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Reducing the impact of summer cattle grazing on water quality in the Sierra Nevada Mountains of California: a proposal

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ABSTRACT

The Sierra Nevada Mountain range serves as an important source of drinking water for the State of California. However, summer cattle grazing on federal lands affects the overall water quality yield from this essential watershed as cattle manure is washed into the lakes and streams or directly deposited into these bodies of water. This organic pollution introduces harmful microorganisms and also provides nutrients such as nitrogen and phosphorus which increase algae growth causing eutrophication of otherwise naturally oligotrophic mountain lakes and streams. Disinfection and filtration of this water by municipal water districts after it flows downstream will become increasingly costly. This will be compounded by increasing surface water temperatures and the potential for toxins release by cyanobacteria blooms. With increasing demands for clean water for a state population approaching 40 million, steps need to be implemented to mitigate the impact of cattle on the Sierra Nevada watershed. Compared to lower elevations, high elevation grazing has the greatest impact on the watershed because of fragile unforgiving ecosystems. The societal costs from non-point pollution exceed the benefit achieved through grazing of relatively few cattle at the higher elevations. We propose limiting summer cattle grazing on public lands to lower elevations, with a final goal of allowing summer grazing on public lands only below 1,500 m elevation in the Central and Northern Sierra and 2,000 m elevation in the Southern Sierra.

Key words | cattle grazing, eutrophication, non-point pollution, Sierra Nevada, water quality, watersheds

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INTRODUCTION

Cattle grazing has been a part of the landscape in remote regions of the western United States since the 1850s. In the past, much of this land was not cultivatable and not inviting to human settlement due to the harsh climate, rugged terrain or inaccessibility (Young & Sparks 1985). Thus cattle grazing over an otherwise unusable landscape served a purpose in the development and advancement of the West. However, as far back as the 1880s the detrimental effect of cattle on alpine water quality was noted, and cited as one of the reasons to establish Yosemite National Park in 1890 (Farquhar 1965; Runte 1992).

The greatest economic value of the Sierra Nevada Mountains is derived from the provision of abundant quantities of fresh water for California (Goldman 2000). Since 1900, California's population has increased from 1.5 million to over 36 million persons (US Census Bureau 2008). This large increase has placed high demands on the limited available supply of clean drinking water (Carle 2004). California's population will soon approach 40 million, and protected watersheds serve the purpose of providing a clean and unpolluted water source. The Sierra Nevada watersheds provide 50% of California's fresh water

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for domestic use (Carle 2004). Reno, Nevada is also heavily dependent upon the out flow of the Sierra Nevada, primarily from Lake Tahoe which restricted grazing many years ago.

The unique geographic features of the Sierra Nevada have resulted in challenges to maintain water quantity and quality for this essential source. Melting snow must pass through a fragile ecosystem prior to runoff into lowland reservoirs. Much of the watershed consists of surface or near surface granite or metamorphic bedrock, with little topsoil and has little buffering capacity (Moore 2000). As a result small amounts of environmental pollution may have a significant impact on aquatic life since there is little or no biogeochemical retention, transformation, or fixation of trace elements or reduction of major nutrients such as nitrogen and phosphorus. Therefore relatively small amounts of nutrient addition or habitat disturbance leads to significant impacts on nutrient flux and subsequent impacts on the aquatic ecosystems of lakes and streams. Much of this watershed encompasses roadless, remote back-country wilderness areas at high elevations that without pollutant sources should yield outstanding water quality. However, over the past 150 years there have been ongoing threats to water quality from cattle grazing that have continued despite the renewed national focus on source watershed protection and non-point pollution. The 1996 amendments to the 1974 U.S. Safe-Drinking Water Act now require that the states conduct a source water assessment, including non-point pollution monitoring and enforcement (Environmental Protection Agency 1996). The EPA placed additional regulations on specific pathogens in 2006, including *Cryptosporidium,* a protozoon pathogen commonly found in cattle. This act provides a strong legislative mandate to ensure that Sierra Nevada headwaters are not polluted from cattle grazing, or threatened from other domesticated animals. The importance of source watershed protection in the Sierra Nevada is also exemplified by the cooperative agreement between the City of San Francisco-Hetch-Hetchy Authority and Yosemite National Park. Signs exist on public hiking trails in the Tuolumne Meadows area of Yosemite outlining the need for source watershed protection (Derlet 2009, unpublished data).

DEMOGRAPHICS OF CATTLE

California has 5.5 million head of cattle, of which nearly 2 million are cows used in dairy operations (USDA 2008). Many of remaining 3.5 million head are involved primarily in beef production. Most are raised in feedlots. Some ranchers in California practice “transhumance”, by transporting livestock by truck from valley lowlands to the USDA Forest Service and U.S. Bureau of Land Management (BLM) lands in the Sierra Nevada in the summer in relation to forage availability (Sulak & Huntsinger 2002). In California, winter lowland range generally consist of valley and foothill grasslands and oak savanna, less than 300 m in altitude, while the summer Sierra ranges are usually high elevation mountain meadows, at altitudes up to 3,100 m, and are snow covered much of the year. Based on available Forest Service data fewer than 40,000 head of cattle are moved to Sierra Nevada mountain areas for summer pasturing. Such use of mountain range grazing on public lands in the Sierra Nevada predates the establishment of the National Forests in 1906, but was institutionalized and is now controlled through the granting of summer grazing permits by the U.S. Forest Service. To accommodate differences in forage productivity with ecotype and use of rangelands by different types of livestock, the Forest Service and other federal agencies allocate grazing privileges on public lands based on an Animal Unit Month (AUM) or “head month” which is the amount of forage that a mature cow and her calf (or the equivalent, in sheep or horses) can eat in 1 month. In California as a whole, the Forest Service allows livestock grazing on about 12.4 million acres of forest land that have the potential to provide about 486,384 AUM of forage of which some 374,089 AUM (76.9%) were used in 2004 (GAO 2005). Grazing allotments in the Sierra are less than half of the entire state. The Forest Service charges livestock operators $1.35 per AUM to graze livestock on the federal lands, or about $4.05 per cow for the summer. This is heavily subsidized since the actual cost to the Forest Service is $12.26 per AUM just to recover the costs of administering the grazing program (GAO 2005). While some ranchers may experience a cost benefit of inexpensive grazing land, long-term societal costs are higher, in terms of both ecological and public health costs.

The ecological costs of grazing on public lands can be dramatic, and include loss of diversity, lowering of population densities for a variety of taxa, disruption of nutrient recycling and succession, and changes in the characteristics of terrestrial and aquatic habitats (Fleischner 1994). The problems of cattle grazing on many of natural resources and ecosystems, especially degradation of aquatic habitats are well documented (Belsky *et al.* 1999), as are impacts to water quality (Derlet & Carlson 2006). We believe the public health costs to California of summer livestock grazing in the Sierra Nevada exceed its benefits. As far back as 1965, experts on the Sierra Nevada recognized that there was no real net economic benefit to the cattle industry to summer cattle grazing in the Sierra Nevada (Farquhar 1965). Despite discussions on the impact of cattle grazing in the Sierra Nevada, the some ranchers have recently pressured the USDA Forest Service to expand cattle grazing tracts (USDA Forest Service 2006).

EUTROPHICATION OF THE WATERSHED

Globally, concern has been raised about serious threats to the planet's drinking water supply from eutrophication of watersheds (Conley *et al.* 2009). Over the past 150 years, deposition of rate-limiting substances such as phosphorus (P) and nitrogen (N) compounds has resulted in eutrophication of much of the Sierra Nevada, with increases in phytoplankton species and biomass (Goldman 2000). Cattle manure contains high amounts of both N and P compounds, and 100 head of cattle will collectively deposit 50 kg of N and 25 kg of P each day on the range, based on a mean animal weight of 400 kg (Ohio State University 2006). Thus, fecal matter from cattle with N and P as well as other nutriments contributes to the eutrophication process (Belsky *et al.* 1999). In addition, this has promoted conditions which increase bacteria, other microorganisms, and the frequency of algal blooms (Yers *et al.* 2005; Conley *et al.* 2009). Non-point pollution from cattle waste poses a serious eutrophication threat to both surface and ground water sources at both higher and lower elevations (Klott 2007). This promotes imbalance in the ecosystems with accelerated eutrophication through fertilization of algae favoring the undesirable cyanobacteria at the expense of the more desirable diatoms and green algae (Horne & Goldman 1994). Cyanobacteria have been linked to the death of over 100 head of cattle in alpine regions of Switzerland as a result of excessive growth of this algae and secretion of the toxin microcystin in normally oligotrophic lakes (Mez *et al.* 1997).

In lowland grassland areas many nutrients and toxic substances are fixed or adsorbed to soil particles and soil fungi, which can greatly reduce nutrient loading of surface waters. Although P is adsorbed to soil particles and tends to be retained by the earth, N in contrast moves easily through soil, which then flows into ground water, which in turn reaches stream drainage and eventually to California's lakes and reservoirs (Horne & Goldman 1994). However, because much of the Sierra Nevada is granite with only a thin layer of soil in some areas, the adsorptive ability for P by soil is limited, thus allowing P to enter lakes and streams (Goldman 2000). Cattle grazing can also impact aquatic life. A study in the Golden Trout Wilderness which compared grazed with non-grazed areas showed a decreased fish biomass in grazed areas (Knapp & Matthews 1996). Mountain insects have also been found to have been affected in cattle grazing areas (Del Rosario *et al.* 2002).

Some cattle are grazed in specially designated Wilderness areas of the Sierra Nevada, where over-night human visitation is restricted to limit impact on the wilderness eutrophication by humans. However, the focus on humans is misguided. Range cattle excrete a mean of 50 kg/day of wet weight manure into the alpine landscape (Ohio State University 2006). In contrast, healthy human waste is only 0.10 to 0.15 kg/day (Rendtorff & Kashgarian 1967). Thus, each head of cattle produces up to 500 times as much waste as a single human in a single day and therefore each animal impacts the environment far more than each human.

HARMFUL MICROORGANISMS

Cattle excrete microorganisms which can be harmful to humans (Berry *et al.* 2006). Our studies have also shown significantly higher levels of both heterotrophic and pathogenic microorganisms in the Sierra Nevada areas where cattle graze, compared with non-grazing areas (Derlet & Carlson 2004, 2006; Derlet *et al.* 2008).

In watersheds where cattle have grazed, 96% of surface water samples contained significant indicator levels of *E. coli* of 100 CFU/100 ml or more, placing these waters at high risk for harboring the large variety of harmful micro-organisms (Derlet *et al.* 2008). In contrast, the California water board does not allow more than 2.2 CFU/100 ml of *E. coli* in water used to irrigate vegetable crops. Thus, Sierra water in cattle grazing watersheds may contain 40 times as many *E. coli* as would be allowed to be used on vegetable crops. In contrast, adjacent non-grazed watersheds had a prevalence of less than 10% medically significant *E. coli*. *E. coli* and coliform bacteria have long been established as indicators of fecal pollution of watersheds and water supplies (American Public Health Association 1998). Diseases such as entero-invasive *E. coli*, *Giardia*, *Cryptosporidium*, *Salmonella*, *Campylobacter*, *Yersenia* species and other microbial pathogens, some that can survive for extended periods in the environment, are likely to be among those present. (Harvey *et al.* 1976; Byappanahalli *et al.* 2003). Cattle serve as asymptomatic carriers for many of these organisms. One recent study found as many as over 50,000 *Giardia* cysts/gram of cattle manure in asymptomatic infected cattle (Gow & Waldner 2006). Thus over 2 billion cysts may be excreted from an infected animal each day based on 50 kg of manure/day, enough to infect several million persons with the minimal infective dose of 10 cysts. Removal of the entire list of pathogenic bacteria by municipal water districts is an expensive multi step process. In Milwaukee, municipal water intake of accidental sewage spillage near intake pipes led to nearly one-third of the city population becoming infected with *Cryptosporidium*, despite standard water treatment (Mackenzie *et al.* 1994). Drought conditions increase the prevalence of pathogens and substrate, which may make some municipal purification processes less effective by concentrating pathogens (Derlet *et al.* 2008). Understanding factors that impact the water quality from any watershed is essential for intelligent and effective land management decisions.

Finding medically significant coliforms in surface water below cattle grazing areas is not unique to the Sierra Nevada, as several studies from other areas of the U.S. have demonstrated a high prevalence of coliforms in watersheds grazed by cattle (Yers *et al.* 2005). A study of South Carolina watersheds found non-point pollution with *E. coli* to be high in cattle grazing areas (Klott 2007). Miller found up to 14,000 *Giardia* cysts per liter of water in storm surface water below coastal California dairies (Miller *et al.* 2007). Cattle are also noted to carry the shiga toxin containing *E. coli* strain O157:H7 at a rate of 1 to 30%, which can be acquired from drinking partially treated or untreated water and cause illness and death in humans (Swerdlow *et al.* 1992; Renter *et al.* 2003). Shiga toxin containing *E. coli* may also be acquired from swimming, thus placing children who unknowingly play in the water downstream from remote grazing areas at risk for a disease (McCarthy *et al.* 2001). Studies on this strain have also shown it to survive in cold water so characteristic of high Sierra lakes and streams (Want & Doyle 1998). In addition as previously noted cattle manure contains high amounts of N, P and other growth factors for algae. These particulate and dissolved organic substances also create an aquatic environment that supports survival of pathogenic microorganisms (Horne & Goldman 1994; Miettinen *et al.* 1997; Jasson *et al.* 2006; Tao *et al.* 2007). Despite these human health concerns, the US Forest Service initially increased cattle grazing tracts in a Sierra Nevada Wilderness (USDA Forest Service 2006).

IMPACT TO WATERSHED GROUND VEGETATION

Livestock grazing and livestock grazing operations may severely disrupt sensitive ecological communities which in turn affect water quality (Belsky & Blumenthal 1997; Belsky *et al.* 1999). Some authors attribute significant impacts to "overgrazing" implying there is a level of livestock grazing that has less significant impacts (Allen-Diaz *et al.* 1999). Cattle degrade habitat by trampling and eating vegetation, compacting soils, impacting riparian systems, and affecting water quality. When livestock degrade habitat, they also impair the survival of many animal and some of the plant species upon which they depend. For example, aspen groves in the Sierra Nevada forests are rare but important areas of high biodiversity (Rogers *et al.* 2007) that enhance watershed capacity by storing seven times more water than conifers that have been changed in abundance and distribution by livestock grazing (Bartos & Campbell 1998). Kay & Bartos (2000) found that although elk and deer graze on aspen most herbivory of aspen was from livestock not from wildlife. Recent conservation recommendations include reintroduction of top predators to the Sierra Nevada (Rogers *et al.* 2007) but this would require an end to domestic livestock grazing. Aspen restoration has become a priority for California Department of Fish and Game's wildlife management and habitat conservation programs.

Livestock trampling has both direct and indirect effects on vegetation, soils and water runoff. (Abdel-Magid *et al.* 1987). The natural replacement of aged conifers is jeopardized, as new seedlings are trampled to death after germination. The Lens-pod Milk-vetch, *Astragalus lentiformis*, is a rare endemic plant that is only found in one district of Plumas National Forest in the northern Sierra Nevada range. The Forest Service has documented 55 occurrences of the Lens-pod Milk-vetch most of which are located in grazing allotments. Plants in the *Astragalus* family tend to be unpalatable to livestock but the Lens-pod Milk-vetch is susceptible to trampling and, as various Forest Service botanical evaluations admit, "The trend for this narrow endemic is unknown". Despite this, in the past 2 years the Forest Service has reauthorized cattle grazing on nine allotments that account for 49% of the known occurrences of the Lens-pod Milk-vetch without analyzing the cumulative impacts to the plant. Water runoff from snowmelt or rain through trampled areas carry eutrophic substances into lakes and streams.

Impacts to aquatic wildlife may occur at the individual and at the population level. On example is the Yosemite toad, which is a rare amphibian found in high elevation meadows in the central Sierra Nevada that is a candidate for listing under the Endangered Species Act (USDI 2002). Outbreaks of red-leg disease and infection with a Chytrid fungus have contributed to die-offs of Yosemite toad populations (Davidson & Fellers 2005). The occurrence of the toad in high altitude meadows that are National Forest rangeland puts individuals at risk of being trampled by the herds of grazing cattle that concentrate there. Small toads may even get trapped and die in deep hoof prints or under fecal matter. However, population level impacts may also occur. Alterations to meadow hydrology such as lowering of the groundwater table and summer flows can strand tadpoles or make breeding sites unsuitable; lowering of the water table in meadow habitat through stream incision resulting in breeding habitats drying out prior to metamorphosis of the tadpoles; cattle may negatively affect upland habitat through grazing and trampling of willows that are used for refuge, foraging, and over wintering; cattle may also trample and collapse rodent burrows that are used for over-wintering or seasonal refuge. Because cattle move between meadows, they may act as vectors to transmit infective pathogens between different populations. Spores of *Batrachochytrium dendrobatidis*, the fungus linked to the toad die-offs, can survive for at least 7 weeks in water (Johnson & Speare 2003). Livestock carrying mud on their hooves and moving between meadows are likely to spread the pathogenic fungus (Parris 2006). Because cattle routinely move between meadows and may be herded through an entire meadow system during the season, they could move the fungus between meadows leading to local extirpation of the species.

IMPACT OF CLIMATIC CHANGE

The American Society for Microbiology has become concerned about increasing surface water temperatures (Dixon 2008). Predicted increases in temperatures from climatic change will warm streams creating more favorable conditions for growth of toxic algae and pathogenic microorganisms (Coats *et al.* 2006). A number of studies have correlated increased water temperatures with increases in algae growth (Paerl & Huisman 2008). Toxins from species-specific algae have been implicated in waterfowl deaths and human illness and are not removed by standard municipal water disinfection processes (Falconer & Humpage 2005; Lopez-Rodas *et al.* 2008). Several researchers at the University of California, Davis have shown that surface water temperatures in the Sierra like many lakes in the Northern Hemisphere are increasing (Coats *et al.* 2006). Lake Tahoe's entire water column has increased one degree in the last 30 years and surface waters have warmed by four degrees. Climate models predict that the warming trend will continue. Visible algae in many High Sierra lakes and streams has increased over the past 20 years (Goldman & Derlet 2009, unpublished data). In a recent study of Lake Tahoe specifically, planktonic diatom numbers were found to have increased from 1982 to 2006, and after controlling for multiple factors, increased water temperature was shown to be the single factor behind this increased form of algae (Winder *et al.* 2009). This trend may only intensify the problems already related above by increasing the rate of eutrophication and providing an ideal environment for toxic cyanobacteria. Furthermore the predicted increase in rapid melting of the Sierra Nevada annual snow pack will harm ecosystems (Coats *et al.* 2006). In this regard, conifer shading is even more important to slow snowmelt and preserve the "snow pack reservoir" function of these mountains. The tramping of seedlings by cattle can prevent new conifer growth thereby reducing shading vegetation so soil and snow is exposed to direct solar radiation and rapid melting and runoff.

A PROPOSAL TO ENHANCE WATERSHED PROTECTION

We propose limiting summer-time cattle grazing in the Sierra Nevada Mountains on public lands to lower elevations. Our proposal is based on collective research as discussed above and the authors' observations on watershed geology, climate, precipitation, snowmelt, flora and fauna of the alpine regions of these mountains. Summer cattle grazing at the end of a five-year phase in period should be restricted to areas below 1,500 m elevation in the Central and Northern Sierra and 2,000 m elevation in the Southern Sierra. We define Southern Sierra as Sierra south of the Kings-Sequoia NP boundary by latitude, and land north of this as Central and North Sierra. To achieve this goal, a step-wise phase out should occur over a five-year period. As higher elevations are the most ecologically sensitive, it would be preferable if cattle could first be removed from grazing above 2,500 m in the Central and North, and 3,000 m in the South. Each succeeding year the elevation limits should be lowered 200 m until the final goal is achieved. Thus 5 years would have elapsed from initiation to achieving a phase out at these elevations. This will protect the most vulnerable and valuable portion of the Sierra Nevada watershed. In the Lake Tahoe basin, grazing has nearly been phased out with improvement in surface water quality flowing into the lake (Goldman 2008, unpublished data). Certain exceptions to the proposal may be reasonable, for example the large flatlands east of the Sierra crest such as the Bridgeport Valley east of Yosemite and Sierra Valley northwest of Reno. These two large grassland valleys have multiseason use from cattle and other agricultural usage.

As an alternative, the phase out of alpine grazing on public lands in the Sierra Nevada could be accomplished by a permit buyout process. Adoption of a moratorium on issuance of any new permits for currently vacant grazing allotments at altitudes above 2,000 m could be combined with a buy-out option for existing permittees in a voluntary relinquishment program. Funding for these buy-outs could come from federal land and Water Conservation funds, conservation organizations, mitigation agreements, and other federal, state and local government agencies. There are many examples of the success of such programs. For example, the California Desert Protection Act of 1994 allowed for the voluntary relinquishment of permittees to end livestock grazing in the expanded and newly created units administered by the National Park Service. Since that time, most of the permits have been acquired and retired largely through the activity of various conservation organizations. The recent Owyhee Initiative, signed into law in the Omnibus Appropriations Act of 2009, allows for buy out and voluntary relinquishment of grazing privileges to protect Wilderness Areas. While a buy-out process is likely to be slower and less coordinated, both the affected resources and the local ranching communities would benefit, creating a win/win scenario. Impacts to sensitive plants, animals and their habitats would be reduced, water quality enhanced, and ranchers would have the funding to move their operations to more appropriate and productive areas. The long-term cost savings to the Forest Service would be considerable.

Phase out proposals should be adopted as soon as possible to ensure long-term protection for this crucial source of water for California, which from recent reports may face the development of water shortages which will worsen in the face of global climate change.

CONCLUSION

Cattle have a negative impact on high elevation watersheds of the Sierra Nevada Mountains. Phasing out high elevation summer cattle grazing from source watersheds should improve water quality. Restricting cattle from the higher elevations will affect less than one of every hundred head of cattle in California. As a result the impact of this proposal on California's cattle industry would be relatively small and the potential benefits larger to the safety and health of children and adults in the State.

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