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THE EPIZOOTIOLOGY AND PATHOLOGY OF SARCOPTIC MANGE IN COYOTES, *CANIS LATRANS,* FROM SOUTH TEXAS

Danny B. Pence, Lamar A. Windberg,* Barbara C. Pence, and Robert Sprowls†
Department of Pathology, Division of Comparative Pathology, Texas Tech University Health Sciences Center, Lubbock, Texas 79430

ABSTRACT: An epizootic of sarcoptic mange in coyotes from south Texas, *Canis latrans,* was studied over a 7-yr period, 1975 through 1981. From a four-county area centered in Webb County, Texas the epizootic radiated centrifugally to include a 27-county area. The disease progressed from initial, scabby encrustations on the ischium and fore and hind legs to severe, thickened, slate-gray hyperkeratotic lesions with almost complete alopecia. There were significant decreases in α-globulin and albumin, significant increases in γ-globulin, and significant decreases in fat deposits and total body weight indicative of a chronic infection with establishment of a humoral antibody response as the infection progressed in severity. Significant differences in prevalence of mange across habitat variables of host age and sex, and across seasons were related to the juvenile/adult ratio in the coyote population at any particular time because the infection progressed more rapidly in juveniles. Population dynamics and abundance of coyotes were generally unaffected by the mange epizootic. Although higher mortality was associated with mange-infected animals, this had no effect on overall mortality in the coyote population.

Epizootics of sarcoptic mange caused by *Sarcoptes scabiei* (Linnaeus, 1858) were reported from coyotes (*Canis latrans*) in Montana (Knowles, 1909), coyotes, timber wolves (*Canis lupus*), and red foxes (*Vulpes vulpes*) from Alberta (Cowan, 1947; Green, 1951; Todd et al., 1981), red foxes and coyotes in Wisconsin (Trainer and Hale, 1969), red foxes in Pennsylvania (Pryor, 1956), red foxes and coyotelike hybrids from New York (Stone et al., 1972; Stone et al., 1974), coyotes in Kansas (Gier et al., 1978), and coyotes, red wolves (*Canis rufus*) and coyote–red wolf hybrids from Texas and Louisiana (Pence et al., 1981). Despite the apparent widespread geographic distribution and commonly documented epizootics, there is little definitive information on the relative effects of these epizootics on the population dynamics of wild canids in North America. However, it has been suggested that mange may be important in reducing the number of individuals in a canid population (Pryor, 1956; Parks, 1968; Trainer and Hale, 1969; Stone et al., 1972; Young and Jackson, 1951; Gier et al., 1978; Cowan, 1947, 1951; Green, 1951; Russell and Shaw, 1971; Todd et al., 1981), and sarcoptic mange has been suggested as a means for reducing coyote populations (Knowles, 1914). Conversely, other investigators suggested that sarcoptic mange was unimportant in reducing numbers in red fox populations (Storm et al., 1976).

With the outbreak of an extensive epizootic of sarcoptic mange observed during continuing research on demography of a coyote population in south Texas, the present study was designed to (1) elucidate the gross and microscopic pathology and to correlate selected serologic parameters to the severity of mange; (2) examine the influence of host and environmental variables such as age, sex, physical condition, and season on the prevalence and severity of the disease in this host population; (3) examine the dynamics of the epizootic within a geographically-defined host population and attempt to monitor the geographic expansion of the epizootic, and (4) determine the relationships between the epizootic and host reproductive performance, mortality rates, and population abundance.

MATERIALS AND METHODS

Description of study areas

The area of intensive study was in Webb County, Texas, within a 50-km radius of Laredo (Fig. 1). Coyotes were trapped from individual areas of representative habitat ranging in size from approximately 4,000 ha to 10,000 ha. In fall 1979, 40 coyotes were marked with radiotransmitters on a 15,000-ha area approximately 35 km northeast of Laredo and 24 additional coyotes were marked on a 12,000-ha area 45 km southeast of Laredo.

The entire study area was privately owned land used primarily for cattle grazing. Vegetational type was classified as a mesquite–acacia savanna (Kuchler, 1964) with a diversity of woody and herbaceous species in varying stages of secondary succession characterizing

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* U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Laredo Field Station, Laredo, Texas 78041.
† Texas A&M University Diagnostic Laboratory, Amarillo, Texas 79106.

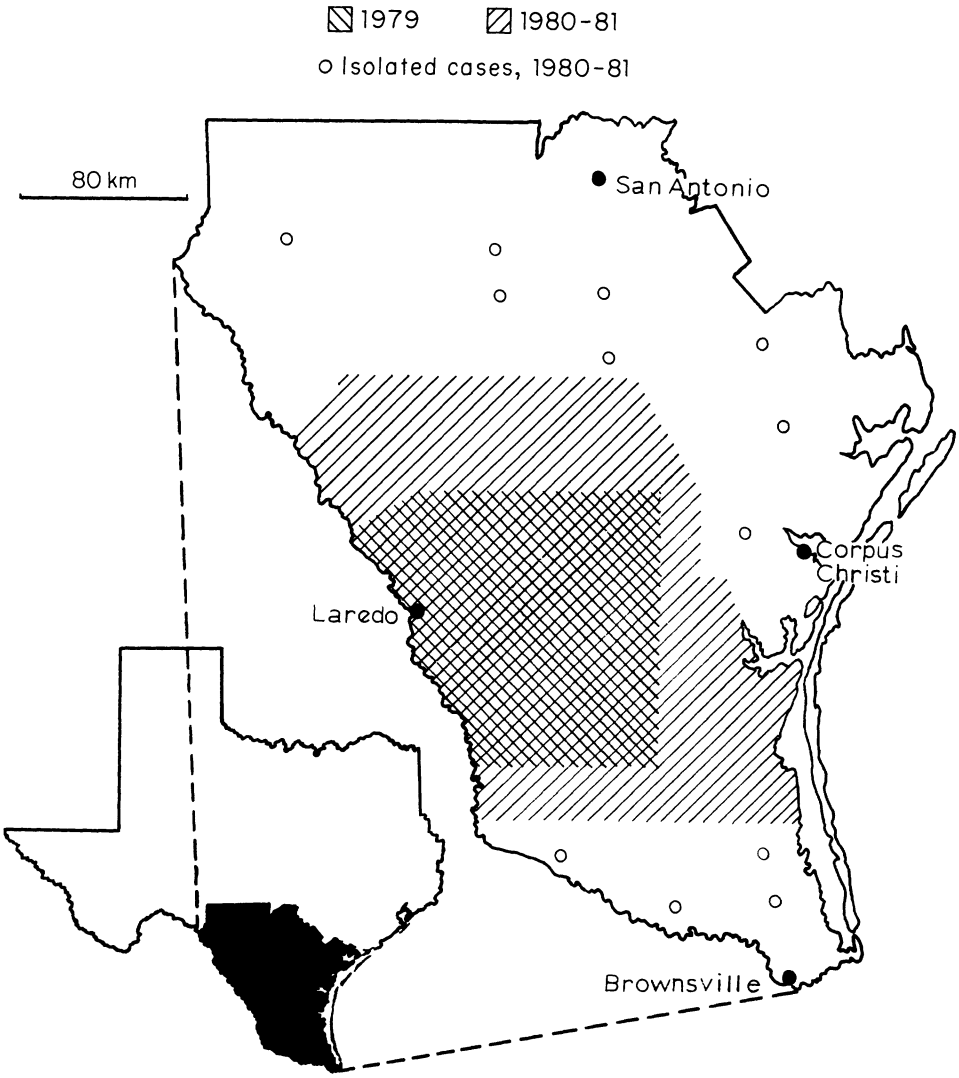

FIGURE 1. Geographic expansion of sarcoptic mange in south Texas coyotes, *Canis latrans*.

the community. At least 70 species of woody shrubs are found in Webb County (S. A. Nelle, 1981, pers. comm.). Predominant species are mesquite (*Prosopis glandulosa*), blackbrush acacia (*Acacia rigidula*), guajillo (*A. berlandieri*), and prickly pear (*Opuntia lindheimeri*). Mean annual rainfall at Laredo is 47 cm (U.S. Department of State, 1978), but it is erratic within and between years.

Collection of data

Samples of the coyote population were collected with steel, leghold traps during spring (March–April) and fall (October–November). Location, sex, estimated age (juvenile or adult), weight, body length, degree of mange infection, presence of ectoparasites (fleas, lice, ticks), description of foot injury, and general physical condition were recorded for each animal. Two, thin, bloodfilms and 5 to 20 ml of whole blood were collected from most animals. Canine and premolar teeth were extracted for age determinations. Intraperitoneal fat was subjectively rated and recorded. The distribution of mange lesions on infected coyotes were shaded on prepared dorsal, ventral, and lateral sketches of the animal. Skin biopsies from mange lesions were preserved in 10% buffered formalin. Each biopsy was swabbed and inoculated on Sabouraud's agar slants. Skin scrapings from active lesions were preserved in 70% ethyl alcohol.

Coyotes were aged as juveniles ($\leq$ 1 yr old) or adults ($>$ 1 yr old) by the ratio of the pulp cavity width to total tooth width (canine or first-premolar) at the gumline as determined by radiography. Adult coyotes were aged by an interpretation of cementum annuli from standard tooth sections (Linhart and Knowlton, 1967) prepared by a commercial laboratory (Matson's, Milltown, Montana). In analyses of age versus selected se-

rum parameters, reproductive parameters, and body weights, coyotes were categorized as: Age Group I, ≤ 1 yr old; Age Group II, 1.5 to 2 yr old; Age Group III, ≥ 2.5 yr old. In all other analyses animals were classed as juveniles or adults.

As a crude index to physical condition, the amount of fat on the kidneys and mesenteries (IPF) was rated subjectively as absent, light, and moderate-to-heavy (0, 1, and 2, respectively).

Bloodfilms were stained with Wright-Giemsa. Histological sections from skin biopsies were cut at 4 to 6 μm and stained with hematoxylin and eosin. Skin scrapings were examined with a stereomicroscope for mites. Sera from both mangy and uninfected coyotes were analyzed for total protein (Dow Diagnostics, Indianapolis, Indiana), creatinine (Dow Diagnostic Laboratories, Indianapolis, Indiana), and albumin and α-, β-, and γ-globulins (Helena Laboratories, Beaumont, Texas). Additionally, albumin (ALB) calcium (Ca), phosphorus (P), glucose (GLU), blood urea nitrogen (BUN), creatinine (CREAT), total bilirubin (T. BILI), serum alkaline phosphatase (SAP), creatine phosphokinase (CPK), lactic dehydrogenase (LDH), serum glutamic-oxalacetic transaminase (SGOT), and serum glutamic-pyruvic transaminase (SGPT) were analyzed by an SMA-12 autoanalyzer (Technicon SMA 12/60). Fungal cultures were subcultured on potato dextrose agar, stained with lacto-phenol cotton blue, and identified according to sporulation characteristics.

Female uteri were opened immediately after removal to count fetuses, placental scars, and resorption sites. Ovaries were fixed in 10% formalin and later sectioned for macroscopic count of corpora lutea or corpora rubra.

Data forms were supplied to District Field Assistants of the Texas Rodent and Predatory Animal Control Service in winter, 1979 to 1980 and spring, 1981 requesting information on prevalence and patterns of mange in coyotes from six south Texas counties. Additional information was obtained by personal interviews with other District Field Assistants, private fur trappers, and game wardens. Information on mange in coyotes south of the Rio Grande River was obtained by personal interviews with game wardens, game managers, veterinarians, and ranchers in the states of Coahuila, Nuevo Leon, and Tamaulipas, Republic of Mexico.

Indices to relative coyote abundance in spring (May) were obtained using the scent-station procedures described by Roughton and Sweeny (1982). The indices were derived from 16, 10-station transects from 1977 to 1979 and 36 transects in 1980 and 1981.

Radiotelemetry marking

Sixty-four coyotes were captured in fall 1979 with steel, leghold traps equipped with tranquilizer tabs (Balser, 1965) containing 100 to 500 mg of propiopromazine hydrochloride (Diamond Laboratories, Des Moines, Iowa). Data were collected as described above and each animal with mange was photographed. Each coyote was collared with a multiple-use transmitter (Kolz et al., 1973) to facilitate relocation and detection of mortality. The transmitters and ear tags on each marked coyote were stamped with a request for a return of information. Wound-Kote antiseptic (Farnum Company, Omaha, Nebraska) was applied to the trap wound. Collared animals were usually released immediately following capture, but because of prolonged tranquilization certain animals were restrained overnight in a steel cage at the trap site. Instrumented coyotes were monitored from a fixed-wing aircraft at 1- to 4-wk intervals using a Model LA12 radio receiver (AVM Instrument Company, Champaign, Illinois). Upon detection of mortality signals from the transmitter, carcasses of the instrumented coyotes were retrieved with the aid of a radio receiver and hand-held antenna. Fresh carcasses were necropsied in an attempt to determine the cause of death.

Definitions

Prevalence refers to the ratio, expressed as a percent, of the number of hosts infected with mange to the total number examined. Infected refers to mange-infected animals and uninfected refers to mange-free hosts. Except where specifically designated as Age Group I, II, and III, the terms juvenile and adult refer to coyotes ≤ 1 yr old and > 1 yr old, respectively. Significant and significantly refer to statistical significance established as $P \leq 0.05$. Weight refers to total body weight expressed in kg.

Statistical treatments

The age classes, sex, and season of collection versus TSP, ALB, Ca, P, GLU, BUN, CREAT, T. BILI, SAP, CPK, LDH, SGOT, SGPT, and α-, β-, and γ-globulins of infected and uninfected coyotes were compared with one-way analysis of variance (pooled variance) (BMDP Statistical Software, 1981, Berkeley, California). Likewise, each of these serum parameters versus uninfected and infected hosts with different mange classes (I, II and III) were compared with one-way analysis of variance or *t*-tests.

Weights of infected and uninfected animals were compared with one-way analysis of variance (common variance) and *t*-tests (unpaired observations, common variance) within six separate sex and age classes. Intraperitoneal fat indices were analyzed separately for juveniles and adults by chi-square analyses of 2 × 2 contingency tables.

Prevalence data of infected coyotes across sex, age, and season variables were compared by chi-square analyses of 2 × 2 contingency tables. Ovulation, pregnancy, and resorption rates were also compared by chi-square analyses of 2 × 2 contingency tables between infected and uninfected females within Age Group II and III. The mean number of fetuses in infected and uninfected females from Age Group II and III were compared by *t*-tests.

Survival rates of coyotes marked with radio-transmitters were calculated using the methods described by Trent and Rongstad (1974). Because the daily status (dead or alive) of transmitter-equipped individuals was verified periodically, the number surviving or dying on any sample-day was known. Hence, two assumptions were made: (1) each coyote-day was an independent trial, and (2) for each trial over a period of *n* days, the probability of survival or death was constant. Because each coyote-day was a binomial event, the distribution of deaths followed a Poisson distribution over a period of *n* days. A weighted mean daily survival rate ($\overline{Sd}$) for *n* days was calculated:

$$(\overline{Sd})^n = (C - D/C)^n$$

where C is the number of coyote-days and D equals the number of coyote mortalities. Confidence intervals ($P = 0.95$) for survival rates were determined by the method of Fisher and Yates (1963) for a Poisson distribution. Differences in survival rates between infected and uninfected sample groups were tested using the method of Steel and Torrie (1960) for determining the difference between two small binomial probabilities assuming a Poisson distribution.

The coyote population abundance index was calculated as the total number of coyote visits to scent stations divided by the total number of operable scent-station nights times 1,000 (Roughton and Sweeny, 1982). Probabilities of differences between years were determined by the Wilcoxon signed-rank test (Steel and Torrie, 1960).

RESULTS

Prevalence

Data on prevalence of mange were from trapped coyotes and may not exactly reflect the actual prevalence in the population because there could have been biases in susceptibility to capture between infected and uninfected coyotes. However, prevalence data should be comparable between sampling periods because methods were consistent.

Two hundred sixty-seven of 843 (32%) coyotes examined in Webb County, Texas, from fall 1974 through spring 1981 were infected with sarcoptic mange (Table I). During spring, 1976 to 1978, the prevalence of mange was low, 27 of 171 (16%), and did not differ significantly for the three years. Likewise, during fall periods from 1975 through 1978 the prevalence remained low (44 of 204, 22%) and did not differ significantly between the four years. Beginning in spring, 1979 the prevalence increased markedly. The combined prevalence for spring, 1979 and 1980, was 103 of 152 (68%) and significantly higher than the combined prevalence for spring, 1976 to 1978. The combined prevalence for fall, 1979 and 1980, was significantly higher than for fall samples for the preceding four years with 74 of 236 (31%) coyotes infected. Combined prevalence of spring, 1979 and 1980, was significantly higher than that in the fall of the same 2 yr. Prevalence in spring, 1981, was significantly lower (19 of 44, 43%) than that of the combined prevalence for spring, 1979 and 1980. Prevalence for spring, 1981, was not significantly different from fall, 1980.

Geographic distribution

Quantitative information on prevalence of mange from returned data forms and personal interviews was gathered during winter and spring (January–April) from 27 counties in south Texas and from adjacent areas in the Republic of Mexico. Evaluation of these data allowed a subjective determination of the geographic extent of the mange epizootic in south Texas (Fig. 1). In spring, 1979, a high prevalence of mange was noted only in Webb County and in three adjoining counties. In adjacent counties, only isolated cases of mange were reported. In spring, 1980, the prevalence of mange remained high (20–69%) in these same four counties and was > 10% in parts of 10 adjoining counties (Fig. 1). Prevalence of mange in 1981 again ranged from 10 to 50% in this entire area. Isolated cases of mange (prevalence < 10%) were reported in several other adjacent counties during 1980 and 1981 (Fig. 1). Infected coyotes in the brushland habitat of adjacent areas in the Republic of Mexico were also reported at a prevalence > 10% during spring, 1979 to 1981. The

TABLE I. *Prevalence of sarcoptic mange in Webb County, Texas coyotes.*

	Spring			Fall		
Year	Adult	Juvenile	Total	Adult	Juvenile	Total
1974	–	–	–	–	–	0/36 (0)
1975	–	–	–	–	–	6/28 (21)
1976	5/34 (15)*	1/7 (14)	6/41 (15)	–	–	24/91 (26)†
1977	7/49 (14)	4/28 (28)	11/77 (14)	–	–	2/13 (15)‡
1978	5/22 (23)	5/31 (16)	10/53 (19)	11/50 (22)	1/22 (5)	12/72 (18)
1979	28/39 (72)	16/27 (59)	44/66 (67)	37/104 (36)	20/82 (24)	57/186 (31)
1980	29/47 (62)	30/39 (77)	59/86 (69)	16/45 (36)	1/5 (20)	17/50 (34)
1981	19/41 (46)	0/3 (0)	19/44 (43)	–	–	–
Total	93/232 (40)	56/135 (41)	149/367 (41)	64/199 (32)	22/109 (20)	118/476 (25)

* Number infected/number examined (percent).
† Includes 57 coyotes collected as road mortalities.
‡ Entire sample of road mortalities.

area of the epizootic in south Texas encompassed approximately 18,000 km^2 in 1979 but had expanded to include 40,000 km^2 by 1980 and 1981.

Gross and microscopic pathology

Infected coyotes collected during fall, 1979, through spring, 1981, were arbitrarily assigned to Classes I to IV based on the degree and severity of infection. Forty-two percent of a sample of 366 hosts were infected. Seven, 24, 10 and < 1% of the hosts were assigned to Classes I, II, III, and IV, respectively.

Class I infections included those hosts with initial lesions of one to several, small (usually < 1 cm^2), dry, scabby encrustations with or without alopecia and without suppuration or pronounced thickening of the skin. Lesions were invariably located on the lower fore and hind legs and a small region of the ischium (Fig. 2). Rarely, small lesions were noted on the ear. Histologically, there was mild hyperkeratosis and acanthosis with hyperplasia of the stratum germinativum and a dermal inflammatory response consisting of neutrophils, lymphocytes, and plasma cells. Mites were rarely observed in sections or from skin scrapings.

Coyotes with Class II mange had an active progressing infection with lesions of several centimeters in diameter on the elbow, knee, the ischial regions, almost complete alopecia, some suppurative encrustations, and greatly hyperkeratotic, slate-gray, wrinkled skin. There were Class I lesions with partial alopecia over much of the fore and hind legs and ischial region becoming confluent on the ventral body, flanks, and shoulders, but with less than one-half of the total body involved. Lesions were noted on the ears, muzzle and temporal areas, and base of the tail. The neck, back, most of the rib cage, and tail were rarely involved. Histologically, biopsies from lesions on the ischial region, and elbow or knee were pronouncedly hyperkeratotic with extensive accumulations of serum exudate and extravasated erythrocytes in the stratum corneum, pronounced acanthosis, some parakeratosis, hyperplastic stratum germinativum, and a primary infiltration of neutrophils, lymphocytes, and plasma cells. There was general sparing of connective tissue in the dermis and occasional hemorrhagic areas with extravasated erythrocytes. Hair follicles and sebaceous glands were plugged at the surface and generally hyperplastic with a mild inflammatory response. Mites were occasionally observed in sections or skin scrapings.

Coyotes with advanced active cases of mange were recorded as Class III if more than one-half of the body was affected (Fig. 2). In some hosts almost all of the body was involved with partial to almost total alopecia over the legs, flanks, shoulders, tail (rat-tail), ears, and face (Fig. 3). The skin over much of the legs, flanks, abdomen, chest, shoulders, ischial area, and face was thickened, wrinkled, slate-gray in color, and with numerous suppurative encrustations. Histologically, lesions were identical to those described for Class II animals. Severely affected coyotes were often somewhat emaciated.

Only four of 153 (3%) infected coyotes appeared to have lesions indicative of recovery. These were usually localized on the ischium and lower legs. The skin was somewhat wrinkled with dry, loose cornifications, suppurative lesions were absent, and there was evidence of healing and partial regrowth of hair at the periphery of the lesions. These hosts were placed in Class IV and considered to be recovering from Class I or mild Class II lesions. Histologically, there was an almost normal stratum corneum, only mild hyperplasia of the stratum germinativum and evidence of granulation tissue in the dermis with neocapillaries and no, or only mild, dermal inflammation. However, there was some question as to the validity of this category. Two animals that were initially placed in Class IV upon radiocollaring had developed active lesions when recaptured several months later.

Clinical pathology

Seven dermatophytic or saprophytic fungi were isolated from skin biopsies of eight of 14 (57%) uninfected coyotes. These were *Geotrichum candidum, Helminthosporium* sp., *Microsporum* sp., *Cephalosporium* sp., *Alternaria* sp., *Trichophyton mentagrophytes,* and *Trichophyton* sp. Ten species were isolated from 16 of 25 (64%) infected coyotes. These included *Trichophyton mentagrophytes, Trichophyton rubrum, Trichophyton* sp., *Scopulariopsis* sp., *Aureobasidium* sp., *Cephalosporium* sp., *Cladosporium* sp., *Helminthosporium* sp., *Geotrichum candidum, Rhizopus* sp., and *Malassezia pachydermatis.* The latter consisted of Class II (13), Class III (1), and Class IV (2) animals. There were nine and 26 individual isolates of the above species from coyotes uninfected or infected with mange, respectively.

Selected serologic parameters including TSP, CREAT, ALB, and α-, β-, and γ-globulins from

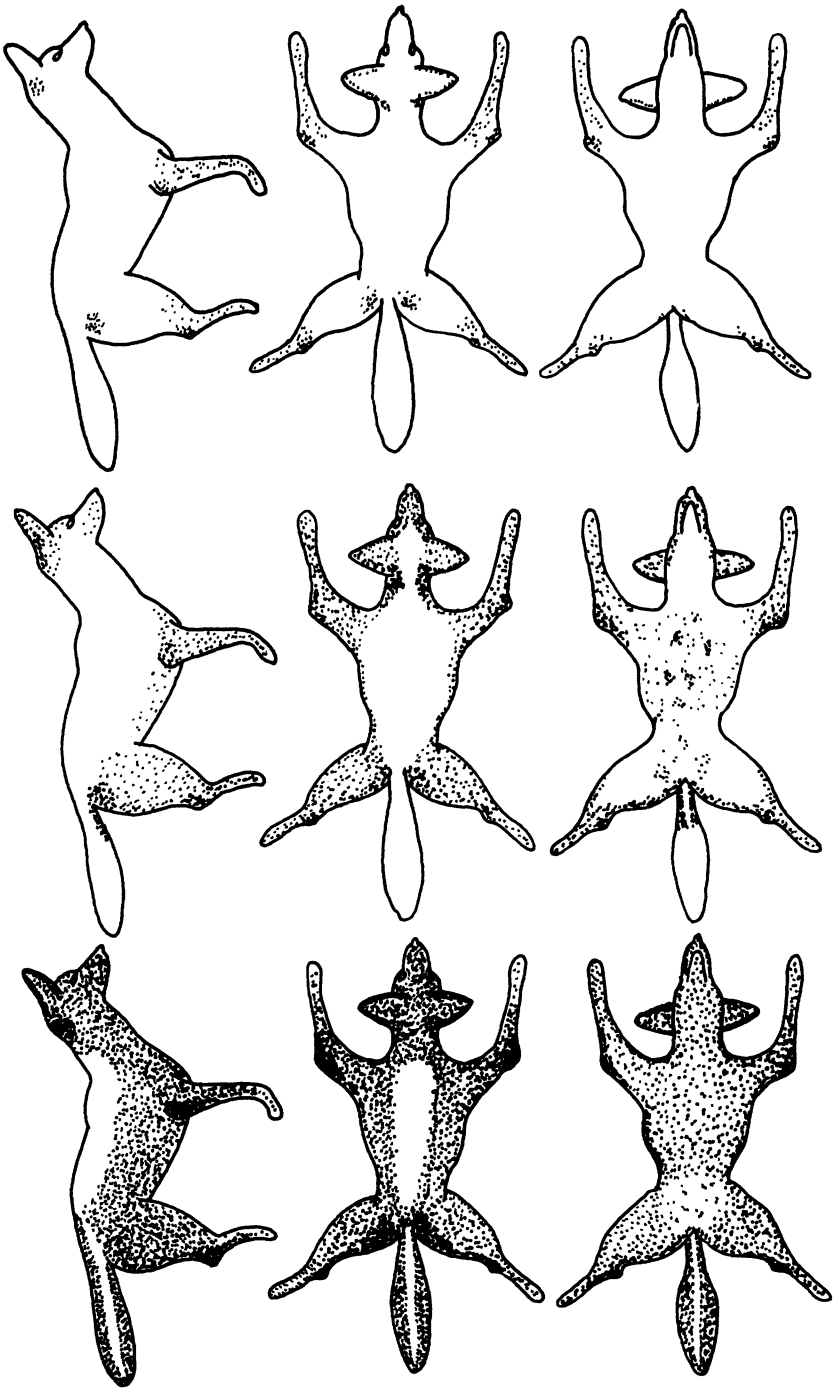

FIGURE 2. Classes of sarcoptic mange in coyotes from south Texas: Class I (top), initial infection involving fore and hind limbs, ischium, and base of ears; Class II (middle); more advanced lesions involving up to ½ total body surface; Class III (bottom) involving > ½ total body surface.

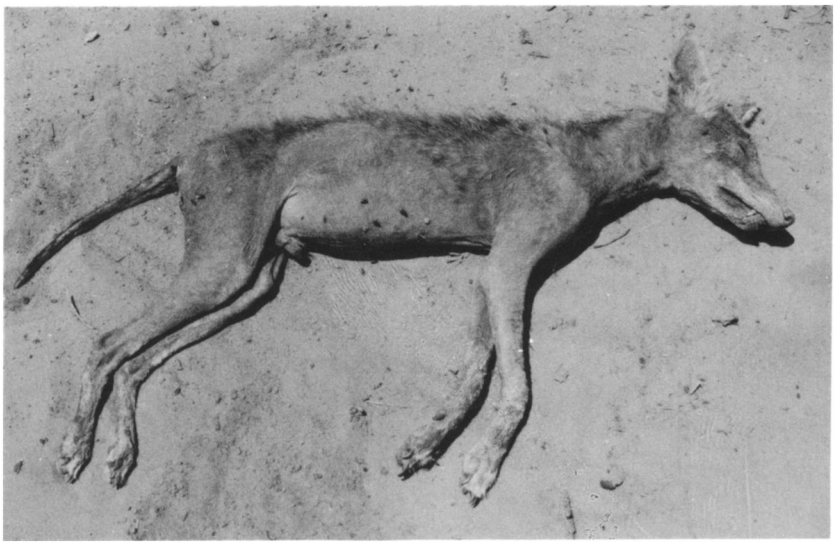

FIGURE 3. Advanced case of Class III mange in a juvenile coyote from south Texas. Note almost complete alopecia, slate-gray thickened skin over much of body surface.

102 uninfected and 101 infected coyotes collected from fall, 1979, through spring, 1981, were evaluated across variables of sex, age, season, and different classes of infections with mange (Table II). TSP was significantly lower in spring-collected animals and both the α-globulin and albumin were significantly higher in Age Groups II and III.

There was a significant decrease in amounts of α-globulin as the mange infection advanced from Class I through Class III. The above variables were further analyzed in terms of infected

TABLE II. *Mean values of selected parameters of uninfected and Mange Class I, II, and III coyotes from Webb County, Texas (fall, 1979–spring, 1981).*

Serologic test	Uninfected	Infected		
		Class I	Class II	Class III
Total serum protein (g/dl)*	7.70	8.45	7.23	7.11
Creatinine (mg/dl)†	1.01	1.03	0.92	0.84
Albumin (%)‡	28.40	24.94	26.67	24.17
Albumin/globulin ratio	0.40	0.34	0.39	0.34
α-Globulin (%)‡	8.10	8.18	7.57	5.41
β-Globulin (%)‡	12.60	12.45	10.86	11.33
γ-Globulin (%)‡	51.20	54.44	56.05	59.46
Total serum protein (%)§	8.28	7.81	9.54	8.48
Albumin (g %)§	3.02	2.53	2.43	2.16
Calcium (mg %)§	8.72	7.96	8.33	7.84
Phosphorus (mg %)§	6.16	5.36	5.97	6.33
Glucose (mg %)§	135.16	130.20	136.61	106.44
Blood urea nitrogen (mg %)§	26.20	23.00	23.76	31.83
Creatinine (mg %)§	0.95	0.97	0.84	0.79
Total bilirubin (mg %)§	0.12	0.16	0.13	0.16
Serum alkaline phosphatase (IU/liter)§	49.09	37.80	28.55	24.83
Creatine phosphokinase (IU/liter)§	1,113.09	1,139.33	1,044.85	832.78
Lactic dehydrogenase (IU/liter)§	344.18	492.80	377.27	578.33

* Biuret method.
† Jaffé Reaction (Dow Diagnostics, Dow Chemical, Indianapolis, Indiana).
‡ Cellulose acetate electrophoresis (Helena Laboratories, Beaumont, Texas).
§ SMA-12 Automated Chemistries (Technicon SMA 12/60).

TABLE III. *Mean weights of coyotes from Webb County, Texas (spring, 1979–spring, 1981).*

Sex and age groups	Uninfected	Infected	
		Mange Class I–II	Mange Class III
Males			
Age Group I	8.2 ± 0.2 (32)*	8.5 ± 0.3 (22)	8.7 ± 0.9 (4)
Age Group II	10.9 ± 0.3 (14)	9.6 ± 0.4 (14)	9.8 ± 0.3 (7)
Age Group III	10.7 ± 0.2 (33)	10.7 ± 0.3 (30)	9.8 ± 0.4 (19)
Females†			
Age Group I	7.1 ± 0.2 (37)	7.6 ± 0.3 (26)	7.6 ± 0.3 (6)
Age Group II	8.7 ± 0.2 (22)	8.3 ± 0.5 (6)	9.2 ± 0.5 (6)
Age Group III	9.3 ± 0.1 (45)	9.0 ± 0.2 (14)	8.4 ± 0.2 (7)

* Mean (kg) ± SE (sample size).
† Excludes all pregnant females during last half of gestation.

(Classes I–IV pooled) and uninfected hosts versus each of the serum parameters. Significantly lower values for ALB and α-globulin and significantly greater values for γ-globulin were noted in infected hosts. Additionally, values for Classes I and II were combined (= moderate infections) and compared with those of uninfected animals and heavy infections (Class III). In this comparison, there were significantly greater values for ALB in uninfected than in moderately infected or heavily infected animals, and amounts of α-globulin were significantly lower in uninfected hosts than those with moderate and heavy infections.

Serum values of ALB, Ca, P, GLU, BUN, CREAT, T. BILI, SAP, CPK, LDH, SGPT, and SGOT were determined for 72 infected and 60 uninfected coyotes. Because values for SGPT and SGOT were significantly higher in hemolyzed than nonhemolyzed samples, these parameters were deleted from the following analyses. The remaining parameters in uninfected animals were compared in terms of sex and age classes. The only significant relationships were decreases in P and SAP values with increasing age. These data were also compared in infected versus uninfected hosts (Table II). There was a significantly greater value of LDH in infected animals and significantly lower values of ALB, Ca, SAP, and CPK in infected than uninfected animals. When the values for these parameters were compared for each of the classes of infection with mange (I–III), there were significant increases from Class I to III in BUN, but significant decreases from Class I to III in values for ALB, SAP, and CPK.

Differential white blood cell counts from 46 uninfected coyotes were: neutrophils, 52 to 93 (76%); lymphocytes, two to 39 (12%); monocytes, zero to eight (4%); eosinophils, zero to 18 (3%); and basophils, zero to five (1%). Concordant values for 78 infected hosts were eight to 96 (77%); one to 34 (10%), zero to seven (5%), zero to 13 (2%), and zero to four (1%), respectively. There was no significant difference in the mean percentage of neutrophils or lymphocytes in infected versus uninfected animals. Sample sizes were insufficient to compare differential counts of monocytes, eosinophils, and basophils.

Physical condition of the host

Body weights of coyotes differed significantly among the six groups of sex and age (Windberg, unpubl. data). Because there was no significant difference in weights of Age Group II and III across sexes and seasons, these data for the five periods from spring, 1979 to 1981 were combined for analysis of weight relationships between mange classes (Table III). Although weights in the fall were significantly lower in both sexes, seasonal weight data for Age Group I were pooled for analyses because sex ratios and prevalence of mange were comparable across seasons.

Weights of both sexes in Age Group I did not differ significantly among uninfected, Class I to II, and Class III infections with mange (Table III). In three of the four adult age groups, coyotes with Class III mange infections had significantly lighter mean body weights than uninfected animals. For adults with light-to-moderate (Class I–II) mange infections, only males of Age Group II had a significantly lighter mean body weight.

For analysis of IPF of infected (n = 153) versus uninfected (n = 153) coyotes, data from all hosts collected from spring, 1979, through spring, 1981, were combined. Because indices of IPF differed significantly between adult and juvenile

TABLE IV. *Indices of intraperitoneal fat (IPF) in coyotes from Webb County, Texas (spring, 1979–spring, 1981).*

	Uninfected			Mange Class I + II			Mange Class III			Mange Classes I–III		
Age	0*	1	2	0	1	2	0	1	2	0	1	2
Adults	9/107† (8)	57/107 (53)	41/107 (38)	20/59 (34)	24/59 (41)	15/59 (25)	27/40 (68)	12/40 (30)	1/40 (2)	47/99 (47)	36/99 (36)	16/99 (16)
Juveniles	8/46 (17)	28/46 (61)	10/46 (22)	10/44 (23)	28/44 (64)	6/44 (14)	7/10 (70)	3/10 (30)	0/10 (0)	17/54 (31)	31/54 (57)	6/54 (11)

* 0 = no fat, 1 = light, 2 = moderate to heavy.
† Number found/number examined (percent).

TABLE V. *Prevalence of mange in relation to host sex from Webb County, Texas coyotes (fall, 1978–spring, 1981).*

	Adult		Juvenile	
Season	♂♂	♀♀	♂♂	♀♀
Spring (1979–1981)	46/62 (74)*	30/65 (46)	21/32 (66)	25/37 (68)
Fall (1978–1980)	45/104 (43)	19/95 (20)	9/44 (20)	13/65 (20)

* Number infected/number examined (percent).

coyotes (irrespective of sex), these age classes were treated separately in the following analyses (Table IV).

There were significantly fewer animals with IPF levels 1 and 2 among all infected versus uninfected adult coyotes. Significantly greater numbers of uninfected adults had greater levels of IPF than either Class I to II or Class III infected hosts. There were significantly fewer animals with high IPF levels in Class III infected versus uninfected juveniles.

Host sex

For analysis of prevalence of mange versus host sex, data were segregated by age and season (Table V). Data for 504 coyotes collected from fall, 1978, through spring, 1981, were pooled for analyses because there were no significant sex-related differences between years. There were no significant differences in prevalence of mange between sexes in juvenile coyotes, but the prevalence was significantly higher during both seasons in adult males.

Host age

For analyses of prevalence of mange versus host age, data were segregated by season for fall, 1978, through spring, 1981 (Table I). Prevalence of mange was significantly higher in adults versus juveniles only during the fall. However, there were no significant differences in prevalences across classes of infection with mange versus age during the fall. During spring (1980–1981) the prevalence of Class III mange was significantly higher in adults than juveniles, but during the same period there was a significantly greater prevalence of Classes I and II in juveniles (Table VI).

Seasonality

A definite trend of differences between the spring and fall sampling periods was noted only in 1979 and 1980 (Table I). In spring, 1979, prevalence of mange in the total population of coyotes increased significantly (67% of animals infected) from that of the preceding fall (1978) (18%). Prevalence significantly decreased from 67% in

TABLE VI. *Prevalence of mange classes in adult and juvenile coyotes from Webb County, Texas (fall, 1979–spring, 1981).*

	Mange Class I		Mange Class II		Mange Class III	
Season	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Spring (1980–1981)	8/88 (9)*	9/42 (21)	21/88 (24)	18/42 (43)	19/88 (22)	3/42 (7)
Fall (1979–1980)	9/149 (6)	1/87 (1)	32/149 (21)	16/87 (18)	9/149 (6)	4/87 (5)

* Number infected/number examined (percent).

TABLE VII. *Reproductive parameters of coyotes from Webb County, Texas (spring, 1977–spring, 1981).*

Reproductive parameters	Age Group II		Age Group III	
	Uninfected	Infected	Uninfected	Infected
Ovulation rate	0.68 (19)*	0.38 (13)	0.95 (40)	0.91 (22)
Pregnancy rate	0.53 (19)	0.23 (13)	0.76 (40)	0.64 (22)
Resorption rate†	0.14 (59)	0.20 (20)	0.09 (217)	0.28 (109)
Mean number of viable fetuses ± SE‡	5.1 ± 0.4 (10)	5.3 ± 0.3 (3)	6.4 ± 0.4 (31)	5.6 ± 0.7 (14)

* (Sample size).
† Number embryos resorbed/total number embryos.
‡ Placental scars.

spring, 1979, to 31% in fall, 1979. Prevalence again significantly increased to 69% in spring, 1980, but significantly decreased to 34% in fall 1980. However, prevalence in spring 1981 (43%) was similar to that of the preceding fall (34%).

Prevalences of Class I and II infections of mange in adult coyotes were comparable between spring and fall sampling periods (Table VI). There was a significant increase of Class I and II infections in juveniles from fall to spring. There was a significant increase in prevalence of Class III overwinter (fall to spring) in adults, but not in juveniles.

Host reproductive performance

Ovulation rates, pregnancy rates, resorption rates, and number of viable fetuses varied significantly between Age Group II and III (Windberg, unpubl. data). Because these reproductive parameters were comparable between years within each of the age groups these data were combined for the 94 adult coyotes collected during spring, 1977 to 1981 (Table VII). Juvenile coyotes were reproductively inactive (< 0.05 ovulation rate) on this study area. Ovulation rates, pregnancy rates, and mean number of viable fetuses were similar between infected and uninfected coyotes of Age Group II and III (Table VII). The resorption rate in infected females in Age Group III was significantly higher than in uninfected animals.

Host survival rates

Sixty-four coyotes (31 infected, 33 uninfected) were collared with radiotransmitters during a 6-wk period (September–November) in fall, 1979. There were 5/28 juvenile and 2/36 adult (six infected and one uninfected) capture-related mortalities within a 21-day period following marking. Four of the seven mortalities were directly related to ischemic necrosis that involved the extremity that had been held within the trap jaws. The condition was noted only in infected animals. Thus, 57/64 (25 infected and 32 uninfected) marked coyotes were used for analysis of survival rates (Table VIII).

Survival rates were similar between infected and uninfected adults over the winter period (Table VIII). Survival of infected adults was significantly lower over the spring to summer period. The survival rate for infected, juvenile coyotes was zero and total mortality (based on 6/8 ju-

TABLE VIII. *Estimated survival rates of instrumented coyotes in Webb County, Texas (fall, 1979–fall, 1980).*

Age group	Total number marked	Total number of mortalities	Time intervals		
			Nov–Feb	Mar–Oct	Total (Nov–Oct)
Adults					
Infected	17*	11	0.53 (0.28–0.76)†	0.44 (0.09–0.85)	0.23 (0.05–0.42)
Uninfected	17	3	0.79 (0.51–0.95)	1.00 (–)	0.79 (0.41–0.94)
Juveniles					
Infected	8	6	0.12 (0.01–0.46)	0‡	0.00 (0.00–0.09)
Uninfected	15	7	0.56 (0.28–0.81)	0.81 (0.31–0.99)	0.45 (0.11–0.66)

* Exclusive of capture related mortalities.
† Mean followed by confidence limits in parentheses, $P = 0.95$.
‡ No survivors at beginning of sample period.

veniles with operational transmitters) was accounted for in the first four months (overwinter) of the study (Table VIII). The annual survival rates (November 1979 to October 1980) were significantly higher in both uninfected adults and juveniles.

Of the 23 infected animals with functional radiotransmitters followed for the duration of the study, there were two and 21 coyotes with Class I and II infections with mange at marking, respectively. Only eight of the 23 infected coyotes (6 adults and 2 juveniles) were recovered in a condition such that the class of infection could be determined. In both juveniles the infection advanced from Class II (5–15% of body surface involved) to Class III (60–75% of body surface involved) in 3 and 4 mo, respectively. In two adults with Class II infections that were found within 2 mo, the infection had not advanced appreciably. In the single, Class I-infected adult the infection had advanced to Class II in a 4-mo period (approximately 5–15% of body surface involved). In the remaining three Class II-infected adults the infection advanced to Class III (50–75% of body surface involved) in 7, 8, and 11 mo, respectively.

Among the 27 recoveries of radio-equipped coyotes, there were five human-related deaths (all shot) and five undetermined deaths in infected coyotes and nine human-caused (6 shot, 1 trapped, and 2 road-killed) and eight undetermined deaths in uninfected coyotes. The proportion of human-related deaths of coyotes was comparable between infected and uninfected animals.

Host population abundance

An abundance index for the coyote population in Webb County, Texas was obtained each year in spring (May) from 1977 through 1981. The spring coyote abundance index was similar for 4 yr from 1977 to 1980 (211, 182, 206, 248, respectively). The relative abundance index (123) was significantly lower in spring, 1981.

From 1976 through 1980 the age ratio of the population during fall included the following percentages of juveniles: 35% ($n = 34$), 54% (52), 31% (72), 42% (79), and 10% (50), respectively. From 1976 through 1979 there were no significant differences in percent juveniles, but the proportion of juveniles was significantly lower in fall, 1980. This difference reflected lower population recruitment during 1980 and was the major factor for lower coyote population abundance recorded in spring, 1981.

DISCUSSION

Dynamics of the epizootic

The prevalence (32%) of sarcoptic mange in coyotes in south Texas was higher than reported in other wild canid mange epizootics in North America (Trainer and Hale, 1969; Stone et al., 1974; Pryor, 1956; Pence et al., 1981; Todd et al., 1981). Although changes in prevalence throughout a mange epizootic are documented (Todd et al., 1981), there are no reports comparable to the dramatic three-fold increase in prevalence (15–26%) in 1975 to 1978 to 67% in spring, 1979 as noted in this study.

Sarcoptic mange is enzootic in certain wild canid populations in North America. It has been present in coyotes in Alberta and Montana since the early 1900's (Cowan, 1947; Green, 1951; Knowles, 1909, 1914) and in Wisconsin, Kansas, Iowa, Missouri, and Oklahoma since the 1950's (Trainer and Hale, 1969; Gier et al., 1978). Although mange in coyotes in south Texas was previously undocumented, personal interviews with long-time professional trappers indicated that occasional mangy coyotes were regularly observed since the 1920's. Three of these trappers described an extensive mange epizootic in Webb, Dimmit, and Maverick counties beginning in the late 1920's and lasting about 10 yr. The prevalence remained very low (1% or less) until the 1975 epizootic. The dynamics of the present epizootic indicated the development of mange in a highly susceptible population with previous exposure.

Potential sources of this epizootic include (1) introduction of a new virulent strain of *S. scabiei* from an external source, (2) mutagenesis of an established, but previously less pathogenic, strain of *S. scabiei* in this host population, and/or (3) increased susceptibility of the host population. Because mange occurred since the late 1920's, there were no concurrent epizootics in domestic canids, and there were no known introductions of wild canid stock into the coyote population, the latter alternatives seem most feasible. Gier et al. (1978) and Todd et al. (1981) suggested a density-dependent relationship in mange prevalence in coyote populations in Kansas and coyote and timber wolf populations in Alberta, respectively. In both instances, a mange epizootic was considered directly linked with significant

increases in coyote (and wolf) numbers and also associated with reduced natural food. A density-dependent relationship in the present epizootic was not substantiated because (1) coyote population densities in south Texas (indices) were concomitantly higher (2–10 times) than in other regions in the western United States (U.S. Fish and Wildlife Service, 1978; Bean and Roughton, 1980) and (2) the population of the study area was stable at similar abundance indices from 1977 to 1980. Also, prey population (lagomorph and rodent) indices were relatively high during the peak of the mange epizootic (1978–1980) (Windberg, unpubl. data). Although a threshold density of susceptible hosts is required for maintaining transmission potential during an epizootic, we contend that high host population densities alone do not necessarily predispose a wild canid population to a mange epizootic.

Based on studies of chaetotactic anomalies of *S. scabiei,* Pence et al. (1975) suggested that these phenotypic expressions (1) could have resulted from a decrease in selection pressures and subsequent proliferation of individuals that occurs during an epizootic or, alternatively, (2) that anomalous individuals may be the consequence of many generations produced over a short period of time from the restricted gene pool of a few founders. These phenotypic expressions indicate considerable genetic plasticity of *S. scabiei* in terms of expressed morphometric characteristics. It is reasonable to assume a similar phenomenon for many physiological, biochemical, or antigenic characteristics that may influence the pathogenicity of the species. Thus, mutation of an existing strain of low virulence to become more pathogenic seems to be the most tenable of the three above alternatives for sources of the epizootic.

There is little information on the horizontal transmission and subsequent geographic spread of mange in wild canid populations. Gier et al. (1978) indicated that in the 1972 to 1974 epizootic, prevalence of mange in coyotes was 50% in Iowa, northwest Missouri, and northeast Kansas and ranged to 10% in southeast Kansas and northern Oklahoma. This implied a decreasing prevalence from a central region of high prevalence. Green (1951) suggested that mange in Alberta wild canids originated from Montana after Knowles (1909) introduced *S. scabiei* into the coyote population for control purposes. Mange was observed in coyotes from southern Alberta in 1911 and further north in 1914. These studies tend to suggest the centrifugal radiation of an epizootic from a single focus of infection.

The focal point of the mange epizootic in coyotes in south Texas was within the four-county area centered in southeastern Webb County. The epizootic began in 1975 with low prevalences (14–26%) for the first 4 yr. The prevalence was higher (31–69%) in these counties from spring, 1979, through spring, 1981. During spring, 1979, only isolated cases were reported from adjacent counties, but by spring, 1980, prevalences > 10% were noted in counties north, south, and east of the original four-county area. The epizootic area doubled in size in 1 yr. During spring, 1981, prevalence of mange across the entire area was 10 to 50% and numerous isolated cases were reported from additional adjoining counties. At this time the epizootic encompassed a 27-county area of south Texas and adjacent areas of brushland habitat in the Republic of Mexico.

A host population density-dependent relationship of a mange epizootic in wild canids could provide an explanation of the nature of geographic expansion observed in the south Texas epizootic because prevalence of mange was highest in the region of the highest coyote population abundance. The epizootic did not progress into regions of intense cultivation to the southeast or northeast where abundance of coyotes was consistently lower. Likewise, abundance of coyotes was lower to the northwest (Bean and Roughton, 1980) because of intensive reduction of predators associated with sheep and goat production.

From the present and previous studies (Gier et al., 1978; Todd et al., 1981), we suggest that (1) sarcoptic mange is enzootic in many wild canid populations, but only periodically becomes epizootic; (2) epizootics of mange may originate from a single focus resulting from changes in the virulence or pathogenicity in the existing mite population; (3) there is an apparent density-dependent relationship between the number of wild canids and an epizootic of mange that is related only to transmission potential because canid populations may be regulated at high densities for long periods without necessarily predisposing the population to an epizootic of mange; and (4) the expansion of an epizootic of mange may be related to canid population densities across a geographic area and ultimately delimited by the peripheral overreach of the minimum threshold density necessary for transmission.

Pathology

Lesions of sarcoptic mange in coyotes from south Texas were similar to those reported in wild canids from the coastal prairies of Texas and Louisiana by Pence et al. (1981) and from New York by Stone et al. (1972). However, the ears were less frequently involved than observed in wild canids from the Gulf coast and lesions occurred less frequently on the head and muzzle than noted in domestic canids (Muller and Kirk, 1976).

Recovery from sarcoptic mange by wild canids is rarely documented. Todd et al. (1981) found only two of several hundred coyotes examined that had apparently recovered from mange. Four of 367 coyotes from south Texas demonstrated regrowth of hair and apparent healing of lesions. This indicated that certain animals in this population were capable of recovery from mange.

Of the fungi isolated from south Texas coyotes only *Trichophyton mentagrophytes, T. rubrum, Trichophyton* sp., and *Microsporum canis* are recognized pathogens (Van Breuseghem et al., 1978). However, the extent to which these fungi contribute to the pathology of mange is unknown. Recently, *Malassezia pachydermatis* was found as a consistent associate with sarcoptic mange in red foxes, porcupines, and coyotes in New York and it was suggested that this species was a possible secondary pathogen (Salkin et al., 1980). In the present study, *M. pachydermatis* was isolated in only two of 39 coyotes and it is easily isolated from healthy dogs and cats using Sabouraud's media at 25 C (Van Breuseghem et al., 1978). Thus, its role as a secondary pathogen in mange infections is questionable.

In infected coyotes the significant decreases in ALB as the infection increased in severity was attributed to loss of lower molecular weight components of serum through the skin. This occurs in clinical entities similar to mange such as severe burns, pyoderma (Duncan and Prasse, 1977), or other debilitating conditions. The significant decrease in α-globulins associated with increasing severity of mange is more difficult to explain because this is rarely observed and is usually only related to severe liver dysfunction (Coles, 1974). It warrants further investigation.

The increase in γ-globulin in infected coyotes as well as increases correlated with progressing severity of infection was attributed to the development of a humoral antibody response. However, the nature of the specific immunoglobulin response remains to be elucidated.

Increases in LDH in infected coyotes have been explained in terms of dermal hemorrhage and general tissue necrosis in the skin (Wolf et al., 1973). The decreased amounts of ALB and CA in infected animals were related because loss of protein removes the binding material for the bound portion of serum calcium (Widmann, 1979). The decreased amounts of SAP in infected coyotes and as the mange infection progressed in severity is difficult to interpret, but decreased amounts of SAP have been noted in conditions of cachexia resulting from malnourishment (Wolf et al., 1973) and in altered protein catabolism (Widmann, 1979). The decrease in CPK in infected coyotes and as the infection progresses in severity cannot be readily interpreted, but may only reflect trauma associated with capture. The increases in BUN as the mange infection increased in severity corresponds to the decreased ALB (increased protein catabolism) resulting in increased urea formation from renal perfusion such as occurs in cachexia and burns (Widmann, 1979).

The range and mean of differential white blood cell counts for coyotes from south Texas were similar to those obtained from conditioned, captive coyotes by Gates and Goering (1976). There was no measurable shift in the white cell differential of infected versus uninfected animals.

Numerous authors have alluded to the debilitated condition of wild and domestic canids with severe sarcoptic mange (Kutzer, 1970; Stone et al., 1972; Zumpt, 1972; Muller and Kirk, 1976; Pence et al., 1981; Samuel, 1981; Todd et al., 1981). Todd et al. (1981) found that body weights of mangy timber wolves averaged 4 to 10% less than uninfected wolves, but these differences only approached significance in pups. In coyotes from south Texas, only adults with advanced mange had significantly lighter body weights.

Todd et al. (1981) reported significantly lower xiphoid-process fat globule weights for infected adult and juvenile coyotes and timber wolves. In coyotes from south Texas there were fewer individuals with intraperitoneal fat among both adults and juveniles with severe mange, and adults with light to moderate infections. Fat accumulation appears to be more sensitive than body weight as a measure of condition in mange-infected canids.

These data indicated that mange in south Tex-

as coyotes was a progressive chronic debilitating infection with (1) concurrent development of a significant humoral antibody response and (2) some loss of physiological condition as the infection progressed in severity.

Host and seasonal variables

Adult male coyotes had a significantly greater prevalence of mange in the present study and in Alberta (Todd et al., 1981). Adult male coyotes may have greater contact with other coyotes and hence greater potential to become infected with mange because Harris and Hibler (1983) reported that adult males spent significantly more time exploring outside their home range than adult females or juveniles.

Todd et al. (1981) found no age-related differences in prevalence of mange in wolves and coyotes from Alberta. The greater proportion of adult than juvenile coyotes from south Texas infected during fall at the peak of the epizootic (1978–1980) was probably related to the relative time of exposure. The juveniles had a shorter time for exposure and development of an infection. The significantly greater prevalences of Class I and II infections of mange in juveniles in the following spring was a reflection of the additional period of exposure. Thus, because of the relative potential for exposure, prevalence of mange in wild canid populations should always be considered in terms of the juvenile/adult ratio.

In the initial years of the epizootic (1975–1978) mange prevalence did not differ between spring and fall. During the peak of the epizootic (1979–1980) prevalence in spring was significantly higher. High mortality associated with extreme cold in coyotes and timber wolves from northern latitudes (W. M. Samuel, 1981, pers. comm.) is certainly much less of a mortality factor in coyotes from the warmer, southerly latitude of south Texas. The higher prevalence of adults with severe mange in spring was indirect evidence of overwinter survival of those hosts with Class I and II infections during the fall. Therefore, the seasonal trend of higher prevalence of mange in the entire spring population resulted from overwinter survival of adult coyotes coupled with increased exposure of uninfected juveniles.

Mange and host population dynamics

Ovulation rates, pregnancy rates, and litter size were not impaired in mange-infected coyotes. Greater fetal resorption rates in coyotes with advanced mange reflects a common response in individual animals physiologically unable to complete pregnancies.

There is little information on the duration of a sarcoptic mange infection in wild canids. Stone et al. (1972) reported that all of 16 experimentally infected red foxes died over a period of 2 to 4 mo PI. Samuel (1981) found that 2- to 6-mo-old captive coyotes died or were terminally ill from 52 to 75 days PI. Recovery of instrumented, infected coyotes in our study indicated that mange in two juveniles advanced from Class II to severe Class III within 3 to 4 mo. The infection in six adults advanced more slowly over several months. This suggested mange progressed more rapidly in juveniles than adults. Todd et al. (1981) also suggested higher mortality among pups based on an inverse relationship between prevalence of mange and proportion of juveniles in winter wolf populations.

Survival data for instrumented coyotes showed (1) a significantly lower survival rate among infected adults over a 1-yr period and (2) that all infected juveniles died within 4 mo postmarking. Retrieval of marked carcasses of coyotes provided no evidence that mange was the direct cause of death. Our results indicate that it is reasonable to assume that mange predisposes afflicted individuals to various factors that increase mortality. Our data suggested that although mortality rates of infected coyotes were higher in the south Texas population, the immediate causes of death were similar to uninfected animals. Hence, mortality associated with mange was compensatory with other mortality factors operating within this coyote population such that overall mortality was not increased.

In contrast to the findings of Todd et al. (1981), abundance indices for the population of coyotes in south Texas from 1976 to 1981 were not related to prevalence of mange. However, in spring, 1981, when mange prevalence had decreased from the previous spring, abundance of coyotes was indexed lower than in any of the previous 4 yr. This resulted from extremely low recruitment in 1980. High mortality of juveniles from birth to fall in 1980 appeared to be the primary factor contributing to low recruitment because reproductive rates did not vary from 1976 to 1980 (Windberg, unpubl. data). However, high juvenile mortality in 1980 was unrelated to the epizootic of mange because recruitment was very low only in 1980, whereas prevalence of mange was very high in 1979 (67%) and 1980 (69%). Serological studies indicated that canine *Parvo-*

virus was introduced into this coyote population in 1979 and that an epizootic probably occurred in 1980 to 1981 (Foreyt, 1981, Wildlife Disease Conf., Laramie, 43: 14; and pers. comm.). Data from *Parvovirus* epizootics in domestic dogs and captive coyotes indicate high mortality of juveniles. High juvenile mortality in coyotes in south Texas in 1980 was, therefore, attributed to a *Parvovirus* epizootic.

In summary, reproductive performance of coyotes with sarcoptic mange in the south Texas population was not adversely affected. Infected adults had a higher mortality rate. Infected juveniles apparently succumbed more rapidly than adults. However, the higher mortality of infected juveniles and adults was compensatory with overall coyote mortality and did not alter the age ratio of the population or reduce abundance.

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