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INVESTIGATIONS AND MANAGEMENT OF EPIZOOTIC PLAGUE AT ICE HOUSE RESERVOIR, ELDORADO NATIONAL FOREST, CALIFORNIA, 1994 AND 1995

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ABSTRACT: The occurrence of plague (*Yersinia pestic*) at Ice House Reservoir in 1994 and 1995 was characteristic of widespread epizootics in high use recreational areas of California. Staff of the Vector-Borne Disease Section investigated these epizootics and found dense populations of plague susceptible California ground squirrels (*Spermophilus beecheyi*) with high numbers of fleas, primarily *Diamanus montanus*, the most important plague vector. This combination indicated a high risk of plague exposure to campground users. A non-fatal human case of plague, contracted at Mountain Camp II, was reported after the initial epizootic investigation. The patient's exposure occurred prior to the reporting of the epizootic die-off among the California ground squirrels. The plague investigation included direct observations, animal trapping, and laboratory testing of rodent carcasses, sera, and fleas. Plague management and prevention included flea control with 2% Diazinon dust and rodent population reduction using 1% zinc phosphide treated grain. Evaluation of the 1994 applications indicated a successful reduction of rodents and fleas. However, the need for an ongoing management program was emphasized in 1995 when the plague epizootic continued. Intrusion of plague infected rodents and their fleas necessitated a 1995 treatment in the four campgrounds involved.

KEY WORDS: disease management, plague, epizootic, control, flea, California ground squirrel, diazinon, zinc phosphide, California, USA

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INTRODUCTION

In California, involvement of native wild rodents in the ecology of plague began shortly after the 1900 introduction of the plague bacterium (*Yersinia pestis*) into San Francisco. The first reported incidence of infections in California ground squirrels (*Spermophilus beecheyi*) occurred in 1903 (Lien-Teh 1926). In 1908 the bacterium was isolated from this squirrel (McCoy 1908). Ground squirrel epizootics occurred throughout the San Francisco Bay area during the early part of the 20th century, even though disease eradication by shooting ground squirrels had been attempted (Murray 1964). Since the outbreak in Los Angeles in 1924, involving both commensal rats and California ground squirrels, human cases have been associated with sylvatic rodents only. The California ground squirrel continues to be the most important rodent in plague epidemiology in California (Nelson 1980). The Vector-Borne Disease Section of the California Department of Health Services (CDHS) is charged under the California Health and Safety Code to provide surveillance, investigations, and control of plague in the state. Plague activity in California during the 1990s has recently been described by Smith (1994, 1996).

Investigations of California ground squirrel and chipmunk (*Tamias quadrimaculatus*) related plague epizootics at four campgrounds at Ice House Reservoir during the 1994 and 1995 plague seasons are described and documented in this paper. It is often difficult to document the full extent of plague epizootics due to insufficient resources. Once direct evidence of plague at a site is established from a carcass, flea pool, or series of antibody titers, sampling is normally reduced. In an effort to obtain more data, a broad range of human and epizootic plague management and prevention activities were carried out by the Vector-Borne Disease Section and other cooperating agencies at Ice House Reservoir. The epizootics were well documented by extensive observations of rodent activity or abandonment, and by laboratory confirmatory testing of samples from trapped rodents and their ectoparasites (fleas).

For consistency and comparative value, only laboratory test results of flea pools and sera collected from ground squirrels pretreatment (before an insecticide application) are reported. Not included in the data are: three plague positive squirrel serologies from the Ice House Campground, taken during the only post treatment bleeding in both years; two positive chipmunk serologies from 1995; and three negative chipmunk flea pools from 1995. The exact role of chipmunks in the epizootics could not be determined because of the few samples collected.

SITE DESCRIPTION

Ice House Reservoir is approximately three miles long and one mile wide. It is located at an elevation of approximately 5,500 feet in El Dorado County, California. The area is administered under the jurisdiction of the Pacific Ranger District in the Eldorado National Forest, United States Department of Agriculture, Forest Service (USFS). The landscape is typical habitat at this elevation on the west slope of the Sierra Nevada Mountains, showing evidence of glaciation and having abundant granite outcrops and boulders. The area is montane forest; predominately ponderosa pine (*Pinus ponderosa*), sugar pine (*P. lambertiana*), white fir (*Abies concolor*), with ground cover of snow brush (*Ceanothus cordulatus*), and greenleaf manzanita (*Arctostaphylos patula*).

The investigation involved four primary sites at the reservoir:

1. Mountain Camp II

An exclusive 26-acre private camp located on USFS land about midpoint on the north side of the reservoir. The camp is situated on a hillside, with conifers providing heavy shade. Approximately 110 campers and 45 staff utilize three main buildings for cooking, eating, medical supervision and showering. Sleeping facilities at the site are primitive. Staff and campers used tents on the ground or on elevated platforms for housing.

2. Strawberry Point Campground

A 10-unit campground owned and operated by the USFS, adjacent to the reservoir on 32 acres. This widely spaced campground is adjacent to site 1. The campsites are located in open forest and are surrounded by dense brush and large boulders.

3. Northwind Campground

A 10-unit campground owned and operated by the USFS covering approximately 37 acres. The campground, located on a rocky ridge, is about 0.5 mile west of sites 1 and 2. The widely spaced campsites overlook the reservoir and are surrounded by dense brush.

4. Ice House Campground

An 83-unit campground of about 50 acres owned by USFS and operated by a concessionaire. The campground is located on the western end of the reservoir approximately 1.5 miles west of sites 1 and 2, and includes picnic and boat launching facilities. Ice House Campground has two major loops about 0.5 mile apart; one is located on an open forest ridge, and the second is located in dense forest near the reservoir.

INVESTIGATION AND CONTROL, 1994

The first indication of an epizootic in progress began with observations of two dead chipmunks at Mountain Camp II in July. One long-eared chipmunk carcass was collected by camp staff and submitted for plague testing to the CDHS, Microbial Diseases Laboratory (MDL). The animal was bacteriologically plague positive, prompting an on-site evaluation by the Vector-Borne Disease Section and the El Dorado County Environmental Health Department. The following observations were made at Mountain Camp II, Strawberry Point Campground, and Northwind Campground:

1. An extremely high concentration of California ground squirrels populated the sites.
2. Campers were living and sleeping in close proximity to rodents and rodent burrows.
3. Rodents had direct access to camper living areas.
4. There appeared to be an absence of long-eared chipmunks in areas of dense cover.

Overall, there was direct evidence of plague in the area, with a high risk of human exposure to vector fleas. The California ground squirrel flea (*Diamanus montanus*) is the primary plague vector in California (Barnes 1982). Recommendations were made to close Mountain Camp II at the end of the camping session (two days away) and to immediately close the two nearby USFS campgrounds (Strawberry Point and Northwind). Staff and campers at Mountain Camp II were provided informational handouts about plague. Parents, when picking up their children, were instructed to contact a physician if plague compatible symptoms appeared. Recommendations were made to control fleas before reopening the camp and campgrounds. Management of Mountain Camp II and the USFS accepted the recommendations and voluntarily closed the areas to public use.

Animals were trapped, anesthetized, combed for fleas and bled to establish the flea index and incidence of animal plague at each site. Trap success at Mountain Camp II was 54% in one hour of mid-morning trapping. Trap shyness and aversion were not observed at this or the other three campgrounds sampled. Flea indices on California ground squirrels preapplication and post insecticide application were 10.7 and 0.5, respectively (Table 1). During the 1994 epizootic, 14 of 56 (25.0%) California ground squirrels sampled showed antibody titers to plague, range 1:32 to 1:8192. Strawberry Point had the highest percentage of positive squirrels, 62.5% (Table 2). Additional evidence obtained at the sites included isolations of the plague bacteria from one of two flea pools from Mountain Camp II, and from one of two flea pools tested from Strawberry Point. These plague positive findings confirmed an extensive epizootic.

Table 1. Pre- and post-insecticide application flea indicies[1] at four sites in 1994 and 1995, Ice House Reservoir, Eldorado National Forest, California.

	1994		1995	
Campground	Pretreatment	Post Treatment	Pretreatment	Post Treatment
Mountain Camp II	10.3	0.6	--	--
Strawberry Point	9.0	0.1	7.5	0.4
Northwind	12.7	0.7	7.7	0.0
Ice House	11.0	0.3	2.2	0.1
Overall[2]	10.7	0.5	5.2	0.2

[1] Average number of fleas per animal.
[2] Total number of animals/total number of fleas.

Table 2. Number of serological plague positive California ground squirrels and the number tested during the 1994 and 1995 plague epizootic, Ice House Reservoir, Eldorado National Forest, California.

	1994		1995	
Campground	Positive/Tested	Percent	Positive/Tested	Percent
Mountain Camp	5/21	23.8	1/6	16.7
Strawberry Point	5/8	62.5	5/6	83.3
Northwind	2/12	16.7	1/11	9.1
Ice House	2/15	13.3	4/14	28.6
Overall	14/56	25.0	11/37	29.7

Cooperators, under supervision, began flea control immediately after the camping areas were vacated. Flea reduction was accomplished by hand and bait-dust station application of 2% Diazinon dust, Gold Crest 2D, EPA Reg. No. 1037-43-432 under SLN Reg. No. CA-800157. Diazinon 2D is the only product registered for flea control in California campgrounds and is to be used only under supervision of the California Department of Health Services. The insecticide was applied one time to burrows using B&G 1152-A DUST-R hand operated plunger dust dispensers. Approximately three ounces of the product was applied to each burrow located within 30 yards of the targeted campground areas. One bait-dust station was placed at each campsite and, if needed, between campsites to cover the target area. Bait was a four ounce solid bait block made of oats lightly coated with peanut butter and impregnated with wax. The bait block was wired into the center of each station. Approximately six ounces of the insecticide were spooned into each end of the 4" x 18" PVC pipe bait-dust station. Bait stations were checked for five to seven consecutive days and dust or bait was replenished as necessary. Eight hundred seventy-five pounds of insecticide (Table 3) were applied in all four campgrounds to achieve a 96% reduction in the overall flea index.

Table 3. Pounds of 2% Diazinon dust applied by hand duster and bait stations at four sites during the 1994 and 1995 epizootics, Ice House Reservoir, Eldorado National Forest, California.

Campground	1994	1995
Mountain Camp II	275	not treated[1]
Strawberry Point	70	25
Northwind	130	45
Ice House	400	140
Overall	875	210

[1]Mountain Camp II closed for the season, to be treated before opening.

After successful flea control, the camping areas were allowed to reopen. During the application, six California ground squirrel carcasses were found, none fresh. Although a positive carcass is an absolute indicator of bacterial activity, only one California ground squirrel was suitable for testing and it was plague negative. The animal was also reported as a possible road kill. A total of eight carcasses were collected in 1994.

One day after the post-treatment evaluation at Mountain Camp II, El Dorado County Environmental Health notified the Vector-Borne Disease Section that a 10 year old male resident of Menlo Park, San Mateo County, was a suspect human plague case. Approximately one week after returning home from a week stay at Mountain Camp II (June 19-25), the boy developed headache and malaise, followed by temperatures of 103 to 104°F., and generalized adenopathy with very tender right inguinal swelling (0.8" node). The pain was such that the patient was unwilling to move that leg. At his first emergency room visit (July 13), he was started on Keflex and switched to cefuroxime when he did not improve. The boy improved but relapsed when treatment was discontinued. On July 25, the boy was started on tetracycline after a history of camping was given and plague was considered. He responded well to the tetracycline and fully recovered. El Dorado County Environmental Health obtained a list of all previous campers and contacted their families to identify other possible illnesses and to provide information on plague. Children and their families were often difficult to contact, many having traveled to Europe and various areas in the United States. Several children were identified with fevers consistent with viral infections, but none had symptoms consistent with plague. By this time, epizootic plague had been identified and actions had been taken to reduce risks of plague transmission (or, as it turned out, to reduce risks of further transmission). Patient serum was submitted to CDHS and forwarded to the Center for Disease Control and Prevention (CDC), Fort Collins, Colorado, where a plague titer of 1:512 was reported (California Morbidity, November 1995). San Mateo County Health, El Dorado County Environmental Health, and CDHS completed a CDC case report follow-up.

After the report from CDC, the investigation expanded to include Ice House Campground at the west end of the reservoir and additional campgrounds in the Crystal Basin Recreation Area. Ice House Campground was trapped and animals sampled to establish flea indices and test for evidence of plague. Trap success at this campground was 75% for 20 traps in a one hour period. Thirteen percent of the animals tested were plague positive (Table 2). Campers were notified, the campground closed, and flea control was initiated, as previously described. Campgrounds outside of Ice House Reservoir but within Crystal Basin (20 mile radius) were visually inspected for epizootic plague activity. Campground hosts were alerted to the importance of plague in recreational areas, asked to display plague warning posters, and to report dead rodents. Indications of plague were not found in the other campgrounds.

Rodent control, coupled with flea control, can be used in a plague management program to reduce the number of disease-bearing hosts, as well as providing some relief from damage caused by rodent burrowing and gnawing. Evidence of rodent damage at Ice House Reservoir included structural damage to roads and buildings, and electrical damage to vehicles. Over $1,000 was paid for electrical repairs to CDHS vehicles. The overall costs or revenue loss attributed to the rodents and the plague epizootic was not assessed. The USFS agreed that it was necessary to reduce ground squirrel populations and provide an ongoing management program. All cooperators agreed that an application of zinc phosphide to all four sites was the appropriate control method, even though its effectiveness on ground squirrels had been reported to be mediocre and inconsistent, ranging from poor to fair (Marsh 1994). Based on bait acceptance during flea control and observed feeding habits of the "campground peanut population," bait shyness with zinc phosphide treated grain was not anticipated. Low risk of secondary poisonings is well documented (Matschke 1992; Ramey 1994). Use of zinc phosphide treated grain appeared ideal under the circumstances observed during the investigations. The El Dorado County Department of Agriculture formulated and provided the 1% zinc phosphide treated grain, Calif. Reg. No. 10965-50014-ZA and EPA SLN No. CA 890026. They also provided safety and application training.

Seven hundred pounds of prebait were applied to evaluate bait acceptance and consumption. This amount was determined to be excessive. Two days later, 270 pounds of zinc bait were selectively scattered near rodent burrows (Table 4). Twenty-four hours after the application, eight observers walked the campgrounds for a five-hour period to evaluate bait acceptance, observe squirrel mortality, collect any carcasses, and check for non-target mortality. Bait acceptance was excellent, and only two live squirrels were observed—one in Ice House campground and one in Northwind campground. Pretreatment road counts of ground squirrels averaged 32 sightings in a 10 minute period in a portion of Ice House campground (campsites 17-27), while no squirrels were spotted post treatment. Three California ground squirrel carcasses were collected on the surface during the evaluation. One deer mouse (*Peromyscus maniculatus*) carcass, a potential carrier of plague and hantavirus, was also found. No other mortality was observed. Following the post treatment observations, a work crew closed all rodent burrows in the treatment area with shovels to contain any remaining fleas and allow for monitoring reuse of burrows. One week after the application, two observers spotted two ground squirrels in Ice House Campground, and one in Northwind Campground, over a two hour period.

Table 4. Pounds of 1% zinc phosphide selectively scattered near burrows durng the 1994 and 1995 epizootics, Ice House Reservoir, Eldorado National Forest, California.

Campground	1994	1995
Mountain Camp II	30	25
Strawberry Point	15	50
Northwind	30	75
Ice House	195	250
Overall	270	400

INVESTIGATION AND CONTROL, 1995

Plague surveillance in the same four sites at Ice House Reservoir during July 1995 detected 30% serological positive California ground squirrels (Table 2). Additionally, two of nine chipmunks (23%) trapped from Ice House Campground were also seropositive. Only one other chipmunk was collected during the 1994 and 1995 investigations, and was seronegative. The wide range of antibody titers (1:32 to 1:2048) among ground squirrels indicated a continuation of the epizootic. During this surveillance, 37 California ground squirrels were captured per two hours of trapping and the overall flea index on squirrels averaged 5.2 fleas per animal (Table 1). The sites were again treated with Diazinon 2D, as previously described, to reduce the risk of plague transmission by fleas. Two hundred ten pounds of insecticide dust (Table 3) were used in the campgrounds for burrow dusting and in bait stations, 25% of that used in 1994. The insecticide application reduced the overall ground squirrel flea index by 96%. Flea control operations were not undertaken at Mountain Camp II at this time. The camp remained open for three days before closing for the season. Management was notified that the camp would remain closed until flea control operations were completed. The management of Mountain Camp II agreed to additional precautionary measures: 1) to notify current and past campers of plague conditions; 2) to distribute literature to all staff, campers and their parents concerning plague symptoms and the need to seek prompt medical attention should symptoms appear; 3) to post the camp with plague warning posters; 4) to provide DHS with addresses and phone numbers of all campers; and 5) to provide assistance in future plague control activities. In the fall, all three USFS campgrounds were temporarily closed and all four camping areas were treated with zinc phosphide grain. The amount used was about 1.5 times that used in 1994 (Table 4). In order to reach ground squirrels in the fringe habitat, the rodenticide target area

was expanded to include squirrel activity sites over 100 yards from campsites. Seventy traps collected 51 animals one day before the zinc phosphide application, and 70 traps at the same locations collected five animals 48 hours after the application (Table 5). Post treatment trapping success indicated a 90% reduction of the ground squirrel.

Table 5. Numbers of trap/captures of California ground squirrels before and after an application of zinc phosphide treated grain at Ice House Campground in 1995, Eldorado National Forest, California.

	Before		After	
Campground	No. Captures/Trap	Percent	No. Captures/Trap	Percent
Strawberry Point	12/15	80	0/15	0
Northwind	11/15	73	2/15	13
Ice House	28/40	70	3/40	8
Overall	51/70	73	5/70	7

DISCUSSION

Comparing epizootic activity between 1994 and 1995 (Table 6), surveillance data suggests that the epizootic intensity was less in 1995. The primary indicator of the 1994 control success was that no additional human cases occurred in an amplified epizootic, even thought the areas were reopened about a week after initial closures. The Geometric Mean Positive Titer (GMPT), an indicator of titer level, declined from 362 to 165 between 1994 and 1995. A 2.2 fold decline in GMPT is indicative of a decline in plague activity (Harrison 1995). Four additional indicators of the decline of plague activity observed between 1994 and 1995 were: 1) lowered animal populations as observed by trap success (56/hour reduced to 19/hour); 2) lower flea index (10.5 reduced to 5.2); 3) negative flea pools in 1995; and 4) the absence of carcasses in 1995. Although the 1995 epizootic showed decreased intensity, it was clear that the 1994 efforts did not prevent the occurrence of plague in 1995. The authors speculate that a population void developed in the preferred campground habitat due to the zinc phosphide application. Squirrels from the fringe habitat reoccupied the camping areas, introducing the epizootic back into the campgrounds. Staff estimated that about one-half of the squirrel burrows in the Ice House Campground had been reoccupied in 1995.

Plague is spread within a rodent population by an interchange of fleas within nesting or burrow sites, by direct contact between rodents, and through cannibalism following mortality. When a rodent dies within a burrow, a new inhabitant is likely to occupy the burrow. Non-resident rodents seeking a new home often enter any available burrow system. Surviving infected fleas residing in burrow systems may infect new hosts entering those systems (flea-host transmission). Invading hosts already infected with plague may enter systems and be fed upon by non-infected fleas, which in turn become infected (host-flea transmission). Both factors allow for a continuation of a plague epizootic in a rodent population.

A high density of susceptible rodent hosts amplifies the potential for increased plague epizootic activity. Control of plague in dense populations of amplifying hosts, such as California ground squirrels, is difficult. Initial control efforts may reduce the number of fleas and lessen the risk of transmission to humans in the immediate area, however, the epizootic may continue among rodents, especially outside of the control area. As disease activity continues, higher numbers of fleas become infective and additional control efforts may become necessary. The continuation of an epizootic and the problems of plague control in a dense ground squirrel population are well documented at Ice House Reservoir.

CONCLUSION

Human cases of plague will continue to occur in association with epizootics among susceptible rodent species in high use recreational areas in California. Because of the sporadic occurrence of cases and the rarity of physicians having to diagnose or treat patients, cases may not be initially recognized and treatment may often be delayed or inappropriate. Removing the campers from the vicinity of a known epizootic eliminates the immediate threat or human disease. Therefore, the closures of Mountain Camp II, Strawberry Point, Northwind, and Ice House Campgrounds were prudent and in the best interest of campers and workers at these sites. However, there is economic incentive to reopen the area as soon as possible, requiring prompt risk reduction through vector suppression. Expanding investigations into adjacent areas, as was done at Ice House, is necessary to define the areas of concern and protect the public health.

Bait and trap shyness of California ground squirrels, as reported in agricultural environments, is not a problem in campgrounds where squirrels are accustomed to people and a variety of man-made foods. This was clearly shown in animal trapping and in flea and rodent control at Ice House Reservoir. Two percent Diazinon dust applied by hand in burrows and in bait stations for five to seven days was shown to be effective in reducing the fleas on California ground squirrels. Following flea control, rodent management should be considered to maintain animals at levels below thresholds of damage or

Table 6. Indicators of reduced epizootic plague activity between 1994 and 1995, from all areas, Ice House Reservoir, Eldorado National Forest, California.

	Number of Positives			Numbers Found	
Antibody Titer	1994	1995	Additional Indicators	1994	1995
1:32	4	1	Human case	1	0
1:64	2	2			
1:128	1	5	Carcasses found	8	0
1:256	0	1			
1:512	1	0	Carcasses pos/number tested	1/2	0/0
1:1024	0	1			
1:2048	3	1	Flea pools pos/number tested	2/8	0/6
1:4096	1	0			
1:8192	2	0			
GMPT[1]	362	165			

[1]GMPT - Geometric Mean Positive Titer

disease transmission. When label instructions on both prebaiting and application are followed, the use of zinc phosphide treated grain can be an effective rodent management tool. Rodent control with zinc phosphide at Ice House Reservoir demonstrated that the majority of the target animals die underground and non-target mortality may not be a problem.

Overall success of a plague and rodent management program cannot be measured in terms of the success of a single season. One must measure the success and failure of the components of an ongoing program, and monitor the information carefully to eventually obtain the desired program goals.

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