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ABSTRACT: Bubonic plague was first found in Los Angeles County in 1908. The largest epidemic of pneumonic plague in the United States occurred in the county in 1924, and the last cases of plague associated with domestic rodents in the United States occurred here in 1925. Sporadic plague activity was recorded from 1925 to 1975. Since 1975, plague has been found annually and is now endemic in the San Gabriel Mountains and the interface, that area where suburban encroachment intermingles with wilderness areas along the southern edge of these mountains. Within these two areas, plague is amplified and is a risk to humans when it occurs in the California ground squirrel, Spermophilus beecheyi. This rodent has been implicated directly in two human cases, and is now peridomestic throughout most of the interface area. A domestic cat was implicated with another case; the role of domestic pets in plague ecology is discussed. Although large populations of Rattus rattus exist within the interface, they currently play no role in plague ecology due to the virtual absence of fleas. The oriental rat flea, however, is seasonally very abundant in Rattus norvegicus living adjacent to the interface area and poses an alarming potential for epidemics if plague ever was introduced into this host population.

The plague surveillance program in Los Angeles County centers on an active intelligence network to report signs of plague activity and on the combined use of serologies taken from wild carnivores and S. beecheyi. Early detection by these means plus active flea and ground squirrel suppression programs have been implemented to reduce plague activity and prevent human cases.

INTRODUCTION

The literature refers to two distinct ecologies for bubonic plague: urban and sylvatic. Urban plague is associated with domestic rodents (Rattus spp. and other murids) and their fleas and exists within villages, towns, and cities where human-rat-flea associations are intimate. Sylvatic plague is associated with native wild rodents and their fleas and exists within rural (agricultural, recreational, and wilderness) settings. In the western United States the fidelity of this ecological dichotomy remained intact until recently. Urban plague virtually disappeared in the late 1940s. Owing to the encroachment of the suburbs and urban development into rural areas and the ensuing development of peridomesticity in certain important species of wild rodents, sylvatic plague was expanded into the suburban-urban environments of both small towns and large cities. Episodes of epizootic (rodent) plague have occurred with increasing frequency along the interface and within the boundaries of many western cities. Human cases have resulted from some epizootics, e.g., in Denver, Colorado (Hudson et al. 1971); in Reno, Nevada and Los Angeles, California (California Morbidity 1979, 1980, 1984a,b); in Albuquerque and Santa Fe, New Mexico (Montman 1985).

The occurrence of three human cases since 1979 and persistence of epizootic activity since 1978 within Los Angeles County have emphasized the need for effective surveillance and suppression programs to prevent other human cases. Besides the actual presence of sylvatic plague activity at recreational sites in the San Gabriel Mountains and along the suburban-wilderness interface, concern has been raised over the possible recrudescence of urban plague. Roof rats (Rattus rattus) are abundant within suburban residential communities and along the interface areas where they commingle with many species of wild rodents including the California ground squirrel (Spermophilus beecheyi), the most important source of plague infection amongst humans in California. Also, Norway rats (Rattus norvegicus) are abundant within commercial, industrial, and old residential areas of many cities in the county. Although the status of sylvatic plague in the county is indeed serious, the public health and economic consequences of urban plague, should it occur, would be drastic.

This paper describes the complexity of plague ecology, particularly within the interface area of Los Angeles County. The roles of various species of rodents, their fleas, domestic pets, and human activity are discussed. Also described are the surveillance program used to detect and monitor plague activity and flea suppression and the S. beecheyi management program implemented to reduce plague activity and prevent human cases.

*Paper presented by Minoo B. Madon.

HISTORY OF PLAGUE IN LOS ANGELES COUNTY

The first evidence of plague in Los Angeles County was a human case reported in August 1908. During the ensuing investigation, one infected ground squirrel was found. Plague in domestic rats or other human cases was not discovered. In October 1924, an epidemic of pneumonic plague occurred in the City of Los Angeles. During this outbreak, 30 of 32 victims died. This was the largest and the last recorded epidemic of pneumonic plague in the United States. Between 24 October 1924 and 11 January 1925, an additional seven human cases of bubonic plague were also reported. Both the pneumonic outbreak and the bubonic cases originated from domestic rodents. Plague-infected rats were found near the homes of plague victims in the City of Vernon, and at four hog farms located east and west of the City of Los Angeles. Plague-infected ground squirrels were found at two of the four hog farms (Dickie 1926, Link 1954).

Plague-infected Norway rats were detected in 1927 and 1932, but plague was not recovered again from domestic rodents until 1981, when a roof rat from Griffith Park was found positive. Plague-infected ground squirrels and their fleas were found in 1924, 1941, and 1942. Plague was not detected in the county again until 1975, when an intensive epizootic occurred among ground squirrels and woodrats at Arcadia Wilderness Park within the interface area. Between 1942 and 1975, the plague surveillance program was either sporadic or nonexistent. Therefore, it is uncertain whether plague was truly absent or rather went undetected.

Since 1978, plague activity has persisted annually within the county in wild rodents, their fleas, wild carnivores, domestic pets, and occasionally humans. Three nonfatal locally acquired cases have occurred; one in 1979 and two in 1984. Occurrence of plague activity in Los Angeles County from 1975 through 1985 is shown in Table 1. This evidence clearly demonstrates that plague is endemic in this densely populous county.

SURVEILLANCE

Several components comprise the surveillance program established in Los Angeles County. This program is based upon that developed for the rest of California (Nelson 1978), but seeks, to find the most sensitive method(s) for early detection of plague activity within the county.

An intelligence network system has been established involving trained personnel in local, state, and federal agencies that manage out-of-doors activities; these include park managers, foresters, game managers, agricultural agents, and informed individuals of the general public. The occurrence of sick or dead rodents or other signs of suspected plague activity is promptly reported. This program has proven to be effective in the early detection of sylvatic plague outbreaks. An additional system helpful in monitoring observations during outbreaks is available through public awareness created by media coverage.

In 1978, a carnivore serology program was established in Los Angeles County involving trappers employed by the Los Angeles County Agricultural Commissioner and animal control officers in local agencies who obtained carnivore blood samples on special filter paper. California's carnivore serology program has been described by Smith et al. (1984). Among wild carnivores, canids particularly are known to be resistant to plague infection. Although they become infected through eating diseased rodents, they seldom get sick or show symptoms. They do develop antibodies to the plague bacterium, which are detected in the laboratory by the passive hemagglutination and inhibition tests. Los Angeles County has a large coyote population that occurs even within urban areas (Howell 1982). Since carnivores are predacious and cover large areas, the carnivore serology program has proven to be a sensitive sentinel system for monitoring the occurrence and persistence of sylvatic plague.

A domestic pet serology program was set up by Dr. C. P. Ryan of the Los Angeles County Department of Environmental Health Services in 1984, involving adult dogs brought to two animal shelters. This program has detected plague activity in two cases; however, the details and results of this program will be described elsewhere by Dr. Ryan.

Public health biologists have conducted surveys of rodent populations and their fleas at sites with a history of plague activity during and between plague epizootics, and at sites where there appears to be a risk to humans, e.g., all park and recreational sites along the interface area and in the San Gabriel Mountains. Carcasses, fleas, and sera samples have been collected, processed, and tested to find both evidence of plague and a sensitive sentinel rodent(s) among this fauna. Furthermore, data were collected to determine the most important species of rodents and fleas with regard to transmission of this disease to humans.

Although roof rats abound in the interface area, in orchards, and in suburbs, the role and the potential for this species in plague ecology was unknown. In 1983, a 1-year study (Schwan et al. 1985) was undertaken at six sites along the interface to determine the species, density, and seasonal distribution of fleas on this host. In September 1984, a similar study of the fleas associated with Norway rats in the central city was begun to determine the potential for plague transmission. Currently, no study of the seasonal distribution of wild rodent fleas on the California ground squirrel has been made; however, trends are evident and reported herein.

Los Angeles County covers approximately 4,000 square miles (10,240 km) and contains 84 cities and a population of over 8 million people. For convenience of discussion, we divided Los Angeles County into four areas (Figure 1): 1) the semidesert area north of the San Gabriel Mountains; 2) the wilderness/ recreational areas of the San Gabriel Mountains, including the Santa Monica Mountains; 3) the interface

Table 1. Evidence of plague in Los Angeles County, California, since 1975.

Date	Location	Species	Sample(N)	Result
1975	Arcadia Wilderness Park	S. beecheyi	Carcass (3)	+
		S. beecheyi	Serum (10)	1:132-1:4096
		S. beecheyi	Flea pools (12)	+
		N. fuscipes	Carcass	+
1976	Arcadia Wilderness Park	S. beecheyi	Serum (2)	1:512,1:8192
1978	Chantry Flats	S. beecheyi	Serum	1:64
	Crystal Lake	S. beecheyi	Carcass	+
	Diamond Bar	S. beecheyi	Carcass (3)	+
		S. beecheyi	Flea pools (2)	+
		S. auduboni	Carcass	+
	Pasadena	Coyote	Serum (2)	1:16
1979	Diamond Bar	Human	Blood	+
		Cat	Carcass	+
		S. beecheyi (3)	Carcass	+
		N. fuscipes	Carcass	+
	Firestone Boy Scout Camp	S. beecheyi	Serum	1:32
		P. maniculatus	Serum	1:32
	Fellow's Campground	S. beecheyi	Carcass	+
		S. beecheyi	Serum	1:128
1980	Diamond Bar	S. beecheyi	Serum (3)	1:128-1:8192
		S. beecheyi	Carcass	+
1981	Pomona	S. beecheyi	Serum	1:32
	Griffith Park	R. rattus	Carcass	+
	Glendale	Coyote	Serum	1:256
	Altadena	Coyote	Serum (2)	1:256
	Jackson Lake	S. beecheyi	Serum (2)	1:16,1:256
1982	Santa Monica	S. beecheyi	Serum	1:32
	Jackson Lake	S. Beecheyi	Serum (2)	1:512,1:1024
	Griffith Park	Pm. californicus	Serum	1:16
	Arcadia	Coyote	Serum	1:512
	Laurel Canyon	Coyote	Serum	1:1024
	Pasadena	Coyote	Serum	1:128
	Camp Kare	S. beecheyi	Carcass	+
	Big Pines	S. beecheyi	Serum (8)	1:16-1:256
1983	Griffith Park	S. beecheyi	Serum	1:2048
	Camp Kare	S. beecheyi	Serum (2)	1:32-1:64
	Coldbrook Campground	S. beecheyi	Serum	1:32
	Bradbury	Coyote	Serum	1:256
	Pasadena	Coyote	Serum	1:128
1984	Camp Colby	Chipmunk	Carcass	+
		S. beecheyi	Carcass	+
	Claremont	Human	Blood	+
		Coyote	Serum (9)	1:64-1:512
		Dog	Serum (6)	1:32-1:512
		Cat	Serum (3)	1:16-1:512
	Bradbury	Human	Blood	+
	Monte Cristo	S. beecheyi	Flea pool	+
	Azusa	S. beecheyi	Serum (3)	1:16-1:32
	Camp Affloughbaugh	S. beecheyi	Carcass	+
	Altadena	Coyote	Serum	1:128
	Agoura	Dog	Serum (3)	1:16-1:32
1985	Diamond Bar	Coyote	Serum	1:64
	Castiac	Dog	Serum (2)	1:16
	Camp Peavine	S. beecheyi	Serum	1:64
	Chantry Flats	S. beecheyi	Serum	1:16
	Arcadia	Coyote	Serum (4)	1:64-1:128
		Bobcat	Serum	1:64
	Jet Propulsion Laboratory	S. beecheyi	Carcass (2)	+
		S. beecheyi	Serum (6)	1:16-1:64

area along the foothill-canyon-ridge territory of the southern San Gabriel Mountains where the suburbs and the wilderness meet; and 4) the large metropolitan urban area south of the mountains. Plague has not been found in area 1 and is excluded from further discussion. The complexities of plague ecology within areas 2 and 3 are emphasized, and the alarming potential for urban plague among domestic rodents within area 4 is stressed.

The San Gabriel Mountains occupy an oval-shaped area of approximately 1,200 square miles, having an east-west range of 70 miles and a maximum north-south width of 25 miles. The highest peak is 10,080 feet. The mountains are steep and the slopes are deeply carved by canyons. Four life zones occur: Lower Sonoran, Upper Sonoran, Transition, and Canadian. The lower slopes have vast tracts of chaparral with oak woodlands in the few flatland areas. Coniferous forests occupy the crest areas with a few

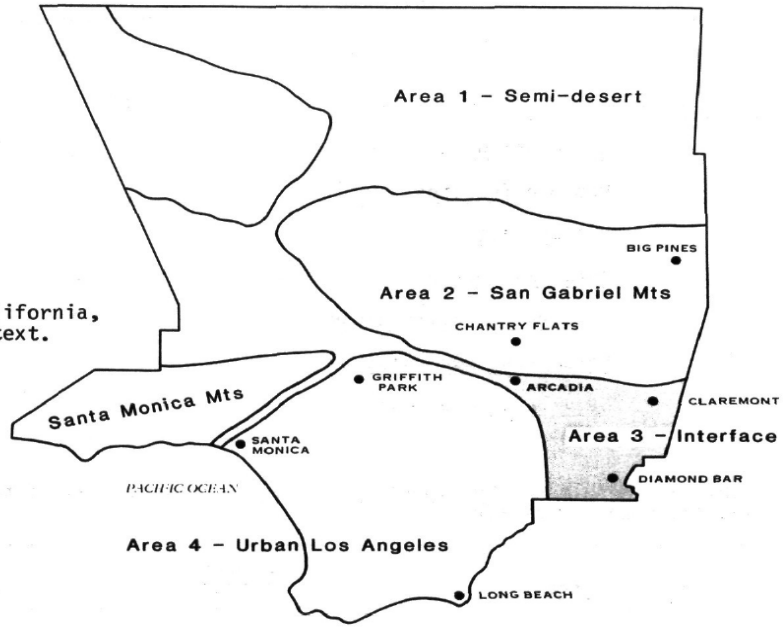

Figure 1. Map of Los Angeles County, California, showing the four areas discussed in the text.

meadows. The topography, vegetation, and rodent fauna of the mountains have been described in detail by Vaughan (1954) and MacMillan (1964).

According to Howell (1982), over 100 miles of interface area occurs between residential suburbs and the undeveloped foothill-canyon-ridge areas along the southern edges of the Santa Monica and San Gabriel Mountains. The interface area is an ecotone where wilderness and native flora and fauna meet and mesh with an area of human development (residential buildings, streets, parks, gardens, orchards, pasture, cemeteries, etc.), and introduction of landscaped vegetation and some fauna. The width of the interface varies with the size and slope of the canyons, ridges, and flat areas; the extent and meandering of the ridges, and the age of the residential development. Its width is narrow and abrupt at Arcadia, wide at Bradbury and Claremont, and extensive in southeastern Los Angeles County where much new development has taken place.

The interface has certain common characteristics. It is a zone of encroachment through human development that has produced a mosaic of residential areas interspersed by wilderness and green belts. This zone is dynamic owing to expanded human growth, and harbors populations of the California ground squirrels that have become peridomestic. Commingling with the peridomesticated ground squirrels are populations of roof rats that have adapted to outdoor habitats in introduced vegetation and even into feral situations. The presence of humans, domestic pets, the California ground squirrel, wild carnivores, and roof rats cohabitating within this ecotone has created a situation that is of growing concern for public health officials.

Vaughan (1954) reported 22 species of sylvatic rodents from the San Gabriel Mountains; 13 of the 22 species have been implicated regularly or casually in plague ecology elsewhere in California. Since 1975, two species, *S. beecheyi* and *Eutamias merriami*, have been found to be plague positive (Table 2). From our surveillance in the interface we have obtained 15 species of rodents, including *R. rattus* and *M. musculus*. Ten of the 15 species have been implicated regularly or casually in plague ecology in California. Since 1975, five species were found plague positive, with *S. beecheyi* again being the most important rodent species (Tables 1 and 2). The only positive flea pools have been those taken from bodies of *S. beecheyi* or their burrows. Two of the three human cases that occurred in Los Angeles County can be traced directly to *S. beecheyi* and their fleas.

Surveillance in Los Angeles County, therefore, has centered on testing carcasses, sera, and fleas of *S. beecheyi*, the best sentinel rodent for plague detection in the interface and the mountainous areas. Since 1975, the incidence of infected ground squirrel carcasses (Table 3) is 8.1%, and that of ground squirrels with detectable antibody titers (Table 4) is 5.2%. This latter figure is rather low when compared to antibody incidence rates in *S. beecheyi* (nearly 30%) from the San Jacinto Mountains of Riverside County (Nelson, unpub. information) and in chipmunks and chickarees (over 20%) from the coniferous forest habitat of northeastern California (Smith et al. in prep.).

The results of the carnivore serology program in Los Angeles County are shown in Table 4. If the 50 sera samples taken from Area 1 (the northern semidesert area) are subtracted from the total of 478, the incidence of infection amongst carnivores is 6.3% (27 of 428); this percentage is again rather low (Smith et al. 1984). Nevertheless, this program component is effective when integrated with serological

Table 2. Number of specimens of rodents and rabbits found plague positive at two areas in Los Angeles County from 1975 to 1985.

Species	Interface Area	San Gabriel Mountain Area
Spermophilus beecheyi	33	31
Neotoma fuscipes	2	0
Rattus rattus	1	0
Eutamias merriami	0	1
Peromyscus californicus	1	0
Peromyscus maniculatus	1	0
Sylvilagus audubonі	1	0

Table 3. Results, of Spermophilus beecheyi carcasses tested for Yersinia pestis from 1975-85 in Los Angeles County, California.

Year	Number tested	Number positive	Percent positive
1975	15	3	20.0
1976	10	0	0.0
1977	14	0	0.0
1978	16	4	25.0
1979	54	4	7.4
1980	15	1	6.7
1981	20	0	0.0
1982	25	1	4.0
1983	18	0	0.0
1984	15	2	13.3
1985	7	2	28.6
Total	209	17	8.1

surveillance in S. beecheyi. These two components form the core of the most sensitive surveillance system yet devised for Los Angeles County.

Direct evidence of plague in the San Gabriel Mountains centers on S. beecheyi. We know that S. beecheyi is not a reservoir of plague but an amplifying and susceptible (recipient) host (Nelson 1980). Other yet unknown species act as reservoirs of plague in these mountains. Ten years of data show apparent foci of plague outbreaks among S. beecheyi in three main areas of the San Gabriel Mountains; Big Pines, Chantry Flats, and the Chilao Recreational areas. Subsequent movement of plague appears to take place from these sites down into canyons and ridges to interface sites at lower elevations. This suggests that plague in the interface ultimately stems from foci in the San Gabriel Mountains. A human case occurred in 1984 in a woman who picnicked at Monte Cristo campground approximately 5 miles west of the Chilao Ranger Station. She apparently acquired her infection from S. beecheyi fleas, as a pool of Hoplopsyllus anomalus collected from a ground squirrel in the campground was positive for plague.

Although no systematic seasonal collections of fleas from S. beecheyi have been made from the San Gabriel Mountains, a trend is noted. Diamanus montanus is the predominant flea throughout the year. The risk of transmission of plague during epizootics involving S. beecheyi remains high throughout the summer months when recreational use is high in the San Gabriels owing to the continuous presence of D. montanus. In the interface area and elsewhere in California with cool moist winters and hot dry summers (Holdenreid et al. 1951, Ryckman et al. 1954, Rutledge et al. 1979), D. montanus, the most effective

Table 4. Results-of serological surveillance for antibodies to Yersinia pestis in wild carnivores (1978-85) and Spermophilus beecheyi (1975-85) by month in Los Angeles County, California.

	Wild carnivore sera			Spermophilus beecheyi sera		
Month	Number tested	Number positive	Percent positive	Number tested	Number positive	Percent positive
January	53	2	3.8	12	0	0.0
February	35	2	5.7	12	0	0.0
March	11	0	0.0	54	1	1.8
April	21	5	23.8	98	1	1.0
May	32	5	15.6	126	10	7.9
June	31	4	12.9	180	15	8.9
July	26	0	0.0	106	2	1.9
August	56	2	3.6	109	9	8.3
September	53	1	1.9	79	1	1.3
October	58	2	3.4	71	8	11.3
November	54	3	5.6	45	0	0.0
December	47	1	2.1	6	0	0.0
Total	478	27	5.6	898	47	5.2

sylvatic flea vector of plague to humans, is replaced by Hoplopsyllus anomalus, a less effective vector (Barnes 1982), in the hot, dry summer months. In the interface, H. anomalus becomes the dominant flea in collections from S. beecheyi in June and remains so until cooler weather or rains return in the autumn; therefore, after June the risk of transmission to humans is lessened when D. montanus population drops, or becomes a minor component of the flea fauna of S. beecheyi. Most epizootics in the interface occur during the spring and autumn months. Epizootics in the mountains occur from spring through autumn with a lull during the winter months.

Epizootics in the interface have often been violent, killing off large populations of S. beecheyi at Arcadia Wilderness Park in 1975, at Sycamore Canyon County Park at Diamond Bar in 1978, and at the Palmer Canyon site north of Claremont in 1984. Plague apparently also decimated populations of woodrats and various species of mice at the latter site where few animals were trapped.

Three significant findings developed from these three episodes. In April 1984, a human pneumonic plague case in a veterinarian occurred from the Palmer Canyon outbreak (Fig. 2). The victim acquired his infection during examination of a sick domestic cat that lived in the canyon. The cat presumably acquired its infection while hunting wild rodents. The cat died, and the veterinarian was *very* fortunate to survive. Sera taken from resident pet dogs and cats in the canyon revealed that two other cats and six dogs had been infected. This episode has added to the growing number of human plague cases acquired from pet cats (Rollag et al. 1981, Werner, et al. 1984). and the alarming role that cats and possibly pet dogs can play in plague epidemiology.

The epizootic among S. beecheyi in 1978 at Diamond Bar demonstrated that plague in this suburban community continued to exist from 1978 through 1980, and recurred in 1985. In May 1979, in a tract of residential homes approximately 2 miles southwest of Sycamore Canyon County Park, a man contracted plague during an epizootic of S. beecheyi which occurred on the hillside behind his home. A plague-positive carcass was found within 100 feet of his home. This was the first human case of plague acquired within a suburban-urban area in California since 1925. Furthermore, it revealed the persistence of plague activity within a relatively small area, the presence of plague in the suburban home environment, and the documentation of the peridomesticity of S. beecheyi living in backyards, on school grounds, parks, and playgrounds. It also necessitated the development of an effective surveillance system in suburban-urban environments, and revealed the difficulty of controlling plague in urban settings.

The outbreak in Arcadia in 1975 occurred where populations of S. beecheyi and R. rattus commingle. Because elsewhere in the world roof rats are important rodents in plague outbreaks and in transmission to humans in domestic settings, we carefully monitored this episode. In spite of the violent epizootic among S. beecheyi and the abundance of roof rats in the dense landscaped vegetation that characterized this older, affluent residential area, no involvement of roof rats in this epizootic was seen, and roof

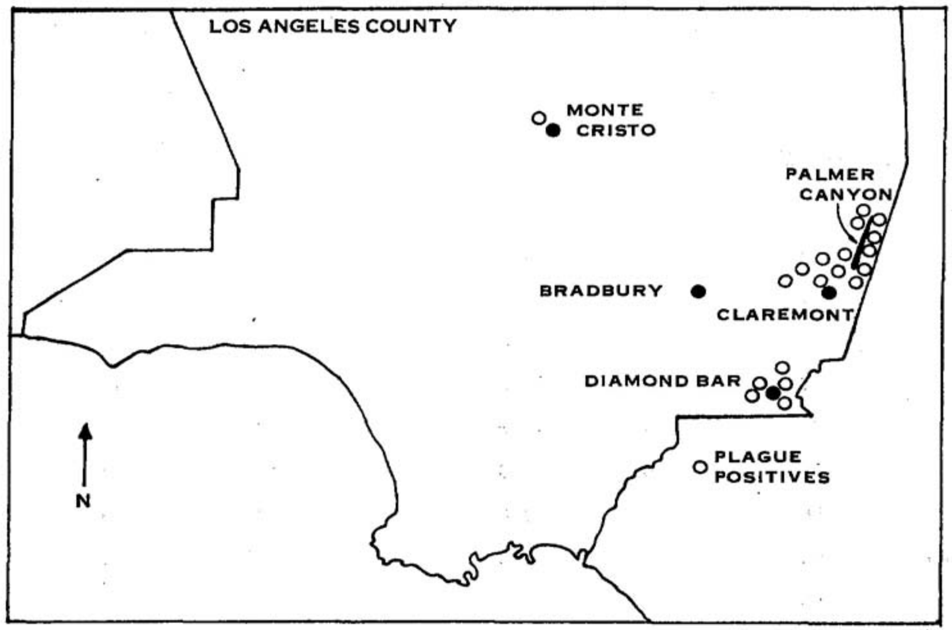

Figure 2. Map of Los Angeles County, California, showing sites of three human cases of plague (Diamond Bar, 1979; Claremont, 1984; and Bradbury-Monte Christo, 1984), with sites where plague positive material was found during each case (open circles).

rats captured were devoid of fleas. Similar observations were made during other outbreaks where S. beecheyi and roof rats commingled. Except for the one positive roof rat found in Griffith Park in 1981, roof rats and their fleas have not yet been involved with plague epizootics in Los Angeles County. Griffith Park, the largest known urban park in the United States, encompasses 4,108 acres of naturally undeveloped land within the confines of metropolitan Los Angeles County. This geographic link between the Coastal Santa Monica Mountain Range and the inland San Gabriel Mountain Range could serve as the ecological connection between these two developing foci for sylvatic plague.

In plague ecology fleas are essential for transmission among rodents and people. Because roof rats seem to have few or no fleas and were not involved in plague epizootics, a 1-year study was undertaken at several sites in the interface area to determine the seasonal composition, density, and distribution (Schwan et al. 1985). Samples of fleas were obtained each month from at least 20 roof rats at each site. From a total of 1,206 roof rats, 23.3% were infested with a total of 827 fleas (x = 0.7 flea per host). Monthly flea indices for Leptopsylla segnis, a poor plague vector that does not typically bite humans, and Nosopsyllus fasciatus, a good vector that bites humans, are given in Figure 3. Seasonal densities and species composition of fleas varied with each site. The two species of roof rat fleas mentioned above were dominant at three sites whereas wild rodent fleas prevailed at three other sites. Only one specimen of Diamanus montanus was recorded from a roof rat.

The authors concluded that other areas should be sampled, as each study site in the investigation had its particular attributes. The hypothesis formulated indicates that the roof rat with so few fleas was acting as a "barrier" or "buffer" in plague ecology between the California ground squirrels and their fleas in the interface and between Rattus norvegicus and its flea, Xenopsylla cheopis, in the inner cities. This hypothesis that the role of the roof rat is rather insignificant in plague ecology is heretical, controversial, and has already drawn skeptics (Baker 1984). Nevertheless, the hypothesis appears to fit the pattern observed of the role of roof rats and their fleas in plague ecology in Los Angeles County.

Studies are now in progress to assess the R. norvegicus fleas in the city areas that are adjacent to the inner or southern edge of the interface. Preliminary results for 16 months of this study show that, of the 677 Norway rats captured to date, 61% are infested with the oriental rat flea, X. cheopis, the most important flea vector of plague throughout the world. An overall index of 5.8 is recorded, and monthly indices are presented in Figure 4. The X. cheopis infestation rates on Norway rats during the summer and autumn are alarming, and the potential for violent epizootics and possible human epidemics may be very high if plague should ever bridge the gap between the interface and the inner city.

The absence of X. cheopis on Norway rats and the abundance of D. montanus on S. beecheyi in the spring months may preclude any transmission to Norway rats at this time. Late summer and autumn, when both species of fleas are abundant, would appear to be the most likely period during which potential outbreaks could occur with high risk for humans living and working in commercial and older residential areas of the central city.

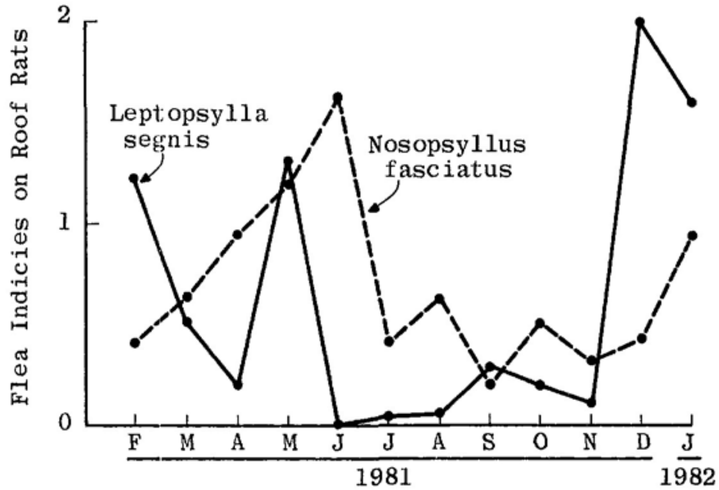

Figure 3. Seasonal distribution of two species of fleas taken from roof rats (Rattus rattus) collected from the interface area of Los Angeles County, California (adopted from Schwan et al. 1985).

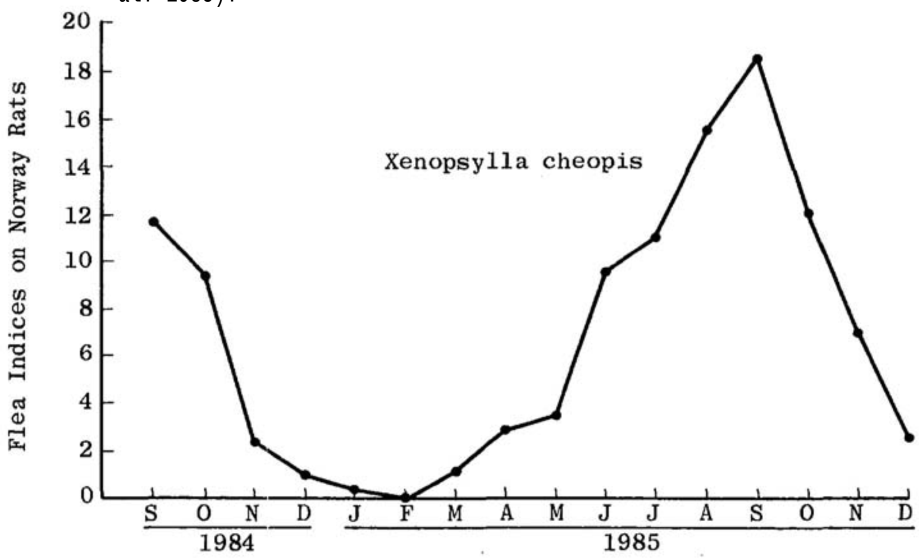

Figure 4. Seasonal distribution of Xenopsylla cheopis taken from Norway rats (Rattus norvegicus) collected in urban settings adjacent to the south-central edge of the interface in Los Angeles County, California.

CONCLUSION

Plague has been active in Los Angeles County since 1975, in the San Gabriel Mountains and at the interface, the ecotone of intermingling of wilderness habitats and suburban encroachment. Within these two areas plague is amplified by and is a risk to humans when it occurs in S. beecheyi and its fleas. A nonfatal human case occurred at a picnic ground in the San Gabriel Mountains during an epizootic involving this ground squirrel.

Plague, which appears to exist in reservoir rodents in these mountains, moves between a variety of wild rodents, including S. beecheyi, down canyons and ridges into populations of rodents inhabiting the interface. Here it causes epizootics, particularly among S. beecheyi, and is known to persist within small areas of the interface for several years. Two nonfatal human cases have occurred within the interface: one directly from an intense epizootic in S. beecheyi within a suburban residential tract development, and one indirectly from a sick pet cat that acquired its infection through contact with wild rodents during a violent epizootic near its owner's home. The increasing role of domestic pets in plague epidemiology is ominous.

We support the hypothesis of Schwan et al. (1985) that roof rats are currently playing an insignificant role in plague ecology, except as an inadvertent "barrier," or "buffer" between S. beecheyi and its fleas, and the Norway rat and its flea, X. cheopis, in the central city. The density of X. cheopis on Norway rats in the commercial and older residential sections of the central city is alarming, and poses a high potential risk for human epidemics if plague ever bridges the interface and enters into the Norway rat population.

We recommend the continuance of the surveillance program using sentinel carnivore and *S. beecheyi* serology, as this is the most sensitive system yet devised for detection of plague activity in Los Angeles County. We recommend continued support for the active suppression program of *S. beecheyi* populations in, the San Gabriel Mountains and the interface areas. Suppression of the flea population must precede rodent control especially in those areas where public use is high. Although current information supports the hypothesis that the role of roof rats may be insignificant as far as plague is concerned, their populations should be monitored, especially during epizootic periods. Surveillance for contact sites between populations of *S. beecheyi* and *R. norvegicus* is imperative, as are control programs for reducing populations of *X. cheopis* in the central city.

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