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A Review of Over a Hundred Years of Plague Surveillance in Orange County, California, 1909-2022

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ABSTRACT: Plague, caused by the bacterium *Yersinia pestis*, has been in California for over a century, infecting humans, animals, and fleas. The first human case in Southern California was reported in 1908 in the city of Long Beach, Los Angeles County. Since then, sporadic detections of plague have occurred in animals, fleas, and people across the region, including an urban outbreak that resulted in at least 32 confirmed human cases and 31 deaths in 1924 in Los Angeles. In preparation for the 1953 national Boy Scout Jamboree planned in Orange County, *Y. pestis*-positive fleas were detected in 1946 from a pool of 107 fleas collected from seven California ground squirrels at the planned event site. This discovery prompted extensive rodent and flea control efforts in 1952, with state and county health authorities closely monitoring the site to safeguard attendees. Following these measures, no plague-positive fleas or animals were detected at the location. In 1975, responsibility for plague surveillance and rodent control was transferred from the local health department to the Orange County Mosquito Abatement District, which was subsequently renamed the Orange County Vector Control District (OC Vector). OC Vector's program has focused on trapping and sampling both wild and commensal rodents in residential, wildland-urban interfaces, and natural habitats, with plague testing conducted by federal, state, and local laboratories. Since the initial discovery of *Y. pestis*-positive fleas in 1946, Orange County has documented several additional plague detections: two California ground squirrels at a golf course in 1982, a roof rat at a suburban residence in 1998, two bobcats sampled from a foothill community in 2007, and two urban coyotes that tested positive for *Y. pestis* via PCR in 2018. Although no human cases of plague have been reported in Orange County, these findings highlight the persistence of *Y. pestis* in local wildlife. This article provides an overview of plague surveillance in Orange County, examining how past outbreaks and routine detections of plague in humans, animals, and fleas across California have shaped surveillance strategies amid changing environmental conditions.

KEY WORDS: California, fleas, ground squirrels, history, Orange County, plague, *Yersinia pestis*

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INTRODUCTION

Plague is a zoonotic disease caused by infection with the Gram-negative bacterium *Yersinia pestis*. The bacterium typically circulates among a variety of susceptible mammalian hosts through contact with flea vectors, although alternative modes of transmission can occur.

The introduction of plague to the United States occurred in 1900 when plague-infected fleas carried by Norway rats (*Rattus norvegicus*) arrived aboard ships from Hong Kong to the port of San Francisco (Barnes and Poland 1983). This introduction led to the first locally acquired human cases of plague in the country. Over time, the bacterium became established in San Francisco's urban rat populations and subsequently spread to native rodent species in the surrounding areas (McKoy 1908). By 1908, the first human case of plague in Southern California was identified in a young boy who had been exposed to an infected California ground squirrel (*Otospermophilus beecheyi*) near the international port-of-entry in Long Beach (Los Angeles County), approximately 12 miles (20 km) from the Orange County border (Link 1955). Subsequent investigations revealed no additional human cases or infected rodents in the vicinity (Nelson et al. 1986).

Plague Surveillance and Control in Orange County, 1909-1974

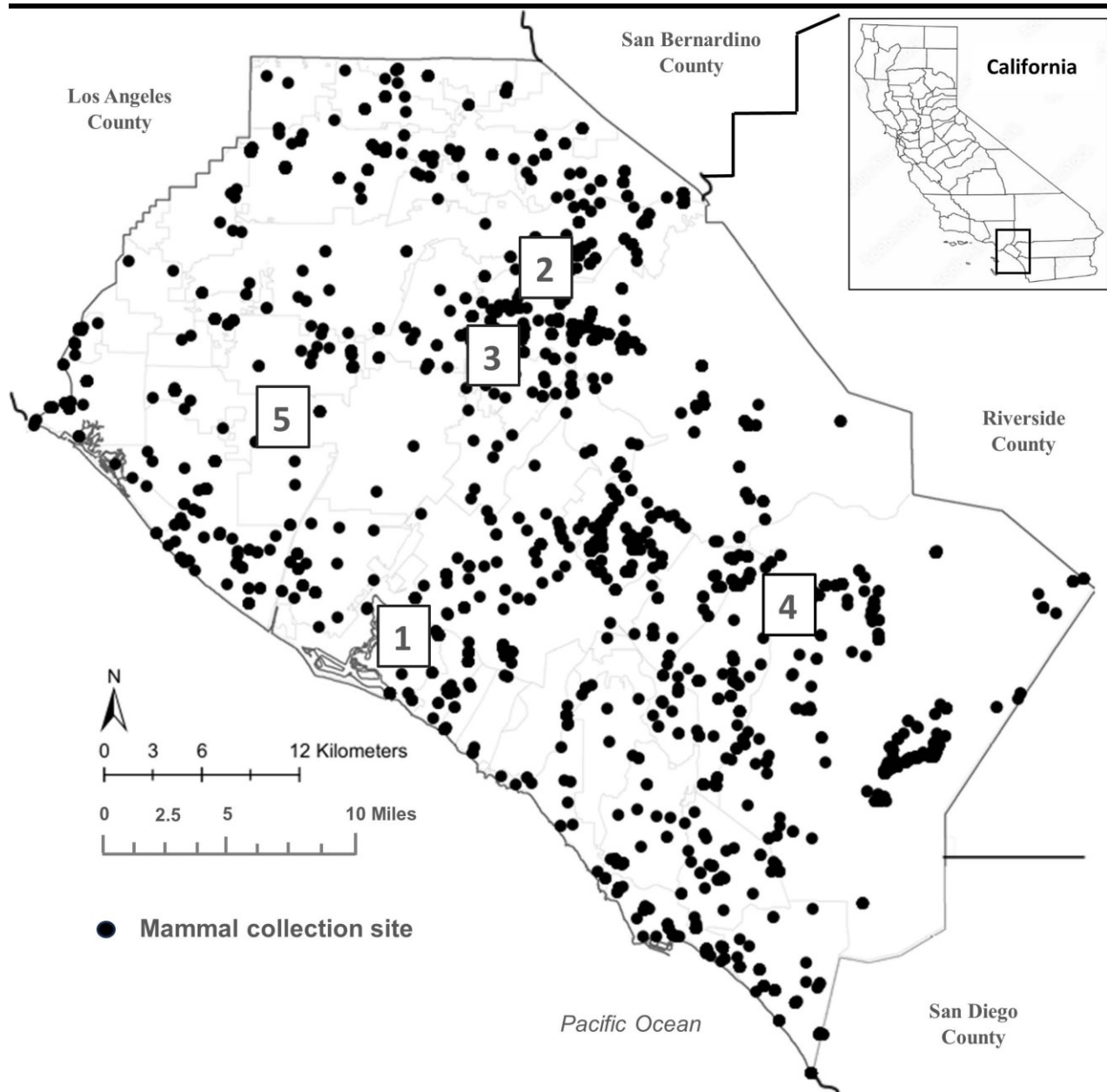
In response to the plague outbreak that had spread to both San Francisco and Los Angeles Counties, the United States Public Health Service (USPHS) developed a three-part plan: (1) eradicate known foci of infection; (2) identify new or previously unrecognized infection sites; and (3) eliminate ground squirrels, which were considered impor-

tant reservoirs of the bacterium (USPHS 1911). As part of this program, the USPHS tested 529 California ground squirrels from Orange County in 1909, all of which were negative for plague. Because plague was not detected, Orange County was not classified as a plague infection hotspot, and federal and state resources were redirected to areas with active animal or human plague cases. Nonetheless, the findings highlighted that while the risk of plague spreading in regions such as Orange County appeared minimal, it remained a genuine concern (Link 1955). Consequently, the USPHS recommended that state and local authorities establish plague surveillance programs to monitor the potential risk.

Plague Found in Orange County, 1946

In June 1946, the California Department of Public Health (CDPH; formerly the California State Department of Public Health) received 107 unidentified fleas collected from seven California ground squirrels trapped on the Irvine Ranch in Newport Beach (Figure 1, Site 1). These fleas tested positive for plague bacteria (CDPH 1946). Following the detection, Orange County was officially designated a plague focus. At the time, standard response procedures to plague detections in humans, rodents, or fleas involved widespread applications of insecticides and rodenticides targeting susceptible and locally abundant rodent hosts – primarily commensal rats and sylvatic California ground squirrels – and their associated flea vectors (Kellogg 1919, Link 1955). This event triggered a 16-year interagency suppression effort involving the Orange County Department of Agriculture (OC Agriculture), the California Department of Agriculture (CA

Figure 1. Locations (N = 866) from which mammals were collected for plague testing, 1946-2020, Orange County, Calif. Numbered sites indicate plague-positive locations. 1) *Y. pestis*-positive fleas off seven California ground squirrels, 1946. 2) Two seropositive California ground squirrels; one *Y. pestis*-positive flea pool off a woodrat, 1982. 3) One seropositive roof rat, 1998. 4) Two seropositive bobcats, 2007 (USGS study). 5) Two *Y. pestis* qPCR-positive coyotes (spleen samples), 2018.



Agriculture), and CDPH to control rodent and flea populations across the approximately 1,000-acre Irvine Ranch (CD Ag 1946, CDPH 1954, OC Ag 1954). The objectives of the suppression effort included intensified control measures targeting field rodents, continued identification and trapping to assess rodent species composition and abundance, and follow-up surveys to confirm reductions in rodent and flea populations (Ryckman et al. 1950, 1954).

Rodent and Ectoparasite Control at the Boy Scout National Jamboree Campsite, 1952-1953

In 1952, one year before the anticipated attendance of 50,000 people at the 1953 Boy Scout Jamboree (scheduled at the same 1,000-acre site where plague-positive fleas had been detected in 1946), an extensive rodent and ectoparasite control program was launched (CDPH 1954, OC Ag 1954). To treat rodent burrows, the program used 6,478 lbs

(2,938 kg) of rodenticides containing active ingredients such as carbon bisulfide, warfarin, 1080, and zinc phosphide (OC Ag 1954). Additionally, the area received an aerial application of 5% Dieldrin dust at a rate of 10 lbs/acre (11.2 kg/ha), totaling 10,000 lbs (4,536 kg) of insecticidal dust (OC Ag 1954). The Orange County Board of Supervisors covered the \$2,500 cost of the aerial application. Because Dieldrin was not officially registered for aerial application to rodent burrows, a special permit was obtained from the CA Agriculture (OC Ag 1954). In total, this 12-month effort involved approximately 2,350 hours of labor and covered 6,219 mi (10,169 km) by county and state vehicles (OC Ag 1954).

The multi-agency effort to control field rodents and fleas was considered successful, and the Boy Scout Jamboree proceeded as planned in July 1953 without any reports of rodent or flea problems from attendees (OC Ag 1954). The Orange County Agricultural Commissioner later published a report summarizing the activities under the title “*Now it can be told: methods and procedure for the control of rodents and ectoparasites on the 1953 Boy Scout Jamboree site*” (OC Ag 1954). Interestingly, the report omitted any mention of plague, suggesting a deliberate effort to manage the situation discreetly. In 1960, following 14 years of plague surveillance that yielded no further plague-positive rodents or fleas, the CDPH removed Orange County’s designation as a plague focus.

PLAGUE PROGRAM UNDER ORANGE COUNTY VECTOR CONTROL DISTRICT

In 1974, a Joint Powers Agreement (JPA) with the County of Orange transferred responsibility for rodent and fly control from OC Health to the Orange County Mosquito Abatement District, which was subsequently renamed the Orange County Vector Control District (OC Vector) (OC Vector 1973, OC Health 1974). The JPA authorized OC Vector to take all necessary measures for the prevention, abatement, and control of rodents throughout Orange County. The implementation of the new program proved timely: beginning in 1978 and continuing thereafter, plague was detected in Los Angeles County in the city of Diamond Bar and the unincorporated Tonner and Palmer Canyons area near the border with Orange County, infecting California ground squirrels, a pet cat (*Felis catus*), a veterinarian who treated the cat, and flea samples (Nelson et al. 1986). In response, CDPH and the Los Angeles County Vector Management Program, with assistance from OC Vector, collaborated on plague surveillance and public education efforts in the affected border areas. Surveillance activities targeted regional parks and golf courses throughout Orange County, where California ground squirrels were abundant. These sites were prioritized due to their high human use and their resemblance to plague-positive areas in Los Angeles County, raising concerns about potential disease transmission to humans.

Plague Detection in California Ground Squirrels from Anaheim Hills, 1982

In August 1982, CDPH informed OC Vector that two California ground squirrels trapped at a golf course in Anaheim Hills (Figure 1, Site 2) tested positive for plague antibodies at titers of 1:256 and 1:512 (CDPH 1983).

Subsequent trapping at the site yielded blood samples from 75 small mammals, including wood rats (*Neotoma* spp.), field mice (*Peromyscus* spp.), cottontail rabbits (*Sylvilagus audubonii*), and California ground squirrels. The same two ground squirrels were recaptured, and their antibody titers had decreased to 1:16 and 1:32, respectively (CDPH 1983). Additionally, an unidentified flea pool collected from a wood rat reportedly tested positive for *Y. pestis* (OC Vector 1982).

OC Vector Control collaborated with CDPH, OC Agriculture, and OC Health to implement control measures in the area. Public education efforts were launched through newspapers, television, and radio. OC Vector treated rodent burrows with Ficam® D at a rate of 2.0 oz per burrow to control fleas. Pre- and post-treatment indices confirmed excellent flea suppression. About three weeks later, OC Agriculture initiated ground squirrel control using anticoagulant grains, acute rodenticides, and carbon monoxide cartridges. Plague surveillance and control continued through 1983 until the ground squirrel population at the golf course was significantly reduced. Following consultation with CDPH, it was concluded that the combination of effective flea and rodent control and declining antibody titers substantially reduced the risk of human exposure to plague in the area. No die-offs of ground squirrels or other animals were reported at the Anaheim Hills golf course before, during, or after the 1982–1983 plague surveillance and control efforts (OC Vector 1982).

Plague Detection in a Roof Rat from Orange, 1998

In August 1998, routine plague surveillance by OC Vector led to the detection of a plague-positive roof rat (*Rattus rattus*) in the backyard of a residential home in the city of Orange, (Figure 1, Site 3). OC Vector promptly initiated rat and flea control measures, enhanced surveillance, and conducted public education outreach to cities and local media in the surrounding area. Approximately 100 California rodent burrows (primarily California ground squirrels) along a nearby creek (Santiago Creek) and flood control basin (Villa Park) were treated with deltamethrin dust (0.05%, 11–14 g/burrow) to control flea populations (OC Vector 1999).

In the subsequent months, 342 additional mammals, including 21 stray cats from Orange County Animal Control, were collected from the targeted area, all of which tested negative for plague antibodies. No animal die-offs were reported in the neighborhood before or after the positive detection. Several *Y. pestis*-competent flea species, including *Malareus telchinus*, *Orchopeas sexdentatus*, *Orchopeas howardi*, and *Oropsylla montana* (Eisen et al. 2009, Abbott and Rocke 2012), were recovered from mammalian hosts during the follow-up survey. However, no fleas were found on the plague-positive roof rat, and no fleas were tested as none of the additional mammals were positive for plague. The flea indices (average number of fleas per host animal, Eisen et al. 2009) for plague vectors were considered low (OC Vector 1999).

MULTIAGENCY STUDIES ON PLAGUE IN ORANGE COUNTY

In 2007, a collaborative effort involving the United States Geological Survey (USGS), University of Cali-

foria (Davis), Colorado State University (Ft. Collins), and CDC (Ft. Collins) identified plague-positive serology in 2 of 73 bobcats (*Lynx rufus*) collected in Orange County between 2002 and 2008 (Bevins et al. 2009). Both antibody-positive bobcats were trapped in the city of Rancho Santa Margarita, located in the foothills of the Santa Ana Mountains (Figure 1, Site 4) (Bevins et al. 2009). Similarly, in 2017, a partnership among the University of California, the California Department of Fish and Wildlife (CA F&W), and the National Park Service (NPS) analyzed archived urban mammal tissue samples from Southern California during 2011 to 2020 (Shultz et al. 2023). This study detected *Y. pestis* DNA using qPCR in spleen samples from two coyotes (*Canis latrans*) collected in the city of Huntington Beach in 2018 (Figure 1, Site 5). However, the researchers were unable to sequence *Y. pestis* DNA from the PCR amplicons obtained from these two coyote samples (Shultz et al. 2023).

MATERIALS AND METHODS, ORANGE COUNTY VECTOR CONTROL DISTRICT

Habitat Descriptions

Orange County, located along the Pacific Ocean in Southern California, is the third-most-populous county in the state, with an estimated population of 3.17 million residents within a predominantly metropolitan area of 790.6 mi² (2,047 km²) (US Census Bureau 2023). The county has a Mediterranean climate, with a mean annual temperature of 65.2°F (18.4°C) and an average annual rainfall of 12.5 inches (318 mm) (TimeandDate 2024). Historically known for its orange groves, Orange County transitioned from a primarily agricultural landscape to a largely urbanized region by the 1960s.

Habitats from which mammals were collected were classified based on landscape type and proximity to human development (Table 1). Agricultural areas included farm plots situated near urban development. Natural habitats comprised primarily chaparral, coastal sagebrush, oak woodlands, open grasslands, and other vegetation typical of coastal Southern California within county, state, or federal parklands, and were not adjacent to human development. The Wildland Urban Interface (WUI) comprises open or natural habitats, such as fields, canyons, and ravines, which are bordered by residential developments. Collections in the WUI were made on open land and residential properties adjacent to these open spaces. Lastly, mammal collections were conducted in residential properties within suburban or urban areas that lacked open space or natural habitats.

Animal Sampling, Flea Collection, and Laboratory Testing

Native mammals in Orange County susceptible to infection with *Y. pestis* include California ground squirrels, woodrats, deer mice (*Peromyscus* spp.), California voles (*Microtus californicus*), desert cottontail rabbits (*Sylvilagus audubonii*), and bobcats (CDPH 2021). In contrast, coyotes and other canids are considered relatively resistant to *Y. pestis* infection. Introduced species such as rats and domestic cats are highly susceptible to plague. Key flea species parasitizing these mammalian hosts and capable of trans-

mitting *Y. pestis* include *Hoplopsyllus anomalus*, *Malareus telchinus*, *Orchopeas* spp., *Oropsylla montana*, *Pulex irritans/simulans*, among others (Lewis et al. 1988, Eisen et al. 2009, Abbott and Locke 2012). Of these, *Oropsylla montana* is considered the most important sylvatic vector for plague, with its principal host, the California ground squirrel, serving as the primary sylvatic rodent for plague in California (CDPH 2021). The relative abundance, diversity, and degree of comingling of fleas (host shifting) on ground squirrels and other hosts can vary widely depending on habitat and seasonality (Ryckman et al. 1950, 1954; Baker 1984, Lewis et al. 1988, Davis et al. 2002).

Beginning in 1975, in response to the newly expanded mandate to include rodent control, OC Vector conducted plague surveillance jointly with the CDPH's Vector-Borne Disease Section (VBDS). These efforts focused on plague-susceptible mammals, such as California ground squirrels, other field rodents, and wildlife sampled from agricultural lands, natural landscapes, the wildland-urban interface, and urban/suburban neighborhoods. From 1975 to 1995, plague surveillance was a joint effort between OC Vector and CDPH VBDS; in 1996, OC Vector assumed full responsibility for plague surveillance activities, including animal trapping and in-house plague testing, until the program was reassessed in 2018.

As part of OC Vector's mammalian reservoir host pathogen surveillance programs – including plague, flea-borne typhus, hantavirus, Lyme borreliosis, and others – California ground squirrels were captured using Tomahawk live traps (Tomahawk Live Traps, LLC, Hazelhurst, WI) baited with rolled oats. Traps were set in the morning and checked a few hours later. For nocturnally active mammals, Sherman traps (Tomahawk Live Traps, LLC,) were set in the afternoon with the same bait and checked the following morning. Captured animals were transported to OC Vector for processing. Each animal was euthanized with carbon dioxide, identified to species, sexed, and assessed for age and reproductive status. Blood samples were collected via cardiac puncture and processed for plague antibody testing using either sera or applied to Nobuto filter strips. All animals collected by OC Vector or other contributing agencies (e.g., school districts, animal care agencies, and wildlife rehabilitators) were humanely trapped and euthanized in accordance with guidelines from the American Veterinary Medical Association (AVMA 2013).

Fleas on euthanized animals were killed either by freezing the carcass or by spraying an aerosolized insecticide directly into the bag containing the carcass. During processing, the euthanized mammal was placed in a white tray and dead fleas were subsequently removed from the pelage using combs and forceps. Fleas were placed into uniquely labeled vials and stored in freezers for plague testing if the host animal tested positive. Archived fleas were later identified to species and sex using standard taxonomic keys (Hubbard 1947, Pratt 1962, Lewis et al. 1988, OC Vector 2017) and enumerated. The species-specific flea index for fleas of importance for plague transmission was calculated to further estimate flea-borne disease risk (Krasnov et al. 2004). Historically, flea indices, combined with host abundance data, have informed risk assessments and guided intervention strategies aimed

Table 1. Mammal collections for plague surveillance by landscape type, Orange County Vector Control District, 1982-2017. WUI = Wildland Urban Interface

Order and Family	Genus	Species	Agricultural/Ranch	Natural areas chapparral, sage, oak	WUI habitat in residential area	Residence next to WUI	Property in urban/suburban area	Total
Rodentia								
Cricetidae	<i>Neotoma</i>	<i>lepida</i>	12	665	233	34	1	945
		<i>macrotis</i>	4	382	95	60	4	545
		<i>bryanti</i>	0	0	3	9	0	12
	<i>Microtus</i>	<i>californicus</i>	5	8	4	5	0	22
	<i>Peromyscus</i>	<i>sonoriensis</i>	0	96	33	1	0	130
		<i>boylii</i>	0	41	3	0	0	44
		<i>californicus</i>	0	30	6	0	0	36
		<i>eremicus</i>	0	28	8	0	0	36
		<i>truei</i>	0	10	0	0	0	10
	<i>Reithrodontomys</i>	<i>megalotis</i>	0	14	13	1	0	28
Muridae	<i>Rattus</i>	<i>rattus</i>	14	19	183	108	424	748
		<i>norvegicus</i>	0	0	2	0	1	3
	<i>Mus</i>	<i>musculus</i>	1	1	1	0	0	3
Sciuridae	<i>Otospermophilus</i>	<i>beecheyi</i>	35	492	513	147	62	1,249
	<i>Sciurus</i>	<i>niger</i>	0	0	5	0	39	44
Heteromyidae	<i>Chaetodipus</i>	<i>fallax</i>	0	7	3	0	0	10
	<i>Perognathus</i>	sp.	0	1	0	0	0	1
Carnivora								
Canidae	<i>Canis</i>	<i>latrans</i>	0	0	17	2	11	30
Felidae	<i>Felis</i>	<i>catus</i>	0	0	0	0	26	26
	<i>Lynx</i>	<i>rufus</i>	0	6	0	0	0	6
Mephitidae	<i>Mephitis</i>	<i>mephitis</i>	0	0	0	0	1	1
Lagomorpha								
Leporidae	<i>Sylvilagus</i>	<i>audubonii</i>	1	7	15	5	25	53
Didelphimorphia								
Didelphidae	<i>Didelphis</i>	<i>virginiana</i>	0	0	1	0	0	1
4 Orders and 9 Families	16 Genera	23 species	72	1,807	1,138	372	594	3,983

at reducing and preventing the transmission of flea-borne infectious agents (Dennis et al. 1999, Krasnov et al. 2004). From 1975 to 1995, OC Vector submitted blood samples, either as sera or dried Nobuto filter strips, from Orange County mammals to the CDPH VBDS or LAPH laborator-

ies for testing for antibodies against *Y. pestis* using the passive hemagglutination assay (PHA) (Hudson and Kartman 1967). From 1996 to 2017, serologic plague testing was performed in-house by OC Vector's staff microbiologist using the PHA. Tissue, blood, and flea

samples collected from 2011 to 2020 by the UC Davis-led study were evaluated using quantitative PCR (qPCR) (Shultz et al. 2023).

RESULTS

Mammals Sampled for Plague by Landscape Type

From 1982 to 2017, during which OC Vector administered its own plague surveillance, the program took blood samples from 3,983 mammals, representing 23 species across 16 genera and four orders (Table 1). The most frequently sampled animals consisted of four species (or genera) of rodents: California ground squirrels (31.4%: 1,249/3,983), woodrats (*Neotoma* spp., 37.7%: 1,502/3,983), and commensal rodents (primarily *R. rattus*) (18.9%: 754/3,983) (Table 1). Most animals were collected from natural areas (45.4%: 1,807/3,983); second, were mammals from WUI habitats, such as green belts, parks, golf courses, and adjacent housing (37.9%: 1,510/3,983). Dense suburban and urban neighborhoods accounted for a smaller proportion of samples, representing approximately 14.9% (594/3,983) of the total. Finally, agricultural plots were the source of approximately 1.8% (72/3,983) of collected mammals (Table 1).

Flea Identifications

Of the 3,983 mammals sampled for plague testing, 3,796 fleas were collected and approximately 2,000 were identified to species level, representing three families, 13 genera, and 15 species. An additional 11,403 fleas were collected from hosts during flea-borne typhus studies (Krueger et al. 2016, Penicks et al. 2019, 2020), identified to species, and used to calculate flea indices, primarily for urban-adapted mammals captured in residential settings. The most frequently identified *Y. pestis*-competent flea species, with varying levels of vector efficiency for plague transmission, included squirrel fleas (*Hoplopsyllus anomalus*, *Oropsylla montana*, *Orchopeas howardi*, *Orchopeas sexdentatus*), the northern rat flea (*Nosopsyllus fasciatus*), the human flea (*Pulex irritans/simulans* complex), the sticktight flea (*Echidnophaga gallinacea*), and the deer mouse and vole fleas (*Aetheca wagneri*, *Malareus telchinus*). The principal urban plague vector, the oriental rat flea, (*Xenopsylla cheopis*), was rarely encountered. The cat flea (*Ctenocephalides felis*), an inefficient plague vector (Eisen et al. 2009), was abundant on opossums (*Didelphis virginiana*), feral cats, and striped skunks (*Mephitis mephitis*) in urban areas of the county (Krueger et al. 2016, Penicks et al. 2019, 2020). *Pulex irritans/P. simulans*, which are morphologically similar, were not identified as separate species during the studies. Flea indices for plague-competent species during investigations (1967-1968, 1975-1985, 2015-2019) were consistently low, ranging from approximately 10 fleas per California ground squirrel to fewer than 1 flea per roof rat for these two hosts. Other backyard mammalian wildlife, such as opossums, raccoons (*Procyon lotor*), and skunks, were largely parasitized by flea species with low vectorial capacity for *Y. pestis* (Challet 1986, OC Vector 1999, Krueger et al. 2016, Penicks et al. 2019, 2020). No fleas collected by OC Vector were tested for the presence of *Y. pestis* bacteria.

Positive Plague Detections in Mammals and Fleas

Evidence of plague infection or exposure to plague bacteria was detected in Orange County through various sources (Table 2). These positive detections occurred in five cities at elevations ranging from 56 - 925 ft (17 - 282 m) above sea level. By season, detections were distributed as follows: two in spring (fleas; bobcats, USGS study), two in summer (flea pool, California ground squirrels, and a roof rat), and two with unknown seasonality (coyotes, Shultz et al. 2023). Only two rodents from WUI areas were antibody-positive for plague. No woodrats, deer mice, voles, or rabbits tested plague-positive from any habitats, including higher altitude inland areas. An examination of the historical surveillance documents revealed no records documents revealed no records of animal die-offs associated with plague detections in Orange County from 1909 to 2020.

DISCUSSION

The introduction of plague into California was facilitated by the translocation of infected animals, or people, through international ports in San Francisco, Los Angeles, and Oakland (Adjemian et al. 2007). The first confirmed human plague case in Southern California occurred in 1908 in Los Angeles County, near the Port of Los Angeles, and was likely associated with exposure to fleas and infected squirrels during a local epizootic (Adjemian 2007). The detection of plague-positive squirrels indicated active plague transmission near the port. Given the proximity of the Orange County border to the Port of Los Angeles (<10 mi/16 km) and unconfirmed evidence of epizootic plague activity in squirrels as early as 1908, it is notable that the first detection of plague in animals or fleas in Orange County did not occur until 1946. Research suggests that animal cases of plague typically precede human cases (Noble 1974). However, no validated reports of animal die-offs have been documented in Orange County, even in areas where seropositive animals or fleas were collected. Furthermore, no human plague cases have been linked to an exposure site in Orange County.

When responsibility for plague surveillance transferred from OC Health to OC Vector in 1975, OC Vector focused its efforts on habitats within the county believed to support enzootic plague activity and pose a potential risk of epizootic spillover into residential areas, similar to isolated cases reported in Los Angeles County (Nelson et al. 1986). Between 1982 and 2017, OC Vector tested an average of 110 animal blood samples per year (n = 3,983 total) for antibodies to *Y. pestis*. None of the approximately 1,800 native rodents considered important in enzootic plague cycles, such as field mice and woodrats, tested positive. The limited plague seroprevalence detected in the county was restricted to two epizootic host species: two California ground squirrels at an urban-wildlife interface site and one roof rat in a suburban backyard. Since 1998, OC Vector has not detected any additional plague-positive samples in Orange County.

OC Vector maintained its plague surveillance program until 2018, when resources were redirected to address the persistent threat of West Nile virus transmission in the county (CDPH 2015). Recent CDPH guidance emphasizes

Table 2. Positive plague detections in mammals and fleas collected in Orange County, California, 1946-2020.
Diagnostic testing included inoculations of mice, cell culture, microscopy, and passive hemagglutination assay (PHA).

Date	Sample	Location (lat/long)	Elevation ft (m)	Habitat	Animal Die-off	Collecting Agency	Testing Agency	Test
25 Apr 1946	Pool (107 fleas) off 7 ground squirrels	Newport Beach (33.6051/-115.8622)	56 (17)	Agriculture Ranching	No	CDPH	CDPH	Mice, culture
31 Aug 1982	2 ground squirrels; 1 flea pool, woodrat	Anaheim (33.8412/-117.7593)	410 (125)	WUI golf course	No	CDPH, OC Vector	CDPH	PHA; mice, culture
18 Aug 1998	1 roof rat	Orange (33.8041/-117.8267)	190 (58)	Suburban residence	No	OC Vector	OC Vector, CDC	PHA
19 Mar 2007	2 bobcats	Rancho Santa Margarita (33.6406/-117.6060)	925 (282)	WUI roadway	No	USGS	CDC	PHA
2018	2 coyotes	Huntington Beach (unknown)	39 (12)	Urban residential	No	UC Davis	UC Davis	PCR

a standardized, evidence-based approach to plague surveillance, prioritizing historical endemic hotspots characterized by rodent die-offs, plague-positive flea activity, or human cases (CDPH 2021). Because Orange County exhibits few such indicators, it is not classified as an endemic plague area, unlike its neighboring counties; the reasons for this are unclear. As a result, when OC Vector attempted to restart its plague surveillance program in 2022, OC Vector was ineligible for CDPH-supported serologic testing. However, CDPH continues to accept animal carcasses for plague testing from Orange County when submissions are associated with observed die-offs of possible plague hosts.

The ecology of plague is highly complex, and many aspects of its dynamics remain incompletely understood (Abbott and Rocke 2012). As decades of research in California have advanced the understanding of plague transmission (Davis et al. 2002, Smith et al. 2009), current guidance has shifted away from broad geographic rodent sampling and widespread use of insecticides and rodenticides toward more targeted surveillance and control of fleas and rodents in areas with demonstrated human risk. Considering these developments, OC Vector's plague surveillance program warrants reevaluation to align with the latest scientific perspectives.

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