Factors affecting the control of *Cytisus scoparius* and restoration of invaded sites

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Summary

Cytisus scoparius **(Scotch broom) is a leguminous shrub native to Europe and North Africa but it is invading numerous locations in North America, New Zealand, Australia and other countries. Restoration of many sites requires not only the removal of this species but the suppression of its long-lived seeds and an understanding of possible long-term effects following removal. We tested the effectiveness of two methods of manual control (cutting vs. pulling) in conjunction with two post-control mulch treatments (arborist vs.** ***Cytisus*** **chips). The cutting vs. pulling and mulch experiments were conducted in the spring and the cutting vs. pulling portion repeated in the summer. The mulch treatments were effective at suppressing** ***Cytisus*** **seedlings to the following spring and the** ***Cytisus*** **mulch was slightly more effective. For the manual control treatments, season contributed more to success than method, with summer control being more effective than spring. We also performed tests on soil collected beneath the crown of** ***Cytisus*** **plants at four different sites in Washington State (USA) and compared the results with those of soil collected at the same sites where** ***Cytisus*** **was not growing. The** ***Cytisus*** **soil consistently had higher levels of total nitrogen and nitrate and lower pH levels versus the non** ***Cytisus*** **soil. These differences persist for at least several months and may affect restoration efforts.**

Keywords: *Cytisus scoparius*, Scotch broom, invasive species, manual weed control, mulch.

Introduction

Cytisus scoparius (L.) Link, Fabaceae (Scotch broom) is an invasive, *Rhizobium* nodulated shrub that is native to Europe and North Africa. It has been introduced to many countries where it has adapted to a wide range of habitats (Williams 1981, Hoshovsky 1986, Smith 1994, Parker 1996) but it achieves optimal growth when growing on well drained soils in full sunlight (Allen and Allen 1981). *Cytisus scoparius* was introduced to the Pacific Northwest of the United States as an ornamental in the 1850s (Gilkey 1957). It now occurs in disturbed habitats such as roadsides, forest clear cuts and river banks, but is also able to invade undisturbed grasslands, shrub lands and open forests below 1300 m (Bossard 2000).

Cytisus scoparius is a prolific fruiter and the seed bank can therefore be very large. The maximum reported number of pods produced per mature plant ranges from 800 in Washington State (Parker 2000) to 2700 in England (Waloff and Richards 1977). Williams (1981) in New Zealand reported mean seeds per pod between 3.6 and 9.3 while Bossard and Rejmanek (1994) reported a mean of 5.96 seeds per pod in California over a three-year period. They also reported a mean of 14 888 seeds per shrub per year and 9650 viable seeds per shrub per year, with the difference attributed to seed predation. Williams (1998) reported an average seed bank density of 3532 seeds per m^2 on a tussock and scrubland site in New Zealand. *Cytisus scoparius* seed is known to be long-lived, up to 80 years when stored under laboratory conditions (Turner 1933). In one study seven percent of seed remained ungerminated after three years at four centimetres below the soil surface (Smith and Harlen 1991). Any restoration sites containing *C. scoparius* must consider potential repopulation from the seed bank. Anecdotal observations from natural areas (e.g., Rocky Prairie and the Bald Hills in Washington State) suggest seeds can persist for well over a decade (Peter Dunwiddie, The Nature Conservancy, personal communication).

A variety of methods have been used to control *C. scoparius* at restoration sites (Hoshovsky 1986, Deutsch 1997, Drlik *et al*. 1998, Faithfull 1998, Bossard 2000), but manual methods are the most selective and can minimize effects on desired native vegetation. Methods include hand pulling small plants, removal of above-ground biomass by cutting, and whole large plant removal with weed wrenches. Cutting the stem, however, may result in resprouting.

Cytisus scoparius can be pulled either by hand or with a weed wrench. Hand pulling is only feasible with smaller plants and is easiest when the soil is moist. The weed wrench, invented by New Tribe, Inc. for removal of shrubs and small trees, uses a clamp to grasp the plant at its base and a lever action to wrench the roots out of the ground. Weed wrenches have become popular tools to remove *C. scoparius* because they eliminate the possibility of resprouting (Mountjoy 1979, Bossard 1990, Ussery and Krannitz 1998). Weed wrenches, especially with large plants, cause soil disturbance as the roots are pulled out of the ground. While some researchers have found an association between soil disturbance and seedling germination (Bossard 1991, Ussery and Krannitz 1998), the role of disturbance in the establishment of *C. scoparius* seedlings is not clearly understood.

In a study comparing the effects of cutting versus pulling broom in a *Quercus garryana* Dougl. Ex Hook (Oregon white oak) meadow in British Columbia, Canada, Ussery and Krannitz (1998) found that volunteers caused significantly higher levels of soil disturbance and trampling of vegetation while pulling versus cutting broom. They also found that on average, 50% fewer seedlings emerged from the cut plots in the following year. The authors concluded that in areas of high ecological value, where minimizing disturbance or trampling of the native vegetation is a primary goal, cutting plants is a better method. They also concluded that for their site it was better to control the plants in the summer than in the spring. Summer control resulted in less seedling regeneration the following spring, regardless of method, and in fewer resprouts. While the areas of soil disturbance and trampled vegetation were larger in the summer, there was more vegetation and the plants being affected were primarily European grasses and of less conservation concern than the native forbs which were flowering and setting seed in the spring.

Mulches have been used for weed suppression in tree plantations but their ability to control weeds on open sites has not received much attention. However, preliminary results from a mulch experiment on a rehabilitated landfill at the University of Washington indicate mulching may be effective for suppressing shrubby invasive species (Kern Ewing, University of Washington, personal communication 2002). In a Tasmanian demonstration project, successful control of a mature stand of *C. scoparius* was achieved by cutting the plants using a tractor with a mulcher attachment (Talbot 2000). This method was attempted after control attempts using herbicides or bulldozers and fire failed on similar stands. Two passes of the tractor reduced the stand to a 15–20 cm layer of mulch. After 24 months there was only sparse regeneration of broom on the site and a covering of grasses that excluded most seedlings.

Previous research on the effect of *C. scoparius* on soil chemistry has been limited to total nitrogen accumulation (Wheeler *et al*. 1987, Helgerson 1981) and seasonal accumulation of nitrogen (Wheeler *et al*. 1979). The effect on post-control restoration has not been previously considered.

The primary objective of this study was to quantify the effects of a number of manual control methods on *C. scoparius*. We asked the following questions:

1. Is cutting versus uprooting adult plants more effective in suppressing seedling establishment?
2. How does the seasonal timing of manual control affect seedling establishment?
3. Do subsequent mulch applications following manual control suppress seedling establishment and does the type of mulch make a difference?

In addition, we also asked:

4. Are soil characteristics such as texture, pH, ammonia, and nitrate levels of soil affected by *C. scoparius*, with potentially long-lasting effects that may influence restoration success?

Study area

We conducted the experiment at a nature preserve owned by The San Juan Preservation Trust on Guemes Island, one of the San Juan Islands in northwestern Washington (48°31′36″N, 122°38′16″W). The nature preserve consists of 17.5 hectares of waterfront on the south shore of the island along Guemes Channel. The area infested with *C. scoparius* is on a sandy berm located just behind a long established tidal strand. *Cytisus scoparius* reportedly first appeared on this site in the 1970s and had spread to cover about half a hectare of land by the time this work commenced the spring of 2001.

Methods

Experimental design

To determine which manual control method was most successful at suppressing seedling establishment, we set up an experiment using several removal treatments. We tested two treatments for manual control: pulling the entire plant, including roots, with a weed wrench and cutting plants off as near the soil surface as possible. We chose these methods as they are those most commonly used by volunteer work parties. We also assessed two additional treatments: mulching with arborist tree mulch and mulching with chipped *C. scoparius*. We measured the effectiveness of control by counting the number of seedlings that germinated by the following spring. The cut and pull treatments were performed in both the spring and the summer. The mulch treatments were only done on spring plots.

For the spring phase, we established 16 blocks each with four sampling sub-plots. Areas of uniform broom coverage were mapped out and the plots randomly placed in these areas. In all cases, the blocks had at least 75% *C. scoparius* cover. The sampling sub-plots were a 0.5 × 1 m rectangle with a 0.5 m buffer on each side. The buffers were established to lessen the need for precision in areas where cutting and pulling was occurring in adjacent areas and to ensure the sampling sub-plots received a uniform coverage of mulch. Eight of the blocks received the cut treatment with broom plants cut off at the base of the stem as close to the ground as possible. The other eight blocks received the pull treatment with the entire plant removed from the ground with a weed wrench. For either treatment the smallest plants, those less than 2 cm in diameter, were hand pulled when that could be done without causing soil disturbance. Once the blocks were established, the two mulch treatments were randomly distributed over the four sampling sub-plots. One of the four plots received arborist mulch (mixed species wood chips), another received *C. scoparius* mulch and the remaining two were left unmulched. The arborist chip mulch was obtained from an arborist company in Seattle and the *C. scoparius* was chipped on site. Approximately 1 m^3 of mulch was spread over the plot and into the buffer area to achieved uniformity in coverage on the sampling plots. This resulted in a mulch depth over the sampling sub-plot of about 10 cm. This design, with 16 blocks and 4 sub-plots each, results in 64 sub-plots, however with only two mulch types two sub-plots in each block received identical treatments. Therefore, data were only gathered on three sub-plots from each block (48 in total) – the two mulch sub-plots and one randomly chosen non-mulch sub-plots.

The summer treatment was designed in a similar manner. Twelve blocks with two sampling sub-plots each were sited in areas of uniform *C. scoparius* coverage. As before, the sampling plots were 1 × 0.5 m with a 0.5 m buffer on each side. In each block one plot was randomly assigned the cut treatment and the other the pull treatment.

The spring removal treatments took place over a three-week period in March and April of 2001 during the region's rainy season when any seeds disturbed by the control process would have ample soil moisture available for germination. The summer removal phase took place on July 20 and 21, 2001 after the end of the rainy season in the Pacific Northwest.

We returned to the site the following spring to measure the effectiveness of the control processes. The number of new seedlings in each sampling plot was recorded over a two-week period beginning on May 22, 2002.

Soil chemistry

To determine how *C. scoparius* can affect soil chemistry and potentially affect restoration success, we compared texture, pH and nutrient composition of soil where *C. scoparius* was present versus soil where *C. scoparius* was absent. We collected soil from 0–10 cm depth at four sites that had large stands of mature *C. scoparius*. These included the test site – Guemes Island, plus Discovery Park, Glacial Heritage and Mima Mounds. Discovery Park (47°39′37″N, 122°38′16″W) is a formerly forested urban park in Seattle and the other sites are Puget Sound glacial outwash prairies where *C. scoparius* is abundant. The Glacial Heritage site (46°52′32″N, 123°03′00″W) and Mima Mounds (46°54′33″N, 123°02′53″W) are both located near Littlerock, Washington. At each site the *C. scoparius* soil was collected beneath mature *C. scoparius* plants from at least six different plants. The non *C. scoparius* soil was collected in nearby open areas that were covered with grasses and forbs and were more than 2 m away from any large woody plants, including *C. scoparius*. The soil collection at Guemes Island was done six months after the *C. scoparius* had been removed with the soil being collected immediately adjacent to the remaining stumps. pH was measured in 5:1 de-ionized water on a model pHM85 meter from Radiometer Copenhagen and the nutrient percentages were determined from dry combustion using a Perkin Elmer 2400 Series II.

Statistics

We used SAS procedure GLM with Type III sums of squares (SAS Institute Inc., Cary, NC, USA, 1996) for the Guemes spring data analysis. Normality of distribution for each variable was checked using the Shapiro-Wilkes test. Equality of variances was analysed by plotting residuals using the general linear models procedure. The Shapiro-Wilkes test showed a slight deviation from normality so we checked the results by running a nonparametric ANOVA on the ranks. The results of the ranks ANOVA were slightly more significant, but did not change the results from the non-ranked data. Since the ANOVA F test is considered robust against departures from normal distribution (Kuehl 2000), we have reported the results of the ANOVA on the non-ranked data. The ANOVA for seedlings per plot included effects of treatment (cutting vs. pulling) and mulch (none, arborist or *C. scoparius*) and their pair-wise interaction. We used the Least Significant Difference Model for pair-wise comparisons of the mulch types. For the spring cut vs. pull comparison, comparisons between spring and summer plots and soil tests data, a two-sample t test was used. For the summer cut vs. pull comparisons we used a paired-sample *t* test. The paired test was used because the cut and pull data came from adjacent plots.

Results

We performed a two-factor ANOVA on the 48 spring plots (Tables 1 and 2). The main effects were treatment (cut or pull) and mulch (none, arborist chip or *C. scoparius*). The results from the ANOVA indicate differences in treatment and mulch are significant. There was no interaction effect between the treatment and the mulch.

Cutting versus pulling

The results of cutting *C. scoparius* plants off at the base versus uprooting the plants were not definitive (Figure 1). For the spring plots, pulling resulted in fewer seedlings the following spring: 196.8 ± 59.5 vs. 301.1 ± 81.1 (mean ± 1 SE, *N* = 16), but due to high levels of variance this difference was not significant (P = 0.32 *t*-test). On the summer plots, the results were substantially better for the cut plots than for the pulled – 157.6 ± 14.4 vs. 195.9 ± 25.3 seedlings (mean ± 1 SE, N = 24, P = 0.061 paired *t*-test).

Seasonal timing

To determine the differences associated with removing the *C. scoparius* in spring versus summer we only examined the non-mulched plots in the averages. Fewer seedlings emerged after the summer treatment versus the spring treatment: 176.8 ± 14.8, (*N* = 12) vs. 248.9 ± 50.4 (*N* = 16). However, this difference was not statistically significant (P = 0.12, *t*-test) (Figure 2). Comparing by method across the season, there was virtually no difference in pull plots (spring – 196.8 ± 59.5 *N* = 8 vs. summer – 195.9 ± 25.3 *N* = 12), while there was a significant difference between cut plots (spring – 301.1 ± 81.1 *N* = 8 vs. summer – 157.6 ± 14.4 *N* = 12, P = 0.048 *t*-test, Figure 1).

Mulch treatment

The differences between mulch treatments on seedling recruitment the following year were significant (P = 0.0001, ANOVA). The non-mulch plots had an average of 249 ± 50 seedlings (mean ± 1 SE, *N*=16) per plot, plots with arborist chip mulch 133 ± 36 and plots with chipped *C. scoparius* mulch 47 ± 13 seedlings (Figure 3). Using a Least Significant Difference model the difference between arborist chip and *C. scoparius* mulch approached significance (0.100 < P < 0.11).

Soil chemistry

One of the results, %N of Discovery Park non *C. scoparius*, was too low to be measurable. We recorded that result as 0.01 percent to be able to present C/N ratios.

Nitrogen levels were consistently and significantly higher for the *C. scoparius* soil samples from all locations, while the pH of the *C. scoparius* soil samples was consistently and significantly lower than the non *C. scoparius* samples at every site (P = 0.032) (Table 3). While the difference between sites was not significant for ammonium (P = 0.146) they were significant for nitrate (P = 0.048) and for total nitrogen (P = 0.030) (Figure 4). The carbon percentage was also consistently higher across all four sites in the *C. scoparius* soil.

Table 1. Values for main effects in experimental design on spring plots. Values are mean number of seedlings ± 1 SE per 0.5 m^{-2} plot.

	None	Arborist	*Cytisus*
Cut	301.1 + 81.1	177 ± 61.6	70.25 ± 23.8
Pull	196.8 ± 59.5	87.8 ± 36.0	23.4 ± 6.2

Table 2. ANOVA for seedling regeneration of *Cytisus scoparius* following two different removal treatments (cutting vs. full root removal) and three mulch treatments (none, arborist mulch and *C. scoparius* mulch) on spring plots.

Source	df	MS	F	P
Model	5	82725.3	3.92	0.0052
Treatment	1	77120.3	3.66	0.0626
Mulch	2	164699.4	7.81	0.0013
Treatment × Mulch	2	3553.8	0.17	0.8454
Error	42	21083.1	–	–

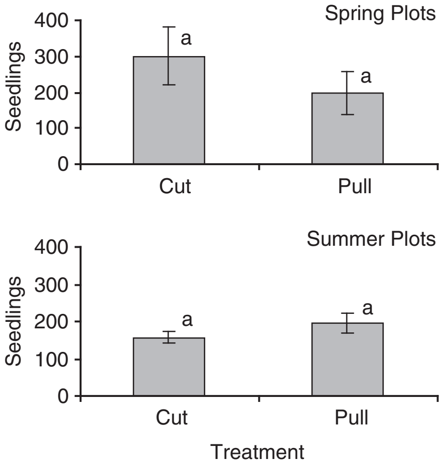

Figure 1. Number of emergent seedlings of *Cytisus scoparius* in plots the spring following two treatments (cutting vs. pulling (uprooting)). Bars with different letters are significantly different at P <0.05.

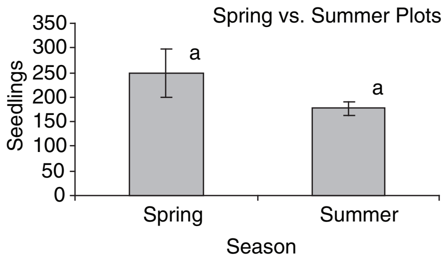

Figure 2. Number of emergent seedlings of *Cytisus scoparius* in plots the spring following two treatment times. Bars with different letters are significantly different at P <0.05.

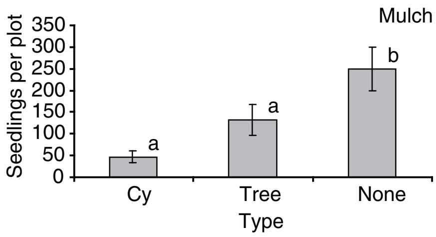

Figure 3. Number of emergent *Cytisus scoparius* seedlings per plot the spring after removal treatment (meant ± 1 SE). Bars with different letters are significantly different at P <0.05.

Discussion

Cutting versus pulling

Our study does not point to a clear choice between these two options. In the spring treatment, pulling yielded better results but the difference was not significant. Cutting worked substantially better in the summer treatment. In another study at an urban park in Seattle, we found that on average, cutting was more effective than pulling, but these results also were not significant (Dougherty 2003). Ussery and Kranitz (1998) had more consistent results finding fewer seedlings in the cut plots, regardless of season, although only the data from summer plots were significantly different.

Table 3. Comparison of *C. scoparius* (Cy) and non *C. scoparius* (No Cy) soil at four sites.

	Texture	pH	NH_4-N mg L^{-1}	NO_3-N mg L^{-1}	Total N	%C	%H	%N	C/N
Guemes Cy	sand	4.68	16.63	23.00	39.63	5.58	0.97	0.17	32.8
Guemes No Cy	sand	6.17	4.20	11.80	16.00	4.24	0.77	0.14	30.3
Glac Heritate Cy	sandy loam	4.25	3.01	202.00	205.01	7.40	1.48	0.10	74.0
Glac Heritate No Cy	sandy loam	5.44	7.40	9.40	16.80	1.67	0.44	0.01	167.0
Discovery Pk Cy	loamy sand	4.87	7.30	81.50	88.80	6.69	1.06	0.12	55.8
Discovery Pk No Cy	loamy sand	5.86	1.23	17.60	18.83	3.19	0.72	0.01	319.0
Mima Cy	sandy loam	4.34	30.95	132.00	162.95	15.27	2.46	0.59	25.9
Mima No Cy	sandy loam	4.66	2.88	21.30	24.18	9.87	2.54	0.45	21.9

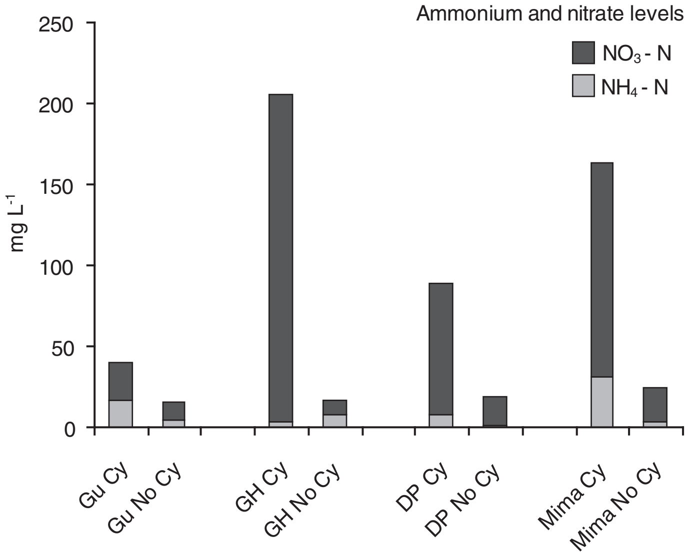

Figure 4. A comparison of ammonium (NH_4-N), nitrate (NO_3-N) and total nitrogen level at four sites in *C. scoparius* (Cy) and non *C. scoparius* (No Cy) soil. The differences for nitrate and total N were significantly different. Abbreviations: Gu – Guemes, GH – Glacial Heritage, DP – Discovery Park.

Seasonal timing

Examining the seasonal differences yielded some surprising results. The effectiveness of pulling did not change with the season, but cutting was more effective in the summer than in the spring. Two factors may have caused this result – disturbance and moisture availability. Pulling large *C. scoparius* plants from an area that has an extensive seedbank has two results – areas of disturbance are created and seeds are brought to the surface. With the hardy seed coat of *C. scoparius* (Gill and Pogge 1974), it is likely those seeds could survive the summer on or near the surface and germinate with the autumn rains. Cutting plants causes less disturbance (Ussery and Kranitz 1998) and would bring few *C. scoparius* seeds to the surface. Absent much disturbance, moisture availability may be the driving factor and there was a higher level of soil moisture in the spring. The rainfall for the two months when the spring controls treatments took place averaged 5.78 cm while the rainfall for July when the summer control took place was 1.12 cm (Western Regional Climate Center). This is an average pattern for this region. Summer treatments can also be seen as favourable toward native species. Many of the native forbs on sites favoured by *C. scoparius* in the Pacific Northwest are early bloomers more likely to be disturbed by spring treatments. By the time the rains have stopped many of those natives have already set seed and non-native grasses like bromes are more prevalent.

There is also a seasonal advantage in terms of the number of resprouts resulting from cut stems. In California, a study found a significant correlation between time of year and number of resprouts, with a less than 10% resprout rate for those plants cut in August compared to a greater than 80% rate for those cut in January or March (Bossard 1990). In a study in British Columbia, there were fewer resprouts when the cutting was done during the summer versus spring, while all those that did resprout died within a year without flowering (Ussery and Krannitz 1998). Those authors surmised that the seasonal difference occurred because during the summer the plant is stressed by putting maximum investment in the above-ground shoot. We also collected data on resprouts, but too few resprouts occurred to establish any seasonal patterns.

The only disadvantage to summer removal of *C. scoparius* is the possible further addition to the seedbank. For the Pacific Northwest the best time for removal may be late June or early July. By this time the dry season is beginning, many native plants have dispersed seed but most *C. scoparius* seeds have not matured. The level of invasion is also a factor. In areas with a canopy of broom, an addition of one more season's seeds may not be significant.

Mulch treatments

Mulches are effective in suppressing *C. scoparius* seedlings. Arborist chip mulch decreased the number of germinating seedlings by about 50% while *C. scoparius* mulch decreased the number of seedlings by nearly 80%. Covering the soil with a layer of organic matter is known to suppress seedlings but that the type of organic matter might make a difference is interesting. A difference might be expected if one of the mulches was decomposing faster than the other and providing less of a barrier to the seedlings. The *C. scoparius* chips, however, appeared to be decomposing faster (see Dougherty 2003 for details). Talbot (2000) also had success using *C. scoparius* mulch to suppress *C. scoparius* seedlings, but did not compare effect relative to other mulches.

One possible explanation for *C. scoparius* mulch suppressing its own seedlings is the presence of allelopathic compounds. *Cytisus scoparius* does have volatile chemicals (Faithfull 1998) that may be responsible, although other compounds can also have that effect. Cut broom plants will burn readily even after sitting in the winter rains for several months (personal observation), indicating that at least the volatile compounds persist after death. Any allelopathic effect may be species-specific but that theory will require further testing.

Important questions about the use of either mulch include what long-term effect the mulch has on soil chemistry and what happens after the mulch has decomposed. Most organic mulches, especially woody ones like the arborist and *Cytisus* chip mulches we used, have a high carbon to nitrogen ratio. While these mulches can cause a nitrogen deficiency in the soil for a few years as microorganisms tie up the nitrogen, this problem is lessened if the mulch is applied on top of the soil and not incorporated (Del Tredeci 2000, Harris *et al*. 1999). Nitrogen is eventually added to the soil as the mulch fully decomposes. It is also possible that covering the soil with mulch only delays the germination of the seeds and that once the mulch decomposes there will be a flush of seedlings in the newly composted soil. One reason to suspect this outcome is the large size of the *C. scoparius* seedbank (Williams 1998, Dougherty 2003) and its lengthy persistence (Turner 1933). While the viability of *C. scoparius* seeds under field conditions is unknown, there is evidence that at least some seeds may persist for decades. The Nature Conservancy began a control program of *C. scoparius* on Rocky Prairie a south Puget glacial outwash prairie in the 1980s and has been largely successful in removing the plants and preventing further flowering. Yet seedlings continued to appear on this site more than ten years after the control began (personal observations). Perhaps the best way to make use of its ability to suppress seedlings is to apply the mulch and plant desired species before the mulch has fully decomposed. This process would work best with woody plants that could be planted and then have their bases covered with mulch. The mulch, in addition to decreasing competition from weeds including *C. scoparius* seedlings, provides other benefits such as better moisture retention and increased soil fertility over time, which may increase the survival of restoration plantings (Harris *et al*. 1999). Mulching would help the plants become established and create a shade barrier to any *C. scoparius* seedlings that emerge after the mulch had broken down. Mulching could also be used for grasses and forbs. Holes could be dug into the mulch and pockets of grasses and forbs planted together. These pockets would have to be weeded annually to keep *C. scoparius* seedlings from emerging, but the grasses and forbs would probably be well-established when the rest of the mulch decomposed.

Soil chemistry

Cytisus scoparius was shown to enrich the soil with nitrogen and have other effects on soil chemistry at the four study sites. These effects are consistent with those found by Dancer *et al*. (1977), Helgerson (1981), Wheeler *et al*. (1979) and Wheeler *et al*. (1987). The lower pH levels of the *C. scoparius* soil that was observed at all four sites may be attributable to the nitrogen added by *C. scoparius*. These sites generally also had higher levels of ammonium (NH_4^+) that may either have leached from the nitrogen-fixing rhizobium nodules or was a product of the decomposition of the nitrogen-rich detritus from the *C. scoparius* plants. Much of the ammonium in the soil is converted into nitrate (NO_3^-) in a two-step process. In the first step ammonium and O_2 in the presence of the nitrosomas bacteria are converted into energy, NO_2^-, H_2O and $2H^+$. In the second step the NO_2^- and O_2 in the presence of the nitrobacter bacteria are converted into energy and NO_3^- (Brady and Weil 1999). It is the extra hydrogen ions in the first step that can cause the lower pH in nitrogen-enriched soils.

The implications of the nitrogen enriched soil and the other changes in soil chemistry on sites invaded by *C. scoparius* are not well understood. It has been found that increasing nitrogen levels can facilitate invasive species (Maron and Connors 1996) and decrease species diversity (Inouye and Tillman 1995), and that some nitrogen fixers can be very aggressive invaders (Walker and Vitousek 1991). In western Washington some of the more problematic *C. scoparius* invasions occur on naturally nutrient poor soils like those of the glacial outwash prairies of the south Puget Sound or coastal beach areas like those on Guemes Island. In a study of the impact of *C. scoparius* on community diversity, Parker *et al*. (1997) found a weak correlation between percent cover of *C. scoparius* and percent cover of exotic species on native prairie sites, but this occurred while *C. scoparius* was still a component of those communities and likely exerting a competitive advantage over native and non-native species alike. A more troubling aspect of this problem may be what happens after the *C. scoparius* is removed. In the one measurement we made of this on the Guemes Island site, elevated ammonium and nitrate levels and a lower pH level were persisting in the *C. scoparius* soil six months after its removal. On a coastal prairie in California, Maron and Connors (1996), showed how the nitrogen fixing native *Lupinus arboreus* Sims (bush lupine) upon its death left areas of nitrogen enriched soil that were more likely to be re-colonized by invasive brome grasses than by the native grasses and forbs. *Cytisus scoparius* may cause a similar effect, especially if adult plants are left on the site after they are cut down or uprooted. This long term effect requires greater investigation, but should be considered in restoration efforts.

In summary, *C. scoparius* is difficult to eradicate solely using manual control methods, but control by cutting in the summer in association with mulching may be more effective in reducing seedling establishment. Mulching may be less effective in areas where conservation of the remaining herbaceous vegetation is desired. It is important to attempt control, however, because in addition to *C. scoparius's* known invasive qualities, it also alters the soil chemistry and can have unforeseen and potentially long-term consequences in soils with naturally low nitrogen levels.

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