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Eliminating Invasive Introduced Species While Preserving Native Species in Coastal Meadow Habitat, a Critically Imperiled Ecosystem

C.Coulter, K.Voelke, W.Vagt / Camp Rilea

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Ground squirrel eating Scotch broom flowers.

Celeste Coulter[1], Katie Voelke[1], William Vagt[2]
[1]North Coast Land Conservancy, Seaside, Oregon 97138
[2]OR ARNG AGI-ENV, Oregon Military Department, 1776 Militia Way SE, PO Box 14350 (AGI-ENV)
Salem, OR 97309, 503-584-3198 (phone), 503-584-3584 (fax), William.vagt@us.army.mil

Purpose: (1) Eradication of the invasive European shrub, *Cytisus scoparius* L.;
(2) protection of native species in a critically imperiled ecosystem on adjacent non-DoD Lands;
(3) improvement of training lands by reducing encroachment of invasive woody species in grasslands.

Regulations: Endangered Species Act, Executive Order 13112

Project Synopsis: Study the effectiveness of large-scale mechanical removal of Scotch broom (*Cytisus scoparius*) and the impacts on native vegetation in a critically imperiled ecosystem (CEGL001774).

Abstract

Reed Ranch is a 100-acre site of degraded coastal meadow habitat that is located 1.3 miles from Camp Rilea, a military installation situated on the Clatsop Plains in northwest Oregon. Restoration of coastal meadow habitat is considered crucial to the recovery of the Oregon silverspot butterfly (*Speyeria zerene hippolyta*), a federally threatened species on the Clatsop Plains. As a part of dune stabilization efforts in the 1930s, Scotch broom (*Cytisus scoparius* L.), a non-native invasive woody shrub species, was widely planted throughout the Clatsop Plains. Within the last 30 years, this invasive shrub has spread across the landscape, dominating much of the historical coastal meadow habitat in the region. We examined the effects of mowing 100 acres of a mature Scotch broom shrubland with a tractor-mounted mower on extant invasive and native species in coastal meadow habitat. Ninety 1-m^2 plots were installed to record the frequency of all species detected in plots. Pre-treatment data were collected in spring prior to mowing treatments. Mowing was conducted twice during the summer (June and September). Post-treatment data were collected in the spring one year following mowing treatments. Frequency comparisons were conducted on Scotch broom data and life-form groups. Percentage of area occupied by Scotch broom dramatically decreased following mowing treatments while the frequency of Scotch broom increased slightly due to recruitment of seedlings from the release of the long-lived seed bank. Two species in the native perennial forb group significantly increased following treatments. The following non-native life-form groups increased significantly following mowing treatments: annual forbs, annual grasses, and perennial shrubs. Invasive perennial pasture grasses were present in all 90 plots before and after mowing treatments. Results suggest that mowing treatments or a combination of different treatments would need to be implemented over many years to significantly reduce Scotch broom populations and enhance native coastal meadow habitat. Further monitoring is needed to substantiate preliminary results from this one-year study.

Introduction

The Coastal Meadow Habitat, classified locally as Red Fescue Stabilized Dune Grassland, CEGL001774, a critically imperiled ecosystem, has been invaded by Scotch broom (*Cytisus scoparius*), European beachgrass (*Ammophila arenaria*), European pasture grasses (*Holcus lanatus, Festuca arundinacea, Dactylis glomerata, Anthoxanthum odoratum,* and *Agrostis alba*), Queen Anne's lace (*Daucus carota*), and European false dandelion (*Hypochaeris radicata*).

This study will focus on methods for mechanically removing Scotch broom from coastal meadow habitat in the Clatsop Plains.

Distribution

Scotch broom is native to the British Isles and central and southern Europe where it is only an occasional weed (Paynter et al. 1998). Scotch broom first became naturalized in North America on the East Coast. It was sold as an ornamental in California in the 1860s. By the turn of the century, it had become naturalized on Vancouver Island (Bailey 1906) and was probably planted throughout the Pacific Northwest as an ornamental. Today, Scotch broom is established along the coast and inland valleys of the Pacific Northwest, extending from British Columbia to central California (Hitchcock and Cronquist 1973). Its northern limits are possibly due to low winter temperatures and the southern limits due to summer drought (Williams 1981).

Scotch broom grows best in dry sandy soils in full sunlight and in soils with pH values ranging from 4.5 to 7.5 (Gill and Pogge 1974). Where it has been introduced, Scotch broom invades pastures and cultivated fields, dry scrubland, native grasslands, roadsides, dry riverbeds, and other waterways (Gilkey 1957, Johnson 1982, Williams 1981). It does not do well in forested areas, but plants can spread rapidly following logging, land clearing, and burning (Mobley 1954, Williams 1981).

Scotch broom Infestations on the Clatsop Plains

Historically, the Clatsop Plains was a dynamic landscape of coastal meadow habitat, changing throughout the year in response to shifting wind-blown sand dunes. Shifting sand was the driver for the ecological system of the coastal meadow. As an early successional plant community type, native meadow plants need constant disturbance to keep shrubs and trees from encroaching. In 1885, the U.S. Army Corps of Engineers began the construction of the south jetty at the mouth of the Columbia River. This led to the rapid progradation of sand dunes (700 m). In his paper Cooper wrote "*Outbuilding of the shore has been too rapid to permit the formation of beach ridges stabilized by vegetation; most of the expanse of sand is bare*." (1958). As European pioneers began to settle the area, however, the shifting dunes were perceived as a nuisance, sometimes half-burying homes in sand after intense winter storms. Inland dune ridges, which were historically stabilized by native coastal prairie plants, became pasture for grazing cattle. Since native prairie plants are shallow-rooted, heavy grazing by cattle began to break down the root structure, destabilizing the dune ridges and causing the sand to begin blowing farther inland. The more the residents tried to stabilize the dunes on the Clatsop Plains, the more the sand blew, and the more talk there was of what to do about this blowing sand. Consequently, in the mid-1930s the Soil Conservation Service (SCS), along with a Civilian Conservation Corps (CCC) in Warrenton, undertook a huge effort to stabilize the dunes. Three thousand acres of shifting sand was targeted for dune stabilization. This project was one of the most extensive dune stabilization efforts in the western United States. Initially, a variety of techniques were utilized including installing sand fences to catch blowing sand, (remnants of these fences can still be seen today);

spraying hot crude oil on the sand to prevent it from drifting, which was deemed an ineffective method and was only used experimentally; and other methods such as piling brush, gravel, rock, and clay on the sand. Eventually it was clear that none of these methods would work as a long-term solution. Land managers finally determined that the establishment of vegetative cover on open sand would be the best approach to permanently stabilize dune ridges throughout the Clatsop Plains. Regrettably for the native ecology, the plants introduced to stabilize dunes were largely non-native invasive species. As an intermediate step toward dune stabilization, the SCS and CCC introduced woody legumes. As a nitrogen fixer, Scotch broom readily established in the sandy, nutrient-poor soils. As acres of dune habitat were planted with Scotch broom, soil chemistry began to change as increases in ammonium (a by-product of nitrogen fixation) and soil moisture, from shading, begin to concentrate in the soil. No longer nutrient-poor and dry, these altered soils allowed invasive grasses and forbs to proliferate. (Rankin 1983; Reckendorf 1998)

Today, the now-stabilized dune system is dominated by invasive grasses and woody species such as Scotch broom. Land that was once used for pasture grazing is being transformed into residential developments. Therefore, the few remaining open spaces in the Clatsop Plains are critical to the protection of remnant populations of coastal meadow species. While many species depend on this disturbance-mediated landscape, one species, the Oregon silverspot butterfly (*Speyeria zerene hippolyta*), a federally listed species, has been extirpated from the Clatsop Plains because of a loss of coastal meadow habitat, a critically imperiled ecosystem. A strategic approach to enhancing coastal meadow habitat by removing invasive species is a priority for land managers and conservation groups working throughout the Clatsop Plains. This study documents the response of Scotch broom to mowing on 100 acres of coastal prairie habitat. Understanding the effectiveness of large-scale mechanical removal of woody species (e.g., Scotch broom) is vital to all military installations that manage open grassland habitat to prevent encroachment of woody species. For example, at the Fort Lewis military installation outside Tacoma, Washington, many acres of prairie habitat are infested with Scotch broom. At Fort Indiantown Gap, a military installation in Pennsylvania, land managers maintain regal fritillary butterfly (a species of immediate concern) habitat from shrub encroachment through the use of prescribed fire. Management of open space using prescribed fire is not always possible because of safety issues and impacts to air quality resulting from smoke and carbon dioxide generated during the burning process. Maintaining open habitat is important because training in open grassland terrain is crucial for maintaining military readiness.

Life History of Scotch Broom

Plant Characteristics

Scotch broom is an invasive perennial shrub of the Fabaceae (Leguminosae) family. The shrubs are 1-2 meters high and deciduous. The green branches (Robbins et al. 1951) are strongly angled (Hitchcock and Cronquist 1973) and appear bare (Munz and Keck 1973). The leaves are trifoliolate with petioles 2-10 mm long. Leaflets are obovate to oblanceolate, entire, strigose and 6-12 mm long. The yellow flowers of Scotch broom are usually borne solitary in axils, blooming

between April and June. The glabrous banner is ovate to rounded; wings are oblong to ovate; and the keel is straight or curved. Petals are about 2 cm long. The flaring calyx is glabrous, about 7 mm long and is two-lipped with short teeth. The brownish black fruit pods, 3.5 to 5 cm long, are villous on the margins only. These pods are compressed, several seeded, with a callous appendage near the base (Munz and Keck 1973).

Ecology and Reproduction

Scotch broom can reproduce by seed or vegetatively. Shrubs can produce up to 60 seed pods per plant by their second year. Each pod usually contains 5-8 seeds (Hoshovsky 2001). Years of heavy pod production are cyclical and are generally followed by years of lighter pod production. Waloff and Richards (1977) concluded that seed production was independent of climatic conditions and reflected more the physiology of individual plants. Broom seeds have hard seed coats that can survive transport in river gravels (Williams 1981). They may remain viable for over 80 years (Turner 1933). Broom pods often open explosively, especially in a drying wind, and the seeds may be widely scattered (McClintock 1985). Seedlings buried more than 10 cm deep fail to emerge. The most rapid resprouting occurs when seeds are buried less than 3 cm deep in a fine-textured substrate (Williams 1981). Seedlings damaged by frost will not be impacted by decreases in total height growth in their early years since shoot-tip growth is soon replaced by growth from lateral buds (Williams 1981).

Within the first year, broom plants can grow over one meter tall (Waloff and Richards 1977). The initial rapid growth during the first four-five years is succeeded by two-three years of relative stability (Waloff 1968). The life cycle of Scotch broom includes six to eight years of growth followed by degeneration accompanied by an increase in the ratio of woody to green material, reduction in seed production, and finally death. Shrubs rarely die in one year, but as the habitat becomes degraded a mosaic of dead, partly dead, and living plants is formed. Broom shrubs rarely live more than 10-15 years (Waloff 1968). Scotch broom can tolerate low soil temperatures and can fix nitrogen throughout the year in regions with mild winters (Hoshovsky 2001). Broom has photosynthetic tissue dispersed throughout the crown in long twigs and small lancet-shaped leaves (Hoshovsky 2001). This makes it well-adapted to the open environments of early succession.

Methods for Removal

Removing Scotch broom from habitats where a native plant community still persists can be challenging for land managers. Mechanical removal is recommended for sensitive habitats where the use of non-selective herbicides would negatively impact native species. Mechanical removal, using a tractor-mounted mower, allows for large stemmed plants to be cut without ripping plants out of the ground causing less ground disturbance (Amme 1983). While mowing is typically considered non-selective in that it targets both native and non-native species, mowing, in this case, targets the Scotch broom without harming diminutive prairie species found in coastal meadow habitats. Multiple mowing treatments implemented before the plants flower each year are required to exhaust the root system and to eliminate resprouting from the root crown (Amme 1983).

Methods

Mowing

A tractor-mounted mower was used to mechanically shred mature Scotch broom plants. Deck height for the mower was set at 6 inches for the first round of mowing (June 2008) due to the number of dense, large, woody stems. The second mowing (September 2008) was conducted with a 4-inch deck height.

First day of mowing, spring 2008.

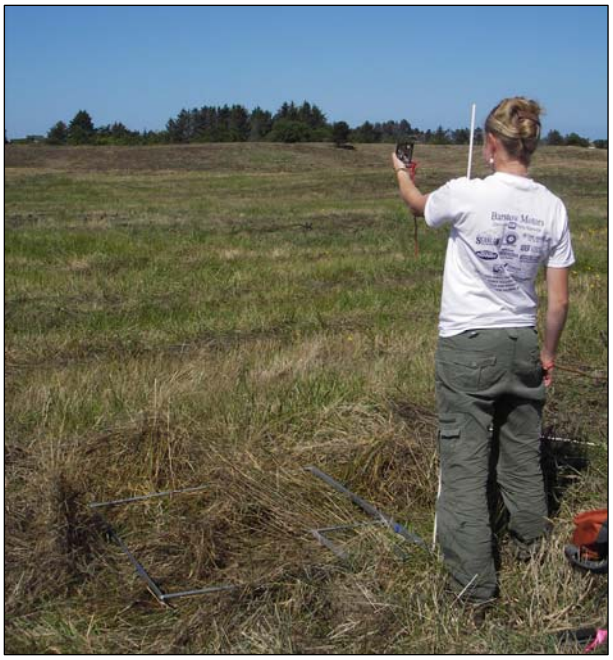
Data Collection

A total of ninety 1-m^2 plots were installed to record frequency (presence/absence) of all plant species detected in each plot. Fifteen transects oriented on an east-west aspect were installed with a spacing of 55 meters between transects. The first and last transects were installed 20 meters in from north and south boundaries of the property. The quadrat frame was placed to the south of the transect line at the zero mark measured for the 55-meter spacing. Hand-held devices were used to record species. Data were collected in spring 2008 prior to mowing treatments. Following two rounds of mowing, once in June and once in September, data were collected again during spring 2009. Additional notes, including observations of flowering nectar species, wildlife, and the early-blue violet (*Viola adunca*), host plant for the endangered Oregon silverspot butterfly, were recorded.

Permanent photo points were installed throughout the study area to document the visual change in broom infestation. Once a photo-point location was determined, a wooden stake was installed and a GPS reading recorded. Photos were taken at each point in four cardinal directions (north, east, south, and west). Photos taken at point locations installed at the edge of the property boundary were taken in three cardinal directions depending on proximity to the rest of the property. Notes regarding the location of the photo point as well as obvious landmarks were recorded to facilitate relocation.

Data collector in pre-treatment plots.

Quardrat frame in pre-treatment plots.



Data collector in post-treatment plots.

Cut stems of mature Scotch broom.

Data Analyses

All species were grouped into life-form guilds (Table 3) to evaluate response to mowing treatments. Data collected for Scotch broom were analyzed separately and as part of the introduced perennial shrub guild (Tables 1 & 2). Comparisons of frequency data were analyzed using Chi-square tests (Zar 1984).

Results

The results suggest that there was not a significant difference in the frequency of Scotch broom between pre-treatment and post-treatment plots (Table 1). While frequency of Scotch broom increased from 44 plots before mowing to 55 plots one year later, Chi-square analyses did not show this frequency increase to be significant. In contrast, percentage of cover for Scotch broom decreased dramatically as evident in the photos taken as part of the photo monitoring (Appendix A). In pre-treatment plots, Scotch broom plants were mature shrubs, often with stems greater than two inches in diameter. One year following treatments, Scotch broom plants recorded in plots were predominately seedlings one-two inches in height with resprouting from root crowns rarely observed. Data indicate that mechanical removal of a mature Scotch broom shrubland caused sufficient disturbance to release the seed bank.

Removing the canopy of the mature Scotch broom shrubland allowed for an increase in the frequency of three non-native life-form groups: non-native annual forbs, non-native annual grasses, and non-native perennial shrubs (Table 2). Increases in non-native annual forbs were a result of significant increases in *Geranium dissectum* (Appendix B). This weedy annual forb responds vigorously to disturbance (Bartolome et al. 2004). Non-native annual grasses increased due to three species (*Aira caryophyllea, Bromus hordeaceus* L. ssp. *hordeaceus, Vulpia bromoides*) being detected following treatments that were not found prior to mowing (Appendix B). Non-native perennial shrubs at Reed Ranch include *Cytisus scoparius, Rubus armeniacus,* and *Rubus laciniatus* (Appendix B). Analyses of Scotch broom (*Cytisus scoparius*) alone did not result in a statistically significant difference between pre- versus post-treatment plots; however, when Scotch broom was analyzed with the other non-native perennial shrubs, results indicated a statistically significant increase in the frequency of non-native perennial shrubs as a whole following mowing.

One native life-form group, perennial forbs, increased in frequency due to higher numbers of *Cerastium arvense* and *Veronica americana* (Appendix B). *C. arvense* is a common native in meadow habitat that showed favorable response to increased light and disturbance from mechanical removal of the aboveground portion of Scotch broom. *V. americana* was not detected in pre-treatment plots and may have been overlooked. Analysis of all other life-form plant groups revealed no statistically significant difference in their frequency between pre- and post-treatment plots (Table 2).

Table 1. Frequency analyses using Chi-square to compare pre-treatment to post-treatment plots.

Species	Response	x^2
Scotch broom (*Cytisus scoparius*)	NS	2.72

**p-value = 0.05; v = 1; critical value = 3.841; NS = no significant difference*

Table 2. Frequency analyses using Chi-square to compare pre-treatment to post-treatment plots.

Life Forms	Response	x^2
Forb, Annual, Introduced	* *increase*	32.91
Forb, Annual, Native	NS	1.20
Forb, Perennial, Introduced	NS	0.60
Forb, Perennial, Native	* *increase*	26.53
Grass, Annual, Introduced	* *increase*	14.01
Grass, Perennial, Introduced	*no change*	NA
Grass, Perennial, Native	NS	3.21
Rush, Perennial, Native	NS	2.25
Shrub, Perennial, Introduced	* *increase*	5.11
Sedge, Perennial, Native	NS	2.03
Shrub, Perennial, Native	NS	1.34

**p-value = 0.05; v = 1; critical value = 3.841; NS = no statistically significant difference*

Discussion

Frequency of broom plants did not significantly decrease following mowing treatments. Photo monitoring at the study site does adequately capture the dramatic changes resulting from removing the aboveground portion of Scotch broom.

Paynter et al. (1998) found that Scotch broom seedling survival was correlated with disturbance. No seedlings survived in plots that did not receive some disturbance treatment. By contrast, 40% survival was documented in plots that were disturbed. Several studies suggest that canopy removal of mature plants is required for successful recruitment of seedlings because young seedlings need sunlight to germinate from seed (Paynter et al. 1998; Sheppard et al. 2002). Competition from surrounding vegetation inhibited seedling survival, while another study found no effect on broom recruitment from competing vegetation (Sheppard et al. 2002). Survival of seedlings to flowering stage increases in immature broom shrublands. The mature broom shrubland may deplete soils of nutrients so that, when the canopy is removed by mowing, seeding survival decreases because of a lack of available nutrients (Sheppard et al. 2002).

A one-year study is not adequate to determine if the frequency of Scotch broom plants would remain at higher levels than pre-treatment conditions (Paynter et al. 1998). Sheppard et al. (2002) concluded that seven years was required to understand the trajectory of broom survival following treatment. Broom shrublands usually require several cuttings before the underground parts of immature plants (stem diameter less than 2 inches) can be weakened (Amme 1985). It is also important to note that variability among observers in recording frequency values may introduce bias or imprecision in the data collection. Several people, for example, were involved in data collection in this study, possibly confounding the data and results.

Mowing alone will not eradicate Scotch broom populations. A combination of treatments may be required to successfully reduce Scotch broom to levels that allow native coastal meadow species to multiply. Small-scale test plots have shown that mechanically cutting mature Scotch broom (greater than 2 inch diameter) at its base below its green stem will permanently kill the plant. This method of removal is preferred to burning which encourages the growth of introduced invasive grasses at the expense of native species. Furthermore, Scotch broom is a highly combustible woody shrub due to its high oil content, increasing the risk of wildfire during the use of prescribed fire. Results from this study are consistent with those of other studies, documenting a greater frequency in seedling recruitment than resprouting from root crowns. The Scotch broom population treated at Reed Ranch was a mature shrubland with a majority of stem diameters greater than two inches. Amme (1983) found that seedlings will resprout from root crowns in greater density if not treated with herbicides. Multiple applications of herbicide on Scotch broom seedlings following mowing have proven to be successful in eradicating infestations but may have negative impacts on native coastal meadow species. A study done in southern France found that mowing followed by grazing may be an effective interaction that will lead to reduced resprouting (Paynter et al. 1998). Native meadow species increased in response to grazing in coastal dune meadows of Wales while invasive woody species decreased (Hewett 1985). In contrast, a study from Australia found Scotch broom seedling abundance increased by a factor of four in response to grazing (Sheppard et al. 2002). The increase may have been due to impacts of heavy grazing on surrounding vegetation, freeing up resources for broom seedlings (Paynter et al. 1998; Sheppard et al. 2002). Recent results from biological control experiments in Oregon found that insects fed on 10-25% of Scotch broom seed pods (Coombs et al. 2004).

Over time, introduced biological control insects may provide the additional level of control needed to eradicate Scotch broom populations on stabilized dunes.

Scotch broom's long-lived seed bank (~80 years) will require management strategies that include repeated treatments over many years. Mowing of Scotch broom and other non-native invasive plants at Reed Ranch will continue to be monitored for effectiveness in the future, with adjustments in treatment made as study results inform us of the best approach to enhance coastal meadow habitat in the Clatsop Plains.

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Appendix A. Monitoring photos showing coastal meadow prairie at Reed Ranch before (2008) and after (2009) mechanical treatment (mowing). Following treatment, grassland habitat dominated by non-native perennial grasses remains.

Pre-Treatment 2008 **Post-Treatment 2009**






Pre-Treatment 2008

Post-Treatment 2009

Appendix B. Plant species according to life-form group.

Introduced, Annual, Forb
Geranium dissectum L.
Geranium molle L.
Trifolium dubium Sibth.
Vicia hirsuta (L.) Gray
Native, Annual, Forb
Galium aparine L.
Introduced, Perennial, Forb
Hypochaeris radicata L.
Lotus corniculatus L.
Plantago lanceolata L.
Ranunculus repens L.
Rumex acetosella L.
Senecio jacobaea L.
Stellaria media (L.) Vill.
Taraxacum officinale F.H. Wigg.
Trifolium repens L.
Vicia sativa L.
Native, Perennial, Forb
Cerastium arvense L.
Equisetum L.
Ranunculus occidentalis Nutt.
Veronica americana Schwein. ex Benth.

Introduced, Annual, Grass
Aira caryophyllea L.
Bromus hordeaceus L. ssp. *hordeaceus*
Vulpia bromoides (L.) Gray
Native, Annual, Grass
No species found
Introduced, Perennial, Grass
Agrostis stolonifera L.
Anthoxanthum odoratum L.
Dactylis glomerata L.
Schedonorus phoenix (Scop.) Holub
Holcus lanatus L.
Lolium perenne L.
Poa pratensis L.
Native, Perennial, Grass
Festuca rubra L.
Introduced, Perennial, Shrub
Cytisus scoparius (L.) Link
Rubus armeniacus Focke
Rubus laciniatus Willd.

Native, Perennial, Shrub
Malus fusca (Raf.) C.K. Schneid.
Rubus ursinus Cham. & Schltdl.
Native, Perennial, Sedge
Carex obnupta L.H. Bailey
Carex pansa L.H. Bailey
Native, Perennial, Rush
Juncus effusus L.
Luzula multiflora (Ehrh.) Lej.