

Exotic and Invasive Herbaceous Range Weeds

By James A. Young and Charlie D. Clements

Introduction

There is a considerable body of terminology developed during the 20th century concerning range weed control. This terminology was developed so individuals concerned with herbaceous range weeds could communicate. Nothing is more boring than terminology, but in the case of range weed control, if everyone gets on the same page in terminology, an artificially cloudy subject becomes much clearer.

A weed is simply a plant growing in a site where it is not desired. You can make up your own standards for what constitutes desirability. It may be forage production, nutritional quality, or season of growth or have little to do with forage characteristics. Watershed protection, chance of ignition and rate of spread of wildfires, and wildlife habitat are all plant characteristics that influence individual perception of plant desirability. A weed may be a desirable plant in one location and a weed in another. For example, in the salt deserts of Nevada, desert salt grass is a desirable forage species in alkaline/saline habitats surrounding playas. It is virtually the only herbaceous forage species adapted to grow in such environments. In the irrigated alfalfa fields of Nevada, it is considered a serious herbaceous weed.

Herbaceous Weeds

The separation from woody range weeds is based on the persistence of woody cells in the stems or trunk of the plants. Obviously, woody species tend to be longer-lived perennials, but herbaceous species can also be perennials. Compare the annual cheatgrass to a pinyon pine and the herbaceous versus woody separation is ridiculously simple. However, if you try to walk through an old-growth stand of the herbaceous



Landscape dominated by cheatgrass. The conversion of millions of acres of big sagebrush/bunchgrass to cheatgrass in the Intermountain area of western North America is one of the most recent and extensive range type changes to occur in the world.

perennial pepperweed, the “woody” separation becomes somewhat nebulous.

Life Form

Herbaceous range weeds can be annuals, biennial, or perennial species. Perennial species are often subdivided into short- and long-lived species. This terminology and classification seems very straightforward, but some of our worst range weeds can be annuals, biennials, or at least short-lived perennials within the same species. Diffuse knapweed is a good example. It can flower and produce seed in 1 year as an annual, remain a rosette for its seedling year and flower the following year as a biennial or, more rarely, continue for at least a 3rd year as a short-lived perennial. Such species often

List of common and scientific plant names

Common	Scientific
African mustard	<i>Malcolmia africana</i>
Alfalfa	<i>Medicago sativa</i>
Barbwire Russian thistle	<i>Salsola vermiculata</i>
Bottlebrush squirreltail	<i>Elymus elymoides</i>
Broom snake weed	<i>Gutierrezia sacrothrae</i>
Bull thistle	<i>Cirsium vulgare</i>
Bur buttercup	<i>Ranunculus testiculatus</i>
Canada thistle	<i>Cirsium arvense</i>
Cheatgrass	<i>Bromus tectorum</i>
Blue mustard	<i>Chorispora tenella</i>
Desert salt grass	<i>Distichlis spicata</i>
Diffuse knapweed	<i>Centaurea diffusa</i>
Filaree	<i>Erodium cicutarium</i>
Gum weed	<i>Grindelia squarrosa</i>
Halogeton	<i>Halogeton glomeratus</i>
Hare's ear	<i>Conringia orientalis</i>
Hoary cress	<i>Cardaria draba</i>
Juniper	<i>Juniperus</i> spp.
Medusahead	<i>Taeniatherum caputmedusae</i>
Musk thistle	<i>Cardus nutans</i>
Perennial pepperweed	<i>Lepidium latifolium</i>
Pinyon	<i>Pinus</i> spp.
Purple starthistle	<i>Centaurea calcitrapa</i>
Rabbitbrush	<i>Chrysothamnus</i> spp.
Russian knapweed	<i>Acroptilon repens</i> = <i>Centaurea repens</i>
Russian thistle	<i>Salsola targus</i>
Scotch thistle	<i>Onopordum acanthium</i>
Sicilian starthistle	<i>Centaurea sulphurea</i>
Skeleton weed	<i>Chondrilla juncea</i>
Small seeded false flax	<i>Camelina microcarpa</i>
Spotted knapweed	<i>Centaurea maculosa</i>
Squarose knapweed	<i>Centaurea squarrosa</i>
Tocalote	<i>Centaurea melitensis</i>
Tumble mustard	<i>Sisymbrium altissimum</i>
Yellow starthistle	<i>Centaurea solstitialis</i>

have plant size (ie, number of leaves in a rosette) and external environmental stimuli (winter chilling or vernalization) requirements to initiate flower production. The environmental quality of the site infested, density of the weed stand, and the amount and distribution of precipitation all interact to condition such weeds in their lifestyle. This variable life habit is surprisingly common among some of our worst herbaceous range weeds.

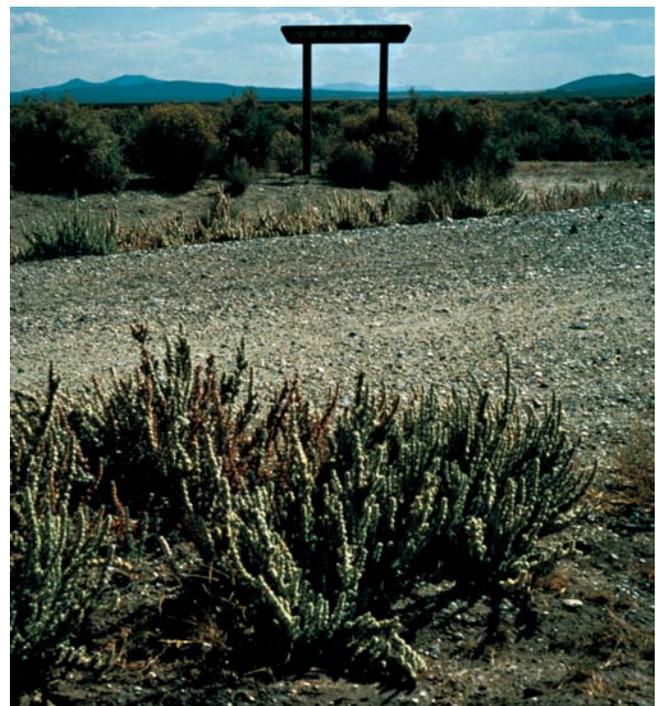
Invasive Weeds

A few decades ago when we started using this term, we modified it with “self-invasive,” meaning weeds that colonize new areas without the conscious efforts of humans. In general, usage of the “self” has been dropped. Weeds that move and invade new habitats are among the most dangerous and

destructive to the environment of the herbaceous range weed species. The common perception is that these weeds spread because of excessive or improperly managed grazing of domestic livestock. The invasive annual cheatgrass is often used for evidence of the validity of this presumption. Dr. Daubenmire clearly showed in the 1940s that cheatgrass could successfully invade bluebunch wheatgrass communities that, because of topographical barriers, had never been grazed by domestic livestock and were in excellent ecological condition.

Cheatgrass now dominates millions of acres of formerly big sagebrush/bunchgrass rangeland in the Intermountain area, but it is necessary to remember that invasion and dominance are separate aspects of the ecology of weeds. Cheatgrass dominates many areas because they were in poor ecological condition because of past excessive grazing. Cheatgrass has the ability to invade communities no matter what their seral status. Why is such knowledge important in the management of herbaceous range weeds? Many well-meaning individuals suggest, “Remove the domestic livestock from rangelands, and the invasive weed problem goes away.” Sorry, this oversimplification misses the invasive potential of cheatgrass.

More recently, Roger Sheley and his associates have clearly demonstrated that diffuse and spotted knapweed can invade range sites in the Pacific Northwest that are in high ecological condition. This does not mean that these 2 knapweeds do not do well on degraded sites. In fact, they can explode across dis-



Herbaceous range weeds are not just cheatgrass. There is an entire series of exotic invasive species that form a seral continuum from bare ground to cheatgrass dominance and beyond. Halogeton is one of the first species to invade disturbed sites. Image made at Tobar, south of Wells, Nevada, where this poisonous annual was first collected in the 1930s.



Russian thistle is another early succession species on rangelands. As indicated by mature plants collected on a fence, Russian thistle has an excellent seed dispersal system.

turbed communities. The important point is that they will have to be managed in rangelands in excellent condition.

On the opposite end of the spectrum are invasive species such as Russian thistle and halogeton. These are herbaceous range weeds that produce huge numbers of seeds per plant and have excellent seed dispersal systems. They need these dispersal systems because these are not highly competitive species and must find bare ground for seedling establishment, growth, and flowering. These species are often referred to as ruderal species because of their omnipresence on roadsides, especially unsurfaced roads that are periodically graded to repair the road surface.

A plant does not have to be exotic (see the next section) to be highly invasive. A good example is gum weed that is native to the central and southern Rocky Mountains. The herbaceous species has spread along roadsides to California, where it is considered an exotic, invasive species.



Left: Cheatgrass dominance truncated plant succession after wildfires and both ensured continued dominance and greatly reduced the interval between wildfires on the same site. Area near Midas, Nevada, burned in the 1999 wildfires that consumed over a million acres during a 10-day period. Note the unburned area on the alluvial fan that escaped the fire by chance distribution of roads. On the mountain escarpment in the middle of the image, a fire safe site is visible between 2 cliffs that probably still has native perennial grasses. Right: Seedbed of area of cheatgrass dominance burned in the 1999 wildfires in Nevada. The site had long been dominated by cheatgrass. The fast-moving wildfire did not even blacken most of the abundant cheatgrass seeds on the seedbed surface. Even the cheatgrass seeds with their awns singed will still germinate. Penny for scale.

Exotic Weeds

Often multiple adjectives such as “exotic invasive” weeds (more properly “exotic, invasive” or “exotic and invasive”) are used to describe herbaceous range weeds. You have to be careful to define “exotic” in this usage. To the best of our knowledge, there are no weeds that are exotic to Earth. There are a lot of herbaceous range weeds in western North America that are exotic to the Western Hemisphere. The previously mentioned gum weed is native to the Rocky Mountains but is considered an exotic, invasive species in California. There are many woody species that are highly invasive of the western range in North America. Rabbitbrush, broom snakeweed, pinyon, and juniper are common highly invasive species of rangelands.

Noxious Weeds

In the case of weeds, “noxious” is a legal as well as a descriptive term. The legal connotation arises when a state or the federal government establishes lists of weed species and regulates these species by restricting their movement in commerce and requiring attempted eradication of the weeds from private and public lands. Normally, state noxious weed lists have a tiered structure with Category A weeds being the most serious pest that the state has either no infestations or very small and limited infestations for which complete eradication is being practiced. Category B weeds might be just as serious a pest, but infestations are sufficient in number and extent that eradication is difficult or impossible and complete containment and suppression is being attempted. If a Category C or greater noxious weed list is included in state regulations, the number and extent of infestations is greater than for A and B, but control is still being attempted. Depending on the state, these legal standards are backed by stiff fines and abatement proceedings where failure to control the weeds on private property can result in the state con-



ducting the weed control practices and billing the property owner.

During the last decade of the 20th century, federal managers of publicly owned rangelands became aware they might be held liable for harboring noxious weeds on lands under their management. This sparked a heightened awareness of noxious weeds and prompted the employment of weed control coordinators in many federal land management agencies. The primary noxious weed laws within the United States are originated by state agencies. Noxious weed lists are similar among states but not necessarily identical. For example, a national forest that spreads across more than 1 state may have to deal with contrasting noxious weed lists, depending on the location of individual infestations.

Often, local administration of noxious weed laws is through a legally constituted weed control district. The most effective way to inhibit noxious weed introduction or to promptly recognize and deal with such infestations is through broad-based citizen groups working through local weed control districts.

Seral Communities of Exotic and Invasive Weeds

The science of range management that evolved during the 20th century in western North America was based on applied ecological concepts delivered by such luminary individuals as F. E. Clements, A. W. Sampson, and E. J. Dyksterhuis, among others. These scientists had in common an appreciation for succession as the controlling factor in the composition of plant communities. For many years in the late 20th century, Ben Roche Jr. was a lone wolf suggesting that a similar succession existed among communities largely composed and dominated by exotic, invasive herbaceous species and that eventually dominance by annual grasses would proceed to biennial and perennial weeds.



Excessive, improperly timed, and continuous grazing during the late 19th and early 20th century greatly reduced the native perennial grasses in the understory of big sagebrush communities. These degraded big sagebrush communities were virtually fireproof because of the lack of herbaceous vegetation to spread fires from shrub to shrub.

Unfortunately for the rangeland environment, Dr. Roche's prophecy is becoming apparent on many rangelands.

Annual Herbaceous Range Weeds

This is the entry level for many exotic, invasive weeds. We previously mentioned Russian thistle, which was accidentally introduced to the Great Plains in the 19th century. It had spread to the West Coast of America before the beginning of the 20th century. It was not the first exotic, invasive annual to invade the western range. Filaree was established in southern California before the first Spanish settlers arrived with livestock. Apparently, it was introduced from Manila galleons that stopped at what became San Diego for fresh water. Filaree had spread to the Great Basin at an early enough date to be the only exotic plant with a name in the Western Shoshone dialect. Another chenopod, halogeton, was not identified in America until the 1930s and a second species of Russian thistle, barbwire Russian thistle, until the 1960s. These entry-level species with tremendous seed production and efficient dispersal systems thrive on areas that have been disturbed to bare ground. They will persist on a given site as long as there is disturbance that perpetuates bare ground. This is well illustrated by the thousands of miles of roads that bisect rangelands in western North America. Road crews spend the winter and early spring scraping up the previous year's accumulation of Russian thistle, and the resulting bare ground ensures their employment for the next year. Russian thistle also illustrates an aspect of exotic, invasive species that is often overlooked as a significant forage species on desert ranges. Certainly there are much more desirable native or introduced forage species compared to Russian thistle, but its unique growth phenology provides green forage with digestible protein after annual and perennial grasses have matured and dried. The abundant seeds of Russian thistle are a huge input in the diet of many native insects, birds, and mammal seed eaters (granivorous rodents). Weeds do not just interact with other plants; they become an integral part of the ecology of a site they invade as well.

Even for the most primitive of the entry-level exotic, invasive species, their germination, seedling growth, maturity, and seed productions have vast ecological ramifications both above and below the soil surface. Accumulations of wind-deposited soil particles, litter fall, and interactions with herbage consumers and a potential myriad of other unrecognized factors combine to change the nature of the seedbed so that species of the next stage of succession become established. This is basic Clementsian ecology that was true in the 1890s and remains a cornerstone of plant science.

Our apologies to range managers in the piney woods of Florida, the coastal plains of Texas, and the diverse rangelands of Mexico and Canada. You share some exotic, invasive species (ie, Russian thistle), but because of the gross differences in environments, you have successional novels with the same plot, played by different characters. We recognize that with environments of greater ecological amplitude, the story



The exotic, highly invasive cheatgrass became established in the degraded big sagebrush communities and provided an early maturing, fine-textured fuel that increased the chance of ignition and rate of spread and extended the season of wildfires.

line may be greatly enhanced, but we continue where our experience lies with examples from the semiarid and arid environments of the far western United States.

The second level of herbaceous annual succession is often dominated by species of the mustard family. Why species of this family? This is one of those obvious questions that slipped through the 20th century without being asked. Many of the exotic, invasive mustard species found on rangelands produce an abundance of small dense seeds that have mucilaginous seed coats. This mucilage appears to enhance the chances of seed germination on the surface of seedbeds, and this is a great advantage in semiarid and arid climates. Some of the mustards tumble at maturity like Russian thistle, and some have explosive capsules that enhance seed dispersal. R. L. Piemeisel, who conducted research on invasive, exotic annuals during the 1930s on Idaho rangelands, suggested that the introduced species that matures first wins the successional battle. His reasoning was based on Russian thistle maturing in late fall in the Intermountain area, tumble mustard in midsummer, and cheatgrass in late spring to early summer. These were virtually the entire complex of species Piemeisel had to deal with at the time. With the addition of more exotic, invasive annual species, the successional picture becomes much more complex. If you view secondary plant succession as a series of more or less distinguishable “steps,” the addition of more species can create new steps while at the same time greatly extending the lateral amplitude and vertical magnitude of existing steps.

You may not have heard of small seeded false flax, desert alyssum, hair’s ear mustard, shield cress, Wilson weed, or African mustard, but if you interact with rangelands where species of sagebrush are native, you are going to become familiar with these mustard family species. Some of these species were introduced a century ago and have remained rare species until the last decade of the 20th century, when they dispersed over vast distances on rangelands. The identi-

fication of environmental precursors that triggered this population expansion awaits some bright and witty (at least fractionally) graduate student.

Why are we having an explosion of exotic, invasive annual species of mustards on western rangelands? You can point at many of the issues that are paramount in science at this time, such as climatic change, and ponder if there is a connection. Remember that exotic, invasive species usually come not from radically different but rather relatively synonymous climates. Many of the exotic, invasive annual weeds that have come to the Intermountain area of North America had their origin in central Asia. Blame the end of the Cold War and increased tourism and commerce with the new republics of the former Soviet Union. In a decade we may be blaming our present military presence in southwestern Asia, even though the Department of Defense is making a concerted effort to prevent weeds hitchhiking back with military equipment.

The mustard stage of seral dominance is followed by annual grass dominance. Over millions of acres of formerly big sagebrush/bunchgrass range in the Intermountain area, the annual grass is cheatgrass. The seeds of cheatgrass do not have significant germination on the surface of bare seedbeds. Cheatgrass seeds need burial, litter cover, or rough microtopography to find safe sites for germination. Dr. Robert Blank has demonstrated that certain microphytic crusts provide a good germination environment for cheatgrass seeds. Once the mustard species have modified the site sufficiently for some cheatgrass plants to establish, the annual herbage litter fall, and the litter provided by the superabundant production of cheatgrass fruits (the embryo and endosperm covered with dry papery floral appendages) provides a self-sustaining litter blanket to ensure safe sites for cheatgrass germination. This litter houses a huge seed bank of dormant but viable cheatgrass seeds that further ensure that cheatgrass is not going to easily relinquish its hold on the site.

Practical Significance of Annual Herbaceous Weeds

Bare ground is one of the striking features of native big sagebrush/bunchgrass communities. A near century (A. W. Sampson started graduate studies in 1907) of graduate students have been surprised that the sum of shrub, perennial grass, and forb herbage cover is well below 100%. Such a site converted to cheatgrass dominance supports about 500 plants per square foot, and the resulting cover is 100%. In semiarid and arid rangelands, there is a finite amount of environmental potential to partition among plants. The precise microenvironmental monitoring studies of Raymond Evans clearly demonstrated that competition for water was the limiting factor in cheatgrass dominated seedbeds. He determined that 4 cheatgrass plants per square foot were sufficient to inhibit the establishment of perennial seedlings. This was first spelled out in the famous paper “Range Seeding and the Closed Community” by Robertson and Pearse published in 1945. Cheatgrass truncates succession

for seedlings of native perennials and ensured for the second half of the 20th century its continued dominance.

The practical significance of the closed community concept was some form of herbaceous range weed control was necessary for the establishment of perennial forage or browse species. The significance of the concept to ecological theory has not received a lot of attention. Truncation of succession by an exotic, invasive annual flies in the face of basic Clementsian theory. If the cheatgrass community was not disturbed, the exotic should disappear, and succession would proceed to dominance by native perennial species. In long-term studies, Min Hironaka, using some of the old Piemeisel study sites in Idaho, showed that with complete freedom from grazing, the short-lived native perennial bottlebrush squirrel-tail would increase in cheatgrass stands and then die, allowing a return to complete cheatgrass dominance, but there never was succession to a long-lived native perennial grass. Minimal disturbance from rodents, wildlife, or even recurring drought is enough to apparently perpetuate cheatgrass.

By the end of the 20th century, it was obvious that there were other exotic, invasive species that on specific soils could invade and in some cases completely replace cheatgrass. These include the annual grasses medusahead, barb goatgrass, and wheatgrass and the broadleaf species yellow starthistle.

The addition of yellow starthistle to exotic, invasive annual plant communities is a dramatic step in environmental degradation. Yellow starthistle is a member of the genus *Centaurea*. We risk the wrath of the editor with this scientific name because the generally accepted common name for these species is “knapweeds,” but not all knapweeds are members of this genus (ie, Russian knapweed), and we just introduced yellow starthistle as a member of the genus that is not known as a knapweed. *Centaurea* is a genus of the sunflower family. The 500 plus species of *Centaurea* are native to southeastern Europe and adjacent Asia. The members of the genus that have been introduced to North America are among our very worst herbaceous weeds of rangelands. The bracts that subtend the flower heads of these species bear spines that range from sharp prickles to viscous spikes. We used to consider yellow starthistle a problem on the annual grass-dominated ranges of the portions of California with a true Mediterranean climate. Since then, it has made spectacular spreads of its range in the Pacific Northwest and is well established in the colder, semiarid climate of the western Great Basin. A very similar species, tocalote, is well established in the warm desert portions of the southern Great Basin. The *Centaurea* are noted for producing various secondary compounds. Yellow starthistle produces a neural toxin for horses. Several species are suspected of being allelopathic, but interpreting the actual ecological impact of even proven allelopathy in the field is a will-of-the-wisp type of adventure. The smoke produced by burning squarose knapweed herbage has sent firefighters to emergency rooms. Unfortunately, anyone interested in rangelands is going to become a lot more familiar with species of *Centaurea*.

Some exotic, invasive weeds are poisonous. Halogeton and bur buttercup are good examples. Many of the herbaceous species on rangelands that are poisonous are native species. Their management is a highly specialized aspect of herbaceous range weed control on rangelands.

Bur buttercup has for the past few decades held the record for rapid spread of an exotic annual species on western rangelands. It is highly poisonous but produces virtually no herbage, so animals have a difficult time consuming enough forage to be poisoned by the weed. At Reno, Nevada, bur buttercup flowers in very early March and matures fruits (spiral, armed burs) by the end of April. Blue mustard is currently in a population explosion that may well eclipse bur buttercup. From vacant urban lots to thousands of acres of rangeland, it has magically appeared.

Succession Beyond the Exotic, Invasive Annuals

In the late 20th century, the skies seemed to rain down exotic, invasive herbaceous biennial and perennial weeds on rangelands. Suddenly, Ben Roche's prophecy changes from the theoretical to reality. Perhaps Clementsian theory is correct, and succession will proceed to perennial domination; but only exotic rather than native perennials?

Exotic, Invasive Biennial Species

Biennial species often form a rosette of leaves the first year. In the case of species such as Mediterranean sage, bull thistle, Dyer's woad, and Scotch thistle, these rosettes smother adjacent annual grass seedlings. These plants spend their first growing season developing root systems that exploit the entire soil profile for moisture and nutrients. The second year, flowering stalks of many of these biennials are leafy and tower above the annual grasses.

As previously mentioned, diffuse and spotted knapweed are nominal biennial weeds that can successfully invade bunchgrass ranges in high ecological condition. Nodding or musk thistle is primarily a species of meadow environments. Scotch thistle is another problem species in meadows, but it



In this image, cheatgrass shares dominance with yellow starthistle and medusahead.



Biennial and perennial herbaceous weed species can replace or share dominance with cheatgrass. Scotch thistle in cheatgrass community located in Big Valley, Lassen County, California.

has the ecological amplitude to invade much drier sites. Bull thistle is one of the most common species in meadows in the sagebrush zone.

Exotic, Invasive Perennial Species

These are the top of the successional heap among exotic herbaceous range weeds. Canada thistle followed the advent of agronomic agriculture across North America. It was reported introduced by missionaries to eastern Canada in the 17th century. The first noxious weed law in California specifically mentions Canada thistle in 1872. Hoary cress is another exotic, invasive perennial species with ties to Canada. Both of these species form nearly monospecific communities, but they usually occur in meadows or the mar-

gins of meadows, not as landscape dominants over vast areas of upland rangelands. There are always exceptions to generalizations, and in Baker County, Oregon, there are extensive upland formerly big sagebrush/bunchgrass areas currently occupied by a mixed community of hoary cress, medusahead, and yellow starthistle.

The exotic perennial herbaceous rangeland weed that has made the most spectacular spread on a regional basis is leafy spurge. This weed is also the model for regional integrated suppression programs and the use of specific types of domestic livestock grazing for suppression.

Klamath weed is often held up as the shining example of suppression through the introduction of a biological control agent. Biological control agents are never supposed to eradicate their host weed species, but Joe Balciunas related to the authors that he visited the site in Humboldt County, California, where the agent for Klamath weed was originally released and could not find a single plant. He did find abundant plants of medusahead, goat grass, and yellow starthistle!

This graphically illustrates the basic point of herbaceous weed control on rangelands. It does no good to kill the herbaceous range weed unless you replace the weed with a desirable plant that fully uses the environmental potential formerly used by the weed. Once this replacement is accomplished, you must implement a management system that ensures the persistence of the desirable replacement or periodically renew the replacement stand.

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