Your Children "Mite" Not be Safe at School: An Outbreak of Biting Rat Mites at a Southern California Elementary School Campus

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ABSTRACT: During May, 2017, the Orange County Mosquito and Vector Control District (OCMVCD) received anonymous calls from distressed school staff and parents of children attending an elementary school (Villa Park Elementary School, VPES) in Orange County, California, about an outbreak of pruritic dermatitis that was believed to be caused by biting arthropods. The incident received intense media coverage and led to a partial closure of the campus. With no identified culprit, OCMVCD interviewed VPES staff and surveyed the school property for vertebrate pests and their ectoparasites to determine the source of the outbreak. After thorough inspections of the exterior and interior of classrooms and a carefully-placed, glue-board trap survey, OCMVCD detected signs of significant roof rat activity (feces, rub marks, and harborage sites) throughout the campus and the presence of rat mites inside multiple classrooms. OCMVCD worked with other governmental agencies (Orange County Health Care's Environmental Health, California Department of Pesticide Regulation's School Integrated Pest Management Program, local city officials) and the VPES administration to educate parents about the vertebrate pests on the school grounds and the complexities of controlling the rat mite infestation during the school year. OCMVCD also identified deficiencies in the school's pest control program and developed an integrated vector management plan to address the immediate and long-term health threats to prevent rodent and rat mite outbreaks in the future. This report details the investigation and methodology used to locate and eradicate the vertebrate and ectoparasite threats on the VPES campus and the challenges encountered during the process.

KEY WORDS: cat flea, *Ctenocephalides felis*, *Ornithonyssus bacoti*, *Rattus rattus*, roof rat, tropical rat mite

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INTRODUCTION

Rodents and their ectoparasites have beleaguered humans for millennia with no end in sight. Two such rodents, the Norway rat (*Rattus norvegicus*) and roof rat (*R. rattus*) are known to host a suite of parasitic mites and can be found nearly worldwide inhabiting a variety of anthropogenically-modified habitats (Watson 2008, Guo et al. 2016). Although some mites are obligate parasites that are dependent on their rodent host to complete their life cycle, humans can become temporary blood meal sources when the definitive host is no longer available, often after some initiating change in the environment, habitat, or host distribution. For many hematophagous mite species, humans are unsuitable hosts for the completion of their life cycle (Webb and Bennett 2002). The tropical rat mite, *Ornithonyssus bacoti*, is an obligate hematophagous parasite commonly found within the nests of wild and commensal rodents and has been documented to negatively impact humans around the world (Hirst 1914, Bishopp 1923, Shlemire and Dove 1931, Theis et al. 1981, Beck 2008).

In the absence of a suitable host, the tropical rat mite can travel 60 m or more in search of a blood meal and invade areas occupied by humans, including, but not limited to, residential dwellings (Ebeling 1960), disabled care facilities (Baumstark et al. 2007), and research laboratories (Fox 1982). In facilities other than those that house animals, outbreaks are often associated with dilapidated buildings that are vulnerable to establishment by commensal rodent populations. Due to their small size and inconspicuous coloration, bite outbreaks, even among dozens of people, can occur for months before the causative organism is discovered, if detected at all (Anderson 1944, Dowlati and Maguire 1970, Chung et al. 1998, Rosen et al. 2002). Tropical rat mites can cause painful, pruritic papular rashes on the human body (Lowell 1946, Charlesworth and Clegern 1977, Theis et al. 1981) and if left unidentified, cause considerable mental anguish and economic loss (Bishopp 1923, Engel et al. 1998, Baumstark et al. 2007, Beck and Folster-Holst 2009). Several laboratory studies have found that tropical rat mites are capable of transmitting infectious pathogens (Shelmire and Dove 1931); however, none have demonstrated transmission to humans (Webb and Bennett 2002, Reeves et al. 2007). Successful and rapid eradication of rat mite infestations can be achieved through an integrated pest management (IPM) strategy concomitantly targeting the rodent host, mite, and environment (Ebeling 1960). However, in some settings such as schools, control efforts may be disruptive, contentious, and logistically complex if the rodent and mite infestation is extensive and requires the use of indoor acaricides and results in the displacement of people (Baumstark et al. 2007, Morgan et al. 2017). Prevention of mite outbreaks can be accomplished through an established IPM plan promoting rapid response to signs or reports of rodent activity, routinely monitored rodent exclusion measures, timely structural and landscape maintenance, and judiciously used chemical control products (Ebeling 1960).

In this paper we report the occurrence of a high-profile, pruritic papular rash outbreak at a suburban elementary school (Villa Park Elementary School, VPES) in the city of Villa Park, Orange County, CA, that garnered region-wide concern and media attention and resulted in an investigation by the Orange County Mosquito and Vector Control District (OCMVCD). Through inspections and

surveillance, OCMVCD was able to identify the cause of the mystery bite outbreak, and provided stakeholders with the appropriate education and resources to remediate the situation and prevent further occurrences on the campus. This paper highlights the outbreak timeline, the factors that contributed to the large-scale outbreak, and recommendations given to eliminate the public health threat.

MATERIALS AND METHODS

Timeline of Bites

On April 22, 2018, a fifth grade VPES teacher (Teacher 1) first noticed unresolved bites on her body while at home over a weekend and believed the bites were occurring while she slept at home. After avoiding sleeping in her bedroom for a week and unsuccessfully identifying a biting arthropod in her home, Teacher 1 hired a pest control operator (PCO) to conduct surveillance in her residence; however, no suspect biting arthropods were found. By May 2, Teacher 1 had counted nearly 20 bites on her body. The following day, a PCO company hired by VPES initiated lethal rodent trapping using snap traps in response to complaints from teachers of noises in the wall around the classrooms of the "50s" building (Rooms 51-53; Figure 1). On May 8, a parent reported that their child was bitten by an unknown source while at school. By May 16, a second fifth grade teacher (Teacher 2) and over twenty of her students reported bites to the school nurse. Both Teachers 1 and 2 and the students experiencing bites were stationed in classrooms 51 and 53, respectively. In contrast, another fifth grade teacher (Teacher 3) and her students, occupying Room 52 between the two classrooms with complaints, were not experiencing bites (Figure 1).

On Friday, May 19, after students had left campus for the weekend break, the school's contracted PCO made a pesticide application with Conquer (3.48% esfenvalerate) and Tekko™ Pro (pyriproxyfen 1.30% and novaluron 1.30%) as a coarse spray to carpeted floor areas inside all three classrooms of the "50s" building without a confirmed identification of a target pest; nevertheless, the school's pesticide application log listed fleas as the target pest.

Following pesticide treatment, students and teachers continued experiencing bites, with no causative organism having been discovered. Teacher 2 and her students moved out of the room on May 25, while Teacher 1 and her students remained in their room, and continued to experience bites. Teacher 3 and two other anonymous sources called OCMVCD between May 22 and 26 and reported the problem and asked for advice on how to proceed with identifying the cause of the "mystery" bites. Surveillance advice for biting arthropods was given; however, a request to assist on-site was not made at that time and the severity of the situation was not apparent. On Saturday, May 27, a second pesticide application was made to Rooms 51 and 53. Because the occupants of Room 52 (Teacher 3's room) were not experiencing bites, a second treatment was not performed there.

On Sunday, May 28, Teacher 1 sought medical treatment at an urgent care facility for extensive bites over her body. On May 30, Rooms 51 and 53 were evacuated until further notice. Around this time, a routine inspection by the local health care agency revealed a rodent infestation in the food storage and distribution area of the school. On May 31, Teacher 3 contacted OCMVCD again, and this time requested an investigation into the cause of the bites.

Surveillance

On May 31, 39 days after the first documented bites on Teacher 1, two vector ecologists and an inspector with the OCMVCD conducted the first of many inspections over a two-month period of the campus to determine the origin and extent of the pest problem. Information gathered from earlier phone conversations with concerned teachers and parents suggested mites as the suspected biting arthropod based on an investigation by OCMVCD at another elementary school in 2017 (Morgan et al. 2017).

Visual inspections of the exterior and interior of the rooms were conducted on all standing structures on the school, with the exception of a condemned historic school building located near the center of the campus (Figure 1). Inspectors were aided by the use of black lights to detect rodent urine within the classroom, flashlights for examining low-lit spaces for rodent rub marks, droppings, gnawing damage, and access points. Hand-held telescoping inspection mirrors were used to examine inconspicuous rodent access points.

Rooms where children or staff spent a significant amount of time during the school day were monitored passively with Trapper® MAX glue traps (Bell Laboratories, Inc., Madison, WI). [The trap consists of a 13 × 20 × 0.08-cm flat section of cardboard coated on one side with a thin layer (ca. 0.04 cm) of adhesive, and is labeled for mice and arthropod collections]. In general, four traps were placed flat, in each corner of a room, on a horizontal surface (e.g., floor, cabinet, counter top) with at least one edge making contact with a wall. Positioning traps in this manner targets arthropods originating either in the ceiling or wall voids, or from beneath the structure. Several traps were taped to the vertical surface of a wall below windows, if the window did not have a suitable ledge to support the board. Previous use of this technique by the authors has proven successful in collecting host-seeking mesostigmatid bird and rat mites (Morgan, unpubl. data). Glue boards were examined onsite with a 20× magnification hand lens or 50× magnification binocular stereoscope. Arthropods not found on glue boards were collected by hand and preserved in 70% ethanol, as were rodent droppings.

All arthropods known to bite humans collected during the investigations were identified to species, when possible. Mites were mounted on glass slides in polyvinyl alcohol media and covered with a glass coverslip. Slides were then incubated at 56°C for 24 hrs to promote clearing of blood and viscera to allow observations of external structures (sclerotized plates and setae) in both the ventral and dorsal aspects. Mites were identified to species using keys in Krantz and Walter (2009) and drawings in Webb and Bennett (2002).

All findings were documented and immediately shared

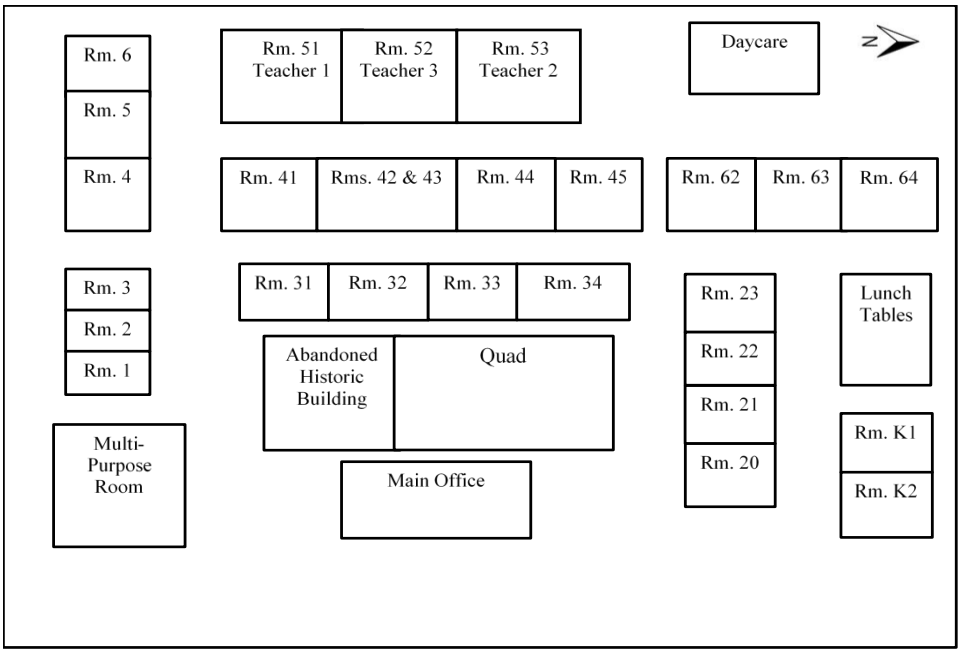

Figure 1. A schematic of the buildings on the school property where biting complaints originated from teachers and students from classrooms in the 50s building.

with school representatives, including the principal, school district maintenance manager, and the school's contracted PCO.

RESULTS

Identification and Control

Careful visual inspections of the room interiors led to the discovery of numerous mites emerging from an electrical panel located approximately 1.5 meters off the ground on the wall in the northeast corner of Room 53 near the main entrance (Teacher 2's room). The presence of mites was confirmed onsite with the aid of a hand-lens. After collection and processing, the mites were identified to species the following morning by OCMVCD as tropical rat mites, *O. bacoti*. No mites were detected in the other rooms during the visual inspections. Glue boards were left in all of the "50s" building rooms and Rooms 42 and 43 of the "40s" building located approximately 5 m from where the mites were detected.

The "40s" and "50s" buildings were modular structures with a raised floor and plywood skirted subarea. These modular classrooms were connected on their short sides to form a single linear structure and were held-up by piers approximately 0.5 meters above the asphalt foundation. The gap around the perimeter, between the asphalt and the bottom of the structure, was skirted with plywood, which functions as an aesthetic feature and to exclude debris and animals. Other older buildings on campus were built on cement slab foundations and did not have a crawl space subarea.

During the first inspection, the contracted PCO reported to OCMVCD staff that more than 15 roof rats had been collected in snap traps around the buildings of concern since the beginning of May. (Norway rats are a rare pest in suburban Orange County and were not involved). Large entrances in the skirting around the base of the buildings with raised foundations were identified and had signs of animal activity in the form of rub-marks. Rabbit feces were also detected in large quantities underneath the "40s" building.

Although reports of rat sounds were noted in the "50s" room ceiling space, no signs, such as urine or feces, were detected by OCMVCD. The ceiling tiles were secured in place with an adhesive and were not removed during the inspection, and no destructive inspection measures were taken by OCMVCD during the investigation. OCMVCD recommended that the PCO or VPES maintenance staff investigate the ceiling and wall voids to further determine the extent of the rodent infestation and to eliminate any nesting materials and feces. A later examination of the ceiling space above the tiles revealed rat nesting materials and droppings.

On June 1, following OCMVCD recommendations, the school's PCO removed sections of the skirting around the "40s" and "50s" building and made an ultra-low volume application with an acaricide (ULD® BP-300, 3.0% pyrethrins and 15.0% PBO) to the subarea and within each classroom.

On June 2, OCMVCD staff returned to the school to meet with concerned parents and conduct further surveillance to determine the extent of the rat and mite infestation and inspect and deploy glue boards in every room on the school campus. Evidence of roof rat activity (droppings or rub-marks) was extensive and was found on the interior or exterior of 63% (19/30) of the rooms on campus. All except three of the rooms with rodent activity were classrooms, and two of the three rooms that were not classrooms were frequently occupied by students (Figure 2).

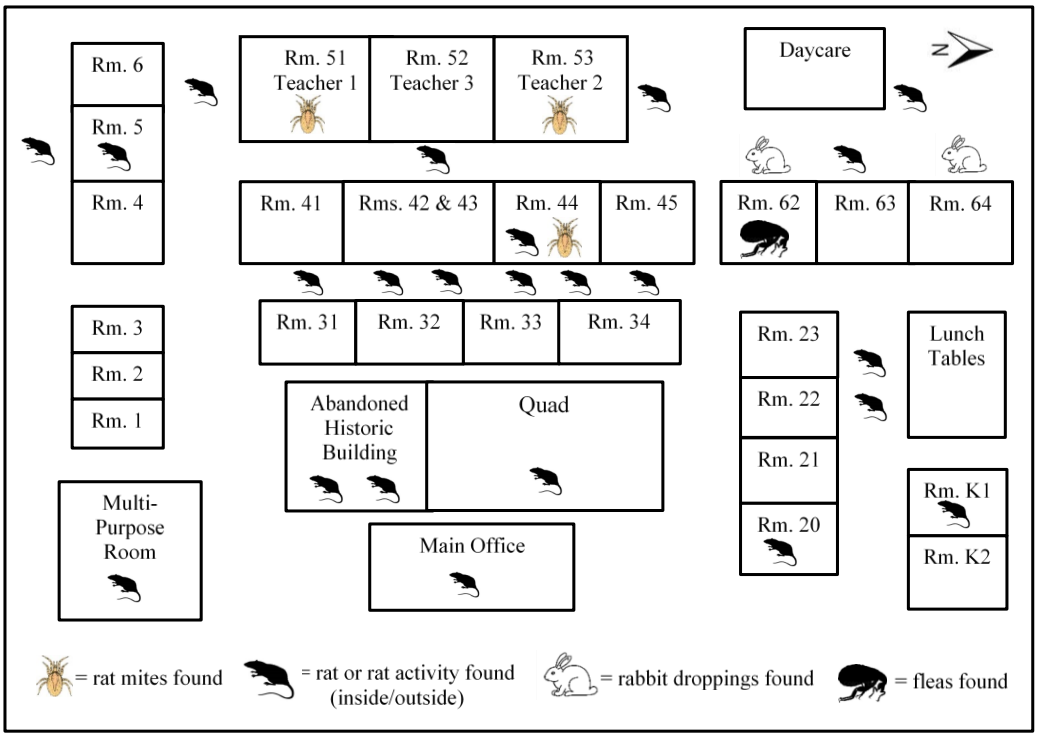

Figure 2. Schematic of the mammal and arthropod detections on VPES property.

OCMVCD met with and answered questions from concerned parents, and assisted in developing a plan to address the displacement of students from three fifth grade classrooms. OCMVCD favored the plan to temporarily bus students to an off-site location until a space on campus could be determined to be mite and rat free. The only room available to accommodate all of the displaced children on campus was a multi-purpose room. The room had signs of an active rat infestation, which were addressed, and the room was subsequently cleared for student use after no mites were detected on glue boards. Fifth grade students completed the school year inside the multi-purpose room while the "40s" and "50s" buildings remained closed.

After 48 hours, OCMVCD staff returned to the campus on June 5 to retrieve and examine adhesive traps. Tropical rat mites were detected in one more "50s" building room (Rm. 51) and inside one "40s" building room (Rm. 44). The detection of mites in new areas, especially in another building, warranted additional surveillance of the entire school. Between June 6 and June 9, over 130 adhesive boards were placed inside rooms across the campus and inspected for presence of mites. No additional mites were detected.

On August 9, after the school implemented the recommended school-wide rat exclusion measures and conducted further targeted treatments, the school was surveyed for mites again by deploying 130 adhesive boards throughout the campus rooms. The adhesive boards were left in place for seven days. No mites were detected.

On August 16, when the glue boards were retrieved, a staff member from OCMVCD detected a flea on his face, prompting a flea survey near the "60s" building (Rooms 62-64, Figure 2) where he had just been on the ground inspecting subarea vents. Glue boards were taped to the asphalt adjacent to the vents and left in place for 24 hours. Cat fleas (*Ctenocephalides felis*) and sticktight fleas (*Echidnophaga gallinacea*) were collected.

DISCUSSION

Immediately after the mites were confirmed to be tropical rat mites, the focus of chemical control shifted from the interior of the classrooms toward the probable nesting areas of the roof rats. OCMVCD concluded that recent rat trapping had caused or exacerbated the mite issue, causing mites to vacate unoccupied rat nests in search of a blood meal. Since many buildings were infested with roof rats, the threat of biting mites to all students and staff was expected to increase if campus-wide rat control continued without removal of vacant nests and simultaneous control of mites. If mites had been detected in more buildings, the resulting control effort may have required the closure of the school due to the displacement of a large number of students. VPES decided in the interest of preventing further dispersal of mites, and to minimize student displacement, that major rodent control work on campus would be suspended until the last day of school, which was approximately two weeks after the identification of the mite problem.

A significant source for roof rat harborage was the condemned historic school building (Figure 2). This structure had been unoccupied for decades and had been recognized as a rodent harborage site. Without completing school-wide rat exclusion measures, the demolition of the building would have dispersed rats into other areas of the school, further complicating the situation. Instead, demolition was delayed until summer recess.

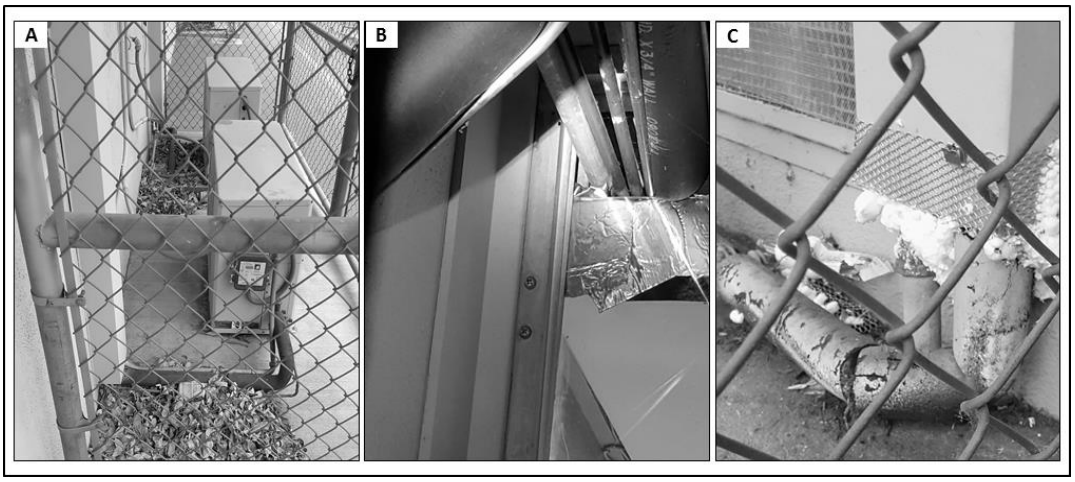

Figure 3. Typical air conditioning unit configuration on the school campus including: A) Condensing unit located on the exterior of the classroom, with electrical and refrigerant lines running from the unit, through the wall; B) into a closet of the classroom. C) Hardware cloth used with expanding foam to fill gaps to prevent rodent and arthropod access to the interior of the classroom.

Student Displacement and Rodent Access

During the rat mite outbreak, students and staff were relocated from their rooms if mites were found or if there was evidence of recent rat activity inside the classroom. Openings into classrooms on slab foundations for rat access were all associated with rooms retrofitted years earlier with air-conditioning units powered by electrical lines and supplied with refrigerant by tubing running from the building exterior to the inside of the classrooms. These retrofitted air conditioning units were installed without care for rodent exclusion, with gaps around the supply lines providing direct and unabated pathways for rats to access the interior of the room (Figure 3A). Nearly all modular classrooms with raised foundations had access points along the plywood skirting around the building, or gaps between stair or access ramps and the subarea of the building (Figure 4). These openings allowed rat and other animal access to the protected space and crevices beneath each classroom. The multi-purpose room had rat access points located on the roof through disconnected and abandoned plumbing, in addition to gaps underneath doors, where a portion of the wooden threshold, on a stage backdoor, had been chewed away.

Exclusion of roof rats was achieved in many rooms by permanently sealing access holes in drywall and large gaps around wall-penetrating plumbing and electrical conduit with joint compound, covering with steel hardware cloth (6.4-mm-wide mesh), and expanding foam (Figure 3B). In the multi-purpose room, the bottom of the gnawed wooden stage door and other doors on the building were modified with a protective steel plate (kick plate) that reduced the opening beneath the door to exclude rats.

Factors Leading to the Outbreak

The VPES handled pest issues reactively rather than proactively. Pest issues were handled through a work-order system, where orders were typically generated through a pest complaint by a school staff member, often a teacher. Issued work orders would then be outsourced to a contracted PCO to correct only the immediate problem. Routine inspections of the entire school and prompt corrective actions of pest problems were never addressed in such a system. In the absence of an effective IPM program, conditions amenable to wide-spread rat infestation compounded over time. Addressing this rat and mite outbreak proved to be a time-consuming and costly effort for multiple agencies and caused distrust and consternation between staff/parents and school administrators.

Control Measures

The difficult decision to yield on rat control while school was in session was necessary to prevent the closure of the entire school. A school-wide rat control effort during the last two weeks threatened to release mites and other ectoparasites from many buildings on the campus that harbored roof rats and other mammals. To reduce human-mite contact, students and teachers were restricted from entering rooms with known mite activity.

Prior to OCMVCD's initial response to the outbreak, two pesticide applications were made hastily to the classrooms to appease the escalating concern of three fifth grade teachers with no forethought as to the consequences. Without a target pest accurately identified, inappropriate pesticide applications were made. This resulted in two teachers and at least three students filing complaints of headaches and nausea after experiencing an unusual odor in the classrooms following the application. An investigation conducted by the Orange County Agricultural Commissioner and the California Department of Pesticide Regulation (CDPR) in response to these complaints found that the treated rooms may have not been ventilated properly before reentry. The PCO was

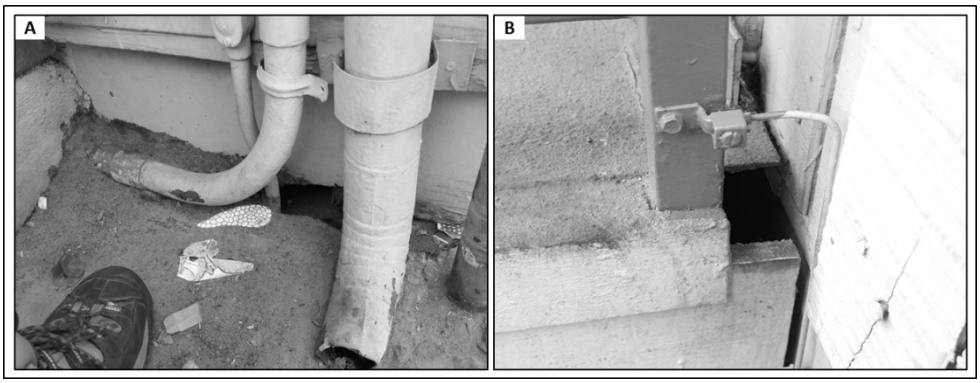

Figure 4. Exterior of the raised foundation buildings on the school campus were in disrepair: A) Plywood skirting with multiple large openings formed in deteriorating plywood; B) Staircases and ramps that led into some classrooms were originally designed with large gaps, creating rodent refugia.

cited by the Orange County Agricultural Commissioner for applying a pesticide not labeled for mites.

After the identification of tropical rat mites, OCMVCD recommended ultra-low volume aerosolized (space sprays) acaricide applications to maximize the penetration of material within the room and throughout the subarea of the structure. The detection of mites within the electrical panel suggested that the mites were traveling through the building on or within the electrical conduit, allowing them access to the service panels. Since these rooms were no longer occupied by students and teachers, subsequent aerosol space spray treatments were made once the subarea and ceiling voids were thoroughly examined and rat nests were removed, after which no mites were detected.

Actions and Recommendations

OCMVCD provided recommendations for control and prevention of mite and rat infestations to school administrators immediately after the first visit. These instructions included removal of the skirting around the modular buildings to clear the subareas of debris and nesting materials, and treating the subarea and inside of the buildings with an appropriate pesticide. Intensive rat trapping was recommended only after major repair and exclusion measures had been made to buildings with poorly sealed subareas. Once the school was closed for the summer, VPES staff was advised to replace all dilapidated plywood skirting and seal all access points leading to wall/ceiling voids or interior of the building with 6.35-mm (1/4-inch) steel hardware cloth. Although a rapid reduction in the roof rat population was desired while the school was still open, rodenticide baits were not recommended during the initial control phase to avoid odors from rat die-off in buildings and subsequent displacement of their mites in search for hosts. After the building had been sealed and all exclusion methods were correctly in place, a rodenticide program was recommended for long-lasting control that required less maintenance than the schools' use of snap-traps and other lethal, non-continuous rat control methods.

OCMVCD encouraged maintenance staff to routinely make inspections of all structures on campus, paying special attention to the foundations of the modular buildings, including vents in the skirting and air-conditioning systems. If proper exclusion measures were to be maintained, rat nesting and therefore, mite-human contact within structures would be reduced significantly and would not be expected to occur in the future. OCMVCD also recommended trimming vegetation next to buildings, keeping trash cans and dumpsters closed when not in use to reduce rat food sources, and encouraged neighboring homeowners to keep fruit from accumulating in yards.

The situation presented in this paper was unusual, in that many people were afflicted with unknown bites for an extended period of time, without anyone noticing the mite infestation. Although tropical rat mites are small in size (0.75 to 1.4 mm), they are visible with an unaided eye, and many are usually congregated in one location during an outbreak. The focus on fleas as the possible culprit, which more people are visually familiar with than mites, may have led to those looking for the cause to have biased their search toward the carpeted floor, where mites would be easily concealed. Unfamiliar to students and staff, the tropical rat mites were found entering the building at eye level or higher.

This situation highlights how improper control measures for one pest, in this case roof rats, can have unintended consequences greater than the initial pest issue. Prior to the mite outbreak and during the subsequent effort to eliminate it, rat and mammal control on the school grounds resulted in the release of at least three species of ectoparasites (tropical rat mites, cat fleas, and sticktight fleas) in search of suitable hosts, resulting in the anguish of many children, teachers, parents, and school officials. The plan of one day resurrecting the derelict, historic building on the campus likely set the stage for a concentrated rodent population in the center of an elementary school, as it stood waiting for a restoration plan to be adopted. The plan never transpired and after students had gone on summer break, the historic building was demolished, ridding the campus of rodent harborage. This paper may serve as a guide to direct future bite investigations, as they may increase in number with aging infrastructure where school funding is scarce and pest management plans are lacking, or poorly implemented.

Preventing Rat Problems in Schools

As legislation in California continues to restrict the use of rodenticides for the control of commensal rodents, the vacuum, if left unfilled by effective quick acting alternatives, poses a threat to public health. Even with the

availability of current rodenticide products, large-scale problems associated with commensal rodents are difficult to control quickly when rodenticide usage is limited. The key to commensal rodent control is quick action in response to reports of rat activity, as should be outlined in an IPM strategy. This paper presented a chronological record of a "mystery" bite outbreak in an elementary school in Orange County, CA, and aimed to provide an example for conducting large-scale "mystery" bite outbreak investigations using an effective approach in identifying and eliminating a logistically-challenging problem. The frequency of these outbreaks are likely to increase if municipalities begin to abandon currently available pesticides, adopt unproven pest control products, or completely remove them from their arsenal, especially in situations involving aging facilities that are maintained in the absence of a well-designed integrated pest management program.

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