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Background *During 2012, a total of 10 overnight visitors to Yosemite National Park (Yosemite) became infected with a hantavirus (Sin Nombre virus [SNV]); three died. SNV infections have been identified among persons with occupational exposure to deer mice (Peromyscus maniculatus).*

Methods *We assessed SNV infection prevalence, work and living environments, mice exposures, and SNV prevention training, knowledge, and practices among workers of two major employers at Yosemite during September–October, 2012 by voluntary blood testing and a questionnaire.*

Results *One of 526 participants had evidence of previous SNV infection. Participants reported frequently observing rodent infestations at work and home and not always following prescribed safety practices for tasks, including infestation cleanup.*

Conclusion *Although participants had multiple exposures to deer mice, we did not find evidence of widespread SNV infections. Nevertheless, employees working around deer mice should receive appropriate training and consistently follow prevention policies for high-risk activities.* Am. J. Ind. Med. 58:658–667, 2015. © 2015 Wiley Periodicals, Inc.

KEY WORDS: hantavirus; Sin Nombre virus; disease transmission; infectious; occupational health

INTRODUCTION

In the United States, the most common hantavirus infection resulting in hantavirus pulmonary syndrome (HPS) is attributable to Sin Nombre virus (SNV). HPS is characterized by a nonspecific febrile illness, followed by severe, rapid onset of pulmonary edema, and collapse. HPS is rare in the United States, with 585 confirmed cases during 1993–2012; approximately 36% of reported HPS cases in the United States are fatal [MacNeil et al., 2011; Centers for Disease and Prevention, 2012a]. The majority of HPS cases occur in the western United States [Knust and Rollin, 2013]. Deer mice (*Peromyscus maniculatus*) are a reservoir for SNV [Childs et al., 1994], and shed virus in their saliva, feces, and urine. Hantavirus infections result from inhalation of aerosolized excreta associated with sweeping, handling, or

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otherwise disturbing rodent excreta or nests in buildings, handling mice or excreta without gloves, and sleeping on the ground or floor [Armstrong et al., 1995; Zeitz et al., 1995; Centers for Disease Control and Prevention, 2002]. Hantavirus infections have been rarely documented among employees who handle or are exposed to mice [Jay et al., 1996; Fulhorst et al., 2007; Kelt et al., 2007; Torres-Perez et al., 2010].

During the summer of 2012, an outbreak of hantavirus infections occurred among overnight visitors to Yosemite National Park (Yosemite) in California [Nunez et al., 2014]. Ten patients were identified, 9 of whom had stayed in signature tent cabins, a type of guest lodging unique to Yosemite. Eight patients experienced HPS, and 3 died. Antibodies reactive to SNV were detected in 10 of 74 (14%) deer mice trapped near Yosemite signature tent cabins during 2012 [Nunez et al., 2014], and in 50 of 255 (20%) trapped at 15 U.S. Forest Service facilities in California during 2004–2005 [Levine et al., 2008].

Yosemite employees might be exposed to mice at work, and a substantial number of Yosemite employees who reside within Yosemite might also be exposed to mice at home. Concurrent with the investigation of hantavirus infections among Yosemite overnight visitors, the National Park Service (NPS) requested assistance from the Occupational Health Branch of the California Department of Public Health (CDPH) in evaluating hantavirus safety practices and the potential for hantavirus exposures among Yosemite workers. The 2 largest employers at Yosemite are a government agency and private-sector employer, hereafter, referred to as Employers A and B.

The Yosemite hantavirus risk reduction program (dated April 25, 2012, herein referred to as the Directive) is a park policy that contains definitions, responsibilities, and procedures for protecting employees from hantavirus exposure, and covers all Yosemite employees, volunteers, and contractors. Thus, it could serve as the standard by which to evaluate employee knowledge and practices. Consistent with recommendations from the Centers for Disease Control and Prevention [Centers for Disease and Prevention, 2012b], the Directive identifies preventing rodent infestations as the most effective method to prevent employee exposure to hantavirus, and specifies practices for rodent exclusion and reduction of rodent shelter and food sources. The Directive defines cleaning a heavy rodent infestation ("piles of feces or numerous nests or dead rodents") and opening seasonally-closed buildings, which can harbor infestations, as high-risk activities that can aerosolize hantavirus-containing particles. Cleaning a light infestation ("few droppings in one area, a few nests, and one or two dead rodents") is considered lower risk. All employees are required to be able to assess whether an infestation is light or heavy and to be able to clean up a light infestation safely. Employees whose duties include performing high-risk activities are to be provided with in-depth training and additional protections (e.g., inclusion in a comprehensive respiratory protection program).

The Directive assigns responsibility for ensuring implementation of safe cleanup procedures to specified health and safety personnel, as well as managers, supervisors, and work leaders. Building and grounds supervisors are responsible for identifying and assigning employees who will perform heavy rodent infestation cleanup. The Directive requires cleaning of light and heavy infestations by saturating dead mice, nests, droppings, and contaminated surfaces with a bleach solution or chemical disinfectant, waiting 10 min to allow for deactivation of any hantavirus, picking up infestations with paper towels, and bagging all waste.

The Directive also identifies required personal protective equipment (PPE) for cleaning a light or heavy infestation and for opening a seasonally-closed building. Employees cleaning a heavy infestation or opening a seasonally-closed building must use respiratory protection (a half-mask negative-pressure air purifying respirator with P-100 filters, or a powered air purifying respirator [PAPR] with equivalent filters). The Directive requires employees cleaning a heavy infestation to wear rubber, latex, or nitrile gloves, protective coveralls, goggles, and shoe covers. Employees cleaning a light infestation are required to wear gloves; use of goggles or respiratory protection is voluntary.

The purpose of this investigation was to (i) detect previous hantavirus infections among employees, (ii) assess exposure risk factors and mitigation measures, and (iii) recommend additional measures to prevent hantavirus exposures among employees if appropriate.

MATERIALS AND METHODS

Survey Design, Setting, and Participants

The cross-sectional survey consisted of a blood test and a self-administered questionnaire. The questionnaire included questions on work activities, living environment, past exposures to mice, training and knowledge about measures to prevent hantavirus infection, and use of exposure prevention measures. The questionnaire development was guided by a review of the Directive and an onsite investigation that included observations of work locations, conditions, and practices related to rodent control measures and disinfection/cleanup procedures; interviews with employees and managers identified as having employee health and safety responsibilities; and review of written materials related to hantavirus prevention and respiratory protection among employees. We designed questions to compare employee knowledge or use of hantavirus safety practices with the policies outlined in the Directive. Employees were recruited through an e-mail from employers, posted flyers,

supervisors, and word-of-mouth. Participation in the survey was completely voluntary, all participants read and signed a written informed consent form before survey administration, and employees had the option of completing the questionnaire, the blood test, or both. At the time of survey administration, workers were screened for acute disease, and any persons who had influenza-like symptoms were excluded and referred to their primary care providers. HPS initially manifests as a nonspecific febrile illness, and the purpose of our screening was to encourage employees who had influenza-like symptoms to seek medical care. We did not follow up with screened individuals.

Employer A invited 100 employees to participate in a pilot survey, which CDPH administered on September 26, 2012. Pilot survey participants completed the survey and then participated in a semi-structured interview with a CDPH investigator to assess questionnaire comprehension, determine how employees received information about hantavirus, and allow participants to discuss hantavirus safety concerns. Information from the semi-structured interviews was used to add three additional questions and to clarify the response choices for employees cleaning heavy and light infestations. Our experience with the pilot survey allowed for planning the logistics of a larger survey, made available to all remaining employees of Employers A and B; our methods did not significantly differ between the pilot and final survey administration, other than logistical considerations. The final survey was administered on October 16–17, 2012.

Blood Specimen Collection and Analysis

Consistent with other published investigations [Fritz et al., 2002; Gardner et al., 2005; Fulhorst et al., 2007], blood samples were analyzed for evidence of previous infection by testing for SNV IgG antibodies. Blood collections were performed at Yosemite by licensed phlebotomists, public health nurses, or volunteer registered nurses. Approximately 8 ml of whole blood was collected in a serum-separator tube from each participant. Blood samples were allowed to clot at room temperature for 2 hr, chilled at 4°C overnight, delivered to the CDPH Viral and Rickettsial Disease Laboratory, and tested for SNV IgG antibodies by enzyme-linked immunosorbent assay [Ksiazek et al., 1999; Bostik et al., 2000]. For any blood sample positive for SNV IgG, SNV IgM was also tested. Fourfold dilutions were performed, 1:100–1:6,400, and titers $\geq$1:400 were considered positive.

Data Analysis

Survey participation rates were estimated on the basis of employee information provided by Employers A and B. Questionnaire responses from the pilot survey and final survey were combined, with the exception of questions that were added after the pilot survey was conducted. All study results, other than participation rates, represent aggregates for Employers A and B. Employees were categorized into mutually exclusive job categories on the basis of self-reported job title and job description information provided by the employers. Employees were classified as residing in the park if they responded that they resided in Yosemite during the previous 12 months. The Yosemite boundary town of El Portal has certain park-owned housing, but the majority of housing in El Portal is privately owned; for this analysis, residing in El Portal was not considered residing in Yosemite. Only employees who opened seasonally-closed buildings, cleaned heavy infestations, or cleaned light infestations were asked about their access to and use of PPE. Analysis of respirator fit testing excluded employees who reported using PAPRs, as use of a loose-fitting PAPR does not require fit testing. Statistical analyses were performed by using SAS® 9.3 (SAS Institute, Inc., Cary, NC).

Human Subjects Review and Participant Notifications

The California Health and Human Services Agency's Committee for the Protection of Human Subjects determined that this investigation was public health practice (i.e., nonresearch). All participants were informed of their individual serologic test results and aggregate employee serologic test results by mail. Aggregate serologic test results were also provided to the 2 employers. CDPH provided aggregate questionnaire results and recommendations (similar to those under Conclusions) to the employers and worked with the employers to make a summary of key findings available to employees.

RESULTS

Survey Participants

Ninety-five employees participated in the pilot survey; 433 employees participated in the final survey (Fig. 1). Two employees reported influenza-like symptoms during the screening process, and were referred to their medical provider; CDPH, CDC, and NPS have received no reports of HPS among these workers. A total of 319/1,008 (32%) of Employer A employees and 209/1,667 (13%) of Employer B employees participated in either the pilot or final survey. Six declined to complete the questionnaire, and 2 declined to provide a blood sample. The majority of participants were men and white; median age was 43 years (Table I). Employees representing a range of occupations and job tenure participated. The majority were year-round employees, college-educated, and resided in Yosemite during at least part of the year.

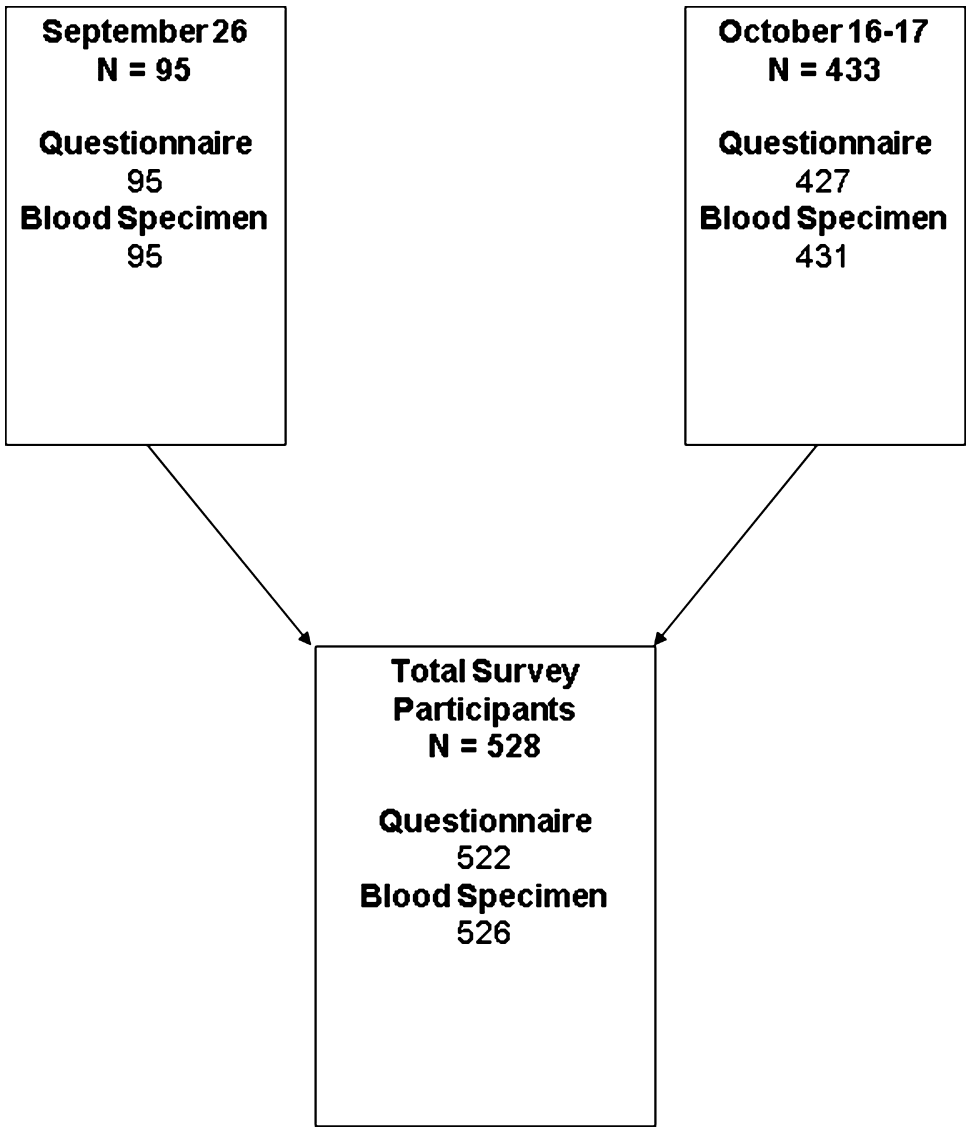

FIGURE 1. Participation in employee survey. Participation is shown by date. All September participants completed the questionnaire and provided a blood specimen. Of October participants, two declined to provide a blood specimen, and six declined to complete the questionnaire.

Blood Testing Results

Of the 526 participants whose blood samples were tested, one had detectable SNV IgG but had no detectable SNV IgM, which indicates a previous infection with SNV. The employee was interviewed by CDPH staff and did not have an illness compatible with HPS during 2012. This employee had opened seasonally-closed buildings at Yosemite previously, but not in the past 12 months. This employee also had cleaned a light infestation at their work and at home in the past 12 months, but had not cleaned a heavy infestation at their work or at home in the past 12 months, and had not worked in the signature tent cabins.

Exposure to Mice

Twenty-five percent of participants reported having cleaned a heavy infestation at work during the previous 12 months (Table II), and 79 of the 351 (23%) participants who resided in Yosemite during the previous 12 months reported having cleaned a heavy infestation at home. In total, 31% of participants reported having cleaned a heavy infestation in Yosemite during the previous 12 months at either work or home. Having cleaned a heavy infestation at work was most commonly reported by laborers (46%) and electrician, maintenance, and sanitation workers (43%; Supplementary Table SI).

TABLE I. Demographic and Occupational Characteristics of Yosemite Employee Questionnaire Respondents, September–October, 2012. N = 522*

	No.	%
Age (yrs)		
18–24	22	4
25–34	110	35
35–44	66	21
45–54	54	17
55–64	61	20
≥65	16	3
Sex		
Men	293	56
Women	228	44
Race		
White	418	84
Other	50	10
Multiracial	28	6
Hispanic	36	7
Education		
High school, GED, or less	56	11
Some college	193	38
Bachelor's degree or higher	264	51
Occupation		
Electrical, maintenance, sanitation, or restoration	97	19
Ranger, trail worker, or forest management	75	14
Food service, customer service, or driver	72	14
Administration, clerical, or office	69	13
Management	67	13
Science	57	11
Medical, search and rescue, security, law, or fire	41	8
Laborer	26	5
Room keepers (housekeeping) or hospitality	18	3
Employment seasonality		
Year-round	402	77
Seasonal	117	23
Resided in Yosemite during past 12 months	351	67
Total time employed at Yosemite		
≤1 year	59	11
1–4 years	162	31
5–9 years	104	20
10–19 years	91	17
20–29 years	59	11
≥30 years	46	9

*Numbers might not always total 522 because not all participants responded to every question.

Sixty-seven percent of participants reported having cleaned a light infestation at work during the previous 12 months (Table II), and 215 of the 351 (61%) participants who resided in Yosemite during the previous 12 months reported having cleaned a light infestation at home. In total, the majority of participants (78%) reported having cleaned a light infestation in Yosemite during the previous 12 months either at work or home. Having cleaned a light infestation was most commonly reported by laborers (81%); room keepers and hospitality workers (79%); electrician, maintenance, and sanitation workers (78%); rangers, trail workers, and forest management personnel (77%); and management (75%; Supplementary Table SI).

TABLE II. Work Duties Associated With Mice Exposure as Reported by Yosemite Employee Questionnaire Respondents, September–October, 2012. N = 522

Employee activity	No.	%
Cleaned a heavy infestation at work	129	25
Cleaned a light infestation at work	350	67
Opened a seasonally-closed building	220	42
Worked in or around signature tent cabins	84	16

Forty-two percent of participants reported having opened a seasonally-closed building during the previous 12 months as part of their work duties (Table II). Having opened a seasonally-closed building was most commonly reported by electrical, maintenance, and sanitation workers (70%); rangers and trail workers (54%); and laborers (46%; Supplementary Table SI).

Sixteen percent of participants reported having worked in or around signature tent cabins during the previous 12 months (Table II), most commonly room keepers and hospitality workers (50%); and electrical, maintenance, and sanitation workers (35%; Supplementary Table SI).

Cleaning Practices

Among participants who reported having cleaned a heavy infestation at work, 73% reported always having access to a chemical disinfectant or bleach (Table III), and of these, 85% reported always using a disinfectant. Of participants who reported they always used a disinfectant, 67% reported always waiting ≥10 min after applying a disinfectant before cleaning the infestation. Taken together, 42% of participants who reported having cleaned a heavy infestation also reported that they always followed both of these employer guidelines for safe disinfection of heavy infestations.

Seventy-seven percent of participants who reported having cleaned a light infestation at work reported always having access to a disinfectant, and 69% who reported cleaning a light infestation at work reported using a disinfectant when cleaning.

Access to and Use of PPE

Of the 129 participants who reported having cleaned a heavy infestation at work, 32 (25%) reported being fit-tested

TABLE III. Access to Gloves, Goggles, and Disinfectant, and Use of Disinfectant for Cleaning Heavy Infestations at Work, as Reported by Yosemite Employee Questionnaire Respondents, October, 2012. N = 108*, Unless Otherwise Noted

	No.	%
Always had access to bleach or chemical disinfectant	79	73
Always had access to disinfectant and always used disinfectant (N = 79)	67	85
Always had access to disinfectant, always used disinfectant, and always waited ≥10 min after applying disinfectant before cleaning (N = 67)	45	67
Always had access to gloves	90	83
Always had access to goggles	42	39

*These questions were not included in the pilot survey; 108 employees participating in the final survey reported having cleaned a heavy infestation at work.

for a respirator during the previous 12 months or using a loose-fitting PAPR. Of the 220 who reported having opened a seasonally-closed building during the previous 12 months, 44 (20%) reported being either being fit-tested for a respirator during the previous 12 months or using a loose-fitting PAPR.

Among participants who reported having cleaned a heavy infestation at work, 83% reported always having access to gloves, and 74% always using gloves (Tables III and IV). Only 39% reported always having access to goggles, and 17% reported always using goggles. A limited number of participants reported wearing coveralls (4%) or shoe covers (2%). Eleven percent reported having used either a half-mask negative pressure air purifying respirator with P-100 filters or a PAPR when cleaning a heavy infestation. Participants' use of respiratory protection when opening a seasonally-closed buildings was not assessed.

Among the 350 participants who reported having cleaned a light infestation at work, 280 (80%) reported always having access to gloves, and 224 (64%) reported always using gloves.

Hantavirus Safety Training and Knowledge

As displayed in Table V, 42% of participants reported having received hantavirus training during the previous 12 months with a hands-on component (i.e., performing the task under supervision and receiving feedback). However, 30% reported that their only training was in the form of a written brochure or a copy of the Directive. Three percent reported receiving no training regarding hantavirus safety.

Our survey included multiple choice knowledge questions based on information contained in the Directive, as listed in Table VI; detailed responses for each question are provided in Supplementary Table SII. Questions 3, 4, and 5 were answered correctly by 97%, 89%, and 89% of participants, respectively, indicating that participants were substantially aware of how persons are exposed to hantavirus (inhalation of contaminated particles), whether hantavirus infection is spread from person to person (has never been documented), and the period for developing symptoms after exposure (1–6 weeks). However, only 58% correctly answered Question 1 (hantavirus can be destroyed by ordinary chemical disinfectants), and 40% correctly answered Question 2 (all employees are responsible for determining whether an infestation is light or heavy when

TABLE IV. Use of Personal Protective Equipment for Cleaning Heavy Infestations at Work as Reported by Yosemite Employee Questionnaire Respondents, September–October, 2012. N = 129*

	No.	%
Used rubber, latex, or nitrile gloves	95	74
Used goggles	22	17
Used coveralls	5	4
Used shoe covers	3	2
Used a half-mask negative pressure air purifying respirator with P-100 filters or PAPR	14	11
Used other[a] respiratory protection	49	38
Did not use respiratory protection	66	51

*One hundred twenty-nine employees reported having cleaned a heavy infestation at work.
[a]Includes N95 filtering facepiece respirators, respirators of unknown type, or a mix of specified respiratory protection and other types.

TABLE V. Type of Hantavirus Training Received During the Previous 12 Months, as Reported by Yosemite Employee Questionnaire Respondents, October, 2012. N = 427*,[a]

	No.	%
Written brochure or Directive[b] only	129	30
Hands-on training	179	42
One-on-one training	29	7
Group training	172	40
Hantavirus discussion at work meeting	213	50
Other	32	7
None of the above	14	3

*These questions were not included in the pilot survey.
[a]Multiple responses were permitted.
[b]The Directive is an NPS document detailing hantavirus worker safety policy and procedures in Yosemite.

TABLE VI. Hantavirus Knowledge Questions as Reported by Yosemite Employee Questionnaire Respondents, September–October, 2012. N = 522

	No.	%
Employees correctly answering hantavirus knowledge questions:		
Question 1: Can ordinary disinfectants (not exclusively for hantavirus) be used to kill the virus in mice droppings?	301	58
Question 2: Who is responsible for assessing whether an infestation is light or heavy?	208	40
Question 3: How are people most likely to be infected with hantavirus?	504	97
Question 4: How frequently is hantavirus transmitted person to person?	462	89
Question 5: When are symptoms of hantavirus pulmonary syndrome most likely to occur after exposure?	462	89

doing a general exposure assessment). We identified no consistent associations between self-reported type of training and use of PPE when opening a seasonally-closed building or cleaning a heavy infestation at work, or use of disinfectants when cleaning a heavy infestation (data not shown).

DISCUSSION

Deer mice are common in Yosemite, and a majority of employees reported having cleaned a rodent infestation at work, regardless of their job description or length of time employed at Yosemite. Only 1 of 526 employees had evidence of previous hantavirus infection, indicating risk is low. This employee did not have a history of illness compatible with HPS during 2012, when certain Yosemite visitors became ill with HPS. Determining when or how the employee became infected is not possible from our investigation. However, the employee's exposure to mice did not include work in or around the signature tent cabins, which were associated with the visitor illnesses, or cleaning a heavy infestation or opening a seasonally-closed building in the previous 12 months.

Nine overnight visitors who became infected with SNV had lodged in signature tent cabins [Nunez et al., 2014], and because more than 10,000 guests had registered to stay in a signature tent cabin during June 1, 2012–August 28, 2012, the risk of infection among overnight guests in signature tent cabins was <0.1%. Our sample size is too small to compare the exact risk of infection among employees to that of overnight guests, and Yosemite employees are not necessarily comparable to visitors in terms of demographics, job duties, and exposures to mice. Nevertheless, it is notable that no infections were identified among employees who reported cleaning a heavy infestation at work, opening a seasonally-closed building, or working in or around signature tent cabins in the past 12 months, further highlighting the elevated risk associated with staying overnight in a signature tent cabin. The seroprevalence among workers in Yosemite was consistent with other seroprevalance reports of <1%, including studies among park workers in the southwestern United States [Vitek et al., 1996], farmers [Gardner et al., 2005], workers in multiple industries with frequent mouse contact (e.g., farming, plumbing or heating, or forestry; Zeitz et al., 1995), and other occupations (field biologists and laboratory workers; Fritz et al., 2002; Fulhorst et al., 2007).

The Directive takes a reasonable approach to hantavirus illness prevention by encouraging the practice of standard precautions whenever an activity is conducted that might expose an employee to hantavirus. This method assumes that all mice are potentially infected and likewise that all contact with mice infestations poses risk for employee exposure to infectious rodent excreta through inhalation, breaks in the skin, or the eyes. The procedures and protective measures outlined in the Directive for conducting activities that might expose an employee to hantavirus are consistent with sound industrial hygiene practice.

Effective implementation of the Directive depends on a training program that incorporates both basic andin-depth training; basic training includes training for employees to correctly identify a heavy rodent infestation, and therefore, to avoid cleaning if they are not more highly trained and equipped with required protective gear, andin-depth training provided for those employees who clean heavy infestations as part of their duties. Participants were knowledgeable regarding hantavirus exposure, transmission, and symptoms, indicating that these aspects of hantavirus safety had been well communicated. In contrast, a majority of participants did not know that all employees are responsible for determining whether an infestation is light or heavy. However, the 13% of participants who answered that managers and supervisors are responsible for determining whether an infestation is light or heavy may have found the question ambiguous because the Directive states that supervisors will ensure that employees are correctly trained to perform rodent activity assessments. Substantial evidence exists that occupational health and safety training improves protective behaviors among workers, including those who might be exposed to infectious diseases [Robson et al., 2012]. Our results indicate that participants might have benefitted from training that effectively addresses the differences between cleanup of light versus heavy infestations and the appropriate use of disinfectants during infestation cleanup.

A substantial number of participants reported not always having access to disinfectant and gloves when cleaning an infestation, and most participants who reported cleaning a heavy infestation or opening a seasonally-closed building also reported not being fit-tested for a respirator during the previous 12 months. Difficulties with ensuring employee access to and use of PPE and disinfectants can be addressed by additional training for supervisors that emphasizes their critical role in ensuring that all employees have the necessary equipment and training to reduce their risk for hantavirus exposure.

A limited number of investigations have evaluated employee-reported knowledge of infectious disease hazards and adherence to employer safety and disease prevention guidelines. In 2008, employees at U.S. Forest Service sites in *Peromyscus*-endemic areas of California reported no extensive training in prevention strategies for rodent-borne diseases [Levine et al., 2008]. In contrast to our investigation, employees interviewed by Levine et al. were more knowledgeable about disinfection techniques than specific elements of hantavirus biology. In studies of health care workers, variable (13–88%) knowledge of recommended PPE was reported among physicians caring for influenza patients at 4 hospitals during the 2009 influenza H1N1 pandemic; 30% of those not using recommended PPE cited a lack of PPE availability near patient rooms as their reason for not using recommended equipment [de Perio et al., 2012]. Associations between training in standard precautions and PPE compliance, as well as between a perceived safety climate and PPE compliance, have also been reported among hospital-based physicians [Michalsen et al., 1997].

Our survey has certain limitations, including that it was conducted during September and October, 2012, and by that time, a substantial number of seasonal employees had left for the year; we were unable to estimate the number of seasonal employees at Yosemite and therefore are unable to determine whether participation rates of seasonal and year-round employees differ. Participation rates were calculated from employee telephone and payroll lists, which might have been incomplete. The differential participation rate between employees of Employer A (32%) and Employer B (13%), as well as the low overall participation rate, limit the generalizability of our findings to all Yosemite employees. Furthermore, bias due to self-selection might have occurred, either because employees who perceived their work duties as higher risk volunteered for the survey or because highly exposed workers were reluctant to participate. Prevalence of previous hantavirus infection might differ among employees who participated in the survey compared with those who did not, and because we screened for evidence of SNV infection by presence of SNV IgG, it is therefore possible that employees with recent onset infection were not identified. However, we are unaware of any reports of HPS among Yosemite employees, and given the low prevalence of previous hantavirus infection among outdoor workers [Zeitz et al., 1995; Vitek et al., 1996; Fritz et al., 2002; Gardner et al., 2005; Fulhorst et al., 2007], it is unlikely that a substantial number of Yosemite employees had unidentified infections. Extensive media coverage of the outbreak might have influenced employee responses or resulted in reinforcement of safety practices after the outbreak. Self-reporting through questionnaires introduces the possibility of recall bias. Finally, although definitions of a heavy and a light infestation were stated in the questionnaire, employees might have subjectively perceived a light infestation as a heavy infestation.

Workers at Yosemite and similar outdoor environments in the United States are commonly exposed to rodent excreta and settings that are known risks for HPS. Although we did not find evidence of occupational illness in this setting, HPS is a severe illness and prevention efforts are warranted, given the exposures identified at Yosemite. Hantavirus is not the only zoonotic risk for employees at Yosemite and in similar outdoor settings across the United States. Leptospirosis, plague, rat-bite fever, salmonellosis, tularemia, Rocky Mountain spotted fever, relapsing fever, and other illnesses can be transmitted directly or indirectly (e.g., by mosquitos or ticks) from rodents to humans. Incident infections of leptospirosis, La Crosse virus, and spotted fever group rickettsiae have been identified among NPS workers in the Great Smoky Mountains and Rocky Mountain National Parks [Adjemian et al., 2012]. Methods for reducing worker exposure to mice might also reduce worker exposure to other rodent-borne zoonoses.

The results of this survey identified multiple gaps in participants' knowledge and training, and additional opportunities for exposure, including cleaning an infestation at home among employees residing in Yosemite, not using or inappropriately using disinfectants when cleaning up an infestation, not using PPE when cleaning an infestation, not using a respirator (or not being fit-tested for the respirator) when cleaning a heavy infestation or opening a seasonally-closed building, and not knowing who is responsible for determining whether an infestation is light or heavy.

Therefore, the authors recommend measures to prevent exposure to rodent-borne zoonotic diseases, including but not limited to hantavirus, among workers in outdoor settings in the United States similar to Yosemite. Our recommendations include the following specific points.

Implement effective rodent exclusion and control efforts in employee workspaces. Apply rodent exclusion methods, following guidance in the NPS Rodent Exclusion Manual [Hoddenbach et al., 2005].

Implement effective rodent exclusion and control measures in employee housing. Apply rodent exclusion efforts to employee housing, and ensure clarity in the process and responsibility for cleaning heavy mice infestations in employee housing. Offer opportunities for employee family

members who reside in employer-provided housing to receive information or participate in hantavirus awareness training to learn about symptoms, how to exclude mice, and how to clean up light infestations among other skills.

Ensure that employees who clean heavy mice infestations or perform other high-risk tasks have in-depth training about how to perform this work safely and have necessary supplies and equipment. Employees whose job includes cleaning a heavy infestation should be identified in advance, should be provided in-depth training regarding cleanup procedures, should receive instruction how to select and wear PPE, including respiratory protection, and should demonstrate their ability to safely clean up a heavy infestation. Employees should always wear a particulate respirator (half-mask with P-100 filtration or higher level such as powered air-purifying respirator with equivalent filters) when cleaning a heavy infestation. Supervisors or managers should be responsible for ensuring that PPE and disinfectants are available to employees cleaning a heavy infestation, and that safety procedures are consistently followed. If preferred, face shields can also be used in place of goggles.

Ensure provision of basic hantavirus awareness and safety training to all employees at least annually. Train all employees to be able to distinguish between light and heavy mice infestations, including a hands-on component, with demonstrations of prescribed light infestation cleaning practices, and provide periodic reinforcement of training as needed. Ensure that seasonal employees and contractors are trained in hantavirus prevention and light infestation cleaning before they start work for the season.

Ensure implementation of an OSHA-compliant respiratory protection program that includes all employees who might clean heavy infestations, open seasonally-closed buildings, or perform any other job duties considered high-risk for hantavirus exposure. Employer respiratory protection programs should include written procedures for all components of a comprehensive respirator program, including respirator selection, medical clearance, annual fit testing (for wearers of tight-fitting respirators), annual training, program evaluation, and recordkeeping that documents provision of these services for all employees included in the programs [29 Code of Federal Regulations, 1910.134].

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REFERENCES

29 Code of Federal Regulations. 1910.134. Respiratory protection.

Adjemian J,Weber IB, McQuiston J, Griffith KS, Mead PS, Nicholson W, Roche A, Schriefer M, Fischer M, Kosoy O, et al. 2012. Zoonotic infections among employees from Great Smoky Mountains and Rocky Mountain National Parks, 2008–2009. Vector Borne Zoonotic Dis 12:922–9.

Armstrong LR, Zaki SR, Goldoft MJ, Todd RL, Khan AS, Khabbaz RF, Ksiazek TG, Peters CJ. 1995. Hantavirus pulmonary syndrome associated with entering or cleaning rarely used, rodent-infested structures. J Infect Dis 172:1166.

Bostik P, Winter J, Ksiazek TG, Rollin PE, Villinger F, Zaki SR, Peters CJ, Ansari AA. 2000. Sin nombre virus (SNV) Ig isotype antibody response during acute and convalescent phases of hantavirus pulmonary syndrome. Emerg Infect Dis 6:184–187.

Centers for Disease Control and Prevention. 2002. Hantavirus pulmonary syndrome– United States: Updated recommendations for risk reduction. MMWR 51:1-12.

Centers for Disease Control and Prevention. 2012a. Reported Cases of HPS. Accessed July 14, 2014. http://www.cdc.gov/hantavirus/surveillance/index.html

Centers for Disease Control and Prevention. 2012b. How People Get Hantavirus Pulmonary Syndrome (HPS). Accessed July 14, 2014. http://www.cdc.gov/hantavirus/hps/transmission.html

Childs JE, Ksiazek TG, Spiropoulou CF, Krebs JW, Morzunov S, Maupin GO, Gage KL, Rollin PE, Sarisky J, Enscore RE, et al. 1994. Serologic and genetic identification of Peromyscus maniculatus as the primary rodent reservoir for a new hantavirus in the southwestern United States. J Infect Dis 169:1271–1280.

de Perio MA, Brueck SE, Mueller CA, Milne CK, Rubin MA, Gundlapalli AV, Mayer J. 2012. Evaluation of 2009 pandemic influenza A (H1N1) exposures and illness among physicians in training. Am J Infect Control 40:617–621.

Fritz CL, Fulhorst CF, Enge B, Winthrop KL, Glaser CA, Vugia DJ. 2002. Exposure to rodents and rodent-borne viruses among persons with elevated occupational risk. J Occup Environ Med 44:962–967.

Fulhorst CF, Milazzo ML, Armstrong LR, Childs JE, Rollin PE, Khabbaz R, Peters CJ, Ksiazek TG. 2007. Hantavirus and arenavirus antibodies in persons with occupational rodent exposure. Emerg Infect Dis 13:532–538.

Gardner SL, Von Essen S, Berger J, Hjelle B. 2005. Low seroprevalence among farmers from Nebraska and vicinity suggests low level of human exposure to sin nombre virus. J Agromedicine 10:59–61.

Hoddenbach G, Johnson J, DiSalvo C. 2005. National Park Service Rodent-Exclusion Manual, Mechanical Rodent-Proofing Techniques, A Training Guide: National Park Service.

Jay M, Hjelle B, Davis R, Ascher M, Baylies HN, Reilly K, Vugia D. 1996. Occupational exposure leading to hantavirus pulmonary syndrome in a utility company employee. Clin Infect Dis 22:841–844.

Kelt DA, Van Vuren DH, Hafner MS, Danielson BJ, Kelly MJ. 2007. Threat of hantavirus pulmonary syndrome to field biologists working with small mammals. Emerg Infect Dis 13:1285–1287.

Knust B, Rollin PE. 2013. Twenty-year summary of surveillance for human hantavirus infections, United States. Emerg Infect Dis 19: 1934–1937.

Ksiazek TG, West CP, Rollin PE, Jahrling PB, Peters CJ. 1999. ELISA for the detection of antibodies to Ebola viruses. J Infect Dis 179(Suppl 1):S192–S198.

Levine JR, Fritz CL, Novak MG. 2008. Occupational risk of exposure to rodent-borne hantavirus at US forest service facilities in California. Am J Trop Med Hyg 78:352–357.

MacNeil A, Ksiazek TG, Rollin PE. 2011. Hantavirus pulmonary syndrome, United States 1993-2009. Emerg Infect Dis 17:1195–1201.

Michalsen A, Delclos GL, Felknor SA, Davidson AL, Johnson PC, Vesley D, Murphy LR, Kelen GD, Gershon RR. 1997. Compliance with universal precautions among physicians. J Occup Environ Med 39:130–137.

Nunez JJ, Fritz CL, Knust B, Buttke D, Enge B, Novak MG, Kramer V, Osadebe L, Messenger S, Albarino CG, et al. 2014. Hantavirus infections among overnight visitors to Yosemite National Park, California, USA, 2012. Emerg Infect Dis 20:386–393.

Robson LS, Stephenson CM, Schulte PA, Amick BC, 3rd, Irvin EL, Eggerth DE, Chan S, Bielecky AR, Wang AM, Heidotting TL, et al. 2012. A systematic review of the effectiveness of occupational health and safety training. Scand J Work Environ Health 38:193–208.

Torres-Perez F, Wilson L, Collinge SK, Harmon H, Ray C, Medina RA, Hjelle B. 2010. Sin Nombre virus infection in field workers, Colorado, USA. Emerg Infect Dis 16:308–310.

Vitek CR, Ksiazek TG, Peters CJ, Breiman RF. 1996. Evidence against infection with hantaviruses among forest and park workers in the southwestern United States. Clin Infect Dis 23:283–285.

Zeitz PS, Butler JC, Cheek JE, Samuel MC, Childs JE, Shands LA, Turner RE, Voorhees RE, Sarisky J, Rollin PE, et al. 1995. A case-control study of hantavirus pulmonary syndrome during an outbreak in the southwestern United States. J Infect Dis 171: 864–870.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

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SUPPLEMENTARY TABLE I. Having Cleaned a Heavy Infestation at Work, Having Cleaned a Light Infestation at Work, Having Opened a Seasonally-closed Building, and Having Worked in or Around a Signature Tent Cabin, by Occupation, as Reported by Yosemite Employee Questionnaire Respondents, September–October 2012. N=522.

Job title	No.	Cleaned a heavy infestation, No. (%)	Cleaned a light infestation, No. (%)	Opened a seasonally-closed building, No. (%)	Worked in or around a signature tent cabin, No. (%)
Electrical, maintenance, sanitation, or restoration	97	42 (43)	76 (78)	67 (70)	34 (35)
Ranger, trail worker, or forest management	75	23 (31)	58 (77)	40 (54)	6 (8)
Food service, customer service, or driver	72	10 (13)	32 (44)	18 (25)	4 (6)
Administration, clerical, or office	69	3 (4)	34 (49)	15 (22)	3 (4)
Management	67	18 (27)	50 (75)	28 (42)	12 (18)
Science	57	4 (7)	39 (68)	17 (30)	6 (11)
Medical, search and rescue, security, law, or fire	41	11 (27)	26 (63)	17 (41)	5 (12)
Laborer	26	12 (46)	21 (81)	12 (46)	5 (19)
Rooms keeper or hospitality	18	6 (33)	14 (79)	6 (33)	9 (50)

SUPPLEMENTARY TABLE II. Answers to Hantavirus Knowledge Questions as Provided by Yosemite Employee Questionnaire Respondents, September–October 2012. N=522.

	No.	%
Question 1: Can ordinary disinfectants (not exclusively for the hantavirus) be used to kill the virus in mice droppings?		
Yes[a]	301	58
No	127	24
Do not know or no answer given	94	18
Question 2: Who is responsible for assessing whether an infestation is light or heavy?		
The person who finds the infestation[a]	208	40
Environmental health officer	87	17
Managers and supervisors	70	13
Buildings and grounds	18	3
Do not know or no answer given	139	27
Question 3: How are people most likely to be infected with hantavirus?		
Skin contact with rodents	3	1
Bites by mosquitos that previously bit an infected rodent	0	0
Inhalation of airborne particles contaminated with rodent urine, saliva, or droppings[a]	504	97
None of the above	0	0
Other	13	3
Do not know or no answer given	2	0
Question 4: How frequently is hantavirus transmitted person to person?		
Very frequently	1	0
Somewhat frequently	3	1
Not very frequently	19	4
Person to person transmission of hantavirus has never been documented in the United States[a]	463	89
Do not know or no answer given	36	7
Question 5: When are symptoms of hantavirus pulmonary syndrome most likely to occur after exposure?		
Within 1 hour after exposure	3	1
During 2–3 days after exposure	12	2
More than 4 days, but less than 1 week after exposure	11	2
From 1 to 6 weeks after exposure[a]	463	89

Do not know or no answer given	32	6

[a]Correct answer.