuela, 1998). It is likely that the decline in coati density in Cuixmala, where water and food are abundant, was probably related to weakness caused by mange.

MANAGEMENT IMPLICATIONS

Diseases such as noteoendric mange may not represent a long-term threat for common and abundant animals like coyotes (*Canis latrans*) that may quickly attain in densities similar to those before the disease epizootic (Pence et al., 1994). In the present study, coatis, which were the species affected, were very abundant and the long-term negative effects of the epizootic were probably negligible. A major concern are, however, endangered species with low densities, where an epizootic disease combined with other factors such as small population size and poaching could exacerbate a critical condition (e.g., Caughley and Gunn, 1996).

Our results are relevant for the long-term conservation of the biological diversity of the Chamela-Cuixmala Biosphere Reserve. Alternatively, based on our study we have begun the implementation of a permanent control and monitoring program. Such a program consists of a continuous observation of coatis or other mammals showing abnormal behavior or signs of disease (e.g., apparent weakness, loss of hair, crusted skin, etc.) and the eradication of feral cats and dogs. On the other hand, we learned that the population of coatis recovered in a few years, and that the notendric mange has almost disappeared from the reserve. So the long-term effects of the diseases on coatis were, apparently, negligible.

Diseases should be an important factor to consider in long-term plans for management and conservation of protected areas. We suggest, however, that to clearly determine cause and effects, experimental studies on the long-term impact of diseases in populations of wild animals should be expedited (Pence et al., 1994; McCallum and Dobson, 1995). An interesting experiment should be the comparison of the effect of diseases in reserves with different degrees of fragmentation. Learning from cases like the present one can provide useful information to successfully deal with this kind of problems and to form a basis for designing and performing those experimental studies.

ACKNOWLEDGMENTS

This work was supported by the Fundacion Ecologica de Cuixmala, A. C., the Instituto de Ecologia of the National University of Mexico and the National Research Council (CONACYT). We dedicate this work to the late J. Goldsmith. We would like to express our gratitude to G. Marcaccini and E. Campos for their logistic support. Katherine Renton's assistance with the English version was invaluable. M. Valtierra helped us during trapping efforts. A. Mendoza, C. Chavez, R. Nuñez, C. Lopez, and E. Martinez kindly shared with us their data on rodents, bats, and carnivores. Suggestions given by C. Chavez and two anonymous reviewers for an earlier version of the manuscript greatly helped us. P. R. Ehrlich and the Stanford's Center for Conservation Biology kindly provided logistic support for G. Ceballos during the final phase of the preparation of the manuscript.

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Received for publication 11 September 1998.