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Control of Scot's Broom (*Cytisus scoparius* (L.) Link.): The Relative Conservation Merits of Pulling versus Cutting

Abstract

The control of invasive exotic plant species in sites of high conservation value should minimize both the impacts on the ecosystem of concern and the potential for regeneration of the exotic species. We examined how the method and timing of the removal of the invasive shrub Scot's broom (*Cytisus scoparius*) affected the level of site disturbance and subsequent broom regeneration from seed and resprouting in remnant Garry oak (*Quercus garryana*) meadow communities in Victoria, British Columbia. We compared manual uprooting versus cutting at two time periods: May, when the shrub was in flower, and in July, just prior to seed dispersal. Soil disturbance, trampling, and seedling regeneration were significantly higher in plots where broom plants were uprooted as compared to plots where broom plants were cut at the base. Amount of trampling was higher in July than in May, but in July the trampled plants were exotic grasses, while in May these included fruiting stalks of native common camas (*Camassia quamash*). Resprouting of cut stems was observed in only 7 of the 75 broom stems cut and these died-back within one year. These results suggest that the preferred Scot's broom removal strategy in Garry oak meadow communities of high conservation value is to cut broom after native herbaceous species have set and distributed seed. This approach will minimize damage to native vegetation and reduce the amount of broom seedling regeneration.

Introduction

Remnant Garry oak (*Quercus garryana*) meadow communities in British Columbia are designated "critically imperiled" by the British Columbia Conservation Data Centre (Erickson 1993, and see http://www.elp.gov.bc.ca:80/wld/cdc/). Most of what is now the City of Victoria (approximately 23 km^2) was Garry oak parkland at the time of European settlement in 1842 (Roemer 1972, McMinn et al. 1976). This oak parkland was described by early settlers in the Victoria region as open prairie dominated by a rich growth of grasses and attractive and conspicuous flowering forbs under scattered individual and groves of oaks (Douglas 1842). Most of these original oak parkland ecosystems present at the time of European settlement have been destroyed by clearing for agriculture, grazing, and urban development. Hebda (1993) estimates that only 1-5% of the original extent of this community type now remains. The few remaining Garry oak parkland ecosystems are fragments in developed landscapes and have been extensively invaded by the exotic shrub Scot's broom (*Cytisus scoparius*) (Erickson 1996).

Scot's broom is an invasive *Rhizobium*-nodulated leguminous shrub, native to the British Isles and Europe, but introduced to many other countries where it has become established in a wide range of habitats (Williams 1981, Wheeler et al. 1987, Hoshovsky 1991). Scot's broom readily establishes in pastures, cultivated fields, dry scrubland, native grasslands, open forests, roadsides, and dry waterways (Gilkey 1957, Williams 1981, Johnson 1982) and has extensively invaded susceptible areas in the Pacific Northwest (Gilkey 1957, Thilenius 1968, Franklin and Dyrness 1973, Taylor 1974, Zielke et al. 1992). The spread of broom is facilitated by disturbances, such as logging, land clearing, road building, and burning (Williams 1981, Zielke et al. 1992). Scot's broom typically forms dense stands in areas where shrubs had previously been absent or were minor components of the community. They displace native herbaceous plant species and prevent the regeneration of native trees (Williams 1981, Waterhouse 1986 and 1988).

A variety of manual, mechanical, thermal, chemical, and biological techniques have been

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employed to control or eradicate Scot's broom (Hoshovsky 1991 and Zielke et al. 1992 provide reviews). Manual broom removal, either by uprooting or cutting, is often used in sites of high conservation value, presumably since these methods are perceived to be the least damaging to the ecological values of the site. Manual Scot's broom removal efforts in British Columbia have not been well documented, but uprooting seems to be the preferred option. However, evidence suggests that there is an association between soil disturbance and broom regeneration from seed (Waloff 1968, Bossard 1991, Hoshovsky 1991, Smith and Harlen 1991, Zielke et al. 1992). Soil disturbance can also lead to the colonization of the site by other weedy plant species. In addition, uprooting broom can also have negative impacts on the native herbaceous vegetation on the site by exposing bulbs, corms, rhizomes, and roots to desiccation.

Although Scot's broom will resprout readily from a cut stump, sprouting potential seems to vary with the age of the plant (Miller 1992, Hebda 1994) and the season of cutting (Bossard and Rejmanek 1994). In general, sprouting is thought to be minimized by cutting broom plants during a period of maximum stress (i.e., after flowering, during seed production, and summer drought). However, Bravo (1985) advocated cutting broom before seed set to eliminate the further accumulation of seeds in the seedbank.

The goal of this study was to test whether uprooting or cutting Scot's broom was the better option for maximizing conservation of Garry oak meadow communities. Our objectives were to test the effect of the two control methods on several variables that measure impact on the plant community: 1) trampling of vegetation, 2) soil disturbance, and 3) Scot's broom seedling regeneration. We also documented whether or not cut stems of Scot's broom resprouted.

Study Area

The study occurred in a municipal park in the city of Victoria, on the southeast corner of Vancouver Island, British Columbia (48° 25' N, 123° 22' W). This 30.3 ha park contains some of the few remaining Garry oak meadow communities in the urbanized core of Greater Victoria. The climate of this region is characterized by warm, dry summers and mild, wet winters. Total precipitation is on average 650 mm annually, with approximately 95% of precipitation falling as rain (Environment Canada 1983). Mean temperatures range from a high of 15.5° C in July to a low of 4.1° C in January. Warm temperatures and low precipitation during July and August lead to a pronounced drought or moisture deficit (Chilton 1973). The annual moisture deficit in the study area is approximately 375 mm (McMinn et al. 1976).

Although anecdotal reports suggest that much of the park was open meadow beneath scattered Garry oaks until the early twentieth century, dense thickets of the native shrub snowberry (*Symphoricarpus albus*) now form the understory beneath most of the oaks. A few meadow areas containing native herbaceous plant species remain in the park, but these sites are dominated by exotic perennial grasses and are being invaded by Scot's broom (Ussery 1997). For example, the exotic perennial grasses *Agrostis capillaris* and *Dactylis glomerata* dominate most of the study area (Ussery 1997). The May treatment plots of Block 1 were dominated instead by varying proportions of the native grass *Danthonia californica*, and the exotic grasses *Cynosurus echinatus*, and *A. capillaris*.

Methods

We used a randomized block experimental design. Four meadow sites were divided into two blocks of three 6 x 3 m plots running parallel to the direction of Scot's broom invasion. Each block was randomly assigned to either May or July removal. The treatments (cut, pull, control) were then randomly assigned to the plots in each block. In the center of each 6 x 3 m plot we established a 1 x 2 m plot for data collection which allowed for a 1 m buffer against edge effects.

Scot's broom was removed on May 29, 1993, when it was in flower, and on July 15, 1993, before seed dispersal, to time removal with maximum investment of photosynthate in the above-ground shoot. Volunteers from the community were organized for the labor to mimic other Scot's broom control efforts. In 'cut' plots, volunteers were instructed to remove the above-ground portion of all Scot's broom plants greater than approximately 0.5 cm in diameter by cutting the stem as close to the ground as possible. All smaller broom plants were to be pulled. In 'pull' plots the volunteers were asked to uproot and remove all Scot's broom plants.

No attempt was made to restrict the movement of the volunteer laborers in the plots where broom was being removed. All of the broom plants removed from each site were carried in slings by the volunteers to central collection points where the material was fed through a chipper by the staff of the Oak Bay Parks and Recreation Department. The chipped material was removed to the Oak Bay municipal compost facility.

All of the plots were revisited within a week of removal to record the area of trampling of herbaceous vegetation and soil disturbance (i.e., exposed mineral soil). We imbedded rectangles of variable dimensions to measure the area. The edges of exposed soil were distinct enough to be accurate to the nearest square centimeter. Trampled vegetation had blurry edges so that size of area trampled was estimated as accurately as possible using this method. All 1 x 2 m plots were revisited in June 1994 to count the number of newly germinated Scot's broom seedlings and record the diameter, height, and resprouting status of all cut Scot's broom stems.

Analysis of Variance (ANOVA) was used to assess the effects of treatment, season, and an interaction between treatment and season on the amount of disturbed soil and trampled vegetation, and number of Scot's broom seedlings. The error term used to test the significance of removal method and timing was the variation attributable to the interaction between the different blocks and the appropriate treatment. Because of heteroscedasticity, the ANOVA on seedling regeneration in Scot's broom was performed on rank values rather than the raw data (SAS 1990). Contingency analysis (G-test) was used to test the association of different classes of stem diameter with resprouting.

Results

The percent cover of Scot's broom ranged from 20% to 60%, with a mean of 37.5% (± 10.8%, SE). The mean density of broom stems (excluding seedlings <10 cm in height) was 15.6 (± 9.6) per $2m^2$. Height of broom plants ranged from 40 cm to 162 cm.

Trampling affected more plot area than soil disturbance (Figures 1, 2). The proportion of herbaceous vegetation in each plot that was trampled during broom removal ranged from 25% to 100%. Treatments where broom shrubs were pulled rather than cut experienced more trampling (Figure 1, F=83.55, P=0.003, df=1,3). More trampling occurred in July, once the exotic perennial grasses had matured, than in May (F=97.04, P=0.002, df=1,3). However, the plants trampled in May were of greater conservation concern as they included fruiting heads of common camas (*Camassia quamash*).

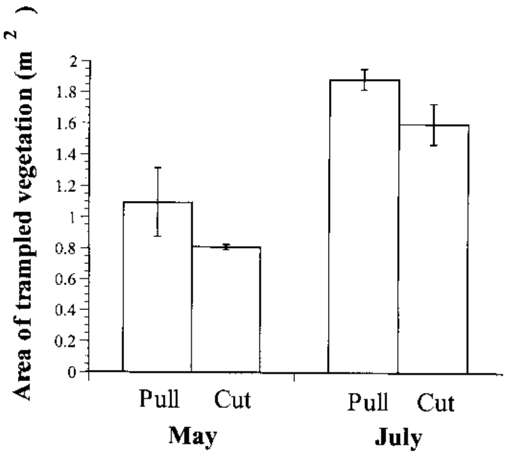

Figure 1. Area trampled per plot of Scot's broom removal, either by pulling or cutting in May or July. Means are shown ± 1 SE. Sample size is 4 plots per treatment.

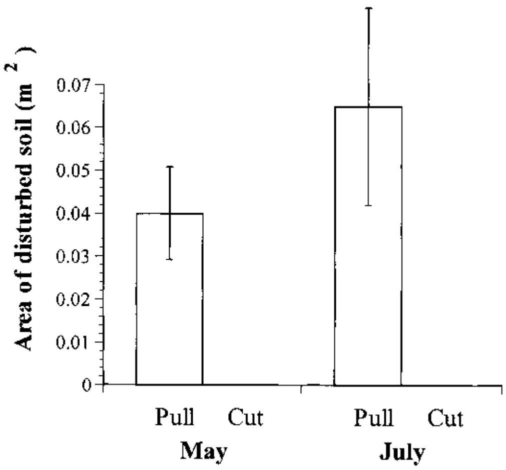

Figure 2. Area of disturbed soil per plot of Scot's broom removal in May and July. No soil was disturbed during the cutting treatments. Means are shown ± 1 SE. Sample size is 4 plots per treatment.

There was a significant relationship between the method of Scot's broom removal and the amount of soil disturbed (F=16.33, P=0.03, df=1,3). Soil disturbance was measurable in all "pull" plots, but not in "cut" plots (Figure 2). The total area of soil disturbed in "pull" plots ranged from 0.02 m^2 (1% of the plot) to 0.13 m^2 (6.5%). The timing of broom removal did not significantly affect the amount of soil disturbed (F=0.97, P=0.40, df=1,3).

More broom seedlings emerged the following spring in plots with adults removed by pulling rather than by cutting (Table 1, Figure 3). In every case, there were fewer broom seedlings in "cut" plots than in "pull" plots. Seedlings also emerged in plots that still had a canopy of adult broom plants ("control"), though fewer than in the treated plots (Figure 3). There was much variation (1-330/m^2) in the number of Scot's broom seedlings recorded within and between blocks (Table 1). The type and amount of grass cover may have affected the number of seedlings; further study will be needed to substantiate this (Ussery 1997).

Resprouting was observed in seven broom stems cut in May out of a total of 75 cut stems that were followed through the season (Table 2). Broom plants with small basal diameter were more likely to resprout upon cutting than plants with large basal diameter (Table 2). The highest rate of resprouting was 12.7 % for stems of less than 1.5 cm in diameter. The new shoots from all seven that resprouted died within the following year, so that no vegetative regeneration occurred from cut stems.

TABLE 1. ANOVA for seedling regeneration of Scot's broom following two different removal treatments (uprooting versus cutting) at two different times (late May and mid July). The r^2 of the model was 92.6%. The ANOVA was performed on rank values because of lack of homogeneity of variance.

Source	df	MS	F	P
A Block	3	171.75	A/G = 12.25	0.0057
B Treatment	2	147.22	B/D = 11.65	0.0086
C Timing	1	24.00	C/E = 0.57	0.51
D Block X Treatment	6	12.64	D/G = 0.90	0.55
E Block X Timing	3	42.19	E/G = 3.01	0.12
F Treatment X Timing	2	11.66	F/G = 0.83	0.48
G Error	6	14.02		

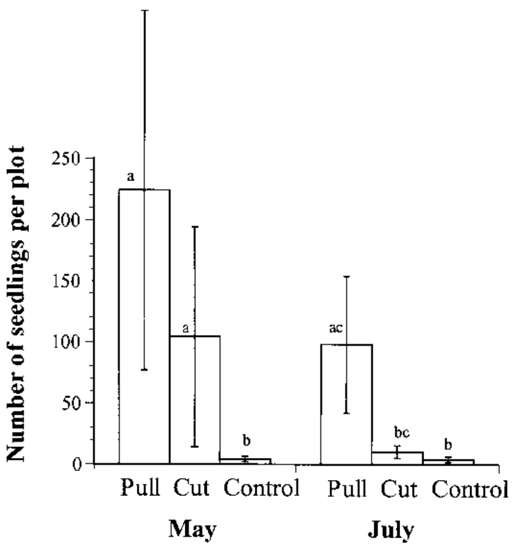

Figure 3. Number of emergent Scot's broom seedlings per plot in the year after adults were removed either in May or July, and either by pulling or cutting. Means are shown ± 1 SE. Sample size is 4 plots per treatment. Bars with different letters are significantly different at P < 0.05 (Fisher's Least Significant Difference Test, SAS 1990). Significant differences were calculated using rank values.

TABLE 2. Frequency of Scot's broom stem resprouting in relation to stem diameter. Expected values are in parentheses, below observed values. G-test: 12.46, df = 4, 0.025 < P < 0.01.

Resprouting Status	Stem Diameter (mm) 1-5	6-10	11-15	16-20	21-25
Resprouted	0	5	2	0	0
	(1.4)	(1.99)	(1.4)	(0.84)	(0.37)
Not Resprouted	10	30	15	9	4
	(13.6)	(29.01)	(13.6)	(8.16)	(3.63)

Discussion

Our results suggest that cutting is a better approach than uprooting for Scot's broom control on Garry oak sites of high conservation value. Trampling, soil disturbance, and subsequent seedling regeneration were less in cut versus uprooted plots. Our results also suggest that uprooting broom to prevent vegetative regeneration through resprouting is unnecessary because resprouting can be prevented or minimized by cutting at times of the year when the plant is most stressed.

The larger area trampled in plots where Scot's broom was pulled rather than cut, could be due to the greater effort needed to uproot most broom plants. When broom plants did not pull out easily, workers would circle to pull from different directions, thereby increasing the amount of trampling. Trampling can negatively affect the growth, reproduction, and the persistence of desirable herbaceous vegetation (Chappel et al. 1971, Burden and Randerson 1972, Liddle 1975). High levels of trampling before native forbs and grasses have been able to set and disperse seed may threaten the long-term viability of native plant populations already in decline. In our study sites, late May was still too early to avoid harming native flowering bulbs, with native common camas still forming fruits and seeds. In areas with established Scot's broom plants and declining native herbs, we recommend that broom plants be cut no earlier than mid June to allow seed dispersal of species of interest.

There was little variation in the area of soil disturbed within both May and July 'pull' plots despite considerable within- and between-site differences in Scot's broom size and density, and differences also in the composition of herbaceous vegetation. These differences may have had an impact on the variation between study plots in broom seedling regeneration, but this factor will have to be substantiated with further study.

Though we can not make a direct connection between soil disturbance and seedling regeneration we can say that the act of uprooting Scot's broom plants resulted in more seedlings than did cutting. Regardless of the method of removal, a flush of Scot's broom seedlings can be expected to appear after the canopy of broom is removed (Hoshovsky 1991, Hebda 1994, Smith 1994). Scot's broom seedlings may continue to appear for years after the initial control effort and annual follow-up treatments will be required to prevent the re-establishment of the species. For example, at a site in Australia, Scot's broom seedlings were still appearing after 16 years of sustained broom removal (Smith and Harlen 1991).

The low stem resprouting rate of Scot's broom plants with stems less than 2.5 cm in diameter was an unexpected result in this study. Both Miller (1992) and Hebda (1994) have recommended pulling broom plants with stem diameters less than 2.5 cm, based on their observations that plants below this size readily resprout from the cut stem. However, seasonal differences in resprouting ability observed by Bossard and Rejmanek (1994) show minimal resprouting (0%-10%) when cut in August. These and our results suggest that Scot's broom plants of all diameters, including those less than 2.5 cm, exhibit minimal resprouting if cut during mid-summer. Bossard and Rejmanek (1994) found the highest resprouting rate (90%-100%) occurred from plants cut in January and March, a period of dormancy and abundant root reserves.

The only drawback to cutting Scot's broom stems in mid summer is that by then its seeds have matured, and removal inevitably results in dispersal of Scot's broom seeds. Scot's broom seeds are viable in the seed bank for many years (Zielke et al. 1992). In sites where broom is not yet well established there is, therefore, a concern that broom removal in the summer might inadvertently lead to spread of the local Scot's broom population. Where Scot's broom is already well established, this is less of a concern; rather the priority becomes minimizing trampling damage to the remnant native herbaceous flora.

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