SHRUB RESPONSE TO WILDFIRE IN UPLAND SUBARCTIC FORESTS

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ABSTRACT

This study was designed to quantify the short-term resprouting success of the dominant deciduous shrub, little tree willow (*Salix arbusculoides*), in a subarctic forest following wildfire. The research site was in the central Mackenzie Valley, Northwest Territories, in a 300-year-old *Picea mariana*-dominated upland forest. An exploration seismic line, simulated transport corridor, and wildfire resulted in the removal of aboveground portions of *S. arbusculoides*. Resprouting occurred from buried root crowns. Current annual shoot and leaf morphology were measured at 1 and 3 growing seasons after mechanical denuding and 2 and 3 growing seasons after wildfire. The main differences among treatments were the increase in number of shoots and leaf size after denuding when compared with undisturbed forest samples. Based on shoot length and leaf area estimates, we predicted there would be more forage available for resident herbivores even during the first growing season after initial denuding. If increased forage availability is a desirable management objective, then denuding by mechanical or burning methods can help increase *S. arbusculoides*.

keywords: little tree willow, Northwest Territories, pipeline, right-of-way, *Salix arbusculoides*, seismic line, shrub resprouting, subarctic, transport corridor, wildfire.

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INTRODUCTION

Many species of shrubs resprout from roots following aboveground denuding (removal of aboveground phytomass) as a result of wildfire and anthropogenic disturbances (Rowe 1983, USDA 2001). *Salix arbusculoides* (little tree willow) is often a dominant understory erect deciduous shrub in forests of northwestern North America (Porsild and Cody 1980). It is common in most upland forest ecosystems west of Hudson Bay and has a probable Russian conspecific—*S. boganidensis* (Argus 1973). *S. arbusculoides* was the subject of a previous clipping experiment and was found to resprout vigorously, particularly in the second growing season (Evans et al. 1988, de Grosbois et al. 1991, de Grosbois and Kershaw 1993). However, its response to fire had been unstudied.

The objectives of this study were to determine the response of *S. arbusculoides* to denuding following different clipping treatments and wildfire. Included in this study were anthropogenic clearings associated with geologic exploration (i.e., seismic mapping) and transport corridors (i.e., winter road, pipeline).

STUDY AREA

A post-disturbance response study was conducted in the central Mackenzie Valley (lat 64°58′N, long 125°33′W) in a 300-year-old upland *Picea mariana*-dominated forest. Canopy closure was 15% with maximum tree height of 9 m, averaging 5.6 m. Initially, part of the site was subjected to a simulated transport corridor with the creation of a 25-m-wide × 700-m-long clearing similar to a pipeline, powerline, seismic line, or winter road right-of-way (ROW). This treatment involved the removal by hand-cutting of aboveground portions of all trees and tall shrubs within the corridor. In June 1995 the original study site was burned by a wildfire. This necessitated the selection of a new control, unburned reference stand. The original study site was 10 km north of Tulita (Fort Norman), Northwest Territories, Canada (Figure 1), and the post-fire reference stand was 3.5 km further north.

METHODS

Treatment blocks were a minimum of 25 × 180 m and sampling sites were randomly located on a 1 × 1-m grid within the blocks. Sample size varied among

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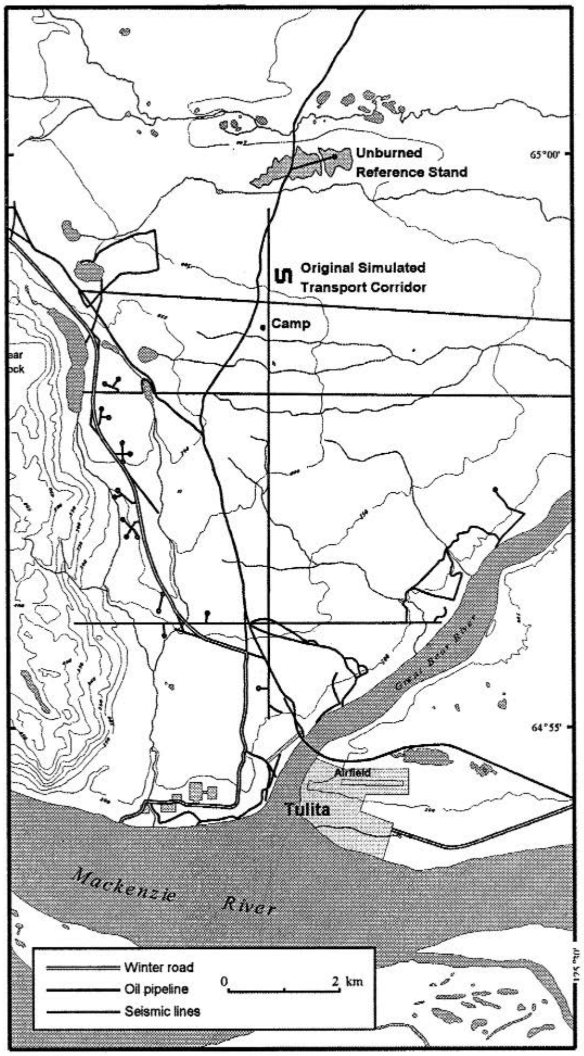

Figure 1. Original study area was 10 km north of Tulita (Fort Norman), Northwest Territories, but after the wildfire, an unburned reference stand was located 3.5 km further north.

the sampling years and treatments (Table 1). Three seasons of sampling were completed (1985, 1986, and 1987) prior to June 1995 when the site was overrun by a severe wildfire that killed all aboveground plant parts. Only the 1st and 3rd pre-fire seasons are reported here. Post-fire sampling was conducted in 1996 and 1997. Thus the sampling seasons were 1st and 3rd after clearcutting; 2nd and 3rd after wildfire. Because pre-fire data were available for *Salix arbusculoides* (Evans et al. 1988, de Grosbois et al. 1991, de Grosbois and Kershaw 1993), this species was selected for post-fire study.

Pre-fire treatments included a simulated transport corridor right-of-way (ROW) cleared as part of the study in 1985 and an exploration seismic line created in 1972. The ROW shrubs were clipped to ground level when the trees were hand-cut. The seismic line was cleared by bulldozer, and based on the depth of blading, this was probably a summer operation prior to the changes in legislation restricting such operations to winter.

An uncleared forest stand was the initial treatment control. After the original control stand was consumed in the 1995 wildfire, a search was conducted and a 20-ha unburned 100-year-old stand was found 3.5 km north of the original study area in which a new control site was established (Figure 1). In summary, there were 7 treatments used in the analysis: 3 pre-fire, 3 post-fire, and 1 unburned control (Table 1).

Aboveground shoots (live and dead) of *S. arbusculoides* were cut at the root crown and counted. Current annual shoots were separated at the previous year's bud scar. Length of each shoot (cumulative of main shoot plus lengths of its branches) and maximum basal diameter were measured as well as the maximum length and width of a randomly selected sample of 10

Table 1. Pre-fire and post-fire treatments and sample sizes used to assess the response of *Salix arbusculoides* to aboveground denuding by clearcutting or wildfire, Tulita, Northwest Territories.

	Sample size (*n*)						
Sampling season	Control	Right-of-way	Seismic line	Burned forest	Burned right-of-way	Burned seismic line	Unburned forest
1st growing season post-clearing 1985	20	20	10	na[a]	na	na	na
3rd growing season post-clearing 1987	30	30	—[b]	na	na	na	na
2nd growing season post-fire 1996	na	na	na	31	32	—	—
3rd growing season post-fire 1997	na	na	na	28	—	34	30

[a]Not applicable.
[b]Data not collected or not analyzed.

fresh leaves from each shrub. Leaf area was calculated using the formula:

$$\text{Leaf area (cm}^2) = \pi\,(\text{Leaf length}/2) \times (\text{Leaf width}/2) \times 0.863 - 0.092 \quad (1)$$

This formula was based on a leaf-area analogue (R^2 = 0.974) for true leaf area (de Grosbois 1989).

Statistical analysis was conducted with SigmaStat version 2.03 (SPSS 1997) and figures were produced with SigmaPlot version 7.0 (SPSS 2001). A Kruskal-Wallis one-way analysis of variance on ranks was followed by a Dunn's pairwise multiple comparison procedure to test for significant differences (P < 0.001) among all treatments and years.

RESULTS AND DISCUSSION

Shoots

Shoot length during the pre-fire period only differed significantly between the 1st and 3rd growing seasons after cutting on the ROW (Figure 2a). After the wildfire there were no significant differences in shoot length even after 3 growing seasons. The number of shoots was significantly greater between shrubs on the ROW and control between the 1st and 3rd growing seasons prior to the wildfire and between the burned seismic line and unburned forest during the 3rd growing season (Figure 2b). Shoot diameter was significantly less on the ROW than in the control stand prior to the wildfire (Figure 2c). By the 3rd growing season, post-fire shoot diameter was significantly higher in the burned forest and the unburned forest than on the seismic line. The greatest differences were found in shoot diameter between the unburned forest and the burned seismic treatment with shorter and fewer, but larger diameter shoots on the forest shrubs.

Although there were some differences in shoot characteristics between cleared (ROW and seismic line) and uncleared treatments there were no obvious trends (Figure 2). The differences that did exist can be attributed to the contribution of existing shoots to new shoot production. Shorter and fewer current growing-season shoots on unburned shrubs perhaps reflects the lack of stress associated with retention of multiple years of biomass, whereas the resprouting shrubs were experiencing compensatory growth following disturbance. Coppice growth form produces many shoots, and the disturbance treatments always had more shoots than associated controls.

Shoot production increases following disturbance have been reported for *Salix* spp. under a variety of

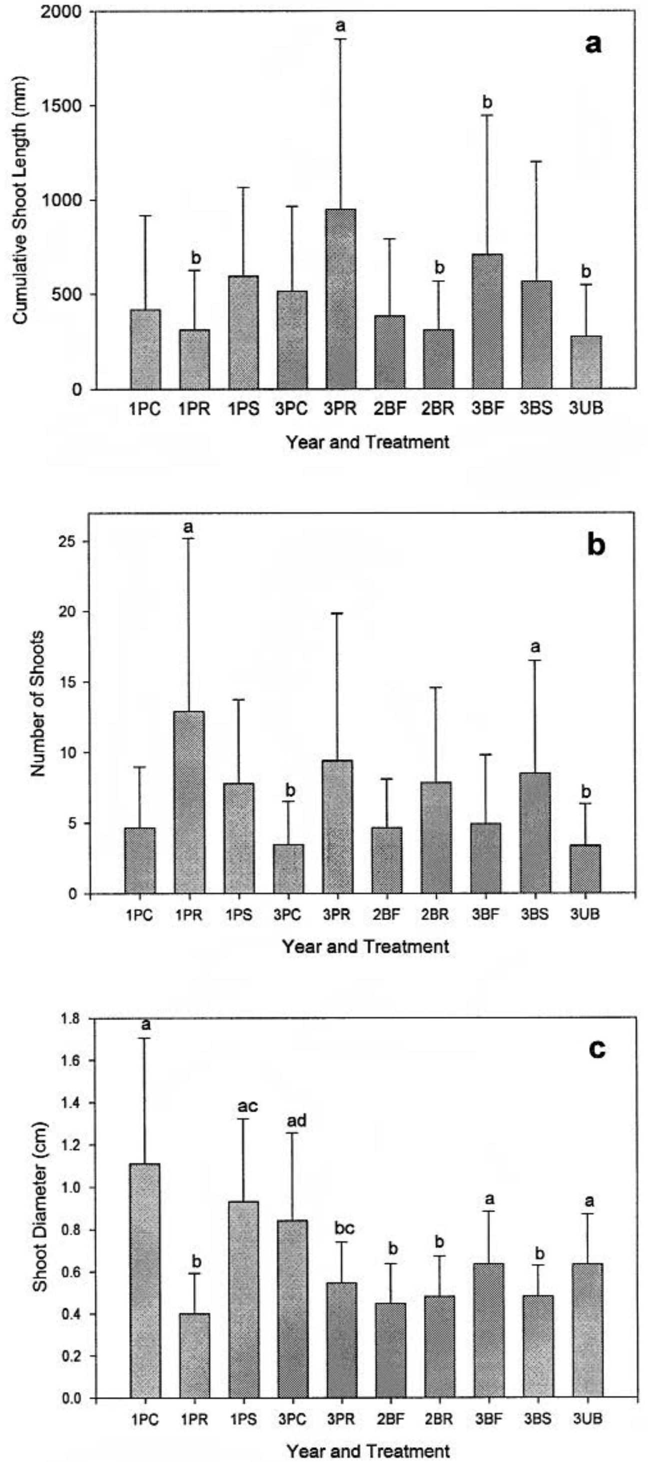

Figure 2. Mean and standard deviation for length (a), number (b), and diameter (c) of *Salix arbusculoides* shoots resprouting from denuded shrubs. Shrubs pre-fire (P) were clipped to ground level; shrubs post-fire (B) had aboveground biomass burned off by a wildfire. Numerals indicate number of growing seasons since denuding; C, control; R, ROW; S, seismic line; F, forest; UB, unburned forest. Different lowercase letters indicate significantly different values (Dunn's pairwise multiple comparison procedure, P < 0.001).

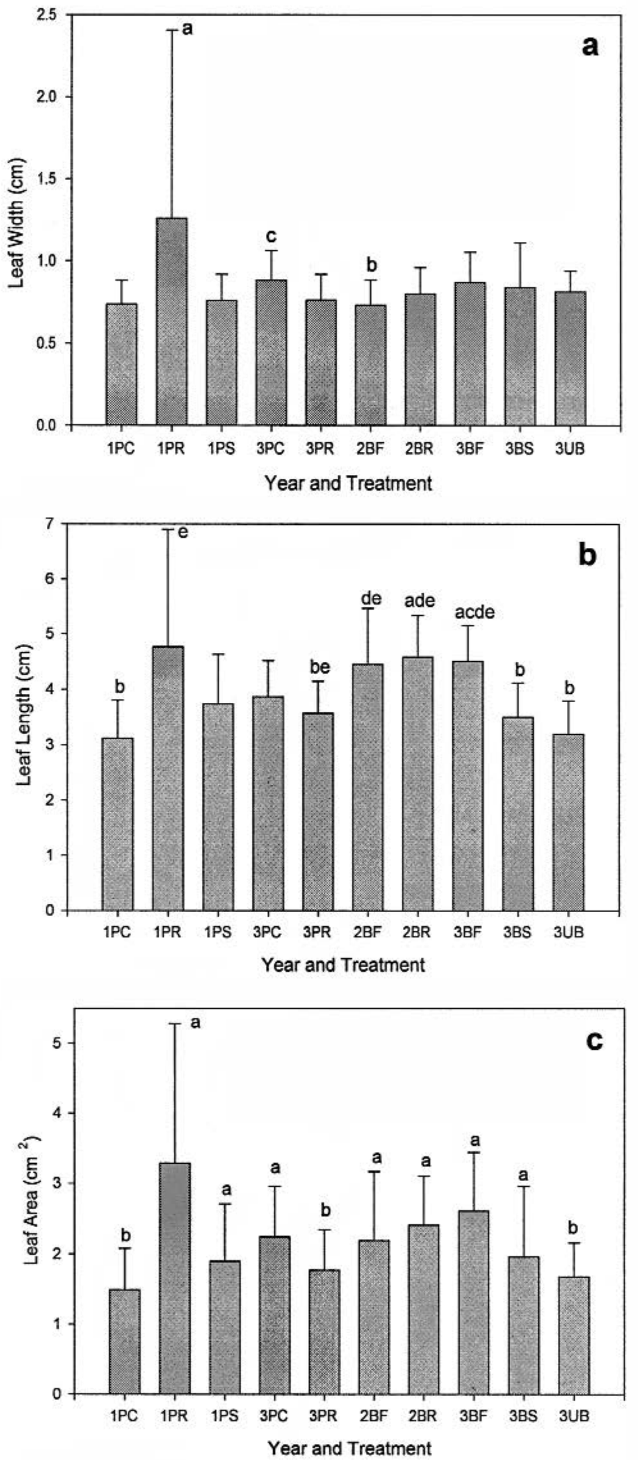

Figure 3. Mean and standard deviation for width (a), length (b), and area (c) of *Salix arbusculoides* leaves resprouting from denuded shrubs. Shrubs pre-fire (P) were clipped to ground level; shrubs post-fire (B) had aboveground biomass burned off by a wildfire. Numerals indicate number of growing seasons since denuding; C, control; R, ROW; S, seismic line; F, forest; UB, unburned forest. Different lowercase letters indicate significantly different values (Dunn's pairwise multiple comparison procedure, $P < 0.001$).

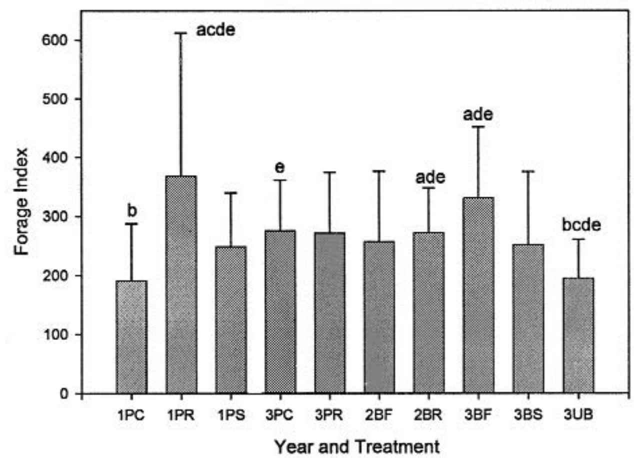

Figure 4. Mean and standard deviation of forage index for *Salix arbusculoides* shrubs resprouting following denuding. Shrubs pre-fire (P) were subjected to clipping; shrubs post-fire (B) had aboveground biomass burned off by a wildfire. Numerals indicate number of growing seasons since denuding; C, control; R, ROW; S, seismic line; F, forest; UB, unburned forest. Different lowercase letters indicate significantly different values (Dunn's pairwise multiple comparison procedure, $P < 0.001$).

disturbances and environmental circumstances. Flooding (Barnes 1985), ice scour (Bégin and Payette 1991), and the extreme environmental stresses experienced in tundra ecosystems (Belisle and Maillette 1988) can all result in enhanced shoot production. These natural events are mimicked by anthropogenic disturbances that denude aboveground shoots. Shrub responses following ROW clearing and seismic line disturbances differ little from natural disturbances such as wildfires.

Leaves

With few exceptions, leaf width was similar among treatments and between years (Figure 3a). Leaf length differed among treatments but was greatest within years. In 1985 the shrub leaves in the control plot were significantly shorter than on the ROW, whereas leaves in the post-fire forest and on the seismic line were longer than in the burned forest (Figure 3b). In the 1st pre-fire growing season the leaf area on the ROW was greater than the undisturbed forest; however, during the 3rd post-fire growing season the leaf area was significantly less in the undisturbed forest than on either treatment.

With leaf width generally not differing but leaf length being greater, the leaf area on disturbance treatments was often significantly larger than in control and unburned treatments (Figure 3c). Leaf area appears to be a proxy for severity of disturbance in that they become larger on disturbed sites. This was more evident in the post-fire seasons when all shrubs in disturbance treatments had significantly larger leaves than the shrubs in the unburned treatment. This response can be partly attributed to enhanced light regime and reduced competition in the post-fire environment (de Grosbois 1989, de Grosbois and Kershaw 1993, Bégin and Filion 1995).

Shrub Resprouting

Shrub resprouting following aboveground denuding is important in areas where wildlife species depend on woody forage (Bryant and Chapin 1986). In the western Northwest Territories there are resident moose (*Alces alces*), caribou (*Rangifer tarandus*), snowshoe hare (*Lepus americanus*), and grouse (Phasianidae) populations that forage on shrub shoots (including buds) in the dormant season and on leaves during the growing season. In order to get an appreciation of the potential availability of forage for resident wildlife the shrub data were used to compose an index of potential forage availability:

$$\text{Forage Index} = (\Sigma\text{Shoot length}/n_{\text{shoots}}) + (\text{Leaf area} \times 100), \qquad (2)$$

where ΣShoot length is cumulative current annual shoot length (cm) and n_{shoots} is the number of current annual shoots on a shrub. The mean area of 10 randomly selected leaves from the shrub was leaf area. Leaf area was then multiplied to provide a base of 100 leaves on each shrub. This was an arbitrarily set number that was large enough to give a more realistic leaf area value than just 10 leaves that were measured on each shrub. Based on this index, it is apparent that disturbance treatments supported shrubs with greater potential forage availability than control or unburned treatments (Figure 4). This effect was most pronounced in the 1st growing season after mechanical denuding and in the 2nd and 3rd growing seasons after wildfire.

MANAGEMENT IMPLICATIONS

There was no consistent or significant difference in response to burning between shrubs that were denuded prior to the wildfire and those that were not. Resprouting shrubs on transport corridors (ROW) responded in a similar fashion to those that were burned in the adjacent forest during a wildfire. However, it should be remembered that the shrubs on the ROW and seismic lines in our study had at least 10 growing seasons to recover from the initial disturbance before being burned by the wildfire. Shrubs denuded by anthropogenic activities that are burned earlier can respond differently, and probably these shrubs would have reduced vigour if root reserves have not recovered from the initial denuding. Disturbance treatments supported shrubs with greater potential forage availability than control or unburned treatments. If a desired management action is to increase forage availability, then denuding by mechanical or burning methods can help increase *Salix arbusculoides*.

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