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Author
Baker, Rex O.

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COMMINGLING OF NORWAY AND ROOF RATS WITH NATIVE RODENTS

REX O. BAKER, Professor, Plant and Soil Science Department, California State Polytechnic University, Pomona, California 91768

ABSTRACT: The ecology of plague relies on the intermixing (commingling) of animal hosts and their ectoparasites. There has been a noticeable increase in commingling of rats and ground squirrels in Southern California in recent years. This paper discusses this phenomenon in Los Angeles and Orange Counties, where it occurs, how it results from man's activities, and the ecology of varying locations. The role of fleas as vectors of plague and the intermixing of fleas between hosts are discussed. Action to reduce the incidence of commingling and the threat of plague to the urban society is addressed.

INTRODUCTION

Commingling is a term associated with activity of different animal species sharing the same habitat. The degree of interspecie exposure depends on the type of commingling activity (e.g., burrows, nests, food, water, runways), the compatibility of the species related to periods of activity, and the degree of competition or other interaction. The primary significance of commingling to man is the increased chance of spreading diseases, especially the plague pathogen, Yersinia pestis, to commensal rodents like Rattus spp. (rats) from wild (sylvatic) rodents in which the disease is endemic in California and much of the western United States. The threat of plague to man from infected rats is much greater because the interface with these rodents is usually very close and more frequent than with sylvatic rodents. Rats were responsible for the spread of plague to humans in San Francisco and Los Angeles, California, in the first quarter of this century, the first epidemics in the United States.

Further epidemics in the United States have been prevented by extensive efforts of governmental agencies to suppress rat and ground squirrel populations and associated flea vectors in known plague-risk areas. The key to the success of these efforts has been the ability of vector control agency surveillance programs to identify these areas where sylvatic epizootics were occurring. Greatly improved living conditions, advancement in methods of plague diagnosis and the treatment of the disease have also helped establish better lines of defense.

The western states have continued to have isolated cases of human plague from exposure to sylvatic rodents since the early 1900s, but these cases have become widespread since 1965. Over 100 plague illnesses were reported in the West in the 1970s, exceeding the total for any decade since 1910, and 19 cases were reported the year of 1982[1].

According to State Vector Control Biologist Donald Rohe[2] and Los Angeles County Deputy Agricultural Commissioner Robert Howell[3], governmental agencies are concerned about this increase but lack the financial resources to properly respond due to drastic budget cuts in surveillance and suppression programs. Heavy rat and ground squirrel population increases have been reported since suspension of suppression programs in the early 1970s. These population increases and a number of other man-made conditions that contribute to the increased commingling of rats and the California ground squirrel, Spermophilus beecheyi (Richardson), have been cause for concern by biologists for a number of years. Concern for the possibility of increased plague risk to humans led to this study of the ecology of plague as it relates to the current habitat and behavior of rats and ground squirrels.

THE ECOLOGY OF PLAGUE AS IT RELATES TO COMMINGLING

The plague bacterium is transmitted from host to host by arthropods (especially fleas), inhalation of droplets (pneumonic), and by ingestion or bite (septicemic) (Nelson 1980). The most well-known route of transmission the last half of this century has been the flea vector. The most commonly accepted theories on how plague is maintained in the environment deal with a definite set of interrelationships between animal carriers, vector recipients and the balance of the ecology in the area (Audy 1958, Pavlovsky 1966). Nelson (1980) and Hudson (1964) suggest that, as long as an interspecies set of relationships exist between susceptible native species (ground squirrels, Spermophilus spp., chipmunks, Eutamias spp., and others) and more resistant species (voles, Microtus californicus, and deer mice, Peromyscus maniculatus), the disease will remain active, going from recipient to reservoir and back. The ecology of each plague location is quite unique. Hosts, ectoparasites, predators, and associated fauna vary as do climate, topography, food and water.

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1 Donald Rohe, Vector Control Biologist, State of California, April 29, 1983.

2 Ibid, February 23, 1982.

3 Robert Howell, Deputy Agricultural Commissioner, County of Los Angeles, Department of Agriculture, February 18, 1982.

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Meyer and Holdenried (1949) stated that the greatest risk of a human epidemic of plague follows an epizootic when infected animals die and ectoparasites leave in search of new hosts. Epizootics frequently cause heavy die-offs of susceptible hosts, especially when their population is at very high levels.

The Role of Fleas as Potential Plague Vectors

Knowledge about flea populations on sylvatic and commensal animal hosts in specific locations may aid in forecasting the likelihood of plague infecting man according to Eskey and Haas (1940). In an effort to apply this theory, extensive field and laboratory studies have been performed to develop a base of knowledge on the efficiency of fleas as vectors, and the interchange of fleas between hosts. Numerous flea species tested have transmitted plague in varying degrees of efficiency with rat fleas known to be human plague vectors, *Xenopsylla cheopis* and *Nosopsyllus fasciatus*, being about equally effective, and several wild rodent fleas common on ground squirrels, *Hoplopsyllus anomalus* and *Diamanus montanus*, and others appearing to be nearly equal to the rat fleas. One of the most common fleas on rats and mice, *Leptosylla segnis*, was a very weak vector and was reluctant to bite man. If these laboratory experiments were truly representative of field conditions, and there have been no biological modifications in the vectors involved, the data could be useful when evaluating the disease potential of specific sites.

Field studies by Ryckman (1954 and 1971), Meyer and Holdenried (1949), and others have conclusively demonstrated that although fleas are quite host specific, there is an interchange of fleas between commingling sylvatic and commensal rodents even when their usual hosts are present in significant numbers, and especially when the original host has died or otherwise been removed from the area.

Most kinds of adult fleas spend much of their time off the host in soil, litter or other adaptable medium, especially in nest or burrow areas. They prefer environments where temperatures are stable, warm, and humidity high (70% or more is ideal for optimum development). Flea eggs, larvae and pupal stages are usually found in these areas also as they will not survive under dry conditions, especially when hot, and the larvae feed on organic matter including dry blood from the excreta of the adults. Adult fleas often survive for months without hosts.

The average number of fleas per host animal (index) often varies at different times of the year and between hosts and locations, depending on how well suited the habitat is for flea development. Flea indexes found on ground squirrels often vary from 20 to 200, while that of rats is usually between 0 and 20 with roof rat (*R. rattus*) having fewer than Norway (*R. norvegicus*) because the latter more often habituates burrows and other more desirable flea habitats. *X. cheopis*, is more common on Norway than roof rats; and since they frequent the harbor and inner city areas, there is less chance of exposure of the Norway to sylvatic plague carriers. According to Worth (1950), however, roof rats are more prone to a feral existence and thus have a greater variety of ectoparasites. This may well be true in Southern California and may lead to a higher risk of infection from sylvatic plague. Few studies have been done over the last 40 years in Southern California.

CURRENT STATUS OF COMMINGLING OF COMMENSAL AND NATIVE RODENTS IN SOUTHERN CALIFORNIA

Man has visited plague-infested areas for years in California, but over the last decade plague has with increasing frequency been found in urban and suburban fringe areas where man resides. There appears to be numerous contributing factors, all of which are man-made!

Man's Alteration of the Environment

One of the primary problems contributing to increased commingling is urban sprawl. Man continues to push out wildlife in fringe areas of the city and suburbs to create individual homes, new housing tracts, or even new communities. This development forces existing native animals into adjacent areas, often where plague is endemic, causing increased density, more interspecies mixing and increased risk of exposure to plague.

It was thought by many that new developments would eliminate most of the wildlife and their habitat, thus removing the threat of property destruction and human safety. While some forms of plant and animal life are unable to survive, some animals are only temporarily displaced and return as man creates fresh habitats that are sometimes more desirable than before to both native and commensal rodents. This is especially true in cut-and-fill operations where highly palatable forbs are planted, allowing gophers, ground squirrels, meadow mice, and other native species to return and establish higher densities than before. This often contributes to severe erosion and landslide problems, plant damage, and increased exposure to the native animals as well as increased commingling. Within 5 to 10 years heavily landscaped areas may become infested with rats seeking the food, water and harborage provided, especially where dense vines, shrubs and trees are abundant. The establishment of parks and other open-space areas, within the urban environment, offers additional habitat for rats and native rodents. Open-space areas are especially vulnerable to commingling of rats and native animals when located adjacent to undeveloped wildland areas.

Locations of Commingling

Commingling is common in many Southern California urban fringes, suburbs, rural areas and even in the midst of cities where parks or other open space exist. The types of commingling and the intensity of each situation must be individually evaluated. The degree of risk associated with the plague threat varies greatly depending on the presence of the bacterium in the native rodents, type and number of flea vectors on each host, kind of rodents and other animals involved, their numbers, and how closely they are associated to man and his pets.

Commingling of rodents has been a controversial subject between biologists for years. Some quote Gause's law as it applies to the principle of competitive exclusion: "No two species with identical niches can occur together indefinitely without one eliminating the other." This, however, does not rule out commingling for, as Ingles (1965) concludes, a niche is not just an environmental situation or place, but a "functional phenomenon concerned in part with energy relations, food sources, and food chains;" and although different species occupy the same place at the same time, each has its own niche and obtains the nutritional and other required needs within the same environmental setting. Some may also be active at different times of the day or night.

California Ground Squirrel, (S. beecheyi) Habitats

Since S. beecheyi is native to most of Southern California, it can be found throughout the area but is most numerous in preferred foothill and canyon areas, from the ocean cliffs of the coastal Palos Verdes and Santa Monica Mountains to inland valleys and the higher Sierra Madre and Santa Ana mountain ranges. In many of the foothill areas, and even within the urban fringe, the other sylvatic hosts necessary in maintaining plague are present. Ground squirrels are gregarious diurnal rodents that usually live in colonies of burrows which are used for shelter, nesting and food storage. Their underground burrows which often form extensive connecting systems, are sometimes found in open grassy fields, scattered chaparral, or rock outcroppings; but squirrels seem to prefer to burrow on hillsides, ravines, ditches, around rocks, at the base of trees, fence lines and embankments and other sites disturbed by man.

Troublesome populations of this pest are found in numerous places on urban fringes and within urban areas, especially where cut-and-fill slopes have been formed in housing developments, industrial areas, or along highways, and in our parks and open space. Many city area landslides and erosion problems have been caused by S. beecheyi.

The California ground squirrel's principal diet includes seeds (especially cereal grains), acorns, fungi, fruit, bird eggs, large arthropods, and greens when available. Necessary water is most often obtained from food, especially green feed. High spots on rocks, poles and in trees are often used to keep watch for predators or other danger. They often have a soft dirt dusting area nearby to clean themselves and reduce ectoparasite pests. Ground squirrels usually move about a home range radius of 450 feet (Clark 1975), but some have been observed to migrate up to 5 miles to new areas (Storer 1965).

Roof Rat Commingling Habitats

This rodent can now be found from the ocean to the desert, in developed urban and most rural areas. It is a pest in urban and numerous agricultural situations. The primary agricultural crop problems with roof rats are in citrus and avocado groves which often become housing tracts in many Southern California areas. Poultry ranches, cattle feed lots, feed stores and mills, horse stables, dairies, food-storage warehouses and processing plants are often sources of nonresidential roof rat infestations which may contribute to nearby urban infestations. They, like Norway rats, are nocturnal rodents that often live in colonies, finding shelter and nesting most often in obscure areas, high in the trees, dense vegetation, woodpiles, attics, sheds, or in burrows. The burrowing is most often found when temperatures are high, other harborage is not as favorable, or when burrows already exist, even when being used by other rodent species.

The greatest populations of roof rat and occurrence of commingling with native animals are found along the urban fringes, especially the foothills of many Southern California communities. The highest residential populations can be found in heavily landscaped areas, especially those with well-established ground covers and vines such as: ivy, coyote bush, honeysuckle, trailing African daisy, vinca, ice plant, Cissus spp. and numerous others. Heavy unthinned shrubs and trees also provide an excellent habitat which includes food (snails, seeds, fruit, greens, birds, small insects, bird eggs and young, etc.), water, and harborage for nests and security.

In Los Angeles County, locations of commingling in sylvatic areas where plague may be endemic, stretch from the Pacific Ocean through the Hollywood Hills and San Fernando Valley, along the San Gabriel Mountains to the eastern county line, and south through the Diamond Bar area. Roof rat commingling areas continue along the Santa Ana range and into the Anaheim Hills of Orange County where sylvatic plague was found in 1983. Roof rat populations, however, are generally very light in much of Orange County's newly developed foothill areas, including much of Anaheim Hills, but some of the previously developed areas have moderate to heavy populations. Few of these older areas are adjacent to wildland areas where sylvatic animals are abundant. An isolated commingling site within urban Fullerton, California, will be discussed extensively as a specific commingling study. Plague has been found in the last several years in Griffith Park, Glendale, Diamond Bar, and other foothill areas of Los Angeles County as well as areas of Orange and Riverside Counties.

I would be remiss if freeway right-of-way landscaping was not mentioned. Many of our beautifully landscaped freeways serve as a constant source of reinfestation to many areas trying to eliminate rat activity, especially those with heavy use of the ground covers preferred by rats, and carob and Acacia longifolia shrubs. Freeways in Los Angeles, Orange, San Bernardino, San Diego, and Riverside have been found to be heavily infested by rats, indicating a need for constant rodent suppression by Caltrans.

Migration or movements of roof rats is common in California and may take place seasonally or more often for the protection provided by buildings to avoid hot or cold weather, or for food, water, or when their habitat is disturbed. The danger of movements from the home into the canyons and hills and back creates another factor in the complex commingling situation.

Roof rats recently surveyed in several landscape locations by the author or health department officials have had flea indexes of 1 or less. The types of fleas found varied from area to area and included several sylvatic rodent fleas, cat fleas and commensal rodent fleas but no X. cheopis.

Norway Rat Commingling Habitats

The Norway rat is definitely an animal of the temperate climate and is confined to seaports or cool, moist situations in areas of warmer, subtropical regions. They are found much closer to cities and towns on the west coast of the United States. They are a moisture-loving creature, especially in hot climates, and must reside near readily available water. Mallis (1982) states that this is one reason they are abundant near sewers, rivers, harbors, and drains, and do not seem to be able to protect or provide for themselves in the wilds of Southern California.

Although rats are neophobic, they can readily adapt themselves to many environments, and their behavior and physical abilities may vary between populations. The prime mode of self-defense is rapid retreat to inaccessible and obscure areas; and when aggressive Norway rats and roof rats compete for the same area, the Norway rat frequently becomes dominant in his ground-preferred environment and the roof rat disappears unless the habitat provides a more favorable niche for the roof rat, or an adequate favorable niche for each.

The heaviest human contact with Norway rat occurs in central and southeast Los Angeles in some of the older and poorer housing areas and around the harbor, beaches, and flood-control channels or rivers leading from the bay to the foothills. We are fortunate that this pest--often found with higher flea indexes and more important species of fleas than roof rat--is much less often found in a commingling situation. However, Norways are now in commingling situations with ground squirrels in several areas along the riprap ocean and harbor jetties, several flood channels and the Los Angeles and San Gabriel Rivers. Norways were found by the author near a flood channel in Vernon with an index of 13 X. cheopis in late 1979, but no ground squirrels were found near the location.

The Whittier Narrows Park and Wildlife Sanctuary Area lies between the Rio Hondo and San Gabriel Rivers and is a source of commingling of Norways, ground squirrels and roof rats. Microtus and Peromyscus are also abundant. There are several other commingling areas along the San Gabriel River within a few miles of the San Gabriel Mountains.

ECOLOGY OF A SPECIFIC ROOF RAT AND GROUND SQUIRREL COMMINGLING SITE

A specific site was chosen to study the ecology of roof rat and ground squirrel commingling. The site was a vocational agriculture farm area and adjacent residential neighborhood of Sunny Hills High School, Fullerton, California. The school site consisted of an office, classrooms, feed and equipment barns, irrigated pasture, livestock and poultry pens, vegetable gardens, and ornamental landscaping. The farm is located on flat bottom land in a canyon bordered on two sides by hilly areas developed with expensive suburban residences, 10 to 20 years old, located on 1- to 2-acre lots, many having horses and other livestock, and all heavily landscaped with lush, mature, ornamental plants. Large avocado, citrus (many remain from previous commercial groves) and deciduous fruit trees are also numerous. Other residential neighborhoods had smaller lots more typical of an urban setting but also with mature, lush landscaped yards. The valley floor consisted of open fields of weeds, a vegetable farm and stables.

The site is typical of Southern California suburban hilly residential areas surrounded by parks, undeveloped open space and farm areas. The site is several miles from wildland mountain ranges where plague is endemic and represents suburban areas where horses, orchards and gardens are maintained and where there is heavy human activity.

Occurrence of Commingling

The study conducted by Baker (1983) revealed the presence of roof rat, California ground squirrel, house mouse (Mus musculus), pocket gopher (Thomomys bottae), meadow mouse (M. californicus), deer mouse (Peromyscus spp.), and cottontail rabbit (Sylvilagus audubonii). Roof rat and ground squirrel populations were both high.

Commingling was evidenced by direct and indirect census methods used over a 6-week period in June and July of 1982. Two of the methods used were trapping and visual observation of rodents and signs of their activity. Over 11 percent of the ground squirrel burrow entrances studied contained roof rat tracks from the previous night's activity when observed early in the morning and four roof rats were trapped at burrows used by squirrels. Those burrows used by rats were within 50 feet of buildings or feed lockers. Dusting areas in the soil were observed to be used by both rodents. All feeding areas observed for roof rats were also used by ground squirrels, including the vegetables, snails, greens and all animal feed areas. Ground squirrels also foraged for greens and weed seeds, especially the rye grass, in areas where roof rats were never seen. Both rodent species were seen frequenting water sources although ground squirrels usually obtain water from their diet of greens and grain, and only roof rats were observed actually obtaining water. Harborage, other than burrows, used by both ground squirrels and rats included: pallets under feed lockers in the sheep and cattle pen areas, the inside of older feed lockers, wood piles, used pipe, refuse, heavy weed areas, and buildings (Table 1). One type of habitat where only the roof rat was observed consisted of high power lines and higher portions of trees.

Specific Ecological Characteristics of the Site

Food and harborage were abundant throughout the school site, stables and landscaped residential areas (see Table 1 for a complete list). The grassy undeveloped areas were densely covered with native plants including: Ballmallow (Malva necaeensis), Italian rye grass (Lolium multiflorum), wild oats (Avena fatua), filaree (Erodium spp.), Bermuda grass (Cynodon dactyeon) and Russian thistle (Salsola kali) which all appeared to be used as feed by the sylvatic animals. Roof rats were also observed foraging on the edges of this grassy area, and along a creek bed that ran through the area.

Table 1. Preferred harborage and food sources, Fullerton, California, 1982.

Harborage and/or Food Sources	Rodent - Use
Trees and Shrubs:	
Acacia latifolia - Bush acacia	R-F,H;G-H
Bambusa spp. - Bamboo	R-H
Ceratonia siliqua - Carob	R-F,H;G-F
Cortaderia selloana - Pampas grass	R-HM-F,H
Cupressus sempervirens	R-H
Eucalyptus polyanthemos - Silver dollar gum	R-H
Ficus retusa (nitide) - Laurel fig	R-H,F
Gleditsia triancanthos - Honey locust	R-F,H
Hibiscus syriacus - Rose of Sharon	R-F
Juniperus sobina tamoriscifolia - Tam juniper	R-H
Lantana montevidensis - Lantana	R-H
Phoenix dactylixera - Date palm	R-F,H
Pinus halopensio	G-F
Pyracantha spp.	R-H
Quercus agufolia - Coast live oak	R-F,H;G-H
Syzygium paniculatum (Euginia myrtifolia - Brush cherry	R-F,H
Washingtonia filifera - California fan palm	R-F,H
Washingtonia robusta - Mexican fan palm	R-F,H
Ground Cover and Vines:	
Baccharis pilularis - Coyote bush	R-F,H
Cynodon dactylon - Bermuda grass (unmanaged)	R-F,H M-F,H;G-F
Hedera canariensis - Algerian ivy	R-F,H
Hedera helix - English ivy	R-F,H
Lonicera japonica - Japanese honeysuckle	R-F,H
Lonicera hildebrandiana - Giant Burmese honeysuckle	R-F,H
Osteospermum fruticosum - Trailing African daisy	R-H
Rubus spp. - Blackberry species	R-F,H
Sorghum halepense - Johnson grass	R-H;M-F,H G-F,H
Trachelospermum jasminoides - Star jasmine	R-H
Vinca major - Periwinkle	R-H
Vegetables - Food:	
Sweet corn, squash (several kinds), tomato	
Fruit and Nut Trees:	
Persea armericana - Avocado	R-F,H;G-F
Citrus spp., Orange, lemon, grapefruit	R-F,H;G-F
Eriobatrya joponica - Loquat	R-F
Guava - Psidium (Strawberry) and Feijoa (Pineapple)	R-F,H
Proteaceae ternifolia - Macadamia nut	R&G-F
Punica granatum - Pomegranate	R-F,H
Prunus spp. - Peach and apricot	G&R-F
Juglans spp. - Walnuts, native and commercial varieties	R&G-F
Additional Food Sources:	
Dog food (dry and canned)	R
Food scraps (school parking lot)	R
Snails and slugs	R&G
Crickets	R&G
Small birds	R&G
Bird eggs	R&G
Livestock feed (grain, pellets, meal and molasses lick blocks)	R&G

Continued

Table 1 (continued)

Harborage and/or Food Sources	Rodent - Use
Additional Harborage Sources:	
Firewood piles	R
Lumber piles	R&G
Sheds	R
Fences	R&G
Garages	R
Rock walls	G
Refuse	R

*Key: R = R. rattus, G = S. beecheyi, M = Microtus spp., F = Food, H = Harborage.

Several highly used food sources of particular interest in the landscaped areas were: alepo pine (Pinus halaponsis), black walnut (Jugeands spp.), and snails eaten by both ground squirrels and roof rats in the same area; coyote bush (Baccharis spp.), young birds and eggs, berries (Euginia myrtifolia), carob bark, pods and seeds (Ceratonia siliqua), and dry dog food eaten by roof rats; and pampas grass (Cortaderia selloana), star jasmine (Trachelospermum jasminoides) and snails consumed by meadow mice.

Any ground cover that was heavily watered resulting in snail and slug populations was frequented by roof rats. Water was abundant throughout the site with water troughs, sprinklers, leaky faucets and the creek being used regularly by roof rats.

The high numbers of rodents present (consumption of census ration indicated that over 200 roof rats were present), especially young, indicate the population was still expanding due to the presence of plentiful conditions. The preferred harborage of this site is quite similar to what Brooks (1966) found in his study of roof rat ecology in California urban areas: wood, refuse (junk), sheds, dense plant growth and fences. Ecke (1964) found that landscaping had greatly increased the available habitat for roof rat, especially where old fruit orchards supplied ample food, a condition found throughout much of Southern California. Fortunately, the adjacent landscaped areas are not as desirable, beyond the fringe, for the ground squirrel as the school farm and open grassy areas.

This set of conditions, including abundant animal feed, harborage and water, appears to be the primary reason for the occurrence of this high population of rats and ground squirrels.

Fleas Collected

Fleas were collected from 24 roof rats, 1 house mouse, and 5 California ground squirrels at the school in landscaped areas, barns, near ground squirrel burrows along fence lines, and in livestock pens. Fleas were collected and identified by Orange County Vector Control District employees.

As shown in Table 2, a flea (L. segnis) common to commensal mice and rats accounted for 96 percent of the fleas on rats (167 out of 174). Recent studies of fleas on rats in overgrown landscaped areas of Los Angeles County have shown this same flea to be the most abundant; and according to B.C. Nelson, they also found no X. cheopsis fleas.[4] A flea (E. gallinacea) common to ground squirrels was found on several rats in this study and accounted for 3.6 percent (6/174), while one flea of sylvatic mice (M. telchinus) was also found. The flea index of this study was 7.3 with the greatest number of one rat being 44 and only three had no fleas.

The index on ground squirrels at the Sunny Hills site was 68 with D. montanus accounting for 58 percent of fleas, H. anomalus 40 percent, and E. gallinacea 7.5 percent. The greatest number on one ground squirrel was 99 and the fewest was 25 fleas. These findings are similar to Ryckman et al (1954b) in his study of seasonal variation of fleas on ground squirrels in Orange County.

The flea index of R. rattus (7.3) and S. beecheyi (68) is high but within the ranges found in reviewed literature. The species of fleas found on these roof rats were not important flea vectors but they demonstrate that roof rats in the right habitat can support a high index and that although fleas are usually very host specific, they do change hosts when necessary for survival and randomly. The high number of efficient plague vectors (D. montanus and H. anomalus) on the California ground squirrel is very important for there is a great chance of host exchange of fleas to rats if a plague epizootic occurred and the preferred host was not present. Both of these fleas are known to bite man.

[4]Bernard C. Nelson, Vector Biology and Control Branch, California Department of Health Services, Personal Communication, January 23, 1983.

Table 2. Fleas on rodents trapped at Sunny Hills High School, Fullerton, California, July 8, 1982.

Fleas	Host Rodent		
	S. beecheyi	R. rattus	M. musculus
Diamanus montanus	77♂	--	--
	122♀	--	--
Hoplopsylla anomalus	59♂	--	--
	79♀	--	--
Leptopsylla segnis	--	62♂	1♂
	--	105♀	1♀
Malaraeus telchinus	--	1♂	--
Echidnophaga gallinacea	2♂	--	--
	3♀	6♀	--
Total trapped	5	24	1
Without fleas	0	3	--
With fleas	5	21	1
Male hosts	--	10	1
Female hosts	5	14	--
Total fleas	342	174	2
Index of all fleas	68	7.3	2

This specific site was in an island of suburban homes in the center of a city area and the chance of the existence of plague or other endemic diseases is very small. The importance of this study lies in the demonstration of how abundant feed and harborage, in areas closely associated with sylvatic areas, can develop heavy commingling between commensal and sylvatic rodents. Also, flea numbers are higher when rats are in a habitat more suitable to the fleas' reproduction. Most urban ornamental areas are not highly suitable for flea development. This site also showed a high degree of interface between man and rodents.

DISCUSSION

The increase in reported cases of human plague and sylvatic epizootics can be attributed solely to man. Through wreckless budget-cutting of rodent suppression programs and plague surveilance activities, the risk of human exposure to plague has been greatly increased. These program cuts were very untimely, for society has greatly increased recreational activity in urban fringes and wildland areas, and increased construction of homes in canyons and foothill areas.

Governmental agencies must become aware of the hazards involved in developing the wildland areas. Part of each building permit on undeveloped land should consider as part of the environmental review process the consequences of displacing sylvatic animals where disease may be endemic to the area or where other hazards are associated with wildlife. It may in some cases be best to initiate suppression programs at the expense of the permit applicant prior to construction.

Although numerous kinds of sylvatic fleas have recently been found on rats in the Southern California area, verifying the exchange of flea hosts in commingling, the absence of X. cheopsis fleas on roof rats may indicate a low potential in areas sampled for fast spread of plague. However, this assumes that no sylvatic flea stays on rats to vector the bacteria once the rat becomes infected; and since D. montanus and H. anomalus are both efficient vectors, freely bite man, and are usually present on ground squirrels throughout Southern California, and are known to freely change hosts when an epizootic occurs, it's conceivable that plague could be spread by roof rats to man or to Norway rats. The Orange County roof rat site also demonstrated that roof rat can sustain high flea populations where ideal flea habitat exists.

A theory has been proposed by vector ecologists in California recently that roof rats act as a buffer species that prevent the spread of infection from sylvatic rodents to urban Norway rats.[5] Since Norway and roof rats do not often demonstrate a preference for the same type habitat in Southern California, and since the larger Norway usually prevails in protecting his preferred ground type habitat, it does not seem likely that the buffer theory occurs to any great extent in this geographical area, but it may have some relevance.

[5] Bernard C. Nelson, Jan. 23, 1983.

CONCLUSIONS

The investigation of the Orange County site conclusively demonstrates that roof rats will harbor high numbers of fleas under conditions favorable to their development. Although only E. gallinacea fleas and not D. montanus or H. anomolus were found to occur on both roof rats and ground squirrels in this small sampling, many former investigations have proven that these fleas do change hosts to rats especially during epizootics. Since D. montanus and H. anomolus are efficient plague vectors, and because of the high numbers of fleas to be found on these known plague reservoir species, the trend of budget-cutting should be reversed in order to increase the effectiveness of future plague surveilance and suppression programs. The fact that there are now numerous areas in Southern California where roof rats and Norway rats are commingling in and around burrows with sylvatic rodents, and the increase in human and sylvatic animal interfacing due to man's activities, further support the urgency of the situation.

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