

In a study of plant succession following the 1989 Long Mesa burn in Mesa Verde National Park (MVNP), Colorado, we documented a rapid invasion and increase in exotic (non-native) weeds into areas subjected to hot fires. Although the 1,200 ha burn covered both mountain shrub (*Quercus gambelii* and *Amelanchier utahensis*) communities and well-developed pinon-juniper (*Pinus edulis* and *Juniperus osteosperma*) woodland, only the latter show prolific non-native plant invasion. These sites were characterized by high mortality and exposure of mineral soils, and now support dense stands of Musk thistle, *Carduus macrocephalus* (nutans).

We presently see no evidence that native species will replace Musk thistle in the 1989 Long Mesa Fire area. Rather, it appears that Musk thistle has preempted extensive areas in the burn, particularly those of high fire intensity, and that this very competitive species will dominate these sites for a very long time—perhaps indefinitely. This fear is nurtured by the persistence of stands of exotic thistles—both Musk and Canada (*Cirsium arvense* L. throughout La Plata and Montezuma counties since their invasion during the 1970s. Where the weeds are abundant, new pathways of succession may be in progress, pathways that never before have been documented and are largely unpredictable with our present knowledge.

Nature reserves are not immune to degradation by aggressive invader species. Indeed, nearly all reserves in the world today are troubled by invasive vascular plants (Mooney and Drake 1989). For instance, Kruger National Park in Africa had 6 non-native plant species in 1937, 43 in the 1950s, and >160 today (Soule 1990).

Why be concerned about invasion of exotic plant species in a national park like Mesa Verde? A major reason is that invasive species have the potential to displace native species and alter natural ecological processes. For example, cheatgrass (*Bromus tectorum*), an annual originally from Eurasia, now is well established throughout the intermountain region in North America, especially in areas disturbed by plowing or heavy grazing, but also in relatively undisturbed areas (Mack 1986). Once cheatgrass forms a dense stand, it alters the fire regime by creating a continuous, highly flammable fuel bed that can readily carry fire across large areas. The species composition and ecological functioning of steppe communities over much of the intermountain west have been altered by the invasion of this single exotic plant species.

An Ecological Irony

At MVNP, natural disturbances such as fires and gaps created by forest pathogens are

Succession and Biological Invasion at Mesa Verde NP

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Look out below! Thistle head weevils are given a helping finger during their application to a field of musk thistles.



common. Man has added to the native regime with roads, visitor facilities, and sewage plants, all necessary to maintain a highly visited park. There is deep irony here, and also a serious dilemma for managers of nature reserves. Recent research in ecology has shown clearly that disturbance is essential to maintain the natural components and processes of the communities and ecosystems we are trying to perpetuate in our national parks and other nature reserves (e.g.

Pickett and White 1986). However, disturbance also promotes invasion and degradation of habitats if seed sources for potential invaders are close by (Hobbs and Huenneke 1992).

How are we to deal with this double-edged process of disturbance? One approach is to recognize that the native species are adapted to the disturbance regime that prevailed in pre-settlement times, i.e. to a particular frequency, intensity, and type(s) of disturbance. The strategy for maintaining native species, then, is to maintain this pre-settlement disturbance regime. In most of our parks and reserves, disturbance regimes and pools of species available have changed dramatically since pre-European settlement times (Hobbs and Huenneke 1992). Reserve managers need to identify and subsequently eliminate or ameliorate changes in disturbance regimes that are "beyond the evolutionary experience of the native biota" (Macdonald et al. 1989).

Natural Disturbances

What was the pre-settlement disturbance regime in MVNP? Research currently is underway to answer this question. We are attempting to determine, for example, the frequency and spatial extent of severe, stand-replacing fires in the pinon-juniper and mountain shrub communities, and the mechanisms by which the dominant species became re-established after fire. Such fires apparently were an important part of the pre-settlement environment of Mesa Verde and therefore should be allowed to continue in some form. Small fires occurred an average of 7.6 times per year between 1927 and 1976, and 13.7 times per year between 1976 and 1989. Large tracts burned in 1934, 1959, and 1972 and they were not invaded by exotic species (unless intentionally seeded with *Bromus inermis*).

The successional pattern changed dramatically with the 1989 Long Mesa fire. The southern sector of the burn supports prolific weedy invasion (the true extent of Musk thistle invasion requires immediate documentation), while the northern sector is dominated primarily by native perennial shrubs. The substantial gradient in post-fire successional patterns across the 1989 fire is alarming. It is clear that pre-fire community structure plays a role in directing subsequent succession. On the southern half of the burn, pinon-juniper woodlands had been destroyed, exposing mineral soils. In contrast, the northern, shrub dominated section was repopulated with sprouts from native perennials within the first year after the burn.

Throughout MVNP, fungal and insect pathogens have killed thousands of pinon pines, leaving patches in the forest that have been invaded by non-native plant species.

The most devastating infestation has come from the Black-root rot, *Verticicladiella wagneri*, which infests patches of pinon pines, killing trees of all ages. The largest invasion of Musk thistle coincided with Black-root invasion patches, although supporting thistle stands, are isolated from one another. However, should the patches become more extensive or common, they eventually may provide "corridors" for movement of weedy seeds.

Disturbances Related to Human Activities

In general, areas disturbed earlier this century and abandoned are free of weedy species. Disturbances that occurred since the mid 1970s or those that are continually disturbed support non-native plant species. Abandoned roadways are found throughout the park and date from the 1930s to the 1960s. Construction upgrades on the existing paved road that took place in 1983 may have directly introduced weedy species through the use of sewage sludge, as well as indirectly by creating open habitats. A pipeline originally built in 1946 to carry water from the "Chicken Creek" National Forest area into the water treatment facility at the park entrance is being replaced. It crosses the steep north-facing escarpment, and then runs south to the heavily used Chapin Mesa facilities. Both roadways and waterline construction serve as effective "corridors" that facilitate weedy dispersal in the park. (The first Musk thistle stands in Mesa Verde were on Chapin Mesa around 1980 following road construction activities that imported gravel from thistle-infested sites.)

Sewage facilities, constructed in 1963, 1965, and 1975, are located on Wetherill Mesa, Chapin Mesa, Far View, and Morefield Canyon. These are moist areas with continual disturbance and support large weedy populations. Such disturbances probably have no evolutionary precedent, and also create absolutely ideal conditions for invasions by exotics. Sewage treatment ponds provide bare substrate and nutrient enrichment, and—not coincidentally—support some of the most vigorous thistle stands in the park.

Grazing of trespass cattle and horses is a problem in Mesa Verde, punctuated by numerous fence breaks on the park's southern boundary. Grazing compacts the soil and reduces native grasses, and the animals may disperse exotic seeds. One example illustrates the extent to which grazing affects native flora. In Navajo Canyon, the average cheatgrass cover was 40 percent between 1980 and 1989. Fences were erected in 1987, and native grasses were returning to the area by 1990. In 1991, western wheatgrass, slender wheatgrass, and salina wild rye covered >60 percent, and cheatgrass was reduced to

Of all the many functions our national parks perform, one of the most important is maintaining examples of natural ecosystems populated by native biota. Today these systems are continually shrinking in size and ecological integrity. In many areas the public has become so accustomed to seeing landscapes dominated by exotic species that they think these are the normal condition (Heywood 1989). Aldo Leopold, in his classic essay on the land ethic, wrote that the ecological damage that already has occurred in the southwest "is quite invisible to the tourist who finds this wrecked landscape colorful and charming (as indeed it is, but it bears scant resemblance to what it was in 1848)."

To the credit of past and present managers, the vegetation of MVNP is still largely intact. To keep it that way, in the face of impending global-scale changes in climate and human impact, will require insightful research, enlightened and assertive management, and informed public support.

<20 percent. It has taken only 4 to 5 years to return the area to a nearly natural native flora.

Biological Invasions

More than a dozen exotic species are considered troublesome at MVNP, but to illustrate the extent of such invasions and possible management scenarios, we will discuss the two thistle species further. Two of the most conspicuous invaders, Musk thistle and Canada thistle, have life history characteristics that make them potentially serious threats to the integrity of the park's natural vegetation. They display rapid rates of population growth, relatively short life cycles, early reproductive maturity, high reproductive allocation, pollination by wind or by generalist pollinators, and rapid response to resource availability. All these are general characteristics of colonizing plant species that can successfully enter new habitats following disturbance (Bazzaz 1986).

In 1976, economically threatening populations of Musk thistle species were located in eastern Colorado (Dunn 1976). Since then, Musk thistle has spread at an alarming rate. Musk thistle is a biennial, reproducing from seed exclusively. Canada thistle is more difficult to control because of horizontal adventitious roots that may extend 2 m deep (Hodgson 1968; Rees 1990).

Control of Biological Invasions

Control of Musk and Canada thistles should be geared specifically to the extent of the

invasion and the degree of expected recurrence of disturbances. In MVNP, only the most extensive disturbances—large, hot fires, waste treatment, waterline construction—facilitate invasion of large acreages of thistles. Thus, treatment of weedy patches of various size and severity must be weighed carefully. Methods used to curtail thistle invasion include:

A. Biological control strategies for Musk thistle: *Rhinocyllus conicus* (Frowl) and *Trichosiocalus horridus* (Panzer) are thistle weevils, which have been used extensively in the U.S. for control of Musk thistle (McCarty and Lamp 1982; Rees 1982). *R. conicus* has spread into MVNP from surrounding agricultural land. In the spring, *R. conicus* females oviposit on the developing flower bud bracts, moving from primary to lateral buds as they become oversaturated with eggs. Eggs hatch in 6 to 8 days, and larvae burrow into the receptacle, reducing seed viability. *T. horridus* attacks the stems and crown and produces feeding scars that allow entry of pathogens, further weakening the plant. Together they are effective in controlling Musk thistle.

Another insect species, *Vanessa cardui* L. is presently established on thistles in many areas. *V. cardui*, the painted lady butterfly, is a migratory herbivore that cannot tolerate winter temperature, migrating to the southwestern U.S. and Mexico in fall. The larvae are locally effective herbivores of Canada and Musk thistle (Larry Hays, Natural Resource Specialist, Wind Cave NP, pers. comm.).

In the summer of 1992, systematic releases of *T. horridus* were made in Morefield Canyon, a densely thistle-infested area of MVNP. One hundred individuals were released on specifically tagged experimental plants in May, 1,000 in June, and control plants were paired with experimental plants. Native thistle species were monitored along with Musk thistles for possible infestations. First year result summaries show 1,748 seedhead weevils emerged from 106 Musk thistle seedheads and only one seedhead weevil emerged from 30 native thistle seedheads. We are confident that the success of the biological control agents by intentional and accidental introductions from surrounding lands will be effective in reducing the spread of Musk thistle in MVNP.

B. Use of mechanical control: Removal of Musk thistle biomass prior to "bolting" (establishment of seed head) seems a reasonable approach to eradication. In MVNP, to the extent possible with YCC, the hazardous fuel crew, the road crews, trail crews, ruins stabilization crew, and concessions personnel, inflorescences have been removed from bolt-

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ing plants prior to seed shed (in 1985-1992). Musk thistles are cut just below ground level in early summer. Generally a well developed rosette has enough root mass to produce a second and often a third head. Elimination of the current year's growth depletes the root carbohydrate reserves and plants experience increased mortality and reduced fecundity.

C. Use of Chemical control: Herbicides are effective means of eradicating most species of thistle. Applications of picloram, Round-up, Glean, Curtail, and other commercial preparations are used locally. Mesa Verde's policy has been to avoid introduction of herbicide into the ecosystem whenever possible. However, because of the extent of the problem, a combination of limited chemical treatment, in conjunction with mechanical and biological controls, is under consideration (B. Heyder, pers. comm.).

Looking to the Future

Biological invasion on disturbed habitats within MVNP illustrates the complexity of problems created by species migration and the role of human interference in plant establishment. Although weedy species are adapted to exactly the habitats that humans maintain, their positive influences -- soil stability and erosion prevention for example -- may be overridden if they tend to re-direct the native successional process. The extent of ecosystem disturbance and the proximity to seed sources of aggressive weeds have created at MVNP a critical biological invasion.

Although we cannot yet predict with confidence the long-term effects of exotic plant invaders in MVNP, from other studies we

know that changes in community or ecosystem function following establishment of exotic species has not always been significant; the potential effects of the new species range from modest usurpation of resources from many native species (hence no extinctions) to intense competition with one or a few natives species, with significant competitive displacement of the native(s) (Westman 1990).

Invaders may have positive ecosystem effects, especially with regard to repair of damaged ecosystems. For example, weedy herbaceous invaders may sequester nutrients more efficiently than the native species in severely disturbed sites (Mooney and Drake 1989). Despite substantial research to date, we still can make only very general predictions about which species are likely to be successful invaders or which communities are most susceptible to invasion. Each species and situation must be examined individually. (Bazzaz 1986; Westman 1990).

Sites disturbed before 1970 and abandoned to natural successional sequences support native flora in Mesa Verde today. But given the rapid expansion of exotic thistles in the park and surrounding region in the last few decades it appears likely they will spread to an even greater area in the near future, especially if disturbances continue to occur.

Disturbance of native vegetation, either natural or anthropogenic, is nearly always inductive to establishment of exotic species in new habitats (Westman 1990). Invasion was particularly severe in the record high precipitation of May 1992. In some areas of MVNP where spring moisture remains high and

disturbance is continual (e.g. sewer ponds and surroundings), thistles predominate despite dense grass cover. What actually happens on any particular site depends on variables such as intensity of disturbance, weather conditions in the first years after a fire, and the local seed bank of aggressive exotic weeds.

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Literature Cited

- Bazzaz, F.A. 1986. Life history of colonizing plants: some demographic, genetic, and physiological features; pp. 96-110 IN Mooney, H.A., and J.A. Drake (editors), *Ecology of biological invasions of North America and Hawaii*. Springer-Verlag, New York.
- Dunn, P.H. 1976. Distribution of *Carduus nutans*, *C. acanthoides*, *C. pycnocephalus* and *C. crispus* in the United States. *Weed Science* 24:518-524.
- Heywood, V.H. 1989. Patterns, extents, and modes of invasions by terrestrial plants; pp. 31-55 IN Drake, J.A., H.A. Mooney, F. diCasti, R.H. Groves, F.J. Kruger, M. Rejmanek, and M. Williamson (editors), *Biological invasions: a global perspective*. SCOPE, Wiley & Sons.
- Hobbs, R.J. and L.F. Huenneke. 1992. Disturbance, diversity, and invasion: implications for conservation. *Conservation Biology* 6:324-337.
- Hodgson, J.M. 1968. The nature, ecology, and control of Canada thistle. USDA Tech. Bull. 1386.
- Leopold, A. 1966. A Sand County almanac, with essays on conservation from Round River. Sierra Club/Ballantine Books, New York.
- Macdonald, I.A.W., L.L. Loope, M.B. Usher, and O. Hamann. 1989. Wildlife conservation and the invasion of nature reserves by introduced species: a global perspective; pp. 215-255 IN Drake, J.A., H.A. Mooney, F. diCasti, R.H. Groves, F.J. Kruger, M. Rejmanek, and M. Williamson (editors), *Biological invasions: a global perspective*. SCOPE, Wiley & Sons.
- Mack, R.N. 1986. Exotic plant invasion into the intermountain west: a case history; pp. 191-213 IN Mooney, H.A., and J.A. Drake (editors), *Ecology of biological invasions of North America and Hawaii*. Springer-Verlag, New York.
- McCarty, M.K. and W.O. Lamp. 1981. Effect of a weevil, *Rhinocyllus conicus* on Musk thistle seed production. *Weed Science* 30:136-140.
- Mooney, H.A., and J.A. Drake. 1989. Biological invasions: a SCOPE program overview; pp. 491-510 IN Drake, J.A., H.A. Mooney, F. deCasti, R.H. Groves, F.J. Kruger, M. Rejmanek, and M. Williamson (editors), *Biological invasions: a global perspective*. SCOPE, Wiley & Sons.
- Pickett, S.T.A., and P.S. White (editors). 1985. The ecology of natural disturbance and patch dynamics. Academic Press.
- Rees, N.E. 1982. Collecting, handling and releasing *Rhinocyllus conicus*, a biological control agent of Musk thistle. USDA Agric. Handbook No. 579.
- Rees, N.E. 1990. Establishment, dispersal, and influences of *Ceuthorrhynchus litura* on Canada thistle in the Gallatin Valley of Montana. *Weed Science* 38:198-200.
- Soule, M.E. 1990. The onslaught of exotic species, and other challenges in the coming decades. *Conservation Biology* 4:233-239.
- Westman, W.E. 1990. Park management and exotic plant species: problems and issues. *Conservation Biology* 4:251-260.

Chenopodium fremontii, lambs quarter or goosefoot, growing in the 1989 Long Mesa burn one year after the fire. Photograph taken October 1990 in Mesa Verde NP.

