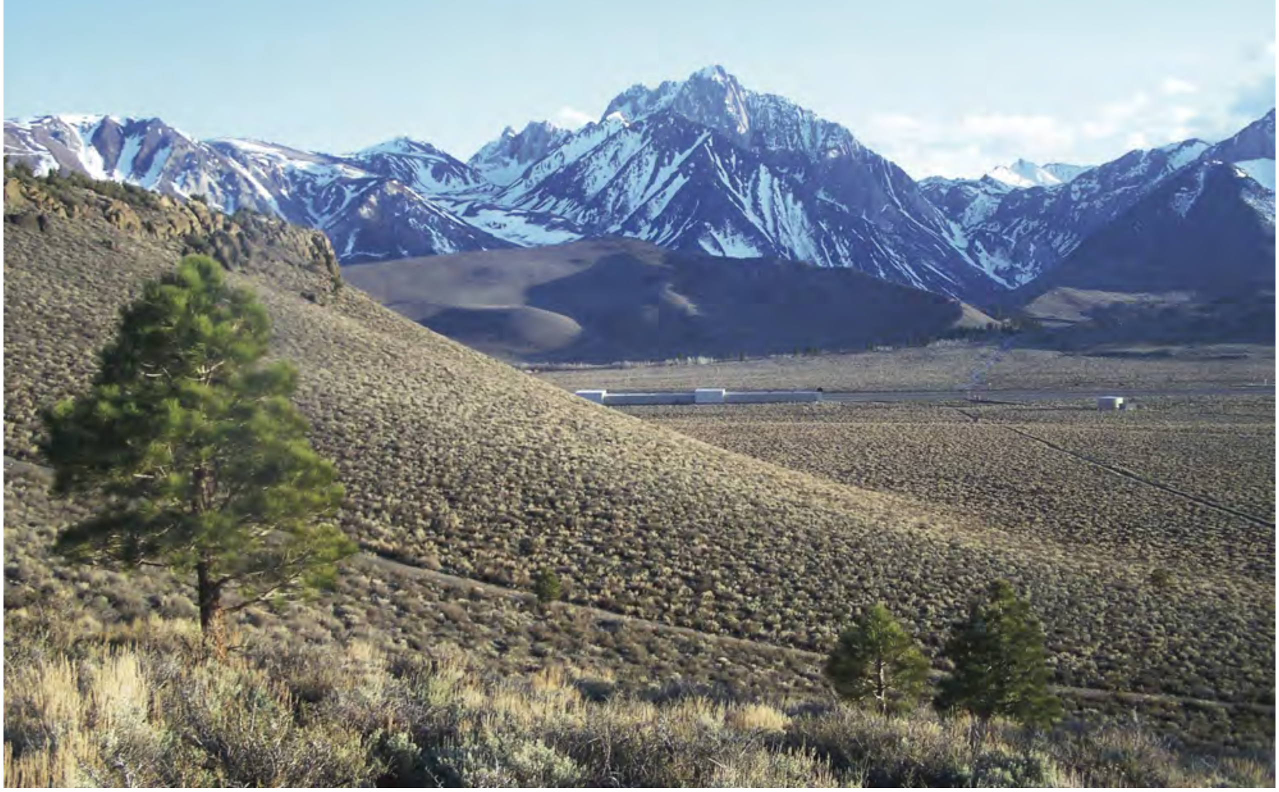


The eastern Sierra Nevada is a land of extremes in climate and topography. Although the region has remained relatively pristine, it faces new challenges with climate change and invasive species encroachment. All photographs by the author unless otherwise noted.

THE SPREAD OF CHEATGRASS INTO THE EASTERN SIERRA

by Amy Concillo

[Author's Note: Amy Concillo was a recipient of an educational research grant from CNPS, which helped to support the restoration component of her doctoral work.]

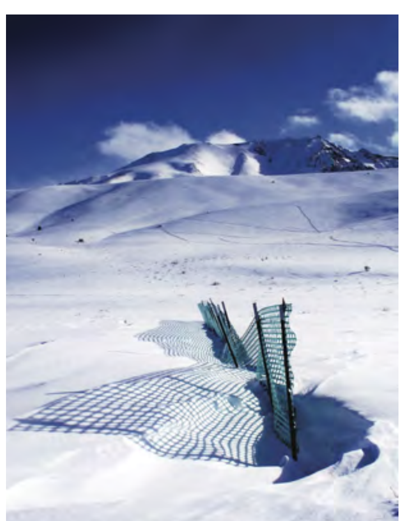
The Sierra Nevada drops sharply along its eastern escarpment from peaks over 14,000 feet in elevation to the Owens Valley 10,000 feet below, providing dramatic, breathtaking views eastward to the White Mountains. This extreme environment has protected native plants and animals at upper elevations from disturbances such as development, roads, traffic, and cattle grazing, leaving ecosystems in a relatively pristine condition. However, montane regions face new challenges from climate change and invasive species (Pauchard 2009).

Temperature drops markedly along the steep topographic gradient of the eastern Sierra Nevada escarpment. It can differ by as much as 25° F from the ridge tops to valley floor and gives rise to a range of different plant communities. Climate change models predict that temperature will increase significantly in the Sierra Nevada over the next century, which is likely to cause species to move to higher elevations. Invasive species may be particularly well-suited to capitalize on these changing conditions due to their high rates of seed dispersal and establishment.

In the eastern Sierra Nevada, of particular concern is the spread of the invasive annual grass, *Bromus tectorum*, commonly known as cheatgrass or downy brome. Although ubiquitous throughout the Great Basin, cheatgrass growth is patchy at high elevation, most likely due to cold winter temperatures and deep snowpack (Chambers et al. 2007, Griffith and Loik 2010).

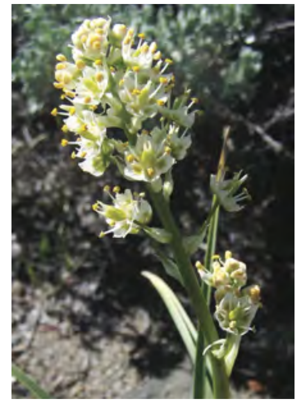
Cheatgrass gains dominance over native plants by increasing the frequency of fire. It germinates in the fall if there is sufficient soil moisture, overwinters as a seedling, completes its life cycle by early spring, and then dries out, thereby creating a fuel load ripe for ignition. Native bunchgrasses and shrubs are poor competitors with cheatgrass at the seedling stage, so more fire promotes

Snow fences have been used to manipulate snow depth and study the effects of climate change on cheatgrass spread in the eastern Sierra Nevada.



more cheatgrass. Although cheatgrass exists in the eastern Sierra Nevada, it has not yet reached the densities necessary to transform the fire cycle. Its impacts have, therefore, been minimal in California compared to those in other parts of the Great Basin. But how might climate change affect its spread?





In the most dense cheatgrass infestations, native forb diversity is markedly reduced. Some species that are often missing from these sites include (LEFT TO RIGHT): desert paintbrush (*Castilleja angustifolia*), Wilcox's eriastrum (*Eriastrum wilcoxii*), and sandcorn (*Toxicoscordion paniculatum*). It is not yet clear whether cheatgrass invasion is leading to reduced biodiversity, or whether areas of high biodiversity are less likely to be invaded by cheatgrass.

CHEATGRASS RANGE EXPANSION

Changing temperatures due to climate change may affect plants directly by increasing (or decreasing) the potential area where they could grow (due to physiological limitations), or indirectly through their effect on precipitation. In an arid region like the Great Basin, precipitation matters a lot! Total precipitation is not the only critical factor—the type of precipitation, as snow or rainfall, and timing are also important.

Rainwater often falls during the hotter times of the year due to monsoon rains, can evaporate quickly from the dry soil surface, and provides water primarily for shallow-rooted species. On the other hand, water from snowmelt percolates into the soil, recharges the groundwater, and provides a more consistent supply that deep-rooted species are able to tap into throughout the long, dry summer. The dominant native shrubs and bunchgrasses of the Great Basin are perennial species that get most of their water from snowmelt. A shift from snow to rain, likely with temperature increases, may favor short-lived annual plants, including cheatgrass. Another consequence of increasing temperature will be a shift toward earlier snowmelt dates, which could mean prolonged drought for the area. Coincident with these changes, we expect to see shifts in plant community composition.

Recent research suggests that cheatgrass expansion at high elevation may depend on the timing of snow and rain events. Alden Griffith and Michael Loik (2010) measured cheatgrass population growth in response to increased and decreased snowpack. They used snow fences to create different snow pack depths to mimic the potential impacts of climate change. They found that decreased snow was associated with decreased cheatgrass population growth, which was attributed to earlier onset of drought. However, research at the same site with an experimental increase in springtime rainfall suggests that a shift from snow to rain may be more likely to facilitate cheatgrass range expansion at high elevation, depending on the timing of rainfall events (Concilio et al. 2013).

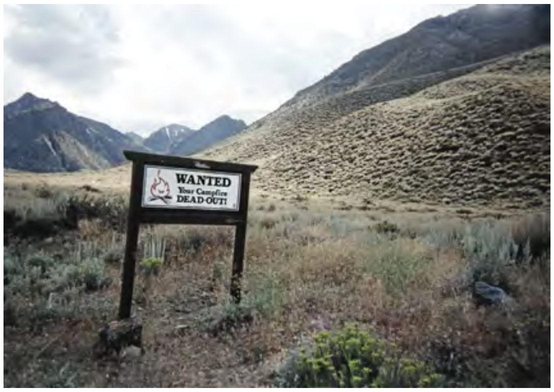
Cheatgrass already appears to be spreading at higher elevations. In 2000, Bruce Orr and Ann Howald surveyed plant communities of the Sierra Nevada Aquatic Research Laboratory, located 10 miles south of Mammoth Lakes, CA at about 6,500 feet in elevation. They described cheatgrass as being "occasional in disturbed areas." We have been monitoring the plant community at the same site in permanent plots since 2007 and found a 150% increase in cheatgrass cover over the last five years (Concilio and Loik forthcoming).

In the five most disturbed research plots (out of 54 plots total, each two square meters in size), cheatgrass cover is now over 50%. This is above the threshold (45%) at which fire danger reaches a maximum in eastern Washington (Link et al. 2006). Although the natural fire flash point for fuels is likely to differ between eastern California and Washington, this dramatic increase in cover is still alarming.

Coincident with higher cheatgrass cover, we measured a decrease in species diversity (calculated with both Shannon-Weiner and Simpson indices), although it is not yet clear whether cheatgrass invasion is affecting biodiversity or biodiversity is affecting cheatgrass invasion. Based on this data, we can expect increased impacts if these infestations are left unchecked. Based on current climatic conditions, cheatgrass has not yet altered the fire cycle. Consequently, there are still opportunities for restoration of invaded sites and conservation of uninvaded sites in the eastern Sierra Nevada.

OPPORTUNITIES FOR CHEATGRASS CONTROL

For widespread invasive weeds such as cheatgrass, control can be incredibly costly. Therefore containment—limiting the invasion to a



At upper elevations in the eastern Sierra Nevada, cheatgrass only exists along roadsides (as shown here) and in other disturbed areas likely because its growth and spread are limited by cold winter temperatures and deep snowpack. These infestations are prime candidates for control measures that could reduce spread to adjacent sites.

core area and eradicating outlier patches to stop its spread—may be a better option. In the western Sierra Nevada, the California Department of Food and Agriculture and partner agencies are using this strategy to contain the spread of yellow starthistle (*Centaurea solstitialis*) at the leading edge of its invaded range. (For more information, see "Yellow Star Thistle Leading Edge Program," http://www.cdfa.ca.gov/plant/ipc/ystmapping/ystmapping_hp.htm.) Similarly, cheatgrass infestations at high elevation along the eastern Sierra Nevada could be prime candidates for this type of management.

Above about 7,000 feet in elevation, cheatgrass occurs only along roadsides and other disturbed areas whereas native sagebrush steppe habitat is still relatively pristine. My dissertation research focused in part on how to control or eradicate these types of infestations in the Mammoth Lakes region (from 6,500 to 8,000 feet). Although herbicides are the most common approach for controlling small patches of invasive weeds such as cheatgrass, it is not always possible to do so for regulatory, economic, or social reasons. I experimented with non-technical, non-chemical weed control methods for reducing cheatgrass infestations at high elevation, including soil solarization, hand pulling, mulching, and reseeding native forbs and bunchgrasses.

Results from this work were promising. Soil solarization and mulching dramatically reduced (by 99%), and sometimes eliminated,

WHAT IS CHEATGRASS?

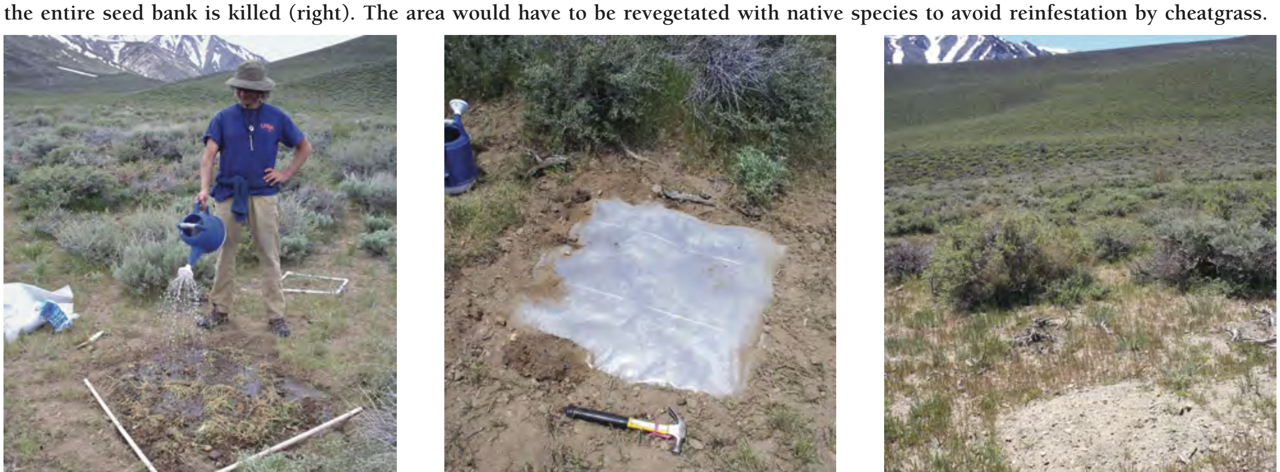
Cheatgrass (*Bromus tectorum*) originated in southern Europe and adjacent regions of Asia and Africa, and was introduced to the US in the mid-1800s, probably through ballast water from ships and contaminated grain seed. It is now present in most states, but is particularly problematic in the Intermountain West (between the Rocky Mountains on the east and the Cascade Range and Sierra Nevada on the west) where it is the dominant annual grass on sagebrush rangelands. Cheatgrass germinates early and grows rapidly, depletes soil moisture down to low levels, and can outcompete native plants at the seedling stage. It dies each year in the spring, leaving a carpet-like cover of dry grass ripe for ignition.

Historically, sagebrush ecosystems of the Intermountain West are estimated to have experienced fire at intervals of about 50 to 300 years. However, where cheatgrass cover is dense, fire frequency can decrease to as little as two to three years, and because cheatgrass is so competitive at the seedling stage, it can easily come to dominate the post-fire plant community.

In addition to its impacts on native plant communities, cheatgrass also increases costs of fire fighting, decreases the abundance of important forage species, and its awns can penetrate an animal's skin and cause painful abscesses. It is a prolific seed producer with a potential output of more than 300 seeds per single individual, and can build up large soil seed banks. Once dominant, cheatgrass is very difficult to control.

Cheatgrass when green, and after it has dried out by summer. Photographs by Jason Willand (TOP) and Steve Dewey, Utah State University, Bugwood.org (BOTTOM).

Soil solarization is one method that has been tested to reduce or eradicate cheatgrass patches. The method involves saturating the soil (left) and covering the area with an airtight tarp (middle) during the hot summer months. The soil heats up to such a degree that nearly the entire seed bank is killed (right). The area would have to be revegetated with native species to avoid reinfestation by cheatgrass.

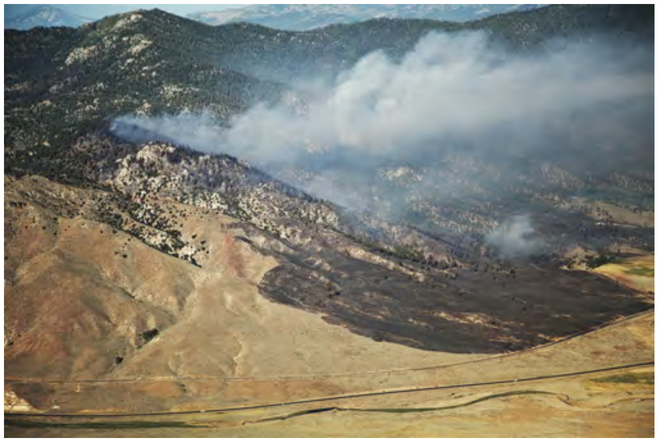


cheatgrass from plots with just a single treatment. The drawback was that these two methods were non-specific and also killed native forbs; follow-up revegetation with native plants would be necessary. Unfortunately, our reseeding trials were completely ineffective, likely due to dry conditions, and so we now think direct planting of seedling plugs would be preferable.

Although tedious and time consuming, hand pulling was also effective at dramatically reducing cheatgrass cover (by 94% after just 2 years) without any negative effects on native plants. Each of these techniques could be used with volunteer groups and would greatly reduce costs. Since funding for invasive plant removal is often not available, this could be a feasible approach for small infestations.

However, cheatgrass also exists as low-density widespread infestations in the region (at about 4,000 to 7,000 feet). In this case, complete removal would be impractical, but a reduction in cheatgrass fuel loads could help reduce its impact and prevent the transition to a grass-fire cycle. One way to manage fuel loads is through timed grazing. The Bishop, CA Bureau of Land Management (BLM) field office conducted an experiment at two sites near Coleville, CA, to determine whether or not grazing sheep in the early spring would effectively reduce cheatgrass biomass and consequently its capacity for carrying fire.

At one site, grazing led to a 30% reduction in fine fuel loads (pounds per acre), but no difference was measured at the other site. Other researchers have been experimenting with a fungus that specifically targets and kills cheatgrass seeds, which could be an effective way to reduce or maintain low cheatgrass density. (For more information, see http://www.fs.fed.us/rm/grassland-shrubland-desert/research/projects/cheatgrass-biocontrol/.)



The 2010 Constantia Fire that burned 1,369 acres in Long Valley, California very likely started in cheatgrass. Fighting such fires drains public coffers. Twelve hand crews, seven engines, one dozer, three water tenders, seven helicopters, and a crew of 452 firefighters were involved. Photograph by Nolan Preece, www.nolanpreece.net.

CHALLENGES TO CONSERVATION

Although opportunities exist to reduce the spread of cheatgrass, their practical implementation is hampered by a host of economic, regulatory, and cultural barriers (see Concilio 2012 for a complete discussion). Land managers at the BLM and US Forest Service are faced with tightening budgets, and rely on volunteer support to help with weed control work. These factors make it difficult to use methods that require technical training. State agencies and the Weed Management Areas also struggle to maintain adequate funding for weed control projects, as there is no stable long-term source of funding that has been allocated toward weed control. The resources that do exist are prioritized for those species on state or federal noxious weed lists (which are mainly agricultural pests and exclude cheatgrass).

Of course these issues are not unique to the eastern Sierra Nevada, nor are they unique to cheatgrass. Invasive species control in California needs stable sources of funding and trained personnel to implement control measures as soon as they spot incipient infestations. This need will become increasingly urgent as new challenges arise from climate change and invasive species encroachment into new areas.

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