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Challenges of responding to flea-borne typhus cases: lessons learned after 15 years of investigations in Orange County

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Abstract

Since 2001, flea-borne typhus (FBT) has reemerged as an important vector-borne disease in Los Angeles and Orange counties. The reasons for this resurgence are unclear, but this rise has been accompanied by changes in how public/private animal control groups manage "nuisance" animal populations, especially opossums and feral cats, the primary hosts for the cat flea, *Ctenocephalides felis*, a key vector of FBT in southern California. These changes include no longer recognizing the removal of opossums and feral cats as a flea control strategy and implementation of "return to field" programs that place, in lieu of euthanization, impounded cats in neighborhoods without on-going flea control treatments. Since the first reported FBT case in 2006 in Orange County (the first since 1993), the Orange County Mosquito and Vector Control District (OC Vector) has investigated 237 of the 249 reported FBT cases in the county. Investigations have included patient interviews, ecologic assessments of putative exposure sites, testing of flea and animal specimens collected from these sites for rickettsial bacteria, and public outreach on FBT prevention in affected areas. These investigations have shown that peridomestic animals, such as opossums and feral cats, support populations of fleas infected with *Rickettsia typhi* and *R. felis*, the bacteria responsible for human FBT. OC Vector and other local health care agencies have recognized a link between feral cat feeding sites and heightened disease risk in FBT-affected neighborhoods. Despite this observation, local human health care agencies, animal care groups, and city code enforcement agencies have been unwilling, or unable, to implement policies to stop the proliferation of feral cat colonies in areas with high FBT disease risk. The continued rise of FBT has proven difficult to mitigate because of conflicting perspectives among governmental agencies and animal rights advocates, who perceive the zoonotic disease risk associated with cat rescue programs at significantly different thresholds of concern.

INTRODUCTION

Since 2001, flea-borne typhus (FBT) has reemerged as an important vector-borne disease in California, with 1,506 human cases (0 deaths) reported through 2021 (CDPH 2012, CDPH 2020, CDPH 2022a). Flea-borne typhus is the second most common vector-borne disease in the state after West Nile virus disease (7,471 cases, 359 deaths, CDPH 2022b), with most FBT typhus cases (95.7%) occurring in Los Angeles and Orange counties [1,192 (79.1%) and 249 (16.5%) cases, respectively, Figure 1] (CDPH 2012, CDPH 2020, CDPH 2022a). Over the last nine years (2013-2021), more locally-acquired FBT cases have been reported in Ventura (3), San Bernardino (13), Riverside (11), and San Diego (8) counties compared to previous decades (CDPH 2012, CDPH 2020, CDPH 2022a). In affected areas, FBT cases appear year-round, with most occurring from May to October (CDPH 2021). Human FBT cases are reportable to the California Dept. of Public Health (CDPH) under Title 17 of the California Code of Regulations, Section 2500 (CDPH 2021). The Orange County Health Care Agency (OC Health Care) reports FBT cases to the Orange County Mosquito and Vector Control District (OC Vector) following guidelines outlined in a 2012 Memorandum of Understanding (MOU) between the two agencies for the confidential exchange of health care information (HIPAA 1996, OC Health Care 2012).

Flea-borne typhus is caused by infection with either of two rickettsial bacteria, *Rickettsia typhi* and *R. felis*, which are transmitted to humans by infected fleas, principally the oriental rat flea (*Xenopsylla cheopis*) and the cat flea (*Ctenocephalides felis*), respectively (Azad et al. 1997, Azad and Beard 1998, Reif and Macaluso 2009). Most infections are reported to be mild or asymptomatic, but for clinical cases, symptoms typically appear 7-14 days after exposure and include high fever, headache, chills, rash, myalgia, and other non-specific symptoms; in more severe cases, respiratory distress, renal failure, encephalitis, and endocarditis can occur (CDPH 2019). Fatalities are rare ($< 1\%$) when treated with appropriate antibiotics (typically, doxycycline), depending on the age and co-morbidities of victims (CDPH 2019). In Orange County, approximately 85 - 91% of FBT victims have been hospitalized, with a median length of stay of 5 days (range 1 - 368 days) (Cummings et al. 2014, OC Health Care 2019).

In southern California, most human FBT cases have been attributed to the suburban rickettsial transmission cycle involving the cat flea and its primary mammalian hosts,

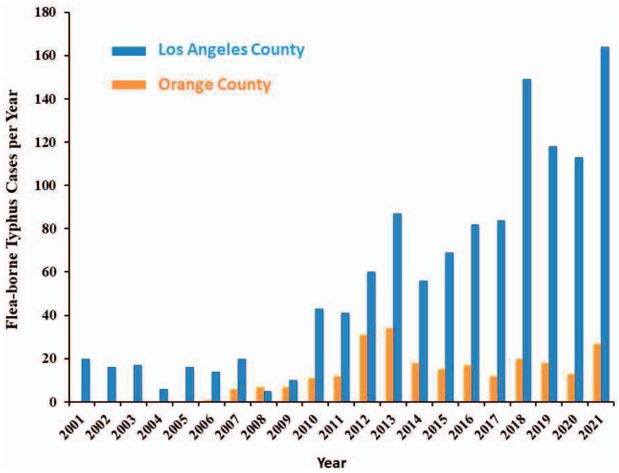

Figure 1.—Flea-borne typhus cases per year in Los Angeles and Orange Counties, 2001-2021.

opossums and cats (Adams et al. 1972, Sorvillo et al. 1992, Eremeeva et al. 2012, Krueger et al. 2016, Maina et al. 2016, Jia et al. 2021). With the exception of a few case clusters in Los Angeles County, the urban (murine) rickettsial transmission cycle, involving the oriental rat flea, commensal rodents (e.g., Norway, roof rats) and *R. typhi* (Dyar 1944), now plays a much smaller role in outbreaks in the region (Adams et al. 1972, Schwan et al. 1985, Sorvillo et al. 1992, Civen and Ngo 2008, Karpathy et al. 2009, Abramowicz et al. 2011, Eremeeva et al. 2012).

In contrast to the urban FBT cycle, *R. felis* may be the primary pathogen in the suburban transmission cycle. *Rickettsia felis* is found substantially more often than *R. typhi* in cat fleas and tissues of domestic and peridomestic animals in southern California (Williams et al. 1992, Eremeeva et al. 2012, Krueger et al. 2016, Maina et al. 2016, Mullins et al. 2018, Penicks et al. 2019, Penicks et al. 2020). However, Wiggers et al. (2005) (Texas), Billeter and Metzger (2017), and Blanton and Walker (2017) (Texas) attribute most FBT cases in Texas and California to infections with *R. typhi*. The serologic cross-reactivity of *R. felis* with the *R. typhi* antigen in standard diagnostic tests (IgM/IgG IFAs) used in the U.S. has precluded differential diagnoses in humans (Schriefer et al. 1994, Wiggers et al. 2005, Civen and Ngo 2008, Eremeeva et al. 2012). In contrast, discriminatory serologic studies in Spain (Nogeras et al. 2006), Mexico (Pérez-Osorio et al. 2008), Australia (Teoh et al. 2016), and Taiwan (Yang et al. 2021) have implicated *R. felis* as an important pathogen for FBT. Although molecular methods offer specificity for diagnosis of acute rickettsial disease, samples of whole blood are often not taken or tested before administration of antibiotics, making direct molecular determination for either *R. typhi/R. felis* infection unlikely; furthermore, rickettsemias are short-lived in the blood of humans (Caravedo-Martinez et al. 2021). To date, no flea-borne rickettsial disease cases attributed to infection with *R. felis* have been diagnosed in California (Billeter and Metzger 2017).

The causes for the increase in FBT cases, the geographical spread, and the specific etiologic agent(s) responsible in affected southern California counties are not well-defined. However, this rise has been accompanied by changes in how public and privately-sponsored animal control groups manage "nuisance" animal populations, especially opossums and feral cats, the most important hosts for *Rickettsia*-infected cat fleas (Eremeeva et al. 2012, Krueger et al. 2016, Penicks et al. 2020, Li et al. 2021). The 1998 passage of the Hayden Law (SB 1785, CA Chapter 752, Statutes of 1998) has required animal shelters to adopt strategies to reduce shelter euthanization rates and pet overpopulation. These strategies have included cessation of euthanasia of uninjured peridomestic wildlife (e.g., opossums, raccoons) and an emphasis on wildlife rehabilitation, and pet adoptions and sterilization.

To address the issue of having to reduce the euthanization of healthy, unadoptable cats surrendered to shelters, public and private animal care agencies have often instituted "Trap-Neuter-Return" (TNR) and "Return-to-Field" (RTF) programs in partnership with cat advocacy and rescue groups. TNR is a program in which feral cats are captured in the field, sterilized, treated for feline diseases and fleas, and returned to the community in which they were found. RTF refers to the practice of sterilizing and releasing non-feral cats not adopted within a specified time period to the field instead of euthanasia. Once cats are relinquished to a designated animal rescue group, TNR/RTF cats are to be cared for in 'cat colonies' by volunteer caretakers (Slater 2004). (By definition, a feral cat is free-roaming and, unlike stray and pet cats, not socialized to people, CA FAC Sec. 31752, 1998). The Orange County Animal Care Agency (OC Animal Care) initiated a pilot TNR program in 2009 in partnership with Feral Alley Cats and Friends of SPCA as an alternative to euthanasia and in an attempt to reduce cat overpopulation; the pilot program became fully operational as "Feral FREE" in 2013 (Cummings et al. 2016).

In southern California, several local public health agencies (health departments, vector control agencies) have expressed concern that these publically/privately-supported TNR programs may be contributing to the rise of FBT cases within their jurisdictions (LAC DPH 2009, OC Vector 2014, OC Grand Jury 2015a, Wekesa et al. 2016, Nelson et al. 2018, LAC DPH 2019). The current paper will outline some of the challenges OC Vector has faced in addressing the rise of FBT in the county and will discuss the development of its comprehensive FBT surveillance and mitigation programs.

Challenge: Defining FBT High Risk Areas

Mapping the spread of FBT in Orange County

From the 1960 to 2000, cases of FBT averaged < 20 cases and < 2 cases per year in Los Angeles and Orange counties, respectively (Wekesa et al. 2016a, Cummings et

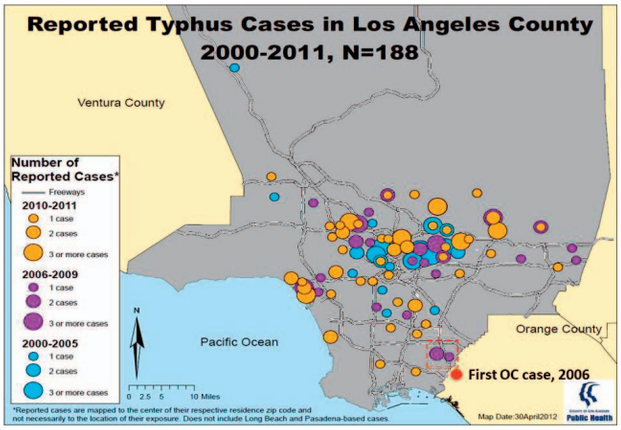

Figure 2.—Location of flea-borne typhus cases in Los Angeles County (2000 – 2011) and the first case identified in Orange County, 2006 (red circle). The OC County case was located near the Los Angeles/Orange County border and was randomly offset by 0.5 km (0.3 mi) for display per HIPAA and OC Health Care/ OC Vector MOU.

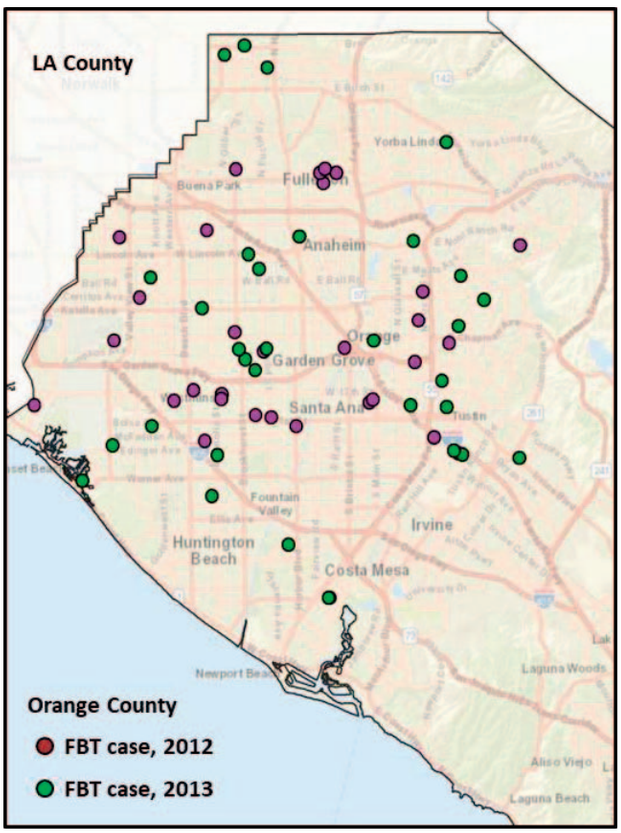

Figure 3.—Distribution of flea-borne typhus cases during 2012 (green) and 2013 (purple) in Orange County. Flea-borne typhus cases were randomly offset by 0.5 km (0.3 mi) for display per HIPAA and OC Health Care/OC Vector MOU.

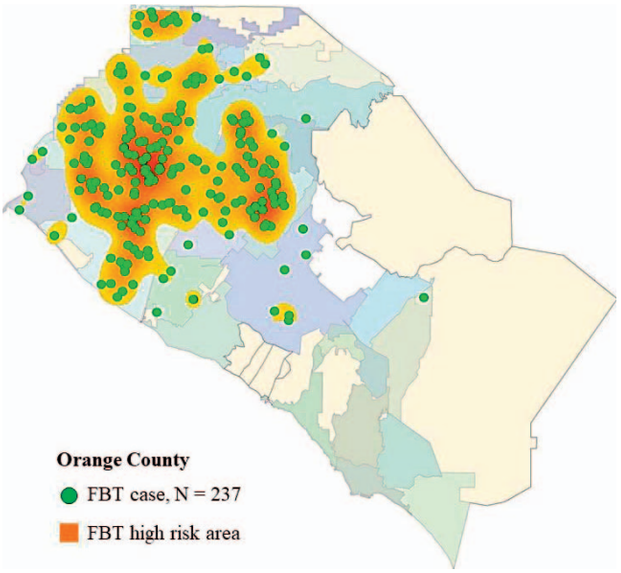

Figure 4.—Hotspot map of flea-borne typhus cases (green circles) in Orange County, 2006 – 2021. FBT cases were randomly offset by 0.5 km (0.3 mi) for display per HIPAA and OC Health Care/ OC Vector MOU. Some cases overlap because of their close proximity to one another. ESRI Spatial Statistics Tool, Hotspot Analysis/Getti-Ord GI*.

al. 2014). In 2006, the city of Long Beach (an L.A. County city adjacent to Orange County) recorded its first FBT cases (6) (LB HHS 2021), and Orange County recorded its first FBT case since 1993 (resident lived on the Long Beach-L.A. County/Orange County border, Figure 2). Within seven years, both the numbers and distributions of FBT cases increased, reaching highs of 31 and 34 cases, respectively, over wide portions of central and northern Orange County during 2012 and 2013 (Figs. 1, 3).

With FBT case addresses provided by OC Health Care, OC Vector has performed annual hotspot analysis (ESRI, ArcMap 10.2, Spatial Statistics Toolset, Hotspot Analysis 2013) to identify high risk FBT areas in the county. Figure 4 shows significant clustering among 198 of the plotted 237 FBT cases (79.7%). For the hotspot areas (shading), FBT case densities ranged from 0.5 – 1.7 cases/km^2 (1.2 – 4.4 cases/mi^2) ($p < 0.05$, Z-score 1.90 – 8.16, Getis-Ord GI*), a significant 7.1% increase in case clustering (99/135, 72.6%, $p < 0.05$, Z-score 3.6 – 11.5), since a similar analysis was done in 2016 (Cummings et al. 2016). (For epidemiological and hotspot mapping purposes, it is assumed that rickettsial transmission occurred at or near the reported case address). Since 2011, FBT cases have averaged 20.5/year (range 12 – 34) and are heavily concentrated in north-central areas of the county (Figs. 1, 4).

After a public information request, OC Animal Care provided OC Vector with the addresses of TNR cat release sites (N = 8,160 cats) for 2013 – 2018. These addresses were assigned geolocation coordinates and plotted on a map; next, a hotspot map depicting a FBT case density analysis for 191 cases from 2006 – 2018 was projected over

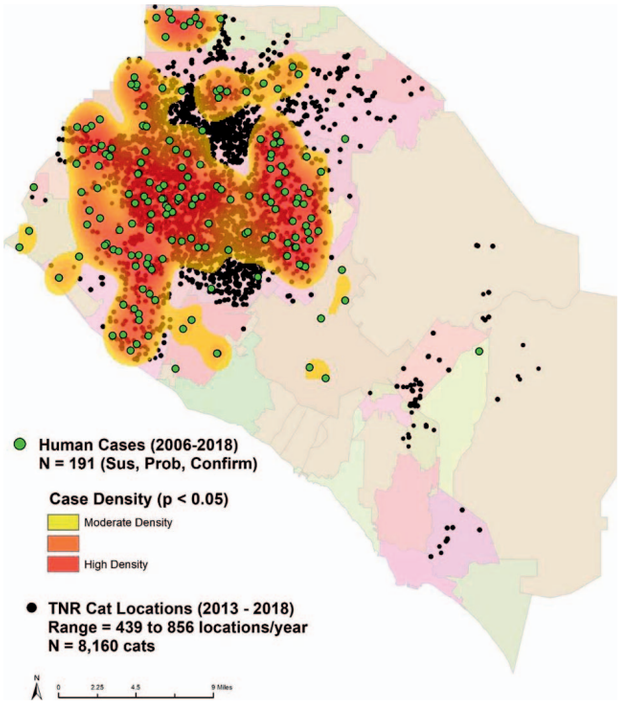

Figure 5.—Hotspot Analysis of flea-borne typhus cases (green circles) (2006 – 2018) and TNR feral cat release sites (black dots), 2013 – 2018. Flea-borne typhus cases were randomly offset by 0.5 km (0.3 mi) for display per HIPAA and OC Health Care/OC Vector MOU. ESRI Spatial Statistics Tool, Hotspot Analysis/ Getti-Ord GI*.

the TNR cat placements (Fig. 5). Although this hotspot analysis of human FBT cases demonstrated the clustering of cases (134/183, 73.2%, $p < 0.05$, Z-score 3.1 – 7.2), it did not indicate a causal relationship between placement of TNR cats and FBT transmission. However, it does show that the majority of Orange County FBT victims live in cities that received TNR cats as part of OC Animal Care's Feral FREE program (Fig. 5), thereby augmenting the flea populations that become vectors of FBT among cats, wildlife, and humans. (For Figs. 3–5, FBT cases addresses were randomly offset by 0.5 km (0.3 mi) for display to comply with the Health Insurance Portability and Accountability Act (HIPAA) and the OC Health Care/OC Vector MOU for patient confidentiality).

Challenge: Lack of local testing for FBT rickettsia in fleas and animal specimens

Cooperative research programs and development of an in-house FBT testing program

At the start of the FBT outbreak in Orange County, no county, state, or university laboratory in California were prepared to conduct routine testing of fleas and animal tissues for FBT bacteria. Because of this lack of local testing capability, OC Vector initiated a multi-agency FBT research study with the Los Angeles County Department of Public Health (LAC DPH), CDPH, and the Center for Disease Control and Prevention (CDC) in 2008. Following the completion of the CDC project (Eremeeva et al. 2012), OC Vector commenced three projects with the U.S. Naval Medical Research Center (NMRC) (Silver Spring, MD) and other interested entities. In Orange County, Maina et al. (2016) examined the prevalence of *R. typhi*/*R.felis* and other *R. felis*-like organisms (RFLOs) in fleas, and Krueger et al. (2016) documented these disease agents in urban opossums; finally, Mullins et al. (2018) explored rickettsial agents in euthanized cats of Riverside County. OC Vector laboratory staff received training for rickettsial testing of flea and animal specimens from NMRC while participating in these studies. After training, OC Vector implemented a singleplex real-time PCR assay in 2012 and recently developed a duplex PCR assay for simultaneous detection of *R. typhi* and *R. felis* in flea and animal specimens (Rangel et al. 2019). OC Vector has hosted several FBT educational workshops with local county/city health care agencies, school districts, vector control agencies, animal care groups, CDPH, and commercial pest control companies to discuss awareness of FBT in communities, control measures, neighborhood notifications, and coordination of responses to outbreaks.

Challenge: Conflicts with cat advocacy groups on FBT control actions

Refocus of animal control agencies to animal care agencies

In the U.S., feral cat advocates have gained political strength and influenced state and local laws regarding the funding and actions of organizations dealing with animals (Longcore 2009). Today, most publically sponsored animal care services focus on animal rehabilitation, adoption and rescue through partnerships with rescue groups, rather than providing animal control through density reduction. Increasingly, many public shelters have defined themselves as agencies designed to save animal lives, not to end them (Kortis 2014). One nationwide effort, the Million Cat Challenge, is a joint project of the UC Davis Koret Shelter Medicine Program and the University of Florida Maddie's Shelter Medicine Program advocating "return-to-field" as one of its five key initiatives to improve feral cat lives (Million Cat Challenge 2022).

With the requirements of the Hayden Law becoming effective in 2010, OC Animal Control was re-named as OC Animal Care and was transferred from the OC Health Care Agency to the OC Community Resources Department in 2008 for better outreach to the public and to emphasize the agency's role as an animal welfare organization. OC Animal Care started a pilot feral cat TNR program in 2009. The Program's objective was to reduce cat overpopulation by increasing sterilization of feral/stray cats and to decrease cat euthanization by adoption and returning impounded, unadoptable cats to the field.

In April, 2012, a teenage child in the city of Santa Ana, who often played at a nearby intermediate school, became ill with FBT. A subsequent ecologic investigation by OC

Vector in May found that the middle school in question had feral cats on the campus. Although some students, staff and public fed and cared for the cats, others at the school complained about cat feces and fleas. With support from the school administration, OC Vector and the Santa Ana Police Department worked together to trap and remove the cats from school property and transfer them to the city's Animal Services. Against OC Vector's advice, the Santa Ana Police Department announced their action plan to the public in a press release. A nationwide outcry quickly ensued against the removal and prospective euthanization of the feral cats. Several cat advocacy groups, *Alley Cat Allies* (2012), *Animal People* (2012), and *Catster* (Kelly 2012), hosted online forums for protesters, resulting in thousands of calls and emails to OC Vector and the Santa Ana Police Department opposing the removal of the cats; deployed traps were found to have been triggered prematurely (Anstead 2020). In response, the traps were withdrawn and a scheduled protest by *Alley Cat Allies* at the school on Saturday, June 2, 2012, was canceled. Instead, OC Vector's Manager and Communications staff met with representatives of *Alley Cat Allies* and held an outreach event on FBT prevention at the school and also provided topical flea medication to pet owners.

As TNR cats have become more abundant in the county, some cities have attempted to regulate the feeding of feral cats. In 2015, the city of Anaheim passed an ordinance restricting cat feeding only to approved cat feeders (Anaheim Municipal Code Section §6.44.1301 2015 2015). This prohibition provoked an outcry from cat advocates and led to a petition called "*Stop the Starvation of Cats of Disneyland and Anaheim*," which supposedly generated 33,430 signatures (Cunningham 2015). In response to the protesters, Anaheim kept the ordinance on file but directed cat feeders to assigned TNR sites (OC Community Cats 2015). In most situations, feral cats are unclassified as neither pet nor wildlife, and city code enforcement entities have no authority to regulate free-roaming cats.

For TNR advocates, program success is defined not by the elimination of feral cats in an area, but rather by the welfare of the cats (Longcore et al. 2009). *Alley Cat Allies* (2016) dismissed the FBT risk from feral cats, and even suggested that feral cats and the public make for a "healthy relationship". Furthermore, cat advocates have often promoted the use of feral cats as "working cats" in communities in a common misconception that feral cats will reduce rat numbers and should be used in urban rat control programs (Parsons et al. 2018).

Challenge: Contrasting views between OC Vector and OC Animal Care's TNR program

Engagement with OC Animal Care regarding FBT and its TNR program

After OC Animal Care started its TNR program in 2009, OC Vector met with OC Animal Care several times during the program's initial years to express concerns about the potential negative public health consequences associated with the proliferation of feral cats (NASPHV 1996, Jessup 2004, Gerhold and Jessup 2012, Roebling et al. 2013). Within the organization, OC Animal Care's veterinarians advised against the TNR program, calling it a potential health hazard, ineffective, and a waste of tax dollars (OC Grand Jury 2015a). Separately, OC Vector and the OC Health Care Agency both requested that the program be subjected to a full environmental impact analysis through a California Environmental Quality Act (CEQA) review (OC Grand Jury 2015a). OC Vector also expressed concerns about OC Animal Care's legal liabilities posed by releasing thousands of animals capable of harboring and transporting *Rickettsia*-infected fleas from areas where FBT disease is present to areas where the disease had not been found and requested that OC Animal Care prepare a TNR procedural manual with harm reduction provisions for FBT.

OC Animal Care rejected OC Vector's request for a CEQA review and never produced a guidance document on its TNR practices. However, after requests by OC Vector, OC Animal Care agreed to not place TNR cats within 0.48 km (0.3 mi) of hospitals, schools, parks, geographic clusters of FBT cases, and mobile home parks; OC Animal Care also agreed to assist OC Vector in its public awareness campaign by distributing flea-borne typhus education materials to veterinarians and the public (Cummings et al. 2014).

In 2014, OC Vector Manager Michael Hearst formally stated OC Vector's opposition to OC Animal Care's TNR program in a letter addressed to the OC Vector Board (OC Vector 2014). In a OC Grand Jury investigation of OC Animal Care (2014-2015), the Grand Jury questioned the effectiveness of the TNR Program at reducing cat overpopulation and identified it as a possible contributor to the spread of zoonotic disease agents, including FBT; they also recommended an immediate evaluation of the program (OC Grand Jury 2015a), which was never done. In a dissenting response, OC Animal Care maintained that the Feral FREE Program was a humane approach to cat population reduction, without creating undue risk of FBT pathogen transmission to the public (OC Grand Jury 2015b).

Challenge: Implementing existing State and local laws and regulations to prevent FBT

FBT at mobile home communities in Los Angeles and Orange counties

Animal rights groups and permissive public attitudes toward free-ranging cats have played a role in limiting the ability of public health agencies to mitigate FBT outbreaks when animal removal and/or depredation measures have been required, in addition to flea control. Within the last decade, FBT outbreaks (i.e., two or more cases at a site) have occurred at a number of mobile home communities in Los Angeles and Orange counties (LAC DPH 2015, Nelson et al. 2018, pers. comm., L. Krueger 2022). Inspections of these sites has revealed widespread cat feeding stations with unattended, surplus cat food for "community cats," a

lack of sanitation associated with the stations (spilled food, animal feces, and uncovered trash bins), flea infestations, and an abundance of cats (owned and unowned), opossums, and other wildlife. Both the San Gabriel Valley Mosquito and Vector Control District (SG Vector) and OC Vector took similar pathways to resolving the animal, feces, and flea problems at these mobile home communities by enforcing State codes [CA Mobilehome Residency Law Civil Code §798.33 (2001) and CA Mobile Home Parks, CCR Title 25, Article 2, Section 1114 (a, b) (2004)] and the communities' own rules and regulations. State and community stipulations limit the number of animals allowed and prohibit free-roaming animals (pet, stray, feral) and "community" feeding of animals at mobile home parks. SG Vector also partnered with the Los Angeles County Department of Public Health (LAC DPH) and issued an abatement warrant under authority of the CA Health and Safety Code (CA HSC, Ch. 1, Div. 3, Sec §2000-2093, 2002) for the removal of feral cats and peridomestic wildlife and for flea control (LAC DPH 2015, Nelson et al. 2016, Wekesa et al. 2016b).

These agency enforcement actions were met with opposition by some residents. In the SG Vector enforcement, the local animal care responsible for the mobile home community refused to remove the animals, and a wildlife trapper authorized for animal depredation had to be used (Nelson et al. 2018). Once completed, no additional FBT cases were reported from the mobile home communities.

DISCUSSION

FBT is an example of a zoonotic disease that is difficult to manage from a public health perspective, because transmission is so closely associated with human behavior, pet cats and dogs, stray/feral cats, and peridomestic wildlife. The ecology of fleas and host animals in urban/suburban environments and the lack of area-wide interventions targeting peridomestic wildlife limit the effectiveness of many of the potential tactics for FBT disease control, both area-wide and at single residential properties (Krueger et al. 2022). Although CDFW regulations prohibit the relocation of wildlife (CDFW CCR Title 14 Sect. 465.5g(1) 2021), many residents and rescue groups relocate nuisance opossums and feral cats to other neighborhoods as a matter of convenience. These relocations by well-meaning individuals or groups may have contributed to the spread and amplification of these pathogens in Los Angeles County (LAC DPH 2016).

Once released, cats managed by TNR/RTF programs are not treated with flea control medication as part of routine colony maintenance and can support large flea infestations throughout their lifetimes. In addition, feral cat feeding stations provide supplemental food for wildlife and act as sites for interspecies exchange of fleas and pathogens among cats, wildlife, and humans (Akucewich et al. 2002, LAC DPH 2009, Hernandez et al. 2018). Current flea control medications are available only as topical or oral formulations to be applied directly to a single cat, and no formulations of oral flea medications are available that can be applied in food to the entire colony. The LA County DPH reports widespread flea infestations and public complaints in areas where cat colonies have been established (LAC DPH 2016, LAC CCP 2020a).

Mapping feral cat releases and where FBT cases occur is important to understanding threats to public health and where to focus mitigation measures. OC Vector's annual hotspot analysis has helped identify areas of high FBT disease occurrence and a greater relative risk for rickettsial transmission compared to other areas of Orange County. With this understanding, OC Vector's Communications Department has conducted targeted FBT informational programs for disease prevention in these affected neighborhoods (Krueger et al. 2022).

Although none of the recommendations from the 2015 Grand Jury were implemented to reduce zoonotic risks, OC Animal Care suspended its TNR program in 2021. OC Animal Care's new Director also informed OC Vector recently (Dec. 2021, personal comm., Laura Krueger) that TNR/RTF is a form of animal abandonment, in violation of CA State law, Cal. Penal Code §597s (2000). Nonetheless, TNR advocates continue to push to re-instate the program in Orange County (Paw Protectors Rescue 2022).

Feral cats have become a common feature in many urban/suburban landscapes in the U.S. and pose serious threats to public health and wildlife (Dutcher et al. 2021). Free-ranging, unowned cat numbers continue to increase in Los Angeles and Orange counties (LAC CCP 2020b, OC Animal Allies 2022), despite attempts to limit their numbers through sterilization efforts. Although OC Animal Care is no longer performing TNR/RTF programs, nonprofit and volunteer organizations are providing TNR and other services for feral/stray cats. OC Animal Care's website (OC Animal Care 2022) directs people to animal rescue groups that offer vouchers for cat spay/neuter, but the demand for services is beyond the capacity of these groups (OC Animal Allies 2022). Altogether, 21 groups care for animals in Orange County (OC Animal Care 2021), with many private groups practicing TNR under no County oversight.

The public health obligation for which governmental animal control agencies were created and their role in animal management must be re-emphasized as one way to prevent outbreaks of zoonotic diseases. Furthermore, TNR and RTF cat programs are inconsistent with an all-encompassing "One Health Approach" that emphasizes prevention over pesticide control measures to mitigate zoonotic disease (UC Davis 2022). No TNR programs have been shown to work at the municipal level, as they spay/neuter fewer than 5% of the feral cats in a community, falling far short of the >70% sterilization rate required for effective population reduction (Jessup 2004, Foley et al. 2005, Longcore et al. 2009). Multi-agency enforcement of existing California State and local city/county codes and regulations regarding unsanitary conditions associated with feral cat colonies (feces accumulation, fleas) by county

agencies (e.g., LAC Code 1959 & 1964), city ordinances (e.g., Anaheim Municipal Code Section 2015), vector control districts (CA HSC Secs. 2060-2067, 2002), California Department of Fish and Wildlife's restrictions on feeding of free-roaming cats (CDFW CCR Title 14, § 251.1 2019), and informed animal control agencies (Cal. Penal Code §597s 2000) would be instrumental in abating and limiting the spread of FBT.

CONCLUSION

A comprehensive flea-borne typhus program includes both public education and management of fleas and vertebrate hosts. OC Vector views FBT as a preventable disease but has encountered many challenges in developing a comprehensive FBT prevention program. Over the past 15 years, OC Vector has participated in studies with other agencies and universities, resulting in many publications; hosted FBT educational workshops for stakeholders; developed its own in-house FBT testing capability (PCR and ELISA); identified FBT high risk areas and developed focused educational outreach efforts; engaged local animal care groups to modify their feral cat TNR/RTF programs to reduce FBT risk; exercised its abatement powers to stop FBT outbreaks over the objections of cat advocates; and implemented a tiered FBT Response Plan.

ACKNOWLEDGEMENTS

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