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FIELD RESEARCH IN MAMMALOGY: AN ENTERPRISE IN PERIL

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This commentary was adapted from an oral presentation delivered at the 86th Annual Meeting of the American Society of Mammalogists in Amherst, Massachusetts, on 18 June 2006 to recognize receipt of the Joseph Grinnell Award for Excellence in Education. Our continued ability to conduct fieldwork in mammalogy and train the next generation of field mammalogists is threatened by social, institutional, and bureaucratic changes that have accelerated over the past decade. These changes include continued decline in field-based natural history studies in the United States, bureaucratic regulations that are increasing in both number and complexity, increased acceptance of radical animal rights propaganda by our youth, increased fear of nature among United States citizens, and poor understanding of risk in an increasingly risk-averse society. These factors, among others, have made it increasingly difficult to conduct field research in mammalogy, and this commentary shows how these changes influenced the national response to discovery of a new rodent-borne disease, hantavirus pulmonary syndrome (HPS), in 1993. Current guidelines to protect field researchers from HPS may, in fact, be destroying the very enterprise whose practitioners they were designed to protect.

Key words: disease, fear of nature, fieldwork, *Hantavirus*, hantavirus pulmonary syndrome, natural history, risk, safety

In his memorable Grinnell Lecture presented before the assembled membership of the American Society of Mammalogists (ASM) in June 2004, David J. Schmidly expressed eloquently his concern for the continued loss of natural history programs in academic institutions across the country. He commented that "... much of it [natural history] is done out-of-doors in moderately wild places ..." and he lamented the fact that "... field natural history ... [is] ... discouraged in many academic biological programs [in the United States today]" (Schmidly 2005:452, 454).

Few of us can forget the excitement and wonder of our 1st experiences in "wild places" (Fig. 1). These are the experiences that eventually led most of us into the field of mammalogy, and occasional trips into the field today refresh and prepare us for optimal performance in the office, classroom, or laboratory. Tacitly, most mammalogists assume that similar field experiences early in the lives of bright and receptive students stimulate the next generation to follow our lead and become professional mammalogists. Fortunately, the history of field mammalogy over the past century, or so, seems to support the widespread and long-held assumption that field mammalogists beget field mammalogists.

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Field mammalogists actively contribute to our next generation by taking students into the field in a tradition that began with C. Hart Merriam and Joseph Grinnell and extends to the field mammalogists of today (Fig. 2). Many of us have sensed a growing and potentially serious threat to this time-honored tradition. For many reasons, some of which I will discuss below, it has become increasingly difficult over the past decade to take students into the field in hopes that some of them might be stimulated to become field biologists. This alarming trend threatens not only the ASM—which prides itself on a long tradition of field-based research—but also the fields of ecology, conservation, biogeography, ethology, systematics, and the many other disciplines that depend heavily on field-gathered data. How can we hope to understand and protect the creatures and landscapes we study when the young biologists we produce are, as Michael A. Mares put it, "... sublimely ignorant of the diversity and complexity of nature" (Mares 2002:232)?

My discussion of the causes underlying the decline in field experiences for young biologists is divided into 5 separate, but not unrelated, topics. If space permitted, each topic could be further subdivided and additional topics could be added, but I will discuss only these 5 because I believe they are sufficient to expose the fundamental threat we face as we strive to train the field mammalogists of the future.

FIVE THREATS TO FIELD MAMMALOGY

The decline in natural history studies in United States universities.—I need not dwell on this topic because it was

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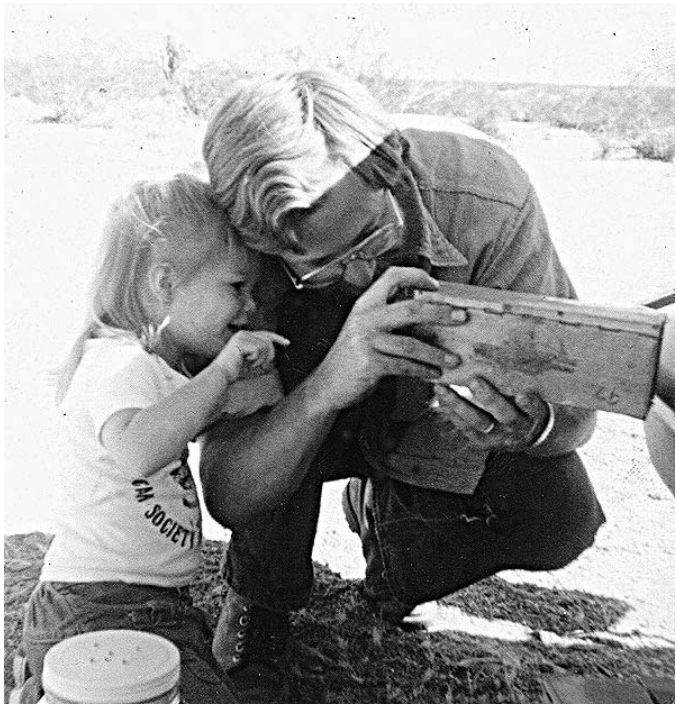


FIG. 1.—My daughter, Emily, and me in the Mojave Desert almost 30 years ago. Did this close encounter with a desert rodent stimulate Emily to become a field biologist? No, but it introduced her to the wonders of nature and showed her the difference between ''wild places'' and ''dangerous places,'' a distinction lost on many, if not most, youths today.



FIG. 2.—My 1st mammalogy class at Louisiana State University in 1979. At least 3 students in this class became professional field biologists, and there may have been others.

covered so fully by Schmidly (2005). Briefly, he explained that increased commercialization and for-profit activities in United States universities since 1945 have significantly devalued research in natural history, which often is less exploitable in a commercial sense and often does not require huge research grants to support. Schmidly (2005:451) mentioned the growing ''faddist'' and ''bandwagon'' movements in biology departments across the nation and said, ''Most significantly, and also most regrettably in my opinion, the biology bandwagon shifted from outdoor to indoor studies.'' This shift away from field studies in favor of laboratory-based studies is not a new threat to field mammalogy, but it is an ongoing issue that has created a passively hostile atmosphere in the academic community that disadvantages field biologists by devaluing the scientific worth of field-based studies in favor of lab-based research. It is difficult to compete with our lab-based colleagues who work in expensive, high-tech laboratories that students find fascinating and see every day on campus. Unfortunately, our laboratory colleagues and our deans have little appreciation for the natural laboratories in which we perform our research. Perhaps we are to blame for not ''selling'' our field research better, but the general perception is that laboratory researchers are more serious and more dedicated scientists and therefore are more deserving of promotions, raises, and other such rewards.

The increasing number and complexity of regulations.—Bureaucratic regulations, including foreign, federal, state, and local research permits; permits for collection, importation, and exportation of biological samples; and various clearances and approvals required by the United States Department of Agriculture, United States Department of Health and Human Services (Public Health Service), and United States Fish and Wildlife Service represent a relatively small, but increasingly complex, obstacle to field research. Although responsible citizens realize the need for most of these regulations, the complexity and nested nature of many of the regulations often makes it difficult to know if we are in full compliance. Faced with these confusing obstacles, some mammalogists may opt out of fieldwork, which means that their students will miss opportunities for field experiences. At least the increase in number of regulations has been reasonably steady over the past decade, giving field researchers time to adjust to existing regulations before tackling new layers of regulations. However, the increasing tendency to ban all or most fieldwork (especially collection and export of research specimens) in certain domestic and foreign jurisdictions is an ongoing threat to field research and the many disciplines that depend heavily on field-gathered data.

Institutional Animal Care and Use Committees (IACUCs) are a relatively new addition to the regulatory maze that field mammalogists must navigate before engaging in field research. IACUCs evaluate detailed research protocols submitted by field researchers to determine if the proposed methods are consistent with animal welfare standards developed originally—and still used almost exclusively—for laboratory animals. The beneficial role of IACUCs is beyond question, but the ability of these committees to distinguish between good and bad field practices (*Does a mouse trap inflict unnecessary pain?*) varies from institution to institution, and as a result IACUCs rely heavily on input from professional societies such as ours (Gannon et al.

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2007; Laber et al. 2007). In many institutions, IACUCs have teamed with occupational health and safety committees to monitor the health and safety of researchers working with animals in both laboratory and field settings. Again, the value and importance of these committees are beyond question, but they nevertheless represent another impediment to field research. The cumulative effect of these bureaucratic impediments, each justified in its own right, puts an onerous burden on the field researcher.

Increased visibility of animal rights groups.—Over the past decade, animal rights activists have become increasingly vocal in the United States, and their message seems to be resonating in a growing proportion of our younger citizens. The activities of responsible groups advocating humane treatment of animals have led to increased quality of life for both captive and wild animals. However, other groups categorically oppose nearly all human interactions with animals, including research on animals that will result in better understanding of the animal's biology and increased likelihood of its conservation.

The basic animal rights message (''be kind to animals'') is an easy product to sell, and people ignorant of the value of animal research are easily convinced of its brutality by sensationalized reports about animal research. Unfortunately, documented incidents of animal brutality in research laboratories in the United States, although rare, have fueled the animal rights cause. Children are particularly vulnerable to animal rights indoctrination, and I know from personal experience that students convinced of the evils of animal research are showing up in increasing numbers on college campuses.

So far, animal researchers have held their ground in the battle against irresponsible animal rights groups, but not without cost. Many college students, even biology and wildlife majors who have been exposed to animal-rights propaganda, will not participate in field trips where animals will be trapped and released, much less killed for use in research. The time spent trying to explain the value of our research to close-minded animal rights activists on our faculties, in our communities, or in the field could be better spent doing research. My point here is not that animal rights activists are a serious impediment to field research, but dealing with animal rights issues is yet another obstacle faced by the mammalogist who simply wants to introduce a group of students to the wonderful experience of field mammalogy.

Our increasing fear of nature.—As its 100th anniversary approaches (in 2016), the United States National Park Service reports that visits to national parks have declined steadily since 1995 (National Park Service, Public Use Statistics Office 2007, http://www2.nature.nps.gov/stats/). Overnight stays in national parks fell 20% between 1995 and 2005, and tent camping and backcountry camping have each decreased nearly 24% during the same time period (Fig. 3). Although Park Service officials worry about the relevance of national parks in an increasingly technology-oriented society, they also realize that fear of the outdoors is keeping many families, especially young families with children, indoors. Those who venture into our national parks face a frightening barrage of signs and pamphlets warning them about bears, mountain lions, snakes, spiders, poison ivy, heat prostration, drowning, and a host of other disclaimers required in an increasingly risk-averse and litigious society. Combined with the constant drumbeat of often-sensationalized media reports of squirrel attacks in city parks (NBC [National Broadcasting Corporation] News 2006, *Squirrels go on attack at south bay park,* http://www.nbc11.com/news/9946298/detail.html?rss=bay&psp=news) and deer attacks on college campuses (Chronicle of Higher Education 2006, *Fear stalks a campus, on 4 legs,* http://chronicle.com/news/article/490/fear-stalks-a-campus-on-4-legs), it is no wonder that people today are increasingly afraid of nature.

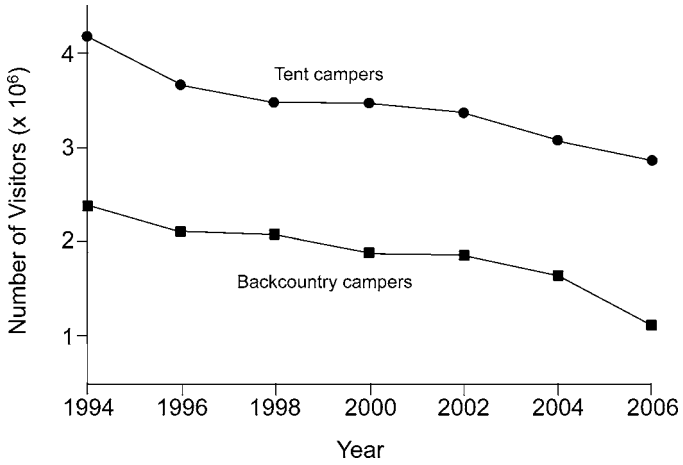


Fig. 3.—Evidence of the consistent decline in 2 categories of users of United States National Parks since 1994. Overall attendance at national parks also has declined steadily since 1994. Data from National Park Service (2007, http://www2.nature.nps.gov/stats/).

Even those who shun ''wild places'' because of their fear of nature face a related phobia in their towns and cities. As Richard Louv (2005) reports in his book *Last Child in the Woods: Saving our Children from Nature-Deficit Disorder*, people are keeping their children indoors more and more today because of fears of kidnapping and crime in city streets and parks. Indoor electronic games are rapidly replacing outdoor games, such as tag and baseball. While traveling on our highways, children in increasing numbers watch digital video recordings instead of the passing countryside. Louv envisions an entire generation of children raised indoors under virtual house arrest. ''Nature-deficit disorder'' in children today lays the psychological and emotional foundations for ''fear of nature'' later in life.

In an article titled *A nation of hypochondriacs?,* Winik (2006:21) quotes Dr. Arthur Barsky of Harvard Medical School, who said ''Things that would not have bothered us a generation ago bother us now.'' Barsky was referring to the rapid increase in medical phobias and the public's increasing fear of diseases. Widespread use of antibiotic sprays, soaps, and lotions without regard to their effectiveness or potential impact on microbial evolution is but one symptom of the public's fear of nature. One of Barsky's recommendations for controlling this hypochondria is to ''stop looking up diseases on the Web ... [because] ... the Internet tends to focus on worst-case scenarios.'' I find it ironic that more knowledge

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about a disease increases fear, rather than understanding, of the disease.

Failure to understand risk.—Although a vast literature exists on the subject of ''risk,'' few people understand risk and fewer yet realize that our minds make countless risk assessments each day of our lives (Adams 1995). Our natural ''fight-or-flight'' instincts, honed through millions of years of evolution, are activated in the relatively rare instances in which we are faced with sudden dangers; for good or bad, our reactions to sudden dangers usually are beyond our conscious control. But situations with potential dangers that unfold more slowly, such as crossing a busy street, consuming alcohol, operating a power tool, or conducting mammalogical research in the field, activate our analytical systems, giving us the opportunity to make so-called ''thoughtful'' decisions. Unfortunately, most people tend to overthink or underthink this kind of risk (Slovic et al. 2004).

Human perception of risk is predominantly emotional. We fear sudden dangers more than slowly unfolding dangers, even if the probability of death from the latter is much greater. Conversely, we fear a slow and prolonged death (such as from AIDS) more than sudden death (from a heart attack) even though heart disease kills nearly 50 times more Americans each year than AIDS (Miniño et al. 2006). We fear catastrophic events that kill multiple people at once more than chronic events that kill many more people distributed over time and space. Finally, we fear new and exotic threats (e.g., newly recognized diseases, such as avian flu) much more than we do familiar diseases (common flu) that kill many more people each year. The common link among these examples is the idea that humans tend to react rapidly and aggressively to new and unpleasant stimuli, but we eventually habituate when exposed to the same stimulus repeatedly. Habituation to a real threat can be dangerous, but it also can be beneficial if our initial reaction to the threat was excessive.

Risk management (communication about risk, risk mitigation, and decision making) is as much a political process as it is a scientific process. The purpose of scientific research on risk is, of course, risk reduction, but the ultimate objective of many regulatory agencies seems to be the absolute removal of *all* risk (Adams 1995:30):

> Governments around the world continue to add to the existing libraries full of safely laws and regulations. Safety campaigners are relentless in their efforts to make the world safer. On achieving a regulatory or statutory goal, they do not stop. They identify a new risk, and press for new laws or regulations, or stricter enforcement of existing ones.

This mindset, although well intentioned, ignores the fact that all people willingly take risks of one degree or another every day of their lives. It also fails to distinguish between those who engage in a risky activity by choice and benefit from the activity, and those who are exposed to the hazard involuntarily and receive no benefit from it. Disputes about risk and risk reduction in which the participants view their opponents as ''foolish risk-takers'' or ''overly protective nannies'' usually stem from differences in premise, risk paradigm, cultural background, personal risk tolerance, life experiences, or goals of risk reduction. For good or bad, such differences are part of the human fabric and will always influence our discussions of risk.

Risk and Field Mammalogy

Field mammalogy exposes the researcher (and accompanying student researchers) to a long list of potential dangers they would not normally encounter at home or in the laboratory. These include falling rocks and trees, spider bites, dengue fever, malaria, rabies, attacks by cougars, bears, wolves, and Africanized bees, tick bites, wasp stings, forest fires, centipede stings, lightning strikes, quicksand, sunburn, spotted fever, murine typhus, dehydration, thistles, scorpion stings, snake bites, tularemia, allergy attacks, histoplasmosis, bubonic plague, toxoplasmosis, chigger bites, frostbite, flash floods, Lyme disease, flea bites, tetanus, rodent bites, exposure, *Pasteurella*, and a host of other potential dangers, many of which may seem trivial but are potentially life-threatening. Add to this list the risk of a car accident on the way to or from the field, and we might begin to wonder why we do fieldwork at all. The answer, of course, is that the benefits of mammalogical fieldwork far outweigh the potential risks. We also know that the probability of occurrence of each of these dangers is quite low for the safety-conscious mammalogist and, fortunately, the probabilities are not additive.

So, mammalogists who work in the field make a conscious decision to accept risk (''calculated'' risk), and heretofore we have assumed that students who accompany us into the field also understand and accept these risks. But, as mentioned earlier, things have changed over the past decade and we now encounter 2 new kinds of students: those who are nature-deprived and do not understand—and therefore cannot accept or decline—the risks of fieldwork; and those who are afraid of nature and refuse to participate in fieldwork. If we want these students to benefit from field experiences, we have to approach them in new ways.

Case Study: ''*Hantavirus* Hysteria'' as a Threat to Field Mammalogy

The following account illustrates how the above threats to field mammalogy, each with its own cause and history, can combine and resonate to produce a truly serious threat to our discipline. The information I present is gleaned from the literature on *Hantavirus* research, but any mistakes of fact or interpretation are strictly my own. The opinions expressed are mine and not those of the ASM.

In 1993, several cases of a severe respiratory illness were reported in the southwestern United States, and it was subsequently determined that this illness (hantavirus pulmonary syndrome [HPS]) was caused by exposure to Sin Nombre virus (SNV), a species in the genus *Hantavirus* (Bunyaviridae). Researchers found the virus resident in populations of native rodents, particularly *Peromyscus maniculatus*, and additional research found related strains of the virus in other species of native rodents throughout much of the United States (Butler and Peters 1994; Nichol 2000, Yates et al. 2002). Phylogenetic studies (Nichol 2000; Plyusnin and Morzunov 2001) suggest

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that SNV and related viruses have been present in rodents of the Western Hemisphere for millennia and may have gone undetected were it not for the cluster of cases in the southwestern United States in 1993.

The discovery of SNV in the United States sent shock waves through the mammalogical community because in the first 3 months after its discovery, 8 (62%) of 13 people diagnosed with HSP died. As a result, the Centers for Disease Control and Prevention (CDC) quickly arranged to analyze blood samples from presumed high-risk groups, including mammalogists, wildlife workers, and rodent exterminators, to see if their blood contained antibodies to SNV. Although blood samples were taken from a large number of mammalogists at the 1994 annual meeting of the ASM, the full results of this survey were not published until 13 years later (Fulhorst et al. 2007).

Meanwhile, an alarmed United States Congress authorized increased funding for the CDC to study *Hantavirus*, and researchers at several nonfederal institutions were funded to study the evolution, ecology, and epidemiology of SNV and its rodent hosts. The CDC posted recommendations for preventing HPS in 1994 (updated in 2002), and guidelines for working with rodents potentially infected with *Hantavirus* were published a year later in the *Journal of Mammalogy* (Mills et al. 1995). The guidelines recommended that field researchers handling potentially infected rodents wear disposable gowns, shoe covers, 2 pairs of latex gloves, and be fitted with full-hood, powered, air-purifying respirators with high-efficiency particulate air (HEPA) filters or goggles and a half-face respirator with HEPA filters. In the absence of infectivity data, several other precautions were recommended, including sterilization of dissecting instruments and traps after each use.

I recall the 1st time I learned of the *Hantavirus* guidelines at a professional meeting in 1995. The speaker, a fellow mammalogist, showed a photo of a gloveless mammalogist skinning a rodent in the field and said, ''This is field mammalogy of the past.'' The speaker then showed a photo of several people dressed in the CDC-recommended outfits carrying Sherman traps at arm's length and said, ''This is field mammalogy of the future.'' Nervous laughter erupted from the audience at the sight of colleagues dressed in what looked like ''moon suits,'' and I doubt that anyone present took the speaker seriously (I certainly did not). Little did we know that many IACUCs across the country would soon learn of the CDC *recommendations* for HPS prevention and turn them into *requirements* for their employees who conduct field research with mammals. Many IACUCs also began requiring their researchers to enroll in medical surveillance programs, take *Hantavirus*-specific medical training, and attend training sessions on small mammal field anesthesia, handling, and euthanasia. Field mammalogy was changing rapidly, and no one seemed to be concerned about the adverse impact this new threat was having on our ability to conduct field research in mammalogy. Perhaps worse, no one seemed worried about the damage these regulations would do to our ability to recruit students into our profession—the need to wear ''moon suits'' while handling rodents in the field only served to confirm the apprehensions of nature-deprived and nature-fearing students.

Social amplification of the Hantavirus threat.—Beginning in 1996, an increasing number of research papers on *Hantavirus*, SNV, and HPS were published, and we began to learn more about this disease. Although the reported mortality rate of HPS dropped steadily from about 60% initially to 35% overall today (as infections were diagnosed earlier and treatment undertaken sooner), fear of the disease grew rapidly in the public arena. I attended numerous presentations on *Hantavirus* at professional meetings where mammalogists studying *Hantavirus* in rodents referred to the initial discovery of HPS as an ''outbreak'' and labeled HPS an ''emerging infectious disease.'' Although the speakers' use of these terms was technically correct, I found the words alarming because they reminded me (and I'm sure other listeners) of the 1995 movie *Outbreak* (Warner Brothers Entertainment, Inc., Hollywood, California), in which the hero (played by Dustin Hoffman) engaged in a life-or-death battle with a rapidly spreading Ebola-like virus. Every talk about *Hantavirus* stressed its high mortality rate and referred to it repeatedly as a deadly (or ''killer'') disease.

Scientists who study risk theory have identified a phenomenon called ''social amplification of risk'' (Kasperson et al. 2003) whereby various social agents, including scientists, scientific institutions, mass media, politicians, governmental agencies, and others generate, receive, interpret, and pass on risk signals. Each of these social agents can participate in risk amplification or risk attenuation, but Trumbo (1996) found that risk amplifiers usually are driven as much by interpersonal communication (what we hear from each other) as they are by mediated communication (e.g., mass media). I know from personal experience that talks given by mammalogists studying *Hantavirus* in the 1990s contributed to the social amplification of *Hantavirus* risk.

By the late 1990s I became sufficiently concerned about the risk of infection with hantaviruses that I stopped taking my students on mammalogy field trips. I soon learned that many of my colleagues at other institutions had done likewise. My concern about *Hantavirus* wasn't the only reason I canceled my field trips, but it was the ''last straw'' after several years of declining interest from the increasing number of nature-deprived and nature-fearing students and the growing complexity of permits and other approvals needed to launch a simple mammalogy field trip. Like most mammalogists, I was completely ignorant of *Hantavirus* research, other than what I learned from the presentations at professional meetings.

In the early 2000s, I began to see a disconnect between what I was hearing about *Hantavirus* at meetings and empirical evidence that was slowly becoming available. Although results of the 1994 ASM blood survey weren't yet published, I heard that only a few of the hundreds of mammalogists tested were seropositive for SNV and that those individuals were alive and well today. This didn't fit the ''killer disease'' epithet for HPS, and it conflicted with comments I heard that a person could acquire HPS from <5 min of exposure to *Hantavirus*. These and similar inconsistencies encouraged me to delve into the *Hantavirus* literature, and I report some of the results of my research below.

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''*Scare words*'' *and social amplification of risk.*—As mentioned earlier, the word ''outbreak'' is frightening to the average person because we use it with reference to wildfires, wars, epidemics, and similar catastrophes that usually radiate from a single point of origin. ''Outbreak,'' however, has a somewhat different and more mundane meaning in the field of epidemiology: an outbreak occurs when disease levels exceed what is expected in a given region (CDC 2007, *Program operations. Guidelines for STD prevention. Outbreak response plan* http://www.cdc.gov/std/program/outbreak.pdf). As the definition implies, outbreaks are usually recognized by a cluster of cases that catch the attention of medical authorities. However, even a single case of a disease outside its normal geographic range is, technically, an outbreak. Outbreaks may lead to epidemics, but an outbreak is not, itself, an epidemic.

We now know that SNV was present in the Four Corners region of the southwestern United States (and in 30 other states in the United States) long before it was recognized and named by medical science in 1993—Navajo medical traditions recognized the disease long ago and realized that it was transmitted by native rodents living in Navajo dwellings (CDC 2007, *Navajo medical traditions and HPS,* http://www.cdc.gov/ncidod/diseases/hanta/hps/noframes/navajo.htm). Although it was technically an outbreak that brought about initial recognition of HPS by the medical community in 1993, the disease did not suddenly appear in the southwestern United States, nor was it introduced there recently from some exotic locale. Repeated use of the emotionally charged word ''outbreak'' in talks and publications aimed at nonepidemiologists without recognizing (and attempting to correct) the audience's very different definition of the word causes, in my opinion, unwarranted amplification of the audience's fear of the disease.

Hantavirus researchers often refer to HPS as an ''emerging infectious disease,'' a phrase that is frightening to many outside the medical community because the word ''emerging'' suggests that the disease is getting worse or spreading, and ''infectious'' often is misconstrued by the public to mean person-to-person transmission of a disease (there is no evidence that HPS is a communicable disease in the United States). Examination of data since 1993 shows that levels of SNV in the native rodent population increase and decrease with population density cycles of rodents in response to climate-driven cycles of food availability (CDC 2007, *Hantavirus pulmonary syndrome cases by outcome,* http://www.cdc.gov/ncidod/diseases/hanta/hps/noframes/epislides/episl2.htm; Yates et al. 2002). Although HPS is an emerging infectious disease based on the technical definition of the phrase (Lederberg et al. 1992), it also is a cyclic disease, and there is no evidence that it is steadily getting worse or spreading. Again, *Hantavirus* researchers whose target audiences are mainly nonepidemiologists and nonvirologists should be careful to define the terms and phrases they use to avoid public misunderstanding of HPS. The only thing ''emerging'' about HPS (by the public's definition of ''emerging'') is our knowledge of it.

The mortality rate reported for HPS (35%) is a particularly frightening, and potentially misleading, statistic. Each year, an average of just under 30 people are diagnosed with HPS, of which approximately 10 die—hence, the 35% morality rate. In the period soon after discovery of HPS, people were unaware of the symptoms of the disease (fatigue, fever, and muscle aches, especially in the large muscle groups), and many cases were advanced beyond treatment by the time the patient was hospitalized. Other cases were misdiagnosed (perhaps as flu) until it was too late to save the patient. Together, these factors resulted in an extremely high (60–70%) mortality rate for the disease in 1993.

Hantavirus pulmonary syndrome is defined as an extremely serious, acute disease of the respiratory tract, so it is not too surprising that it has such a high mortality rate. Most diseases familiar to the general public, such as flu, run the gamut from mild to severe infections, whereas only severe infections with SNV (and related *Hantavirus* strains) meet the clinical definition of HPS. We now know that patients can be infected with SNV and not develop HPS. It seems reasonable to suggest that at least some of these patients will experience some of the earliest symptoms of HPS but will dismiss it as flu and recover shortly thereafter. Others will feel sick enough to seek medical attention, but the physician may misdiagnose the disease as flu or another respiratory illness and the patient will, again, recover fully. We do not know how many people are infected each year with SNV but do not develop HPS or do not seek medical attention (or seek medical attention and are misdiagnosed). Broadening the definition of the disease to include all SNV (and related *Hantavirus*) infections, not just severe infections (HPS), would lower the mortality rate of the disease by some unknown amount. For example, if the medical community restricted the term ''flu'' to only the most severe infections with influenza viruses, the mortality rate for flu would be nearly 20% because about one-fifth of the roughly 200,000 people hospitalized for flu in the United States each year die. This restricted definition of flu would ignore, of course, the other 40–50 million people who get milder influenza infections each year and recover (CDC 2007, *Key facts about influenza and the influenza vaccine,* http://www.cdc.gov/flu/keyfacts.htm). Of the 4 people with antibodies to SNV reported by Fulhorst et al. (2007), only 1 was hospitalized with symptoms consistent with HPS. The other 3 obviously had milder SNV infections that were either asymptomatic or were dismissed (or misdiagnosed) as another illness. Because their infections did not reach severe status (HPS), these 3 cases were ignored when calculating HPS mortality rate, but they would have been included in a calculation of the mortality rate for SNV infection. I suggest that the latter calculation may be more useful and meaningful because, like flu, it includes all SNV (and related virus) infections regardless of severity of the symptoms.

HANTAVIRUS RISK: THE EMPIRICAL EVIDENCE

Approximately 10 people die each year from HPS, and although each of these deaths is a tragedy, empirical evidence (discussed below) documents that HPS is a rare disease that is difficult to contract. Statements suggesting that HPS can be acquired by only brief exposure to infected animals can be found on the CDC Web site (CDC 2007, *Laboratory management of*

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agents associated with hantavirus pulmonary syndrome: interim biosafety guidelines, http://www.cdc.gov/od/ohs/biosfty/hantavir.htm) and on IACUC Web sites nationwide, but these statements refer to a different *Hantavirus* disease (hemorrhagic fever with renal syndrome—Tsai 1987), not HPS. Although there is strong evidence that Old World hantaviruses that cause hemorrhagic fever with renal syndrome can be contracted by brief exposure to infected animals, there is no similar evidence for HPS and substantial evidence to the contrary. It is unfortunate that this misinformation persists on IACUC Websites and in publicly available literature on HPS today.

In each of 4 separate studies of people whose occupations involve close contact with native rodents in North America, frequency of individuals seropositive for SNV has been very low. The study by Fulhorst et al. (2007) of 757 mammalogists and wildlife biologists, combined with results from the 3 other surveys of presumed high-risk groups (Fritz et al. 2002; Vitek et al. 1996; Zeitz et al. 1997), found antibodies to SNV in 4 (0.28%) of 1,412 subjects tested. Only 1 of these 4 subjects recalled having symptoms of HPS in the past, so the frequency of HPS in 1,412 individuals with frequent and prolonged exposure to native rodents was approximately 0.071% (seventy-one one-thousandths of 1%). The study by Fulhorst et al. (2007:532) concluded ''These results suggest that the risk of infection with hantaviruses ... usually is low in persons whose occupations entail close physical contact with ... rodents ... in North America.'' Despite this statement, and contrary to the evidence from their own study, Fulhorst and his colleagues recommended that persons working with rodents potentially infected with SNV adhere to the stringent guidelines for HPS prevention described above (Mills et al. 1995).

Results of serological surveys of high-risk groups, including the survey by Fulhorst et al. (2007) and others cited above, were inconsistent with the expectation (commonly held in the 1990s) that people who handle rodents frequently should show evidence of exposure to SNV and related hantaviruses. Attempts by the authors to explain away this inconsistency generally were not supported by available evidence. For example, Fulhorst et al. (2007:536) suggested that ''the low prevalence of antibody against SNV ... in this study could be because few of the rodents handled by the 757 study subjects were infected with a hantavirus ....'' Although potentially true, Fulhorst et al. (2007) reported that more than one-half of their study subjects came from the southwestern United States, where they are likely to have encountered SNV-infected mice. Yates et al. (2002) also reported antibodies to SNV in the preserved blood of 99 (13.4%) of 740 specimens of *P. maniculatus* collected from locations throughout North America, and Mills et al. (1998) reported that, on average, approximately 10% of *P. maniculatus* tested throughout the range of the species showed evidence of infection with SNV. Considering the huge number of rodent specimens collected by the 757 mammalogists and wildlife biologists throughout their collective careers, it seems likely that many, probably most, skinned at least 1 infected rodent in his or her lifetime. The likelihood that most of these infected rodents were not actively shedding virus when they were trapped may help explain the rarity of infections in mammalogists. Because HPS was unknown before 1993, the 99 SNV-positive specimens (all collected before 1993) identified in the study by Yates et al. (2002) could not have been skinned (and tissues taken) using CDC-recommended protective procedures (Mills et al. 1995). This represents 99 unimpeachable instances of intimate contact between mammalogists and SNV-infected mice without a single known case of HPS.

Fritz et al. (2002) suggested that antibodies to SNV might remain in the circulatory system for only a short period of time after exposure, making such exposures undetectable in blood surveys such as theirs (none of the 72 high-risk subjects in their study was SNV-positive). If true, this would be good news for the mammalogical community because it would suggest that a large number of mammalogists exposed to SNV did not contract HPS. Finally, Fritz et al. (2002) suggested that high-risk individuals exposed to SNV may have died of HPS or may have changed their professions, thereby negatively biasing the SNV risk estimate. This suggestion is contrary to the empirical evidence, which shows very few clinical cases of HPS that were believed to have been occupationally acquired, and in most of these cases, there also was evidence that the infection may have been acquired peridomestically (in the home or other buildings) without direct contact with rodents (Fritz et al. 2002). Besides, mammalogists probably would have noticed a series of deaths, all resulting from the same symptoms, among their colleagues!

Occupational versus peridomestic exposure to SNV.—Hantavirus pulmonary syndrome is a severe respiratory illness, and empirical evidence gathered to date shows that most cases of HPS are acquired by respiratory exposure to aerosolized SNV particles. Among confirmed cases of HPS for which exposure information is available, 70% of the patients had exposures closely associated with peridomestic activities in homes or other structures that showed signs of rodent infestation. As I will show below, there are no confirmed cases of HPS that were acquired by trapping, handling, or dissecting rodents (without gloves, goggles, or mask) in field settings that did not also involve a high likelihood of peridomestic exposure to SNV.

Source of infection is unknown for the 4 subjects who tested positive for SNV in the serological surveys discussed above, but we do know that one of them (the only subject who was hospitalized with HPS symptoms) lived in a cabin infested with native rodents and recalled inhaling a large cloud of dust (from a seasonally used window air-conditioning unit) a few weeks before experiencing HPS symptoms (B. J. Danielson, in litt.). Apparently, the authors of the serological survey that involved this subject were unaware of this incident (Fulhorst et al. 2007).

Reports of 2 recent cases of HPS in wildlife workers, 1 of which was fatal, also are consistent with peridomestic exposure (and inhalation of SNV particles) as the source of infection. The nonfatal case (California Department of Health Services 2005) involved a field technician trapping rodents in California. The technician was handling rodents in the field, but he also

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was living in a seasonally used cabin inhabited by *P. maniculatus*. Subsequent to the technician's illness, a serological survey revealed that 2 of 4 mice trapped inside the cabin were SNV-positive (Kelt et al. 2007). In contrast, only 2 of 18 field sites (where the technician was trapping rodents) had SNV-positive mice with infection rates of 20% and 50%, respectively. Although the technician may have acquired HPS by handling rodents at 1 of the 2 infected field sites, it seems more likely that he acquired the disease by inhalation of SNV particles while inside the cabin. Other cabin residents reported seeing the technician shake dust from old rugs in the cabin on at least 1 occasion (Kelt et al. 2007).

The recent (and fatal) case of HPS in a wildlife worker involved a graduate student collecting rodents in West Virginia (CDC 2004; Sinclair et al. 2007). Similar to the field technician in California, this student used a building as his base camp while trapping rodents, including *P. maniculatus*, at several nearby field sites. After the student's death, serological surveys of rodents collected from near the building and in the vicinity of the student's field sites found no SNV-positive mice. Because they found no evidence of current rodent infestation in the student's living quarters, Sinclair et al. (2007) concluded that the likely source of SNV infection was from rodent bites or scratches in the field. However, the student was observed several weeks before his death attempting to trap rodents in the building's drop ceiling, and one of his coworkers reported seeing him showered with dust as he lifted a ceiling tile (M. J. Kelly, in litt.). Although unconfirmed reports suggest that he was catching only *Rattus* inside the building, it is possible that SNV particles remained in the ceiling dust from a previous infestation of *Peromyscus*. Sinclair et al. (2007) report trapping a specimen of *P. maniculatus* near the building. A 2nd case of HPS was reported in West Virginia only days after the student's death, and Sinclair et al. (2007) concluded that this 2nd case, located only a few kilometers from the 1st, most likely involved peridomestic exposure to SNV (an SNV-positive specimen of *P. maniculatus* was trapped outside the patient's cabin—Sinclair et al. 2007). If either or both of the students in California and West Virginia contracted HPS peridomestically, then the CDC-recommended field gear would not have protected them.

Conclusions

Social and bureaucratic changes in the United States over the past decade have made it increasingly difficult to conduct mammalogical field research. Field researchers must run a gauntlet of federal, state, and local regulations that increase steadily in number and complexity. In our classrooms, we face an increasing number of students who, for a variety of reasons, are ignorant, often afraid, of the natural world. Our efforts to train the next generation of field researchers are thwarted by an increasingly risk-averse society, and we contribute unintentionally to the social amplification of risk when we embellish our exploits in the field and use emotionally charged words (''scare words'') in our talks and publications. At its current rate of decline, mammalogical field research soon will lose an entire generation of practitioners.

Mammalogists must realize that a large and growing proportion of the students we face today have an understanding of nature that is fundamentally different from the understanding we shared as students. We can no longer assume that our students, many of whom are nature-deprived, have a set of basic outdoor skills that will safeguard them in the field; these students need to be taught about fieldwork from the ground up. The unreasonable apprehensions of nature-fearing students must be approached honestly and directly—but also with care and understanding—so that we educate them about nature without triggering negative and counterproductive responses.

I believe that the discovery of HPS in 1993 and the issues swirling around HPS prevention today have contributed significantly to the decline in mammalogical fieldwork and our ability to train students in field mammalogy. As described above, a fearful United States public was emotionally primed in the early 1990s for a dangerous natural ''outbreak,'' and the discovery of HPS reaffirmed and strengthened the public's fear of the outdoors. Many researchers already burdened with bureaucratic red tape and less-than-enthusiastic students considered ''*Hantavirus* hysteria'' the final blow to their field programs.

The CDC and other federal agencies charged with protecting the public from natural disasters responded quickly and aggressively to the HPS threat. Initial concerns that the disease might be communicable or that the virus may have been accidentally or deliberately released (Horgan 1993) were reasonable reactions to a newly discovered health threat. Likewise, the continued efforts of our health and safety agencies to protect the general public from HPS are appropriate and consistent with their mission. Members of the general public are correctly advised to stay away from rodents as much as possible and keep rodents out of their homes and other buildings.

But field biologists who study rodents cannot stay away from rodents, so we are advised to wear special outfits and take other precautions in the field that are designed to protect us from transmission of viruses (CDC 2002). If the outfits and associated precautions are truly necessary, then no responsible person could argue against their use. However, if the probability of acquiring HPS is extremely low without the protective gear (which studies have confirmed), or if the risk of exposure is primarily peridomestic (also confirmed by evidence), then we need to reassess the guidelines for HPS prevention.

It is likely that the CDC was completely unaware of the enormous negative impact its HPS recommendations were having on field mammalogy until the subject was brought to their attention following my 2006 Grinnell lecture (Hafner 2006). Understandably, health officials want to err on the side of caution, and in most circumstances, everyone benefits from this approach. However, officials at the CDC are now aware that their guidelines for HPS prevention, which may be overly conservative and in need of revision, threaten our ability to recruit students into field programs to conduct mammalogical

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research that, ironically, supplies much of the data supporting our current knowledge of mammal-borne diseases.

We have a huge advantage over the previous generation of mammalogists because, thanks to the CDC and other HPS researchers, we know that HPS exists and we know to seek medical attention at the 1st sign of symptoms. Although HPS can be fatal, prognosis is good if aggressive treatment is started immediately after disease onset, and the prognosis for mild cases of HPS is excellent (B. A. Cunha 2006, *Hantavirus pulmonary syndrome,* http://www.emedicine.com/med/topic3402.htm). But HPS is so rare among field biologists that attacking it from the perspective of prevention is equivalent to requiring each of us to carry portable Faraday cages in the field because approximately 80 Americans die each year from lightning strikes (CDC 1998). Rather than going to extreme measures to prevent HPS, it might be more prudent to approach the disease using a combination of common sense, awareness, and rapid treatment. At the very least, common sense, grounded in current knowledge of HPS, demands that all field biologists today, regardless of discipline or location of study site in the United States, be especially mindful of possible exposure to *Hantavirus* in seasonally used dwellings, such as cabins and bunkhouses, that may be (or may have been) inhabited by *Hantavirus*-infected mice.

Now that the CDC is aware of the impact of their guidelines on field research with rodents, I am pleased to report that they have offered to engage mammalogists and wildlife biologists in discussions of field procedures, risks, and guidelines for health and safety in the field. To me, this heralds a new era of cooperation between health and safety officials and the people they are charged to protect. By the time this article appears in print, I hope that new HPS guidelines have been published by the CDC that strike a better balance between our desire to be safe in the field and our imperative to continue studying mammals in their natural environment and train the next generation of biologists to follow in our footsteps. Meanwhile, I urge everyone to comply with all existing regulations pertaining to field research in mammalogy.

The *Hantavirus* issue in the United States is a cautionary tale that reminds us how the mission of a well-intentioned governmental agency can sometimes thwart the missions of the people and institutions they regulate. Although most governmental agencies support the missions of their constituents, they are not always aware of the impact of their regulations, guidelines, or recommendations on the ability of the constituents to fulfill their missions. As a result, it is our duty to make sure that channels of communication are always open between ourselves (the ASM) and the governmental agencies that influence the future of our field. ASM President Robert Timm's recent (April 2007) decision to establish the ASM Working Group on Safety Recommendations for Wildlife Workers is a huge step in this direction.

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