Wilderness and Environmental Medicine, **17**, 15–20 (2006)

ORIGINAL RESEARCH

Coliform Bacteria in Sierra Nevada Wilderness Lakes and Streams: What Is the Impact of Backpackers, Pack Animals, and Cattle?

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Objective.—The presence of coliform bacteria indicates a watershed risk for harboring microbes capable of causing human disease. We hypothesized that water from watersheds that have different human- or animal-use patterns would have differing risks for the presence of coliform bacteria.

Methods.—Water was collected in wilderness areas of the Sierra Nevada range in California. A total of 60 sites from lakes or streams were selected to statistically differentiate the risk categories: 1) high use by backpackers, 2) high use by pack animals, 3) cattle- and sheep-grazing tracts, and 4) natural areas rarely visited by humans or domestic animals. Water was collected in sterile test tubes and Millipore coliform samplers during the summer of 2004. Water was analyzed at the university microbiology lab, where bacteria were harvested and then subjected to analysis by standardized techniques. Confirmation was performed with a Phoenix 100 bacteria analyzer. Statistical analysis to compare site categories was performed with Fisher exact test.

Results.—Only 1 of 15 backpacker sites yielded coliforms. In contrast, 12 of 15 sites with heavy pack-animal traffic yielded coliforms. All 15 sites below the cattle-grazing areas grew coliforms. Differences between backpacker and cattle or pack-animal areas were significant ($P \leq .05$). Only 1 of the 15 wild sites rarely visited by humans grew coliforms. All coliforms were identified as *Escherichia coli*. All samples grew normal aquatic bacteria of the genera *Pseudomonas*, *Ralstonia*, and *Serratia* and nonpathogenic strains of *Yersinia*. No correlation could be made with temperature or elevation. Sites below cattle-grazing tracts and pack-animal usage areas tended to have more total bacteria.

Conclusions.—Alpine wilderness water below cattle-grazing tracts or areas used by pack animals are at risk for containing coliform organisms. Areas exclusively used by backpackers were nearly free of coliforms.

Key words: water, Yosemite National Park, Kings Canyon National Park, Sierra Nevada, *Escherichia coli*

Introduction

The Sierra Nevada range snowpack serves as an important water source for California; its watershed provides nearly 50% of the state's freshwater supply.[1] It is important that this watershed be protected from microbial, chemical, and toxic pollution for users both downstream and upstream.

Within the Sierra Nevada range, over 3 000 000 acres of land have been designated as official wilderness by the National Park Service or United States Department of Agriculture (USDA) Forest Service and protected from development, logging roads, and motor vehicles.[2,3] Some wilderness areas have quotas to limit overnight camping by backpackers and use by pack animals. Most of these protected areas are in high alpine regions between 2000 and 4200 m in elevation. These high alpine lakes and streams are an especially important watershed for California because of presumed purity of water and a large quantity of precipitation in the form of snow. The water is important for not only the distant water users but also the local water users such as backpackers, campers, fishermen, and the USDA Forest Service and

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Table 1. Sites with heavy backpacking*

Wilderness area	*Place*	*Elevation (m)*	*Temperature (°C)*	*Escherichia coli CFU/100 mL*	*Other bacteria CFU/100 mL*
Yosemite	Yosemite Creek	2278	11.1	None	200
Yosemite	Budd Creek	2701	7.8	None	600
Yosemite	Townsley Lake	3154	13.3	None	5200
Emigrant	Wire Lakes	2694	19.4	None	3800
Emigrant	Blue Lake	3048	17.8	None	1100
Mokelumne	Round Top Lake	2834	17.2	None	800
Kings Canyon	East Lake	2493	13.9	None	6400
Kings Canyon	North Fork Woods Creek	2621	11.1	None	1900
Kings Canyon	South Fork Kings River (Upper Basin)	3078	12.2	None	4400
John Muir	Chicken Foot Lake (Little Lakes Valley)	3288	11.6	200	2900
John Muir	Ruwau Lake	3366	12.2	None	4100
Golden Trout	Chicken Spring Lake	3429	15.6	None	4600
Sequoia	Upper Rattlesnake Creek	3169	14.4	None	1100
Sequoia	Kern River	2031	16.7	None	3800
Desolation	Meeks Creek	2133	17.8	None	8900

*CFU indicates colony-forming units.

were performed by standardized automated laboratory procedures. In addition, analysis was also performed with a Phoenix 100 bacteria autoanalyzer. Strains were grown on Colombia agar with 5% sheep red blood cells for 16 to 24 hours at 37°C, replated, and grown again for 16 to 24 hours at 37°C just before testing. A suspension of 0.5 McFarland (accepted range, 0.5–0.6) was prepared in the identification (ID) broth (Becton Dickinson, Erembodegem, Belgium) and poured within 30 minutes into the panel, which was then loaded into the instrument within 30 minutes. Four quality-control strains (*Escherichia coli* ATCC 25922, *Klebsiella pneumonia* ATCC 13883, *Klebsiella pneumoniae* ATCC 700603, and *Pseudomonas aeruginosa* ATCC 27853) were loaded with each study batch, which always met quality-control criteria. The Phoenix instrument gives an ID result when a species or group of species is identified with more than 90% confidence. The confidence value is a measure of the likelihood that the issued ID is the only correct ID. The average time required to reach an ID result ranged from 3 to 12 hours. The autoanalyzer provided a computer printout identifying the bacteria. *E coli* colonies were also subjected to analysis to determine the presence of *E coli* O157 by using latex agglutination methodology.

Statistical significance among groups was calculated with Fisher exact test by STATA 8 Software (STATA Corporation, College Station, TX).

Results

The results are summarized in Tables 1 through 4. Significant differences were found among sample groups. All 15 samples that were taken below areas in which cattle grazed or had recently grazed were positive for coliform growth. From areas frequented by pack animals, 12 of 15 samples had coliforms. In contrast, coliforms were found in only 1 of 15 areas of heavy backpacking. Only 1 of 15 sites rarely visited by humans or pack animals contained coliforms. Backpacker and natural-site groups had significantly fewer sites with coliforms when compared with the cattle-grazing group ($P \geq .01$). Likewise, the pack-animal group had significantly more sites with coliforms when compared with the backpacker and natural areas ($P \geq .05$). No statistical differences were found in numbers of coliform bacteria according to water temperature or elevation.

Noncoliform aquatic bacteria were also identified from the samples. The most common bacteria found included *Achromabacter* species, *Pasteurella haemolytica*, *Rahnella aquatilis*, *Ralstonia paucula*, *Serratia odorifera*, *Serratia plymthica*, *Yersinia intermedia*, *Yersinia kristensenii*, *Yersinia frederiksenii*, *Pseudomonas putida*, and *Pseudomonas fluorescens*. No correlation could be made between site use and types of noncoliform bacteria or total bacteria counts, except for the Hall Natural Research Area, where the total bacteria range was the lowest of any group of samples. Total bacteria in the Hall

Table 3. Cattle-grazing sites*

Wilderness area	*Place*	*Elevation (m)*	*Temperature (°C)*	*Escherichia coli CFU/100 mL*	*Other bacteria CFU/100 mL*
Carson	Upper Clark Fork River	2072	11.2	250	10 000
Carson	Lower Clark Fork River	2316	8.9	300	2600
Carson	Disaster Creek—north fork	2366	10	350	1300
Carson	Disaster Creek—east fork	2438	10.6	200	5700
Carson	Arnot Creek	2000	11.1	100	4600
Carson	Woods Gulch	1976	11.7	100	5200
Hoover	Buckeye Creek (Big Meadows)	2274	12.8	500	3800
Hoover	Buckeye Creek side creek	2377	8.9	450	4700
Hoover	Molydunite Creek	2773	11.1	400	3400
Hoover	South Fork Walker River (Burt Canyon)	2719	11.1	250	2800
Golden Trout	Mulkey Meadows	2840	15.6	100	3500
Golden Trout	Little Whitney Meadow	2560	16.7	100	3500
Emigrant	Borland Lake	2264	8.9	250	8400
Adams	East Fork Chiquito Creek	2212	14.5	100	5200
Adams	Cold Creek	2503	14	150	4600

*CFU indicates colony-forming units.

Open-range cattle are noted to carry *E coli* strain O157: H7 at a rate of 1%, placing humans who drink untreated water below established cow pastures at risk for a very serious disease.[13] Studies on this strain have also shown it to survive in cold water.[18] In addition, many non-O157 *E coli* are capable of inducing serious disease in humans.[10] Although it is possible to genetically differentiate human from animal and ecologic *E coli*, these techniques are very expensive and available only in limited laboratories in the United States.

Finally, we wish to comment on the noncoliform bacteria found in the study. Aquatic bacteria are part of a normal ecosystem of lakes and streams.[19] Indeed, if bacteria were absent, the normal food chain from frogs to fish, as well as the ecological balance, would be in jeopardy. The most common bacteria we found was *R aqua-*

Table 4. Low-impact sites: rare visits by humans*

Wilderness area	*Place*	*Elevation (m)*	*Temperature (°C)*	*Escherichia coli CFU/100 mL*	*Other bacteria CFU/100 mL*
Hall area	Green Treble Lake—lower	3115	10	None	300
Hall area	Green Treble Lake—upper	3116	10	None	400
Hall area	Maul Lake	3117	10.6	None	200
Hall area	Spuller Lake	3132	11.1	None	500
Kings Canyon	Avalanche Creek	1554	8.9	None	5000
Yosemite	Middle Dana Fork Creek	3016	12.8	None	1200
Yosemite	Parker Pass Creek	2971	13.9	None	1500
Yosemite	Granite Lake	3167	14.5	None	1200
Kings Canyon	Cunningham Creek	2621	14.0	None	2300
Sequoia	Upper Buck Creek	2209	16.7	None	3400
John Muir	Little Cottonwood Creek	2996	14.5	None	1900
Kings Canyon	North Guard Creek	2895	14.0	None	2600
Sequoia	Side Spring Creek Franklin Pass Trail	3078	5	None	1200
Sequoia	Laurel Creek	2063	13.9	None	4700
Yosemite	Miguel Creek—upper north fork	1503	12.8	100	1800

*CFU indicates colony-forming units.

The Brown-headed Cowbird in the Sierra Nevada: Impacts on Native Songbirds and Possible Mitigation Measures

Brian C. Spence

Sierra Songbirds on the Decline

In May and June, thousands of songbirds arrive at their breeding sites in the Sierra Nevada, culminating migratory journeys of fifteen hundred miles or more from winter homes in Central and South America. This return *should* be a welcome respite for many. In recent years, the wanton clearing of land in the tropics has rendered inhospitable millions of acres of wintering habitats annually. Yet once back in the Sierra Nevada, songbirds face additional and significant threats to their survival. Among these is the brown-headed cowbird.

Cowbirds are "brood parasites" that lay their eggs in the nests of other birds, often resulting in reduced reproductive success or complete reproductive failure for the host species. Their expanding geographic range and high fecundity have led scientists to implicate them in the regional decline of songbird populations in eastern North America (Brittingham and Temple 1983). Now, biologists are equally concerned about the role cowbirds are playing in the recent and dramatic decline of Sierra songbird populations (Graber 1990).

Cowbirds in the Sierra Nevada

Cowbirds are not native to the High Sierra. Historical records indicate that cowbirds were absent from the entire Sierra Nevada prior to 1930 (Rothstein et al. 1980). They were first recorded in Yosemite Valley in 1934, and have been expanding their Sierran range ever since (Airola 1986, Gaines 1977, Rothstein et al. 1980, Rothstein et al. 1987). Now, cowbirds are frequently seen in mid-to-high elevation areas around human developments, and sightings deep in the Sierra wilderness are not uncommon (Beedy and Granholm, 1985; D. Graber, NPS, pers. comm.).

The cowbirds' habitation of the middle elevations of the Sierra Nevada has resulted from human alteration of natural ecosystems. Logging and other land clearing activities have increased the amount of open habitat, which cowbirds prefer. In the higher elevations of the Sierra Nevada, the invasion of cowbirds has been made possible by the presence of stock, both livestock and recreational (Rothstein et al 1980, Verner and Ritter 1983, Rothstein et al. 1987). Insects and waste grain associated with manure provide a rich food base that allows cowbirds to survive and breed successfully in harsh mountain environments. The cowbird's attraction to pack stations in the Sierra is well documented (Fleischer et al. 1988, Keys et al. 1986, Rothstein et al. 1980, Rothstein et al. 1987, Verner and Ritter 1983, Yokel 1989, and others). On the east side of the Sierra, large aggregations of cowbirds are found primarily near pack stations (since cattle are less common), while in the western Sierra they are abundant at both pack stations and among herds of grazing cattle (Rothstein et al. 1980, Verner and Ritter 1983, Rothstein et al. 1987). Other human-based food resources, such as bird feeders and campgrounds (where unwitting campers feed cowbirds), may compound the problem. Nevertheless, when researchers wish to study or collect cowbirds in the Sierra, they invariably target pack stations and other aggregations of livestock because they are assured of finding birds there.

respectively, in the vicinity of the Sierra Meadows Pack Station at Mammoth Lakes, California. Assuming that females laid eggs at the average rate for this site (30.5 per female; Fleischer et al. 1987), the potential reproductive output for marked birds alone was over 2700 eggs per year during each year of the study. This represents a conservative estimate of the total cowbird egg potential since the authors only captured a portion of the total females present. Yokel (1989) also determined the population density of cowbirds in nearby breeding areas and found it to be 18 females per square kilometer. This indicates that about 550 cowbird eggs were laid *per square kilometer of breeding habitat*.

In some areas, cowbirds may be limited by the availability of host nests, so not all of these eggs necessarily end up resulting in cowbird young or reduced host success. Still, even these conservative estimates illustrate the considerable threat that cowbirds pose to native songbirds, particularly since songbird populations in those areas with limited host-nest availability may be those that are most susceptible to cowbird parasitism (i.e. they are small, localized populations).

Solutions to the Cowbird Problem

There are several potential solutions to the cowbird problem in the High Sierra. Clearly pack stations and herds of cattle within and adjacent to wilderness areas are the primary contributors to the problem in alpine and subalpine areas, as well as many mid-to-high elevation coniferous forests. Trapping of cowbirds has been suggested as one alternative; however, attempts to remove cowbirds by trapping has proven futile elsewhere in the Sierra Nevada. Removal of 125 birds from the Wishon Lakes Pack Station had little effect on the total cowbird population in the area, partly because nearby meadows with cattle provided additional feeding sites (Rothstein et al. 1987). Additionally, conventional traps usually are more successful at catching male cowbirds, rather than females (A. O'Loghlen, UCSB, pers. comm.).

Others have suggested that tape-recorded calls of cowbirds could be used to draw females out of cover, where they could then be shot. This option, though more efficient since it targets female birds, is obviously not viable in national parks, where guns are prohibited. Moreover, such a program would undoubtedly encounter significant public opposition no matter where it was practiced, both because of the public's inherent dislike of such methods, and because it would disrupt the solitude that many visitors come in search of when they visit the Sierra.

Successful elimination of the cowbird problem will only be achieved by removing the unnatural food sources that have allowed these birds to expand their range. This means removing pack stations, cattle, and sheep from areas within and adjacent to wilderness areas. Most cowbirds leave the Sierra Nevada following the peak breeding season of native birds (from May through July). A potential alternative to complete elimination of pack stations and cattle grazing would be to delay these activities until *after* the conclusion of the cowbird breeding season in early August. Neither of these options would necessarily limit recreational stock use by private individuals; problems are most critical where stock density is sufficiently high to attract the birds.

Conclusions

National park and forest lands within and adjacent to wilderness areas offer critical refugia for many songbird species whose lowland and wintering habitats have been irrevocably altered by

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Horses in Diapers Help Mexico's Beach Clean-up

August, 2003

ROSARITO, Mexico — See-through and peek-a-boo are always in style on Mexico's beaches, but this summer, horses are making a fashion splash on the Pacific coast. Beachside entrepreneurs who rent horses for jaunts on Rosarito beach in the Pacific state of Baja California are dressing the animals in diapers as part of a countrywide effort to cut down on pollution along Mexico's nearly 7,000 miles of coastline.

Roberto Machado, who has rented horses in Rosarito beach for 23 years, estimates that one horse produces about 57 pounds of manure each day. When the town was small, it wasn't a serious problem. But the horse rental business boomed along with the tourist industry. Now, 20 corrals rent about 150 horses each day during the peak summer season. Not every horse owner uses the diapers, fabric and leather sacks which have to be emptied every three to five hours. Manure as well as trash from overflowing garbage cans gathers on parts of the beach.

The horse diapers were invented by Martha Nevarez, a Rosarito resident who became concerned a year ago when her daughter developed a rash after an afternoon of fun in the sand. Nevarez had seen large clumps of horse manure and wondered if they could have been the cause. After talking to her doctor and a local veterinarian, Nevarez learned that people can contract a range of diseases from exposure to manure and feces from animals. After months of trial and error, Nevarez came up with a fabric and leather sack that wraps around the horse's chest and rear end. There is a hole for the tail and a heavy bag that collects the manure.

For about $53, local businesses buy the sacks with the business name, address and phone number splashed across the horse's rear, then donate them to the corrals that rent horses. That way, they get some advertising and help keep the beaches clean, Nevarez said.

Source: ENN, Reuters

By Enrique García Sánchez

March 17, 2003

ROSARITO BEACH – Martha Nevárez began to worry on a summer afternoon when her 6-year-old daughter developed bumps on her abdomen after spending a couple of hours in the sand.

After looking into probable causes, including talking to local veterinarians, Nevárez discovered something that showed her worry was justified.

Her daughter, along with thousands of other visitors to the beach, unknowingly faced the risk of contracting diseases – ranging from minor skin infections to tetanus – because of the tons of manure deposited on beaches each year by the hundreds of horses rented by tourists.

That will change by the end of this month, when some of these horses begin wearing a type of diaper, which Nevárez calls a "talaquilla." She developed it to curb the pollution problem. The device, sponsored by the local hotels, is designed to reduce manure on the beaches, thus helping to prevent health problems.

"It's excellent. I believe this product will be used around the world because it's a solution," said Fidelfa Marchesini, the representative in Rosarito of the state tourism department.

Some horse owners have reacted with disbelief over the device, and others were outright rude.

Roberto Machado is one owner who has agreed to try one of the devices after Nevárez worked hard to persuade him.

Machado and other owners manage about 35 horses, which are rented for $7 per half-hour in the heart of Rosarito, the main tourist area.

He does acknowledge the health problems associated with horse manure on the beach, but believes the problems are not as serious as those faced by people and animals in the stables, where the waste is concentrated.

During a workday, a horse can leave about 33 pounds of manure on the beach.

On average, 250 horses are rented by tourists, though the state tourism representative believes that number doubles in the summer.

"We want to use the talaquilla, but once we are all ready, so we can all start at once, and everyone commits to using it," Machado said.

Los Angeles resident Leonardo Carmona Contreras thinks the diaper is a fine idea. Contreras and his family can ride horses for less money in a small area of Griffith Park, but prefer to do it in Rosarito.

"It seems to work, and it's good that they use it. I only wish someone would worry more about these horses," said Contreras, who was visiting Rosarito Beach with his family.

Nevárez has patented the device in Mexico, the United States, Canada, Spain and Portugal, but does not want to market it anywhere else until it proves to be a success in Rosarito, her home.

"This thing is now personal."

Place to purchase

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August 6, 1999

Mr. Jeffrey E. Bailey
Forest Supervisor
Inyo National Forest
873 N. Main Street
Bishop, CA 93514

Dear Jeff:

I wanted to write a brief note and thank you for your invitation to visit the wilderness in your forest. It has always been one of my favorite places in the world--feelings that strongly reemerged on my recent trip. I imagine it must be exciting and a bit intimidating to have the responsibility to maintain or enhance the long-term value of such a place.

I learned a lot in my time there and hopefully was able to share some ideas, knowledge and management philosophy that will be of use there. The backpack trip was quite useful to observe the variation in conditions (particularly trails, campsites and numbers of people) in the different upper tributaries of Mono Creek. Those provided a good sense for what the recreation management strategy could more formally and effectively provide. I remain convinced that the future value of those wildernesses will be highest if it is possible to protect any large areas with low use that remain.

The specifics of what I learned and shared are too numerous to include here. I also choose here--as I did on my visit--not to make specific recommendations. The right thing to do is not science-based--rather it is a reflection of societal values which remain vague and challenging to assess. I continue to suggest collaborative processes within an LAC-type format as the best way to access and plan based on broad societal values. I also believe that the recreation management strategy can be usefully applied in your wilderness and was happy to hear that it will be addressed in the plan. I also suggest that when you consider the array of available actions, that you include legitimate possibilities even if they are politically unfeasible. This will better illustrate how much things have been compromised when a compromise is reached. An example might be my idea about management being an attempt to reduce and ration impact. This implies the need to incorporate the difference in impact potential between a horse group and a hiker group (which often is as much as 10 to 1, given the same party size). You will ultimately not use this information (probably), but not using this is already a concession to horse groups.

Finally, let me tell you how impressed I was with your staff. I do a lot of similar consultations around the U.S., but your group was the best example of a team full of enthusiasm, experience and willingness to think and learn that I have ever met. I am not sure how or why that is the case. Certainly many years of commitment to such an important place is a key. But there also is the appearance of information sharing, experience sharing and working together to generate, criticize and evaluate ideas that seems important and missing most other places. I hope you can continue to maintain that attitude within that team in the future. I am certain it will result in better wilderness management and reflection on you, your team and the Forest Service in general.

I am invested in your issues and efforts. Please do not hesitate to let me know how I can be of further help. And thanks again for the invitation.

Sincerely,

DAVID N. COLE
Research Biologist