Prairie Habitat Restoration and Maintenance on Fort Lewis and within the South Puget Sound Prairie Landscape

Final Report and Summary of Findings

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Fort Lewis, Washington

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Preface

This report summarizes the native prairie habitat restoration and maintenance efforts on Fort Lewis, Washington, and in the South Puget Sound region, which have been conducted since 1993 under the auspices of the subagreement in place between the U.S. Army/Fort Lewis and The Nature Conservancy of Washington. These efforts have included defining the composition of the prairie ecosystem as well as the application of experimental and practical management techniques. These efforts have occurred in large part on Fort Lewis, but they have included and been integrated with off-base efforts which are referenced herein. Funding for this project was originally provided through the Department of Defense Legacy Resource Management Program in 1993. This funding has been supplemented annually by Fort Lewis since then.

In September 1993, Fort Lewis and The Nature Conservancy of Washington entered into a subagreement pursuant to delegation authority contained in the Cooperative Agreement between the Department of Defense and The Nature Conservancy dated December 13, 1988; the Cooperative Management Agreement between the U.S. Army/Fort Lewis and The Nature Conservancy of Washington; and the Sikes Act, 16 USC 670a, as amended. This subagreement is titled "Prairie Habitat Restoration and Maintenance on Fort Lewis" and has been the subject of amendments dated July 1994, March 1995, June 1995, September 1996, and September 1997.

Numerous interim reports summarizing the status, progress, methods, results, and findings of this effort have been provided to the Environmental and Natural Resources Division as well as the Planning, Training, Mobilization, and Security branch of Fort Lewis during the subagreement period. This report constitutes the final report for this project and covers the period from September 30, 1993, to January 1, 1998.

A one-day seminar was held on November 7, 1996, at the University of Washington as a part of this project. The papers from the presentations held there have been edited and published as "Ecology and Conservation of the South Puget Sound Prairie Landscape." This publication details and complements the prairie restoration and maintenance efforts discussed herein.

Project administration, oversight, design, methodology, implementation, analysis, and reporting efforts were led by Patrick Dunn and Curt Soper of The Nature Conservancy of Washington. Numerous other individuals on staff or retained by the Conservancy have participated directly in accomplishing the project's objectives.

The primary purpose of this project was to define, develop, and initiate management practices designed to preserve, restore, and rehabilitate native Puget Sound prairie grasslands and savannas. Specific goals originally identified included the following:

- Define the composition of native Puget Sound prairie grasslands and savannas.
- Identify gaps and initiate needed research or inventory of all components of the prairie ecosystem.
- Develop specific targets and restoration objectives.
- Redirect ongoing inventory efforts where needed and feasible.

- Develop a network of native prairie management specialists, and integrate restoration efforts with off-base efforts.
- Select specific species and prairie/savanna sites for restoration.
- Assess effects of past prescribed burning efforts on invasive species.
- Test methods of control for specific invasive species in coordination with other native prairie management specialists.
- Establish procedures for monitoring effects of all control procedures on key native and invasive species.
- Design and initiate a test planting of native species (including the collection of native seed and growing of seedlings/propagules at on-base or contract facility).
- Test the transplanting of prairie sod taken from areas deemed to be irretrievably damaged.
- Document results of test propagations and plantings.
- Implement planting, transplanting, invasive species control, and other restoration techniques at target sites.
- Implement monitoring program at target sites to assess change in vegetation and other key habitat variables.

Executive Summary

Prairie restoration and management in the South Puget Sound has a long history. Native Americans managed the prairie with their most powerful tool, fire. Fort Lewis has continued this legacy in modern times, initiating prescribed burning on prairies nearly 15 years ago. Only recently, though, has a suite of restoration and management techniques been utilized specifically to improve prairies for their biodiversity values.

The greatest success in maintaining and restoring the biodiversity of prairies has been achieved with controlling woody pest plants, especially Scotch broom and Douglas-fir. A range of tools are effective in controlling these species. Prescribed burning is still widely used as a primary tool to control Scotch broom. The implementation and success of fall burning at Fort Lewis and other prairies is especially encouraging. Mechanical and chemical controls, again initiated at Fort Lewis and elsewhere in the South Puget Sound region, also have proven track records.

The major hurdle for prairie managers in controlling these pests is not the technical skills, but the systematic implementation of known control methods. Often limited resources, shifting priorities and the vagaries of the Northwest's climate keeps managers from executing a complete and effective program to control woody pest plants.

Several herbaceous pest plants become problems once woody pest plants are controlled. Pasture grasses are especially troublesome since their invasion alters basic prairie processes and limits the biodiversity values on the prairie. In addition, several control methods, including prescribed fire and mechanical cutting, are ineffective with most pasture grasses. Fortunately, studies at Fort Lewis have shown that chemical control is promising. In fact, several specific herbicides control most pest grasses while being benign to the most prevalent native prairie species. Further implementation of these techniques will determine if they will be an effective control method over larger areas.

Actively replanting prairie species into disturbed or newly created areas is a more recent activity. The greatest success has occurred by transplanting plugs of prairie plants. This success includes developing techniques to propagate most prairie plant species.

Idaho fescue is especially amenable to transplantation. With more than 90% of several hundred thousand transplants surviving and thriving on Fort Lewis alone, it is a remarkably effective technique. Interestingly, most planting supplements, such as mulch, fertilizer or water, are not helpful for transplanted Idaho fescue, especially when transplanting into bare or open soils. In trials at Fort Lewis many of these supplements facilitated the establishment and growth of nonnative pest plants that soon covered much of the available prairie. Active supplementation may be needed when transplanting into areas where there is substantial competition from nonnative plants. In that case, supplements, such as mulch, that limit competition have proven beneficial.

Transplantation of prairie forbs is less tested, though results for a variety of species has been positive. At both the Rocky Prairie Natural Area Preserve and on Fort Lewis many common and important prairie forbs have been successfully transplanted. This includes rare prairie species, such as white-top aster.

Direct seeding of Idaho fescue was also successful at Fort Lewis. Germination and establishment of seedlings was good, though growth was not as rapid as transplanted plugs.

Trials with direct seeding of other prairie species have been limited, though initial trials with several species have been successful. The development of techniques for the direct seeding of large prairie areas still needs to be accomplished.

Restoration of Oregon white oak woodlands involves a variety of techniques, including several unique ones. Controlling pest plants in oak woodlands is very similar to those same efforts in grasslands. One aspect that does differ significantly is the protection of oak canopy from disturbance and destruction. This protection is especially pertinent when dropping large Douglas-fir trees that have invaded the woodland. Several specific variations on traditional logging practices are needed to minimize that damage.

If damaged oak trees need to be replaced , or a new oak woodland created, then the active transplantation of Oregon white oak is required. Planting of acorns was not productive at Fort Lewis, with both predation and drought severe constraints on successful establishment. In contrast, transplanting oak can be highly successful. Trials at Fort Lewis showed that when seedlings are shaded then survival and growth are very good.

Finally, several additional techniques can improve prairie restoration and management. The persistent working of a comprehensive action plan is an important technique. These plans must include specific alternatives when planned tasks cannot be implemented. These alternatives are especially important in pest control, since pest species continue to invade and degrade prairies when a control action is delayed. Prairie restoration and research is being implemented throughout the South Puget Sound region. Participation in groups such as the South Puget Sound Prairie Landscape Working Group helps assure that collaboration and cooperation throughout the region continues. A similar concern exists with research. Although all types of prairie research are to be encouraged, the development of a set of research priorities will help advance prairie restoration and conservation more quickly and effectively.

Introduction

The prairies of the South Puget Sound region are open, diverse habitats within the broader landscape of the closed, coniferous forests of the Puget Lowlands. Prairie grasslands, oak woodlands, and Douglas-fir and ponderosa pine savannas are all integral parts of the native prairie landscape. In addition, the juxtaposition of these prairie communities with wetlands and coniferous forest creates unique habitats found nowhere else in Washington.

This landscape contains many rare and sensitive plant and animal species. Two of Washington's federally listed plants occur within the landscape, golden Indian paintbrush (*Castilleja levisecta*) in prairie grasslands and water howellia (*Howellia aquatilis*) in wetlands. Several additional state-listed plants occur in the prairie landscape, most notably white-topped aster (*Aster curtus*) in grasslands, and small-flowered trillium (*Trillium parviflorum*) in woodlands. Sensitive animals of the prairie include the mazama pocket gopher (*Thomomys mazama*), western gray squirrel (*Sciurus griseus*), and a suite of prairie-dependent butterflies; all of these animals are state listed or are candidates for listing. Oregon white oak (*Quercus garryana*) woodlands in the South Puget Sound have been identified as sensitive habitat of state-wide importance for neotropical migrant birds. In addition, several species of plants and animals are now locally extinct from the prairie landscape. These include the rose checker-mallow (*Sidalcea malviflora* var. *virgata*), Lewis woodpecker (*Melanerpes lewis*), and racer snake (*Coluber constrictor*).

The decline or local extinction of these species has been caused or aggravated by the destruction and fragmentation of prairie habitat. The prairie landscape in South Puget Sound once extended from just south of Tacoma to beyond Oakville along the Chehalis River (Figure 1). In 1995 less than three percent of that area remained prairie (Crawford and Hall, 1997). Today that figure continues to decline due to outright destruction of habitat, while much of the

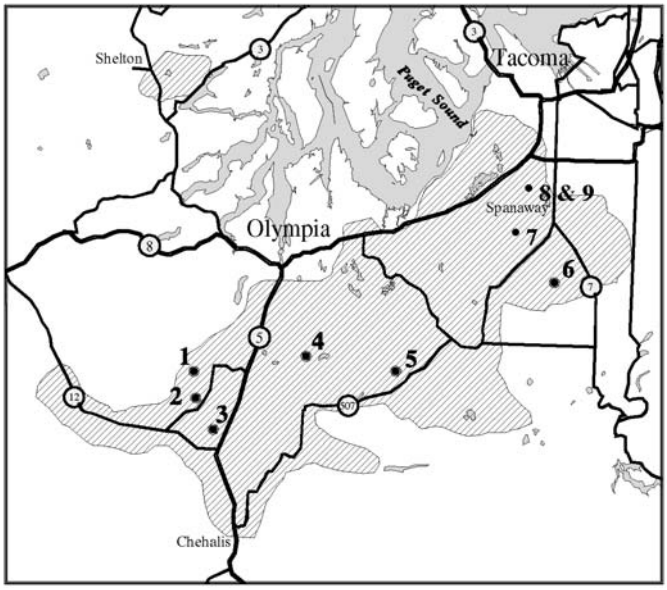


Figure 1. *South Puget Sound prairie region, including major protected prairies.*

1 – Mima Mounds Natural Area Preserve

2 – Black River–Mima Prairie–Glacial Heritage Park

3 – Scatter Creek Wildlife Area

4 – Rocky Prairie Natural Area preserve

5 – Weir Prairie Research Natural Area

6 – Thirteenth Division Prairie Research Natural Area

7 – Bower Woods Ponderosa Pine Forest RNA

8 – Bensten Candidate RNA

9 – Talbot Candidate RNA

remaining habitat is being degraded by alteration of ecological processes, the introduction of invasive pest species, and continued disturbance by excessive human usage.

Prairies are special beyond their biological uniqueness. In the Puget Sound area, the prairie landscape has an important role in regional human history, with the first fort and agricultural centers established on prairies. The prairies were also critical for the Native Americans, generating food and medicine essential for their survival. The remnants of prairies that persist today are reminders of our heritage, a physical link to our ancestors and how they perceived the South Puget Sound.

The act of prairie restoration respects both biological and human qualities. By reestablishing or creating habitats, restoration supports the plants, animals, and ecological processes of the prairies. Restoration also links people to their heritage by actively involving them in preserving that heritage, the prairie landscape of the South Puget Sound.

This report focuses on the practical techniques that were studied and attempted in the past four years and are needed to implement successful restorations within the South Puget Sound prairie landscape. First, the basic ecological components of the prairie, its vegetation states, ecological processes, and landscape configuration are delineated to help identify current status, desired endpoints and restoration pathways. Then we look at control or eradication of several pest species—a primary goal of many restorations. Specific species and the techniques to control them are discussed. Next, techniques that enhance the vegetation of grassland and woodlands, including prairie sod salvage, direct seeding, and transplantation of plugs are detailed. These techniques are evaluated for success and efficacy on both small- and large-scale projects. Restoration of Oregon white oak woodlands is discussed, highlighting techniques that differ from those used in grassland restoration. Finally, several specific methods are described to help improve the likelihood of a successful restoration. These include working your restoration plan, regional networking and cooperative actions and focusing research.

The Prairie Landscape

The South Puget Sound prairie landscape extended historically from just south of Tacoma down through the Chehalis River drainage southwest of Oakville (Figure 1). Today, prairie occurs in only a few locations (Rolph, 1996). A significant portion of the Fort Lewis–McChord Air Force Base complex still contains native prairies. This includes five designated or proposed Research Natural Areas that have been specifically identified as significant prairie landscape resources (Table 1).

Table 1. *Protected prairie areas in the South Puget Sound region.*

Protected Area	Ownership	Size (Acres)
Mima Mounds NAP*	WA State - Dept. of Natural Resources	445
Rocky Prairie NAP	WA State - Dept. of Natural Resources	47
Black River-Mima Prairie-Glacial Heritage Preserve	Thurston County - Dept. of Parks and Recreation	1,020
Scatter Creek Wildlife Area	WA State – Dept. of Fish and Wildlife	1,200
13th Division Prairie RNA**	US Army - Ft. Lewis	234
Weir Prairie RNA	US Army - Ft. Lewis	1,096
Bower Woods Ponderosa Pine Forest RNA	US Army - Ft. Lewis	1,739
Bensten Candidate RNA	McChord Air Force Base	131
Talbot Candidate RNA	McChord Air Force Base	128

* Natural Area Preserve (NAP) ** Research Natural Area (RNA)

Other major occurrences of prairie include State of Washington holdings in Thurston County—the Rocky Prairie and Mima Mounds Natural Area Preserves and the Scatter Creek Wildlife Area. Thurston County has preserved an important part of the landscape in its Black River–Mima Prairie–Glacial Heritage Preserve. In addition, several prairies are still held privately, including parts of Rocky, Rock, and Mima prairies.

Finally, several parcels contain rare prairie components, although they are not considered to be pristine prairie sites. These include areas between airport runways at Olympia and Shelton, and sections of Fort Lewis and McChord that are heavily used for military operations.

Conditions and Processes

Each of these South Puget Sound prairie sites was shaped by conditions and processes that include porous, nutrient-poor soils formed of glacial outwash; summer drought periods; anthropogenic fires; and soil disturbances. These conditions created the open grasslands and savannas of the prairie landscape and continue to keep at bay the invasion of Douglas-fir and subsequent forest formation.

The foundation for Puget Prairies are soils derived from the glacial outwash of the latest ice age. Kruckeberg (1991) gives a good summary of the history of events involved with initial soil formation. Characteristics of the soils pertinent to restoration include low water-holding capacity, and low nutrient supply (Table 2, Ugolini and Schlichte, 1973). These characteristics, combined with summer drought periods, create conditions conducive to grasslands and limit the establishment of Douglas-fir and other forest trees. Summer drought can be a strong mortality factor. Large numbers of conifer seedlings can be found dead, seemingly from drought, on the prairie. Yet this is not an absolute filter, since Douglas-fir regularly becomes established on the prairie.

In historical times the majority of trees that became established on the prairie were killed by another important ecological process, fire. The prairies and woodlands were subjected to periodic fires set by Native Americans (Lang, 1961; Agee, 1993). Fires are a strong mortality factor for small Douglas-fir, other conifers, and even for Oregon white oaks. With modern prescribed fires, most Douglas-fir under 5 ft. are killed (Tveten, 1996). The combined effects of low establishment rates and high mortality of small trees during fires, resulted in the open grasslands and sparse savannas of the prairie landscape.

Several types of disturbances play a significant role in shaping the prairie landscape. Fire has already been mentioned as a force that limits trees and other woody vegetation, a positive effect when managing for prairie grasslands. Fire has several other important impacts, including creation of bare soil suitable for seed germination and establishment (Agee, 1993). The combination of periodic fires and a bunchgrass as the dominant grassland species helps ensure that a entire suite of forbs and grasses will have sufficient sites for establishment.

Table 2. *Soil profile description for Spanaway Soil series (adapted from Ugolini and Schlichte, 1973).*

Horizon	Depth (cm)	Description
O1	3-1	Partially decomposed grasses.
O2	1-0	Black, well-decomposed grasses.
A1	0-40	Black (10YR 2/1) loam; fine crumb structure; friable, nonsticky, nonplastic; many fine roots; clear, smooth boundary.
B2	40-58	Black brown (7.5YR 3/2) sandy loam; fine crumb structure; friable, nonsticky, nonplastic; some fine roots; abrupt smooth boundary.
IIB3	58-81	Yellowish brown (10YR 5/6) gravely sand; single grain; nonsticky, nonplastic; very few roots; abrupt, wavy boundary.
IIC1	81+	Variegated, colored gravely sand; single grain; nonsticky, nonplastic; very few roots.

Another type of disturbance that creates safe sites for plant establishment is the digging of pocket gophers (Figure 2). These fossorial animals create extensive systems of tunnels under the prairie. Much of the dirt excavated during tunnel formation is pushed to the surface and forms small piles of bare earth. These small disturbances have significant effects in a variety of ecosystems, including prairies (Huntley and Inouye, 1988). In the South Puget Sound prairies, pocket gopher disturbances correlate with the occurrence of white-topped aster (*Aster curtus*), an endemic species. In addition, pocket gopher disturbances may be a factor in the rapid invasion by some pest plants, since the small piles of bare dirt are safe sites for these species as well as native prairie species (Hartway and Steinberg, 1997).

Mechanical disturbance from human actions also plays a significant role in shaping prairies. The severity of this disturbance ranges widely, from small occurrences to complete denudation of acres of prairie. Unfortunately, the ramifications of these disturbances are mainly negative, since they usually result in further expansion of nonnative and pest species, fragmentation of remaining prairies, and destruction of rare species.

Figure 2. *The Mazama pocket gopher forms small disturbances on the prairie by excavating soil.*

Figure 3. *Typical grassland vegetation at Mima Mounds Natural Area Preserve.*

PLANT COMMUNITIES

Processes and conditions that effect prairies interact with the plant species present in the prairies to create a range of specific plant community types (Chappell, 1997). Although each of these community types has unique characteristics, they can be simplified to two structural types: open grasslands, and savannas and woodlands with widely to closer spaced trees.

Grasslands are the major constituent of South Puget Sound prairies (Figure 3). Under pristine conditions, the bunchgrass Idaho fescue (*Festuca idahoensis*) dominates these communities with up to 70 percent cover. Only a few other native grasses or sedges are significant in terms of percent cover. These include long-stolon sedge (*Carex pensylvanica*), California oatgrass (*Danthonia californica*), and prairie junegrass (*Koeleria cristata*). None of these grasses, including Idaho fescue, form thick swards over large areas that preclude other species. This leaves room for a suite of forbs, the diversity of which can be tremendous, with dozens of species occurring in a square meter. Interestingly, the majority of these species are perennials; there are few annuals on South Puget Sound grasslands (Table 3, on following page, and Table 4).

Table 4. *Vegetation characteristics within typical Oregon white oak woodland in the South Puget Sound, modified from Hanna and Dunn, 1996.*

Parameter	Mean	Range
Stand density (trees/ha)	69	5–100
Species diversity of trees	3	1–6
Relative density of oak (%)	88	70–100
Relative coverage of oak (%)	79	35–100
***Relative frequency of crown* (%)**		
Open	67	50–90
Partial	34	10–50
Closed	0	0
Snag density	2.8	0–10
Relative coverage of oak snags (%)	32	0–100
Cover of understory oak (m^2/ha)	50	0–200
***Relative frequency of understory oak in DBH classes* (%)**		
.03 - .1m	13	0–30
.1-.2m	31	5–60
.2-.35m	31	15–50
.36-.5m	16	0–50
>.5m	10	0–25
Shrub diversity	2.5	0–6
Cover of shrubs (m^2/ha)	2,690	0–6,000
Cover of graminoids (m^2/ha)	7,400	5,000–9,900

Table 3. *Vegetative composition of typical South Puget Sound prairie grassland and Oregon white oak savanna and woodland, modified from Chappell, 1997.*

	Prairie Grassland		Oak Savanna & Woodland	
Species	**Constancy**	**% Cover**	**Constancy**	**% Cover**
Trees				
Douglas-fir	29	<1	40	2
Oregon ash			20	<1
Oregon white oak			100	53
Shrubs				
Common snowberry	7	<1	70	6
Creeping snowberry			10	13
Indian plum			50	<1
Oceanspray			20	3
Kinniknnick	7	<1		
Graminoids				
California danthonia	79	2	50	3
Field woodrush	71	<1	60	2
Idaho fescue	100	45	60	6
Long-stolon sedge	93	2	100	22
Prairie junegrass	29	2	10	<1
Red fescue			20	22
Forbs				
Bluebells-of-Scotland	29	<1	10	3
Braken	64	5		
Broadpetal strawberry	64	4	20	3
Choclate lily	21	<1	40	<1
Common Camus	86	6	60	5
Common vetch			50	5
Cutleaf microseris	71	<1	40	2
Early blue violet	64	4	70	<1
Henderson's shooting star	50	<1		
Houndstongue hawkweed	86	4	20	2
Meadow death-camus	57	<1	40	<1
Nuttall's peavine			10	3
Pomo-celery lomatium	43	<1	20	4
Prairie lupine	64	2		
Puget balsamroot	21	3	10	13
Slender cinquefoil	57	2	10	3
Spikelike goldenrod	64	2		
Western buttercup	64	2	60	2
White-top aster	71	4	40	<1
Woods strawberry	7	3	20	3
Wooly sunflower	93	2	20	6

Typically, grasslands are degraded along two paths: by the increase of pest grass species or the invasion of woody pests (Figure 4). Pest grass species typically form dense sods which displace other plants, especially forbs. Most of these pests were introduced to the prairies as pasture grasses, and with disturbance they can increase dramatically. The most prevalent sod-forming pest on our prairies is colonial bentgrass (*Agrostis capillaris*).

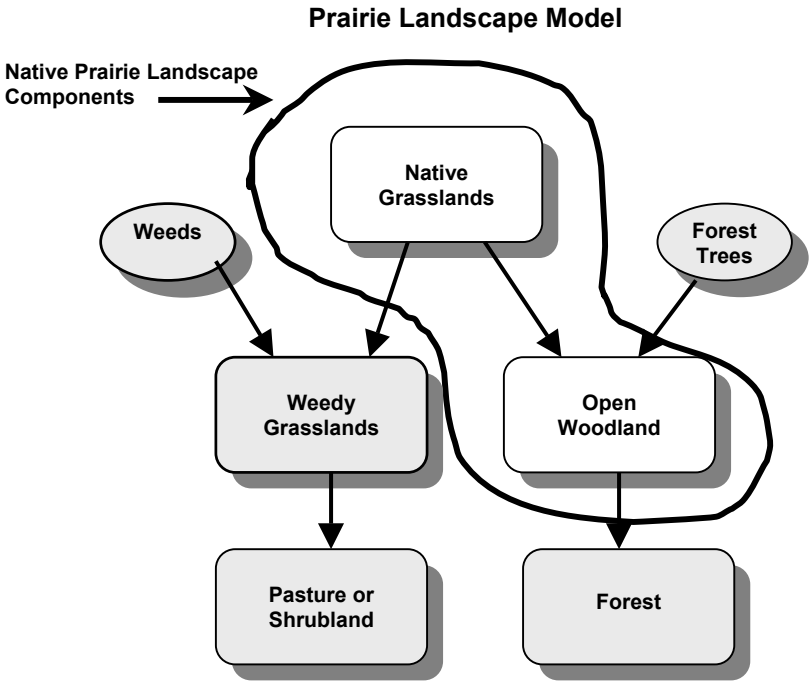


Figure 4. *Conceptual model of native and degraded South Puget Sound Prairie Landscape components. Woodlands are typically dominated by Oregon white oak but may also be dominated by Douglas-fir or lodgepole pine.*

The impacts of woody pest plants are more obvious than those of the pest grass species. A thicket of Scotch broom (*Cytisus scoparius*), for example, has few of the values associated with prairie grasslands. Scotch broom displaces species and changes soil chemistry through nitrogen fixation. Other woody pests include forest trees, especially Douglas-fir. If left unchecked by fire or mechanical thinning, Douglas-fir will displace the prairie. Much of the prairie loss at Fort Lewis has been through conversion of prairie to Douglas-fir forest (Public Forestry Foundation, 1995).

Savannas and woodlands, the secondary structural plant community of the South Puget Sound prairie, look like they are merely grasslands with a few trees thrown in. Yet this is deceiving. Although the understory of savannas can be very similar to open grasslands, where conditions are moister, the understory composition changes dramatically. Even in the most open savanna, the presence of trees, especially oaks, creates habitat for a whole host of different animals.

Several different native tree species form savannas and woodlands in the South Puget Sound region (Figure 5). Garry oak is near its northern extent in Puget prairies and forms a range of pristine and degraded communities (Hanna and Dunn, 1997). This region also has savannas and woodlands of ponderosa pine and Douglas-fir.

Savannas and woodlands can be degraded in ways similar to grasslands. Invasion of pest plants, especially Scotch broom, is a problem. Douglas-fir can invade most oak woodlands, quickly overtopping mature oaks and creating shade, which leads to the death of the oaks. These invasions are especially prevalent if fire has been suppressed in the stand. Even without the presence of pest species, fire suppression can lead to degraded conditions where the trees form dense thickets. These thickets are used rarely by animals that inhabit the open structure of savannas (Hanna and Dunn, 1997).

These prairie and woodland/savanna communities are also interspersed with wetlands and streams. It is the juxtaposition of these upland and wetland communities that forms unique habitats for some of the landscape's rarest animals. In these places, one might observe rare prairie butterflies while standing next to a salmon-bearing stream. And it is the wetland–prairie interface that formed habitat for some of the locally extinct plants and animals such as the western pond turtle (*Clemmys marmorata*). The decline of these "combination" habitats has led to an overall reduction of biodiversity in western Washington. The prairie/wetland interface is used by wildlife in a variety of ways. Western toads (*Bufo boreas*) from a large breeding population in Fiander Lake on Fort Lewis move through dense forest to overwinter in the prairies (Hallock and Leonard, 1997 and personal communication). These toads may be using abandoned burrows of prairie-dependent pocket gophers during the winter. Restoration of prairie communities that are interspersed with wetlands is particularly beneficial in preserving the larger native ecosystem.

The mosaic of communities within this landscape is not static. Several ecological processes help these communities change in both their extent and composition. Historically, the fires of Native Americans was the most powerful process. These fires created and maintained savannas and woodlands of Oregon white oak, Douglas-fir, and ponderosa pine. These fires also dictated the composition of the understory, especially when dynamic weather and fuel loads existed. In addition, small microhabitats, such as those that today support various oak woodland types, also lead to unique mosaics of plant communities and animal habitats.

In modern times the most important dynamic processes are fire suppression and soil disturbance. With fire suppression, grasslands and woodlands are invaded by woody species and can be quickly altered to shrubland or forest. Soil disturbance facilitates the establishment and spread of pest plants. These disturbances are typically human-caused, such as vehicle damage, domestic stock grazing, or damage related to human recreation, but the disturbance caused by pocket gophers is an example of biological disturbances. Managing, controlling, and restoring these disturbances are of primary importance to managers of prairies.

LANDSCAPE-LEVEL RESTORATION CONSIDERATIONS

This report and much of the restoration effort it describes focuses on the level of the plant community. This is both a strength and a weakness. The targets and goals of restoration typically involve plant community parameters. These parameters are fairly easy to measure and are relatively stable, even when considered in the framework of a dynamic system.

Figure 5. *Oak woodland is an important component of South Puget Sound prairies.*

Although plant communities are the level of hands-on restoration, the higher landscape level should not be ignored if the restoration is to be beneficial to the wide range of plant and animal species that inhabit the prairie landscape.

Many animals require several different plant community types to support them (Figure 6). These integrated habitats can be quite extensive and complicated. For example, the western gray squirrel requires the juxtaposition of several different plant communities to create adequate habitat (Ryan and Carey, 1995). Oregon white oak, a permanent water source, and coniferous forest are all part of western gray squirrel habitat requirements (Ryan, 1997). The restoration of only a single element of these habitat requirements would be insufficient for the western gray squirrel. Landscape considerations and planning needs to be incorporated into every restoration effort.

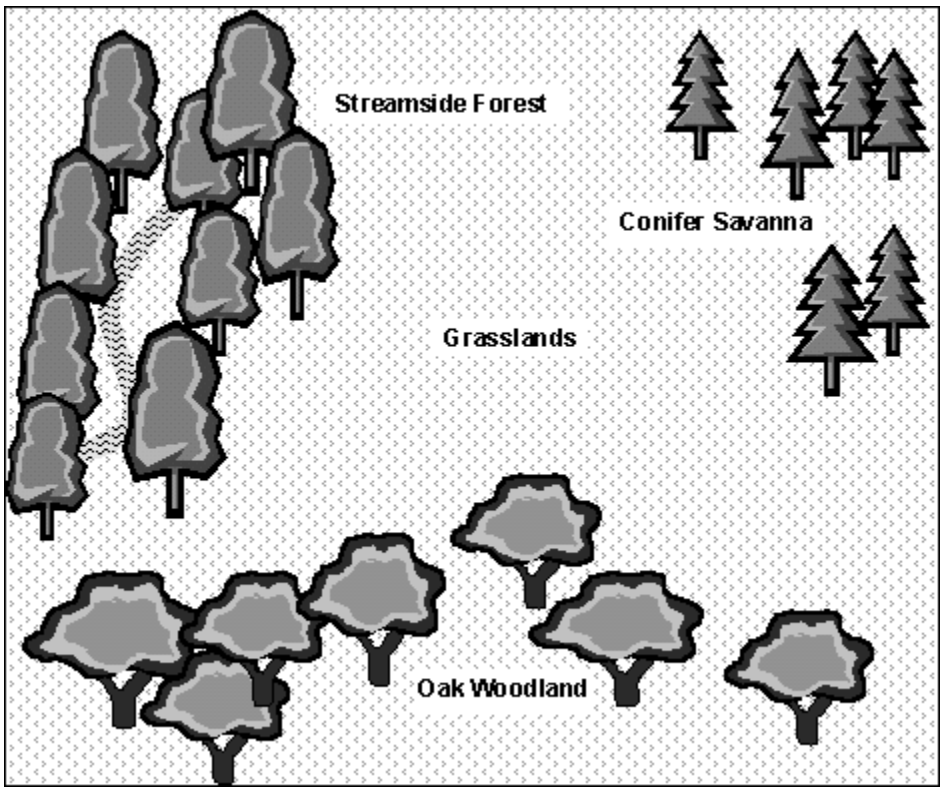


Figure 6. *Schematic representation of South Puget Sound Prairie Landscape components. Numerous species require several of these components for their individual habitats.*

Pest Species

Plant and animal species that invade and alter prairie ecosystems are of importance to prairie managers and a primary target for prairie restoration. These pest species are typically nonnative species that flourish away from their natural predators and pathogens, though native species can also be pests.

Pests degrade prairie by limiting native prairie species and altering basic ecological process. Scotch broom is a good example of a pest species (Figure 7). Scotch broom invades intact prairies and, if left uncontrolled, can convert grassland understory into dense shrubland. This shrubland contains few prairie species, and in fact, very few plant or animal species at all (Parker et al., 1997).

Figure 7. *Scotch broom can form monotypic thickets such as the one above. Few prairie plants or animals occur in these thickets.*

Additionally, Scotch broom alters the nutrient balance in the soil through its ability to fix nitrogen, likely increasing nitrogen pools in the generally nutrient-poor prairie soils. In other nutrient-poor ecosystems, the addition of nitrogen fixers results in a cascade of effects, ameliorating conditions that allow additional pest plants to invade (Vitousek et al., 1987).

Native species can also be pests. The most noticeable example of a native pest species on prairies is Douglas-fir. Douglas-fir readily establishes in prairies, especially during summers that are wetter and cooler than normal. If fire does not kill these newly established individuals before they are 60 cm in diameter (Tveten, 1997), then they will likely be the first step towards conversion of prairie to closed forest. This type of forest conversion has caused a reduction of 39% in Fort Lewis prairies since 1870 (Public Forestry Foundation, 1995).

Not all nonnative species are necessarily pests. Many nonnative species are not sufficiently deleterious to be targets of management or restoration actions. Target species generally have the capacity to alter basic ecological processes or increase to levels where they displace desirable native species. Prioritizing the control of pest species is important in order to focus resources on the most important manageable pest problems.

Pest Animals

Most management and restoration actions concerning pest species of prairies have involved plants. Pest plants can have obvious, large impacts, are easily tracked, and often have an established network of concerned citizens since many are also pests on agricultural lands. Yet pest animals are also of concern. Nonnative animals can have large effects on natural ecosystems (Drake et al., 1989). Feral animals and their associated diseases are causing one of the greatest episodes of modern extinction on the Hawaiian and other tropical islands (Mooney and Drake, 1986).

Within the prairie landscape, Philpott (1997) has shown that nonnative ladybird beetles (ladybugs) can displace native ladybugs. Another known animal pest is the cowbird, which is an egg parasite on the nests of neotropical, migrant birds. At McChord Air Force Base, cowbirds parasitize nearly 25% of the nests surveyed (Rogers et al., 1997). Prairie managers have yet to manage actively these animal pests, but as we learn more of their impacts pest animals may become important targets of prairie management.

Quarantines and Controlling Incipient Invasions

The easiest way to manage pest species is to keep them from entering and becoming established on the prairie landscape. This task is becoming more difficult with increased regional and global travel and commerce. Yet the effort is well worth it, since many pests that are well known threats have yet to invade the South Puget Sound prairies (Buschmann, 1997).

Quarantine methods have the basic goal of preventing new pests from invading natural habitat. The related task of controlling incipient invasions aims to eradicate the pests that slip through the quarantine before they are established widely. Initiating a program that encompasses these two aspects will help reduce the chance of new pests becoming established.

Quarantines can range from simple to elaborate. For natural habitats, quarantine actions are usually rather simple and straightforward. The best way to develop a quarantine program is to develop background information on potential pest species and their vectors, identify the culprits that will likely transport the pests, and then develop specific quarantine methods (Dunn et al., unpublished paper).

A program complementary to quarantine actions is one of monitor and control efforts specifically targeted towards eradicating pests that are newly established. This program needs to include a monitoring component, which looks for newly arrived pests, and a control component that quickly eradicates all new pests. Controlling even the most aggressive pests can be successful and relatively easy if it occurs before they are widely spread. An early eradication program can help limit the costs and damage of additional pests in the prairie landscape.

Figure 8. *Scotch broom is an easily recognized pest in South Puget Sound prairies.*

CONTROL OF SPECIFIC PEST PLANTS

Scotch Broom

Scotch broom is a woody shrub easily recognized by its bright yellow, pea-like flowers, which appear in the spring and early summer (Figure 8, previous page). Its dark-green, broom-like branches are held more or less erect. Leaves on upper portions of branches are simple while those on lower portions are three-parted. Individual shrubs may grow to a height of ten feet and live to seventeen years. Like many other species in the legume family (Fabaceae), Scotch broom forms root nodules with soil bacteria to fix nitrogen.

Scotch broom is deleterious to the prairie in several ways. It can rapidly form dense thickets that become monocultures. This not only displaces prairie vegetation, but few prairie animals use these thickets. Observations of neotropical migrant birds at McChord Air Force Base showed significantly fewer bird species use broom-infested prairies than those where broom is controlled (The Nature Conservancy, 1996). Reductions in native prairie vegetation also occur, with significantly fewer species occurring when broom forms a closed canopy (Parker et al., 1997).

The other significant threat to prairies by Scotch broom is its ability to fix atmospheric nitrogen in the soil. This extra input of nitrogen can result in significant changes in the pool of nitrogen available to plants, which is normally low in prairie soils. The ameliorated conditions caused by the increased nitrogen can lead to invasion by other pest species, resulting in further degradation of the prairie.

Two characteristics of Scotch broom make control difficult. First, the seed produced by the plant can remain dormant for up to 70 years. The seed bank can therefore both accumulate to large size and remain viable after several control efforts. The second characteristic that makes control difficult is Scotch broom's ability to resprout from the base of the plant. This ability reduces the success of both mechanical cutting and fire control efforts.

Several different control techniques are suitable and have been used for Scotch broom. Mechanical methods range from hand pulling to cutting with a tractor-driven "brush hog." Controlled burning has been used extensively at Fort Lewis and Mima Mounds NAP, with both spring and fall burns occurring. Chemical control has been used the least on natural areas, but herbicides are effective on Scotch broom, and some application methods hold promise for effective use in prairies.

<u>Mechanical control</u> – Mechanical methods aim to pull the entire plant or remove all of the above-ground material. Hand pulling is the simplest mechanical method. It is limited to smaller plants and is easiest in the late winter or spring when soils are not frozen and still wet. Hand pulling can be used when a site is small, the infestation low, and a source of laborers available. Hand pulling has been the primary control method at Rocky Prairie Natural Area Preserve, where 47 acres of rare plant habitat has been maintained for more than a decade. Hand pulling was also used effectively as a follow-up to fall prescribed fire at Fort Lewis at Upper Weir Prairie.

If plants are too large for hand pulling, a weed wrench can be used (Figure 9). This commercially available product acts as a lever for more effective pulling of larger plants. Conditions for weed wrenching are similar to those for hand pulling, though weed wrenches can be used effectively throughout the year. Unfortunately, weed wrenching, like hand pulling, is time consuming and should only be applied in targeted areas and situations. A negative side effect of hand pulling and using a weed wrench is the disturbance of the soil, as large chunks of soil will sometimes cling to the pulled plant. This disturbance creates conditions conducive for the germination and establishment of many pest plants, including Scotch broom.

The simplest method of cutting Scotch broom is using hand loppers. Medium- to high-quality garden loppers are suitable and can be used by untrained volunteers. Volunteers using loppers have been effective at Fort Lewis and the Glacial Heritage Park. At Fort Lewis, hand loppers were used to control Scotch broom within sensitive butterfly habitat in the Thirteenth Division Prairie RNA, while at the Glacial Heritage Park volunteers controlled more than 20 acres of Scotch broom using hand loppers.

Figure 9. *A weed wrench is effective in controlling Scotch broom; it is also slow, hard work.*

A hand-held motorized brush cutter is an effective aid in mechanical control (Figure 10). When the brush cutter has a metal cutting blade with a tooth design similar to a chain saw, Scotch broom of almost any size can be cut. These units can be sharpened and maintained in the field and have proven a reliable and safe tool. The operator must be careful to cut the Scotch broom as close to the ground as possible. This limits the number of plants that will resprout. These brush cutters are best limited to trained personnel. The Nature Conservancy has utilized brush cutters with volunteers, but only those specifically trained on the safe use of the machine.

Motorized brush cutters have become a primary tool for mechanical Scotch broom control. They are used in most areas where a tractor with brush hog cannot go. The brush cutters are especially useful in clearing Scotch broom in Oregon white oak woodlands, where numerous oak saplings need to be preserved. At Fort Lewis, oak woodlands surrounding Upper Weir and Johnson Prairies have been managed primarily using motorized brush cutters.

A tractor-pulled brush hog is typically a 5 ft. wide rotary cutter on the back of a two- or four-wheel drive tractor. Larger cutters are available, but their usefulness is limited if the terrain is rough or interspersed with trees and other desirable vegetation. The 5 ft. model is very adaptable and was used to mow mature Scotch broom on the mounded topography of Mima Mounds Natural Area Preserve. Because a brush hog typically cuts Scotch broom three to six inches from the soil surface, it is most effective with large, stressed Scotch broom. Mowing young Scotch broom with a brush hog will result in little mortality and much resprouting, though the plants are set back compared to uncontrolled plants.

In the open terrain of grasslands the tractor-pulled brush hog is the preferred method for mechanical control of Scotch broom. It has been used successfully at a wide range of prairies, including large portions of Weir Prairie and the Thirteenth Division Prairie RNAs at Fort Lewis, much of the Glacial Heritage Park, and even on the rather steep mima mounds at Mima Mounds Natural Area Preserve.

Several problems unique to military installations arise when using a brush hog. The occurrence of "fox holes" is a serious concern, since tractors can rapidly fall and disappear in them. This is not only a

Figure 10. *A hand-held, motorized brush cutter is an effective and efficient mechanical control tool.*

surprise and a safety hazard for the operator, it can also result in unexpected repair and extraction costs. A greater safety hazard is the possibility of mowing over unexploded ordnance. The brush hog operator has little chance to see any ordnance through the Scotch broom. If there is any possibility of unexploded ordnance being present on the site, then mowing with a brush hog, or cutting with hand-held brush cutters, is not recommended.

Timing is critical to the success of all cutting techniques. Cutting is most effective when Scotch broom is stressed. In the Puget prairies the greatest success has occurred with cutting in the summer, particularly in August and September. Cutting early in the spring can result in little mortality, with nearly all plants resprouting. Resprouting is most pronounced in younger Scotch broom. Therefore, the greatest mortality occurs when cutting old Scotch broom in the late summer (Table 5).

Table 5. *Change, one year post-treatment, in the mean percent of 1x2 m plots containing Scotch broom in five size classes.*

	No. of Broom	0 - 0.25 m	0.25 - 0.50 m	0.50 - 1.0 m	1.0 - 2.0 m	> 2.0 m
Control	2	1	-5	-21	-11	33
Weed Wrench	23	15	17	-15	-35	-1
Brush Cutter	8	2	13	-6	-29	0
Brush Hog	4	4	10	1	-17	0

Chemical Control - The Pacific Northwest Weed Control Handbook (Williams et al., 1997) lists several chemical herbicides that are effective on Scotch broom (Table 6). These herbicides are all post-emergence contact formulations and none are restricted-use herbicides. Use of herbicides is often discouraged due to general and specific environmental concerns. On federal lands there are specific goals for the reduction of herbicide use on each installation. Correct and safe use of herbicides is the responsibility of the applicator. Read and follow all regulations, including the herbicide's label.

Table 6. *Common herbicides effective on Scotch broom (from Williams et al., 1997). Please see herbicide labels for additional information and safety precautions prior to application.*

Herbicide	Trade Name	Application and Remarks
triclopyr ester triclopyr amine triclopyr + 2,4,-D LV ester	Garlon 4 Garlon Redeem Crossbow	**Rate:** 0.5 to 1.5% concentration of Garlon 4 or Crossbow to 1.5% concentration of Garlon 3A or Redeem. **Time:** Apply any time the plants are growing actively. Garlon 4 and Crossbow can be used for basal bark applications any time of the year. **Remarks:** A thorough wetting of the foliage is essential. For Garlon 3A and Redeem it is especially important to use a high volume of water (100gal/A or more). **Caution:** Garlon products are registered for use on rights-of-way, industrial sites, and forestry. Crossbow and Redeem can be used on permanent pastures and rangeland with up to 1.5 lb. ae/A. Observe all grazing and harvesting restrictions.
glyphosate	Roundup Accord	**Rate:** 1.5 to 3 lb. ae/A or 1.5 to 2% solution for handgun application. **Time:** Apply to actively growing plants in the spring. **Remarks:** Addition of a recommended surfactant will improve results. **Caution:** Glyphosate will control grasses and other plants that are needed to compete with new seedlings of Scotch broom.

Glyphosate is a non-specific herbicide, commonly known by the trade name, Roundup. This herbicide will control both grasses and forbs. It is best to apply glyphosate when the target plants are actively growing, typically in the spring. Addition of a recommended surfactant will improve results. A caution pertinent to prairie usage is that glyphosate will control grasses and other plants that are needed to compete with new seedlings of Scotch broom (Williams et al., 1997). Care in application is required, since drift can damage all native prairie species as well the target species. The triclopyr ester (Garlon 4), triclopyr amine (Garlon 3a, Redeem), and the combination of triclopyr and 2,4-D LV ester (Crossbow) are all selective herbicides. They control dicots only. Prairie grasses and sedges are not sensitive to these formulations. Again these herbicides must be applied when the target species are actively growing. A thorough wetting of the foliage is essential with these herbicides.

Typical application of these herbicides is contact spraying of Scotch broom foliage. The liquid herbicides are diluted in water and sometimes a surfactant is added. Consult the herbicide label for specific instructions and restrictions.

Application methodology can range from spot spraying with a backpack sprayer to tractor-mounted broadcast spraying or wiping to even aerial application. Unfortunately, secondary damage to desirable prairie plants increases with the amount of broadcast spraying. One application technique that looks promising, but has not been attempted in the prairies, is wick or wiper application with a tractor-pulled boom. The technique is used by commercial grass seed producers and involves a boom with wipe or wick applicators that is pulled across the vegetation. Typically, the boom is set at a height at least six inches above the desired vegetation (Williams et al., 1997). All vegetation above the set height is wiped with herbicide. If infestations are heavy then it is recommended to reduce speed and use two cross-direction applications. When used in grassland areas this technique directly targets Scotch broom, with minimal drift to other species.

These herbicides and application methods are effective on all ages and sizes of Scotch broom, though the rapid growth of younger plants helps ensure the translocation of the herbicides. You can help stimulate this growth by using mechanical control several weeks prior to application. The rapid, succulent growth of the resprouting plant creates good conditions for absorption and translocation of the herbicides.

Trials on Upper Weir Prairie at Fort Lewis, using backpack sprayers with Crossbow, were very successful on resprouting Scotch broom (The Nature Conservancy, 1996). Mortality was high, up to 90%, with nearly one-half of the prairie areas free of Scotch broom after a single application. Another 15% of the prairie areas contained only Scotch broom in the smallest size class, typically seedlings that sprouted from the seed bank after the larger plants were controlled.

This mortality of Scotch broom had positive plant community effects. Both species diversity and the cover of the dominant native grass, Idaho fescue, increased after the Scotch broom control. Within 0.5 m^2 quadrats, plant species diversity increased by a third, while the percent cover of Idaho fescue increased by 3–4 % (The Nature Conservancy, 1996).

In addition to the foliar application discussed above, both Crossbow and Redeem can also be applied with basal bark applications. Researchers in California have used this technique successfully (Miller, 1992; and C. Brossard, personal communication), but it has the

drawback of having to spray each stem of Scotch broom individually. The prospect of crawling under acres of Scotch broom and squirting each stem with concentrated herbicide does not seem appealing or practical. Yet, the technique could be used if the area is small or numerous volunteer laborers were available.

Prescribed Fire - Prescribed fire has been the major tool used to combat Scotch broom at several South Puget Sound prairies, including Fort Lewis and Mima Mounds Natural Area Preserve (Figure 11). This burning is a process similar to the Native American lit fires that previously helped keep prairies free of woody invaders.

Fire is an effective tool in controlling Scotch broom. Direct mortality occurs when cambium tissues are destroyed. An additional effect is the stimulation of the seed bank, with Scotch broom seed germination increased after a burn. This stimulation can be considered a positive or negative effect: positive in that it flushes a set of seed out of the seed bank, thereby reducing the number of viable Scotch broom seed still in the soil; negative in that the flush of new plants grows quickly and can "take over" a site again in just three years.

A major consideration in using prescribed fire to control Scotch broom is the timing of the fire. The effectiveness of fires varies with the season. Traditionally, two seasons are available for prescribed burning on South Puget Sound prairies. Spring fires take advantage of periods

Figure 11. *Prescribed fire has been used extensively at several South Puget Sound prairies to control Scotch broom.*

Table 7. *Fire effects on Scotch broom with spring and fall prescribed burns. Adapted from Tveten, 1996.*

	Fall Burn		Spring Burn		Unburned	
	Pre-burn	Post-burn	Pre-burn	Post-burn	Pre-burn	Post-burn
Density (#/m^2)	52.9	11.4	58.2	51.0	47.8	109.3
Cover (%)	24.8	3.5	13.8	12.0	20.0	48.4
Basal Sprouting (%)	1.8		30.8		--	
Mortality (%)	87.0		47.2		1.8	

Table 8. *Summary of Scotch broom monitoring data within fall and spring prescribed burned areas and unburned areas at one year post-burn. Frequency of occurrence of tallest Scotch broom plant within 1x2m monitoring quadrats.*

		Height (m)				
Area	No. of Broom	0-0.25	0.25-0.5	0.5-1.0	1.0-2.0	>2.0
Fall Burn	93.0	4.6	0.7	1.0	0.7	0.0
Spring Burn	57.0	8.0	22.0	13.0	0.0	0.0
Unburned	56.8	1.3	7.2	17.6	11.4	4.7

between strong winter rains when prairie vegetation greens up. Typical spring fires occur in March and April. Fall fires occur after yearly burn bans are lifted and before fall rains return and plant growth resumes. Fall fires may occur as early as August, but are normally in September.

Spring fires are typically cooler and slower fires than fall fires. In addition, Scotch broom is in a different period of its yearly phenological cycle. These, and likely other factors, result in differing effectiveness in spring and fall fires.

Spring fires are significantly less effective than fall fires in controlling Scotch broom. Two types of data illustrate the differences. Tracking of individual Scotch broom plants within 200 m^2 plots at Fort Lewis found mortality, basal sprouting, and percent cover to differ between seasons (Tveten, 1996). Fall fires exhibited more effective characteristics for each of these than spring fires (Table 7). Similar patterns were found, again with experimentation at Fort Lewis, when Scotch broom distribution was measured over larger areas of 0.5 x 2 m quadrats. Fall fires produced greater amounts of prairie free from Scotch broom, an average of 93%. In addition, the Scotch broom that did survive the fall burn was much smaller than those in the spring burn. Within fall burns only 2.4 % of the quadrats had any Scotch broom taller than 0.25 m. In contrast, 33% of the prairie burned in the spring contained Scotch broom at least that tall (Table 8).

Although prescribed fire can be an effective control technique, several characteristics limit its usefulness. The combination of regulatory, climatic, and biological conditions required for an effective prescribed burn is often hard to obtain. This results in many planned prescribed burns not occurring, and the needed control effort missed or delayed. Each prescribed fire also tends to be unique, with local fuel and weather conditions dictating the effectiveness as a control tool. This characteristic requires thorough post-fire monitoring and an adaptive approach to follow-up control efforts.

Additionally, prescribed fire has numerous effects on the prairie beyond controlling Scotch broom. These effects include the effect of fire on ground nesting birds and invertebrates, creating safe sites for the germination of native and nonnative plants, and nutrient loss (Agee, 1993). Each of these effects needs to considered prior to using prescribed fire for Scotch broom control.

Biological Control - The distribution and abundance of Scotch broom in its native range does not mirror that found in the South Puget Sound. In Scotland, Scotch broom does not form impenetrable thickets, or completely take over open areas. This pattern of being more prevalent and aggressive away from native lands is not unusual for nonnative pest plants and is normally attributed to the lack of predators and diseases in the nonnative areas. The transfer and management of species specific invertebrate predators and diseases of the pest plant from the native to nonnative areas is the basic technique of classical biological control. Typically the addition of a single control agent is insufficient to control the pest. Normally a suite of agents that attack different portions of the plant are needed for effective control of the pest.

Over the last two decades, researchers in California, Oregon, and Washington have introduced several species of natural Scotch broom predators as a biological control (Table 9). These predators are currently established in Washington, though they have proven ineffective in controlling the spread of Scotch broom. Despite the lack of success, the dispersal and management of these agents should be encouraged. Even though these agents have been ineffective in controlling Scotch broom, they can still have sublethal effects that stress individuals and limit seed production.

Table 9. *Biocontrol agents for Scotch broom currently available for use in Washington.*

Control Agent	General Role	Infestation	Control Ability
Agonopterix nervosa	shoot tip moth	Medium	Unknown
Apion fuscirostre	seed weevil	Medium	Fair
Leucoptera spartifoliella	twig mining moth	Medium	Unknown

Establishment of biological control agents in stands of Scotch broom that are likely to be uncontrolled is especially recommended. In these stands the agents can form source populations for areas where Scotch broom is periodically controlled. In addition, any reduction in the seed production and seed bank in these uncontrolled stands will be important if the stand is controlled in the future.

The development of new biological control agents for Scotch broom is likely a slow process. Extensive research is required to guard against undesired agricultural, ornamental, and ecosystem impacts when control species are introduced. These programs have long lead times and are expensive; they are not short-term options for pest management.

Researchers have identified several promising candidates for future broom control: the seed-feeding beetle *Bruchidius villosus*, the nodule-feeding *Sitona regensteinensis*, the stem-mining weevil *Apion immune*, and the gall-forming mite *Aceria genistae*, apparently the only possible control agent capable of killing Scotch broom on its own. Identification and screening of potential agents is also being conducted in New Zealand and Australia, where Scotch broom is also a pest. Hopefully, future biocontrol agents will be effective in limiting the distribution of Scotch broom.

Strategies to Control Scotch Broom

Controlling or eradicating Scotch broom from a site requires more than a single effective treatment. The plant's long-lived seed bank, which assures years of germinating seed, and basal resprouting, which gives seemingly dead Scotch broom a new life, guarantee that control efforts need to be well planned and implemented. Developing a comprehensive strategy to control or eradicate Scotch broom is an important first step. This strategy should contain specific goals and the anticipated tasks needed to reach those goals. The tasks need to match suitable actions to the conditions on the site; different control methods are most effective at different times and life stages of Scotch broom. Additionally, the strategy must have back-up or secondary tasks, which are activated if a primary task cannot be completed. For example, if a fall burn cannot be completed, then implement manual cutting as a back-up control effort.

As discussed in the previous sections, Scotch broom control treatments are most effective at different life stages of Scotch broom. Table 10 summarizes the recommended control techniques for different life stages of Scotch broom. Of course this table cannot cover all contingencies; the specific characteristics of individual sites may alter the recommendation.

Table 10. *Efficacy of recommended control techniques for different ages of Scotch broom.*

	Seedlings	Young (1–2 yrs.)	Mature (3–5 yrs.)	Old (> 5 yrs.)
Prescribed Fire	**Yes** – Requires sufficient fine fuels interspersed in broom seedlings.	**Yes** – Resprouting is common, especially with spring burns.	**Yes** – Burning earlier in this stage minimizes seed bank. Resprouting is common.	**Yes** – Stimulates seed bank, which can be a positive or negative characteristic.
Mechanical	**No**	**Yes** – Hand-pulling or weed wrench is viable if numbers are low.	**Yes** – Resprouting is common, but can be used to minimize seed production.	**Yes** – Best when plants are stressed. Mortality can be high. Good preparation for future prescribed burn.
Chemical	**Yes** – Backpack spraying of limited-sized patches.	**Yes** – Wipe-on foliar application should be tried.	**No** – Foliar sprays require larger amounts of herbicide. Treat mechanically and follow with chemical wipe-on.	**No** – Other treatments are effective with less side-effects.

Douglas-Fir

Controlling Douglas-fir may seem an illogical or unnatural restoration effort. Douglas-fir is the main native forest tree in the region, and it will readily invade prairies without assistance from disturbance or other special occurrences. The natural succession of communities with fire suppression is the replacement of prairies by Douglas-fir forest (Franklin and Dyrness, 1973). But Douglas-fir forests are widespread in the South Puget Sound region, while prairies west of the Cascade mountains are one of the rarest communities in the United States. Therefore, invasion of Douglas-fir on prairies is undesirable and the control of that invasion a priority restoration action (Figure 12).

Figure 12. *Removing Douglas-fir from prairie and oak habitats is often a priority restoration action.*

However, Douglas-fir control needs to be targeted and prudent. Unlike Scotch broom, which has little habitat value, Douglas-fir is an integral part of prairies. Large, widely dispersed Douglas-fir were part of the historic prairie, forming savannas along the edges of large tracts of open grassland. Today, Douglas-fir in that configuration continues to create important foci for wildlife on the prairie. These trees add to the quality of the prairie landscape.

Controlling Douglas-fir is relatively straightforward. They can be cut down or killed with fire. Mechanical control is practiced widely and is suitable for all size classes of Douglas-fir. Prescribed fire is effective only on trees less than 5 ft. in height.

Cutting Douglas-fir is a well-refined activity in the Northwest. Prescriptions for removing Douglas-fir in a restoration context can vary from traditional commercial methods to techniques specially adapted to the site. Decisions concerning removal techniques normally center on the amount of damage the site can take. If there are no concerns about damage to nearby trees, especially Oregon white oak, or to the understory, then a normal commercial operation will be the most economical. Variations can be used to minimize specific damage.

These variations include using an independent team of fellers to drop the trees, limiting the type of skidder and their pathways and skid landings, various slash control limitations, and using helicopters to remove entire trees from the prairie. In restoration actions at Fort Lewis, several of these techniques have been used successfully. An independent team of loggers were used to fell commercial-sized Douglas-fir from within a 110-acre site at Weir Prairie RNA. This same restoration also used restrictions on skidding roads and landing areas. The State of Washington Natural Area Preserves program has used helicopters to remove entire trees from sensitive prairie locations at Mima Mounds and Rocky Prairie Natural Area Preserves.

Some restoration situations require the control of large amounts of precommercial-sized Douglas-fir. If the trees are extremely small, less than two to three inches DBH (diameter breast height), it may be quicker to cut the trees with a motorized brush cutter. In comparison to cutting Scotch broom, dropping small Douglas-fir is very easy for these machines. This method of Douglas-fir removal has been used at several sites on Fort Lewis successfully, including within Oregon white oak stands along the edges of Weir Prairie RNA and Johnson Prairie (The Nature Conservancy, 1996). A limitation with brush cutters occurs when the tree is bigger that the cutting radius of the blade. At that point it is easier to use a chain saw.

One concern with removing precommercial trees is dispensing with the wood and slash. Fort Lewis has held public firewood sales with limited success; most public woodcutters will not take the poorest trees or trees in difficult locations. These sales are then followed with a prescribed burn in an effort to remove slash from the understory. An alternative, used effectively at Thurston County's Glacial Heritage Park, is chipping the slash. Chipping is a relatively expensive and time-consuming effort, though volunteers have aided in the operation. In either case, the timely removal of slash and other debris from prairie understory is normally beneficial. Leaving slash on the ground can smother the prairie understory.

Prescribed fire is an effective means of controlling small Douglas-fir. This is especially true for late season burns. Tveten (1996) found that a summer wildfire on Fort Lewis killed most Douglas-fir less than 60 cm in diameter, while a spring prescribed fire killed only those less than 2 cm.

For the spring prescribed fire, Douglas-fir needed to reach only a meter in height to survive. Similar results occur in other Idaho fescue grasslands and Oregon white oak woodlands, including Montana and California (Gruell et al., 1986; Sugihara and Reed, 1987). In the Oregon white oak woodlands of California, a fall prescribed burn killed nearly all Douglas-fir trees less than 3 m in height (Sugihara and Reed, 1987).

Control fire prescriptions in Montana suggest the manual thinning of thickets of small Douglas-fir prior to burning. This increases fuels and allows fires to burn through areas of dense Douglas-fir where fuel moisture is higher (Gruell et al., 1986). This prescription would likely improve the effectiveness of prescribed fire on South Puget Sound prairies as well.

Pasture Grasses

Rhizomatous grasses widely associated with pastures are pests in South Puget Sound prairies. At Fort Lewis, colonial bentgrass (*Agrostis capillaris*) is especially prevalent, while velvetgrass (*Holcus lanatus*) is common in the prairies of southern Thurston County. Several additional grass species are also pests. These include Kentucky bluegrass (*Poa pratensis*), sweet vernalgrass (*Anthoxanthum odoratum*), orchard grass (*Dactylis glomerata*), and others.

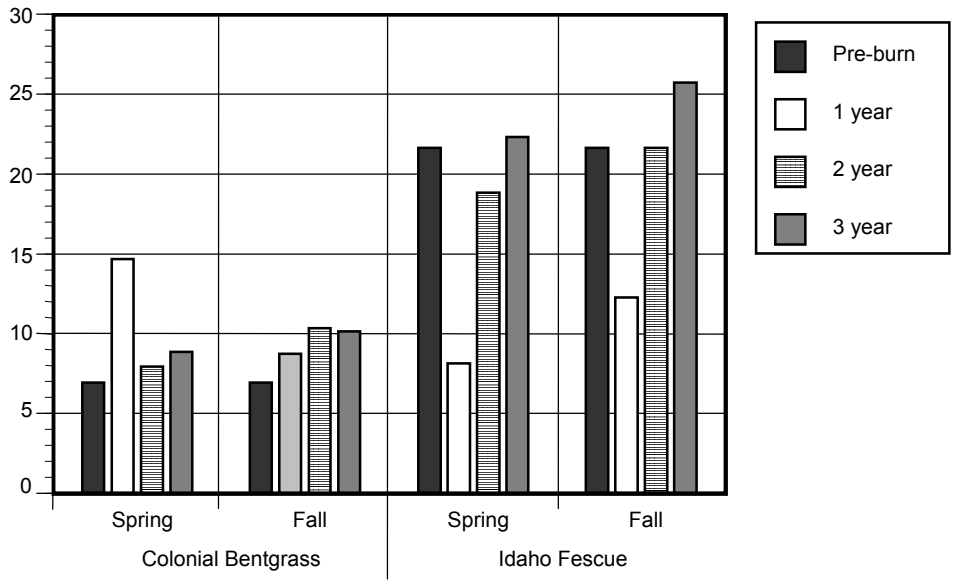
These grasses share several characteristics that make them pests. First, they are successful in dry and disturbed areas. This allows them to tolerate the drought period on South Puget Sound prairies. Additionally, many of these grasses are rhizomatous and form dense sods. These sods are impenetrable for many prairie plants, especially forbs that typically use the interspaces between clumps of Idaho fescue. The dense sod creates prairies low in species diversity and poor habitat for many prairie animals, including butterflies and pocket gophers. The dense sods are also detrimental to transplanted Idaho fescue and other prairie species. Both growth and survival of transplants is reduced when interplanting in swards of pasture grasses, with mortality of transplanted Idaho fescue up to three times greater than control areas (Robohm, 1997).

Effective long-term control of pasture grasses is difficult. These grasses are often tenacious and fecund. Populations can form quickly from individuals that survive control efforts. Two control techniques have been tried as part of this prairie restoration program: prescribed fire and chemical control.

Prescribed fire is ineffective in controlling pasture grasses. Tveten (1996) found the main pasture grass on Fort Lewis, colonial bentgrass, covered more prairie in areas with more frequent fires. Colonial bentgrass was also found to have similar cover and frequency values before and one-year after both fall and spring prescribed fires in Tveten's (1996) trials. In other trials conducted the same year at Fort Lewis, colonial bentgrass increased in cover one-year after both spring and fall fires. This trend extends into the second and third year, though cover was lower in the following years under the spring burn conditions (Figure 13).

Velvetgrass increased substantially following burns at Mima Mounds. Increases in the frequency of velvetgrass occurred in pulses following several fires, including instances with a two-year interval between fires. In contrast, this grass declined in frequency in the control, unburned area (Schuller, 1997). Schuller (1997) also found that two additional pasture grass pests, Kentucky bluegrass and sweet vernalgrass, showed no observable trends with prescribed fire.

Figure 13. *Percent cover of colonial bentgrass and Idaho fescue at intervals of one, two, and three years, following prescribed spring and fall burns at Fort Lewis.*



Control of pasture grasses with chemicals has been more successful. The Northwest Weed Control Handbook suggests several chemicals that are effective on these pests. The non-selective glysophate is effective but will also kill desired prairie grasses and forbs. In contrast, the selective chemicals fluazifop (trade name - Fusilade) and sethoxydim (trade name - Poast) are benign to all dicots, as well as fine-leafed grasses and sedges, including Idaho fescue and *Carex pensylvanica*, two common prairie graminoids.

Trials with Poast at Fort Lewis have been mixed. Single applications are effective in controlling but not eradicating colonial bentgrass. After application, cover declined and plants did not flower during that growing season. Unfortunately, bentgrass produced new growth later that year and flowered again the following year (Robohm, 1997). As suggested in the Northwest Weed Control Handbook, repeat applications may be needed to control well-established grass.

Table 11. *Response of 32 native Washington prairie plant species to germination trials.*

Species	Maximum Germination (%)	Species	Maximum Germination (%)
No Stratification, Warm Germination		**Interaction Between Stratification & Temperature**	
Cerastium arvense	82.7	*Balsamorhiza deltoidea*	30.7
6 Weeks Stratification, Temperature Indifferent		*Delphinium nuttallii*	3.3
Aster curtus	8.7	*Dodecatheon hendersonii*	59
Eriophyllum lanatum	31	*Dodecatheon pulchellum*	44
Hieracium cynoglossoides	42	*Luzula campestris*	58
Lomatium utriculatum	58.7	*Lupinus albicaulis*	31.7
Ranunculus occidentalis	52	*Saxifraga integrifolia*	25.3
Solidago spathulata	12.3	*Zigadenus venenosus*	72.3
12 Weeks Stratification, Temperature Indifferent		**Equal Germination in All Treatments**	
Camassia quamash	84.5	*Antennaria neglecta*	9.7
Marah oregana *	45	**Insignificant Germination in All Treatments**	
Lomatium triternatum	6.7	*Brodiaea coronaria* *	
Silene scouleri *	37	*Brodiaea hyacinthina* *	
Benefit From Either or Both Stratification Regimes		*Lomatium nudicaule* *	
Campanula rotundifolia	80	*Lupinus lepidus* *	
Castilleja hispida *	2.3	*Panicum occidentalis*	
Erigeron speciosus	36	*Sisyrinchium angustifolium*	
Fritillaria lanceolata *	7.3	*Viola adunca* *	
Panicum scribnerianum *	13.7		

Restoration of Prairie Vegetation

Prairie vegetation in the South Puget Sound requires restoration under a variety of circumstances. Severe disturbance may remove most vegetation from a site. Pest plant invasions can reduce plant diversity dramatically. Small disturbances can facilitate the expansion of pest plants. Changes in grassland vegetation may limit the habitat for globally rare plants and animals. Each of these circumstances can require restoration of prairie vegetation.

One restoration technique that has not been successful is passive restoration. Passive restoration allows natural colonization and establishment to restore native prairie. Unfortunately this option is not viable with the present suite of native species, alien pests, and ecological processes. If left without active management and restoration, Puget Sound prairies will succumb to pests and become degraded.

The most obvious evidence showing that passive restoration is ineffective is the acres and acres of Scotch broom and pasture grass on what once was prairie. Most of these areas were native prairie that were used for pasture and then left fallow. The result is not high-quality prairie but a cosmopolitan weed community and habitat for few prairie animals. This degradation pathway is also evident on a smaller scale. Disturbances such as severe car tracks are invaded by pest plants. Even the small disturbances created by Mazama pocket gophers, a natural process that historically enhanced diversity, are now foci for establishment of pest plants (Hartway and Steinberg, 1997).

The need for active management and restoration should not be a surprise. The prairies of South Puget Sound owe their existence to human management through fire and suppression of Douglas-fir invasion. Today's increased pressure from pest plants mirrors the increased need for these historic management actions.

The wide range of conditions that require active restoration of prairie vegetation also require a variety of techniques. Many of these techniques are resource intensive and are best used on smaller-scale projects. Other techniques can be used effectively only in large-scale situations. Each technique requires adaptation to the specific requirements of the given site.

Plant Propagation

The most effective restoration techniques require seed collection or plant propagation. This study included much work on propagation of prairie plants, including the work by the University of Washington by K. Ewing and D. Drake. Several prairie plants were produced efficiently at levels up to the hundreds of thousands. Other species have yet to yield viable seed. Two overviews of prairie plant propagation have been produced recently that provide details on propagating prairie plants effectively (Davenport, 1997; and Drake and Ewing, 1997). On the facing page, Table 11 (modified from Drake and Ewing, 1997) lists the relative ease of propagation for a variety of prairie plants.

Using seed local to a restoration project is the most conservative of choices for plant propagation. Plants near or at a restoration project are assumed to be locally adapted to the specific conditions of the site. Seed collection can be a time-consuming step in restoration and

propagation. Correct timing of collection in the wild is needed, since native prairie plants produce seed over several months (Figure 14).

One alternative that should not be used is purchasing large amounts of seed from commercial seed houses if this seed is collected in different ecotypes. This is most pertinent to Idaho fescue. Seed collected east of the Cascades and in Idaho or other states is likely to have a different genetic makeup and ecological tolerances than the local plants. Recent investigation of the genetics of Idaho fescue from within the South Puget Sound shows significant differences between prairies within the region (Davenport, unpublished data). Whether these genetic differences result in ecological differences is a pertinent question, but this type of data does reinforce the importance of local seed collection.

One situation that requires an active solution is the production of large amounts of seed. When pounds of seed are needed for the restoration of a large area, then collection of wild seed is impractical and ecologically damaging. Collecting large amounts of wild seed is time and labor intensive, and creates an enormous sink for seed that would have dispersed into the prairie. A solution to this situation is to develop a seed crop, a field of plants that are grown solely to produce seed. The cultural practices used to raise the seed crop are intensive and result in high yields. The monocrop of seed is also easily harvested. Seed cropping may be necessary for Idaho fescue and other species if large restoration projects are planned over multiple years.

Transplantation of Prairie Sod

The transplantation of entire pieces of prairie has an innate draw. Concerns about species mixtures, propagation techniques, and maintaining invertebrates can be set aside. And the instant success of laying turf in a home situation generates confidence that the final product will survive and prosper.

To a certain extent this optimism is well founded. Pieces of prairie sod can be removed from a prairie, transported, and relayed in a new prairie successfully. An instant prairie is created. Unfortunately, several drawbacks limit the usefulness of restoring prairies using sod. But if these drawbacks can be overcome, laying sod is a viable restoration technique, and an especially good method for filling small disturbances within larger healthy prairies (Figure 15).

Figure 15. *Small disturbances like this "foxhole" might be the best candidates for restoration using prairie sod.*

Figure 14. *Phenology of common prairie plant species at Fort Lewis.*

Month	Apr		May				Jun				Jul				Aug				Sep	
Species / Week	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**
Luzula campestris																				
Viola nuttallii	X	X	X	?																
Carex pennsylvanica	X	X	X																	
Dodecatheon hendersonii	X	X	X																	
Ranunculus occidentalis	X	X	X	X																
Dodecatheon pulchellum	X	X	X	X																
Saxifraga integrifolia	X	X	X	X	X															
Cerastium arvense	X	X	X	X	X															
Lomatium utriculatum	X	X	X	X	X															
Camassia quamash	X	X	X	X	X															
Balsamorhiza deltoidea	X	X	X	X	X															
Lomatium triternatum		X	X	X	X															
Lomatium nudicale		X	X	X	X															
Viola adunca		X	X	X	X	X	X				?									
Fritillaria lanceolata		X	X	X	X	X	X													
Antennaria microphylla				X																
Sisyrinchium angustifolium				X	X	X														
Zigadenus venenosus				X	X	X	X													
Eriophyllum lanatum				X	X	X	X	X	X											
Castilleja hispida					X	X	X	X												
Lupinus lepidus					X	X	X	X												
Potentilla gracilis					X	X	X	X												
Lupinus albicaulis					X	X	X	X	X											
Microseris laciniata						X	X													
Festuca idahoensis						X	X	X												
Danthonia californica						X	X	X												
Campanula rotundifolia						X	X	X	X	X	X									
Delphinium nuttallii							X													
Apocynum androsaemifolium							X	X	X	X	X	X	X	X	X	X	X			
Panicum occidentale							?													
Marah oregana								X	X	X										
Prunella vulgaris								X	X	X										
Brodiaea hyacinthina								X	X	X	X									
Erigeron speciosus								X	X	X	X	X								
Panicum scribnerianum								?												
Hieracium cynoglossoides										X	X									
Brodiaea coronaria										X	X	X	X	X						
Silene scouleriana											X	X	X	X	X					
Solidago spathulata											X	X	X	X	X					
Aster curtus											X	X	X	X	X	X				

X *Species flowering* — *Fruit ripening* — *Seed ready for collection*

These drawbacks include having a source of material, the use of heavy machinery, and labor-intensive work in site preparation and laying of sod pieces. In addition, any problem pest species present in the original prairie sod are transported to the new site.

The largest problem with using sod transplantation is finding a suitable source of prairie sod. The source site should be doomed with destruction; it is not desirable to remove chunks of sod from a surviving prairie. Optimally, the site also should be accessible to heavy equipment. Although sods can be harvested by hand, using a front loader is easier. The loader not only helps to obtain sufficient rooting material in the source, but also assists in placing the material on a flatbed truck for transport to the new site. Heavy machinery can be a drawback when filling in small disturbances in a larger prairie. The machinery may have to run over high-quality prairie to place the sod in the disturbance. This may degrade the prairie that you are trying to restore.

Even with the assistance of heavy machinery, laying prairie sod is labor intensive. Each site must be prepared and then refined to meet the contours of the pieces of sod. If this fine-tuning is not done, then the final prairie will be especially lumpy, since the sod typically is not removed with a flat bottom. This also can reduce the likelihood of survival for prairie plants at the edges of each piece because they may not be in contact with soil.

A final drawback with transplanting prairie sod is that the pests present in the source prairie will be transplanted to the restored prairie. This can be solved by controlling the pests prior to transplantation, but even this may be difficult since the seed bank is also transplanted. Adult Scotch broom can be easily cut down, but controlling the seeds of Scotch broom in the seed bank is very difficult. If the source prairie contains pest plants not present in the restored prairie, then another source should be found.

In trials at Fort Lewis, a four-person crew, using a loader and truck, were able to transplant approximately 50 m^2 of prairie sod in a day. This sod was placed into a series of small disturbances, from 4 m^2 to 30 m^2 in size. Overall, these transplants were very successful (Tables 12 and 13). Idaho fescue survived extremely well, and the suite of forbs present one year post-transplant was similar to those at the source site. By the next year, the locations of the small disturbances were difficult to locate by merely examining the prairie.

Some specific species are likely not to do well with sod transplantation. The most obvious is Puget balsamroot (*Balsamorhiza deltoidea*), which can have a huge root system. Unless the sod is extremely deep, greater than 75 cm, then the roots of even smaller balsamroot will be disturbed. Other species that may have similar problems include the larger lupine (*Lupinus albicaulis*) and possibly the geophytic bulbs, though these usually occur within 20 cm of the soil surface.

Typical techniques for transplanting sod, involves initial removal, transportation and transplantation. Initial removal is the most critical step. Cut the sod using a loader or by hand. In general, the deeper the cut the better; normally 50 cm is more than sufficient.

Table 12. *Plant community characteristics of source area and transplanted prairie sod at Fort Lewis.*

	Cover of Fescue (%)	Fescue Survival (%)	Species Diversity, Native/Nonnative	Cover of Native Species (%)	Cover of Non-native Species (%)
Source Area	20.4	--	17.6 9.6 / 8.0	39.4	29.0
Transplanted Sod	18.6	84	18.7 10.2 / 8.5	34.6	31.2

Table 13. *Native prairie species successfully transplanted within prairie sod at the Thirteenth Division Prairie RNA, Fort Lewis.*

Aster curtus	*Lomatium trinertatum*
Carex pensylvanica	*Lomatium urtriculatum*
Camassia quamash	*Lupinus bicolor*
Danthonia californica	*Luzula campestris*
Erigeron specious	*Potentilla gracillus*
Eriophyllum lanatum	*Ranunculus occidentalis*
Festuca idahoensis	*Solidago spatulatum*
Heiracium cynoglossoides	*Viola adunca*

Often with a loader, the sod's thickness will be cut in an arc, with thin edges and a thick center. This can be avoided by first establishing the loader's edge below the soil surface and level. The loader can then cut a swath with a more even thickness by merely moving forward. The operator must resist the urge to scoop up the sod as though it is a pile of gravel.

A limitation on the thickness of the sod is its transportation. If cutting and carrying by hand, then a more shallow cut will have to do. The depth of the cut can also be gauged by the soil horizon. Many locations in South Puget Sound prairies contain very shallow fine soils, and there is little need to penetrate below these levels into the gravel below.

Transportation of the sod can occur in any manner that maintains the integrity of the sod blocks. A flatbed truck is easiest to use with a loader, since the loader can pick the sod blocks from the side and the rear of the truck.

Sod blocks can be stored for long periods before final transplantation. Store the sod blocks on bare dirt, wooden pallets, or plastic. Make sure to wedge the sod blocks together tightly to reduce the amount of edges and open soil susceptible to pest plant invasion. Watering and weeding will be needed during storage.

Preparing the bed for the sod blocks involves leveling the site and ensuring that the growing surface is adequate for the sod. Optimally, this surface will be prairie subsoil, though imported soil also can be used. When placing the blocks, make sure that all of the bottom and side surfaces of the blocks contact soil. Pockets of air under the blocks are detrimental. Contouring the soil surface to match the shape of each block is best, but is very time and labor intensive. One alternative is to cut the sides of the sod chunks until they fit the prepared surface. Many times this trimming removes plants that were damaged during removal, and therefore, has little negative effect on the restoration. If placed correctly, prairie sod blocks do not need to be rolled with a heavy turf roller, like lawn sod does. Soil contact is normally adequate without rolling.

Post-transplantation actions are not necessary if the sod was in good shape when transplanted. A deep watering is likely beneficial, but not necessary. Though fertilization has not been tested, it would likely increase undesirable weedy species more than the prairie natives. See the discussion on planting supplements for more information.

TRANSPLANTATION OF INDIVIDUAL PLANTS

The transplantation of individual plants is the most widely used method to restore prairie vegetation in the South Puget Sound. Transplantation of plugs of Idaho fescue and other prairie plants has been used at Mima Mounds and Rocky Prairie Natural Area Preserves and at Fort Lewis. Although transplantation is resource intensive, its success has been high. At Fort Lewis these transplantations included experimentation with a range of treatments, especially with Idaho fescue, the dominant species in South Puget Sound prairies. (Figure 16)

Basic Techniques

Transplantation can occur in both spring and fall. In the spring, the longest growing period is obtained when planting occurs soon after hard freezes stop and the soil becomes workable. These conditions typically occur in late March. Successful plantings have also taken place as late as mid-May. For fall transplantation, the optimal time is soon after the first consistent rainfall, typically in late October, though plantings as early as September have also worked.

Idaho fescue and other prairie graminoids typically have been grown in styroblocks (size 2a). These blocks contain 240 growing cells, which are approximately one inch in diameter and four inches deep. Plants are extracted from the cells and transplanted with the aid of a soil dibble that is similar in size and shape to the growing cell. Prairie forbs have been grown in a variety of containers and therefore transplanted with several techniques. The same or slightly larger celled styroblocks have been successful for several species. In this case transplantation has also used soil dibbles. Four-inch pots and larger plastic “tree cells” have also been used to grow prairie forbs, and transplantation then requires using a hand trowel or shovel to dig each hole.

Figure 16. *Transplantation of prairie plants can be accomplished by individuals with a range of age and skill.*

Most species when transplanted with any of these techniques survive and grow well without further treatments (see Plant Supplements, below). Only a few species of forbs are sensitive to transplantation, including *Lomatium sps., Lupinus sps.,* and *Microseris laciniata* (Table 14, and Davenport, 1997).

Spacing

The correct spacing of transplants is important for several reasons, including the resulting growth rate, reproduction, and effect on competitive plants. Both close and distant spacings have their advantages and disadvantages.

Spacing that is too close may increase competition and decrease the transplants' growth rate and reproductive vigor. Additionally, it is a waste of significant resources. For each halving of the distance between transplants, the total number of transplants increases by a factor of four. Therefore, a planting with individuals every .25m contains 16 times the number of plants compared to when they are planted every 1m. Over larger areas, such differences can be a significant investment.

Spacing plants too widely has drawbacks also. The most significant is that recruitment of desired native species to fill the interspaces is too slow. Invasive nonnative plants fill these areas, which are then unavailable to native prairie species. The result is prairie restored to a degraded state, rather than towards pristine conditions.

Table 14. *Qualitative summary of transplantation success for a range of South Puget Sound prairie plants at Fort Lewis and Rocky Prairie Natural Area Preserve.*

Species	Fort Lewis	Rocky Prairie
Graminoids:		
Festuca idahoensis	Excellent	Excellent
Carex pensylvanica	Excellent	--
Danthonia californica	Good	Good
Luzula campestris	Good	Good
Forbs*:*		
Aster curtus	Excellent	--
Camassia quamash	Good	Poor
Eriophyllum lanatum	Good	Excellent
Erigeron speciosus	--	Good
Hieracium cynoglossoides	Fair	Fair
Lomatium utriculatum	Good	Poor
Lupinus albicaulis	Poor	Poor
Microseris laciniata	Fair	Poor
Potentilla gracilis	--	Good
Ranunculus occidentalis	--	Good
Solidago spathulata	--	Good

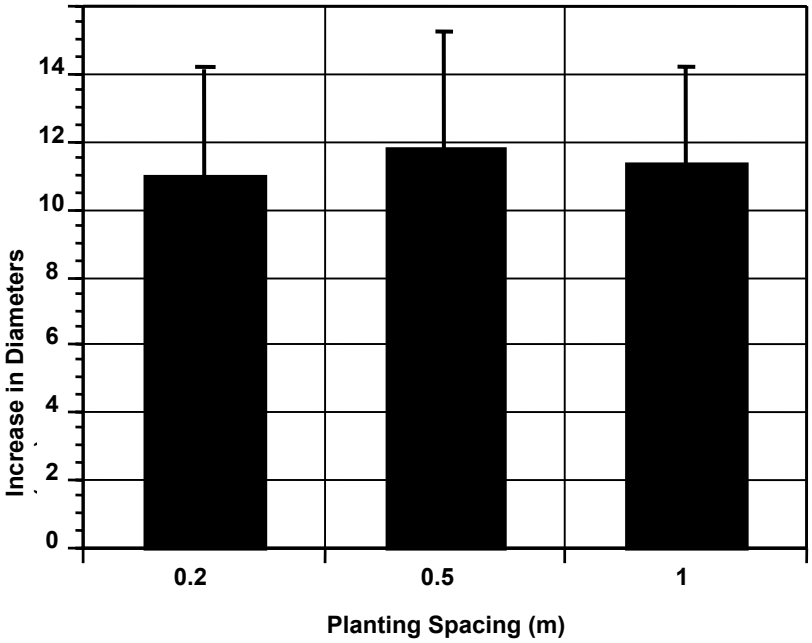


Figure 17. *Increase in diameter of Idaho fescue transplanted at three densities at Mortar Point 10, Fort Lewis.*

A single set of experiments at Mortar Point 10 on Fort Lewis examined the effects of spacing in South Puget Sound prairies (The Nature Conservancy, 1995, 1996, and previously unreported data). Idaho fescue was planted at three spacings: 0.25 m, 0.5 m, and 1.0 m. Growth and survival of the fescue did not vary significantly at these spacings. Diameters increased by about 11 cm in each treatment (Figure 17), while mortality was extremely low at all spacings—1, 2.4, and 0% for the 0.25, 0.5, and 1.0 m spacing respectively.

Several interesting observations were made with the entire plant community in these plots (Table 15). The richness and composition of species were similar at all spacings, since the same suite of plants invaded all three plots. Also, as expected, the estimated cover of Idaho fescue increased with the denser plantings. On the other hand, total cover varied within the plots, with mean cover showing a positive relationship with spacing. However, these differences are not statistically significant because the 0.25 m spacing had 16 times the fescue planted than the 1.0 m spacing. A final observation was that the contribution of native species was higher at 0.25m spacing. This is an expected result since this spacing treatment involved transplanting the most Idaho fescue into the plots.

Final interpretation of the spacing experiment should wait for at least one more set of data collected at four or five years post-transplantation. The data presented here occurred prior to the first cohort of Idaho fescue being produced from the transplanted plants. The recruitment of fescue from seed is an expected occurrence and will need to occur prior to completely evaluating the relative success of each treatment.

Table 15. *Vegetation community characteristics in plots with transplanted Idaho fescue at three densities. Letters signify significant differences at p = 0.05.*

Spacing	Total Cover	Relative Contribution of Native Species	Cover of Fescue	Species Richness
0.25	26.1	76.4-a	14.8-a	6.6
0.5	31	51-b	6.2-b	7.0
1.0	37	44.3-b	1.7-c	8.0

Several conclusions can be reached from these experiments. Restoring the abundance and distribution of a native prairie to its final form directly via transplantation is difficult. Even at the closest spacing, the transplanted fescue did not mimic natural prairie conditions after the first growing season. Nonnative plant species quickly become established and will likely limit establishment of native plants.

The total number of safe sites for germination and establishment seems limited at the Mortar Point 10 sites. The total cover for all planting densities were similar. Though it would be prudent to determine if this trend continues, it suggests that denser plantings could limit access to safe sites for nonnative species. This observation must be qualified, however, since other sites have not followed this pattern. At the southern end of Lower Weir prairie, Fort Lewis, smaller disturbances were saturated quickly, with up to 90% cover at 14–15 months post-disturbance by nonnative pest plants such as hairy catsear and colonial bentgrass (unpublished data).

Competition

Success and growth of transplanted prairie plants has varied the most with the amount of competition present. Transplantation into bare soil yields tremendous growth, with Idaho fescue increasing by more than five times in size by the end of the first growing season and producing more than 100 flowering inflorences the following year. Survival of Idaho fescue under these conditions is outstanding as well, with more than 90% survival in a variety of trials and with specific trials having 98% survival (Robohm, 1997; Davenport, 1997; The Nature Conservancy, 1996 and unpublished data).

In contrast, transplantation into established prairie vegetation has been less successful. Trials by Robohm (1997) focused on transplantation into degraded prairie invaded with colonial bentgrass at the Thirteenth Division Prairie, Fort Lewis. Mortality of Idaho fescue in these conditions was much higher at 18.6% than Idaho fescue transplanted at the same time into bare soils at Mortar Point 10, Fort Lewis, where mortality was less than 2%.

Growth and vigor of the transplanted Idaho fescue also differed between the two sites. Idaho fescue transplanted into established prairie vegetation increased less than 2 mm in diameter after one year. In contrast, the plugs planted into bare ground at Mortar Point 10 increased by 9 to 11 mm (Robohm, 1997).

If competition for prairie transplants is with undesirable nonnative species, then control actions prior to planting can be appropriate. The best trials with this method focused on competition between Idaho fescue and colonial bentgrass (Robohm, 1996, 1997). Control of bentgrass was initiated in two ways: through chemical control with the grass-specific herbicide Poast and by applying a smothering mulch around each transplanted Idaho fescue.

Although the control of bentgrass was incomplete with both control techniques, Idaho fescue transplanted into these areas had better growth than in areas without any control efforts. Diameter of transplanted fescue increased twice as much in the areas with reduced competition. Survival of transplants with mulch was lower than those in either the herbicide or

unmulched areas. Mulched transplants had an average survivorship of 74%, while unmulched transplants averaged 83% survivorship (Robohm, 1997). Similar patterns of reduced growth and survivorship in areas with competition from established vegetation have also been noted at the restoration of Rocky Prairie Natural Area Preserve (Davenport, 1997).

PLANTING SUPPLEMENTS

At Fort Lewis, experiments were conducted to measure the effects of planting supplements such as mulch, watering, and fertilizer (Figure 18).

Mulch

The application of mulch has improved the survival and growth of transplants in other harsh environments. In the South Puget Sound prairies, mulches were applied for two reasons. First, mulches typically reduce water stress, thought to be a critical factor in the drought-prone soils of the prairies. Second, mulches can reduce competition from surrounding plants such as invasive pests like colonial bentgrass.

Two separate applications of mulch were tested at Fort Lewis to research the effects of mulch on water stress and competition. At Mortar Point 10, mulch was applied to transplanted Idaho fescue and other native prairie species in a situation (bare, rocky soil with few competitors) where reduction of water stress was the primary consideration. At the Thirteenth Division Prairie, mulch was applied to transplanted Idaho fescue interplanted into degraded native prairie with a large component of nonnative species, especially colonial bentgrass. This application focused on reducing competition.

Figure 18. *Experimentation with planting supplements such as water, mulch, and fertilizer were conducted at Fort Lewis. Here, water from a wildland fire fighting truck is applied with a low-pressure hose system.*

The effect of mulching in the two situations had strongly contrasting results. At the dry Mortar Point 10 site, mulch had strong negative effects. Mortality of Idaho fescue, and other transplanted prairie species, was significantly higher in mulched plots, at nearly 15%, than those without mulch, at just more than 2% (Robohm, 1997). This mortality alone would preclude further use in this situation, yet other negative effects also occurred. Mulch seemingly facilitated the establishment of nonnative species. Cover of nonnative species within the mulched plots was significantly greater than in those without mulch. Finally, the growth and flowering vigor of the mulched transplants that survived was not any different than those without mulch.

In contrast, the mulch applied at the Thirteenth Division Prairie (with a large component of competitive pest species) had strong positive effects on the growth of surviving transplants. Diameter of mulched Idaho fescue increased by nearly twice that of unmulched transplants. Unfortunately, mulched plants still maintained higher mortality rates than those without mulch (26% vs. 17%).

Although mulching did produce some positive effects, overall it was not an effective treatment. The dramatic increases in mortality are a significant drawback. Even if some of the mortality at Mortar Point 10 was due to errors in applying the mulch (see Robohm,1997), the high mortality at the Thirteenth Division Prairie precludes its recommendation. In addition, the positive effects of reducing competition of pest species can be achieved with other tools, such as herbicides.

Fertilizer

Prairie soils in the South Puget Sound typically contain low levels of key nutrients, including nitrogen (Ugolini and Schlichte, 1973). Supplementing transplants with fertilizer might alleviate this stress and increase growth and flower production. A single trial, involving the transplantation of Idaho fescue at Mortar Point 10, supplemented the transplanted Idaho fescue with fertilizer.

A balanced, pellet grass fertilizer was placed on the surface of plots transplanted with Idaho fescue at Mortar Point 10. This fertilizer was added every two months through the first growing season. Transplants within the fertilized plot grew significantly larger than untreated transplants. Idaho fescue increased in diameter by 14.6 mm in contrast to a mean increase of 11.8 mm for untreated plants. The fertilized plants also produced the greatest number of flower inflorences in the second growing season after transplantation, with single plants producing over 100 (the mean number was 63.8 for fertilized plants vs. 37.3 for unfertilized plants).

Unfortunately, fertilizer also promoted the growth of nonnative invasive plants. The fertilized plots had the highest cover and the highest relative cover of nonnatives, despite having good coverage from the transplanted fescue (Table 16). The fertilized plots were also significantly richer in species, with nearly nine species per plot in contrast to only seven for unfertilized plots.

Table 16. *Vegetation community characteristics in plots of transplanted Idaho fescue with and without supplementation by fertilizer.*

Treatment	Total Cover	Relative Cover of Native Species	Cover of Idaho Fescue	Number of Species
Fertilized	46.7	35.6	9.2	8.8
Unfertilized	31	51	6.2	7.0

Fertilization produces robust native prairie transplants and nonnative pest plants. The prairies of South Puget Sound seem to be a system inhabited by species that are tolerators (sensum, Grime, 1972) and not competitors. Increasing the growth and competitive ability of invasive pests does not yield a good native prairie. Fertilization should be avoided with transplantation.

Watering

A comparison of transplanted Idaho fescue supplemented with and without watering also took place at Mortar Point 10. Supplemented plants received additional water approximately every 10 to 14 days, whenever access and equipment allowed. Water was applied with a low pressure sprinkler from a fire truck until the surface soil was saturated.

Idaho fescue responded to the watering positively in terms of growth. Watered Idaho fescue were larger in diameter than the unwatered plants, though only marginally (11.8 mm vs. 10.99 mm, t-test; $0.1>p>0.05$). Mortality of watered and unwatered transplants were both low, with no significant difference between the means of 1.8% for unwatered and 2.2% for watered (t-test with transformed data; $p>0.05$).

These results are supported by the longer-term survival and growth of transplanted Idaho fescue at Mima Mounds NAP. These plants were not supplemented with watering and have performed very well, with more than satisfactory survival and growth for over four years (B. Davenport, personal communication and unpublished data).

With no large increases in either growth or survivorship of watered Idaho fescue in the short-term and with long-term successes of unwatered plants, the added expense and effort of supplementing transplanted Idaho fescue with water is not warranted.

Summary of Planting Supplements

Although applying supplements to transplanted prairie plants may seem a logical benefit, the results indicate otherwise. Even when supplements result in more robust growth of transplants, the secondary effects on invasive pest plants reduces the overall effectiveness of the restoration effort (Table 17).

Table 17. *Recommendations of planting supplements for transplantation of Idaho fescue.*

Supplement	Positive Effects	Negative Effects	Recommendation
Mulch	Reduces competition from established grasses; increases growth of transplants in that situation.	High mortality for transplants. Increases establishment of invasive species.	Possible use with transplantation into competitive environments.
Fertilizer	Increases growth.	Promotes establishment and growth of invasive pests.	Not beneficial.
Water	Increases growth marginally.	Few.	Of marginal benefit for Idaho fescue; should be tried with “finicky” forbs.
Herbicide Competitors	Controls invasive grasses, limits competition, increases growth of transplants.	Grass-specific herbicides control several desirable species, including *Danthonia* and *Koeleria*.	Looks promising in degraded prairies. Needs more complete trials.

Yet, this is not to say that supplementing transplants is always inappropriate. In several specific circumstances, supplements were found to be beneficial. This is most notable when the supplements had a negative effect on undesirable and competitive pest plants. The strategic use of supplements in these cases may be effective.

The fine-tuning of some supplementation methodologies might make them more effective also. For instance, the fertilizer in these trials was applied by broadcasting onto the soil surface. As a result, pest species, as well as native prairie species, took advantage of the more benign conditions. If fertilizer was targeted more closely to the transplants, such as "grow pellets" applied within each transplant's hole, then pest plants would have only limited access to the supplements.

DIRECT SEEDING

Direct seeding is the primary method of initiating prairie restoration in other prairies, including those of the Midwestern United States. Direct seeding is used with two methods: planting in prepared soil bed and interseeding into degraded prairie sites. The success of these techniques is dependent on the rapid, aggressive growth of many Midwestern prairie species.

Unfortunately, the native prairies and plant species in the South Puget Sound region function differently. South Puget Sound prairie species seem to have neither the growth form or characteristics to actively exclude many invasive pest plants. Yet this does not necessarily mean that direct seeding is not useful, just that its application is not risk free.

Few trials of direct seeding have been attempted in South Puget Sound prairies. Idaho fescue was seeded in the trials at Mortar Point 10, and the tracking of their fate is the only quantitative, repeated trial. Other trials have involved scattering "excess" seed into restoration areas and watching their success.

In general, the effectiveness of specific species in direct seeding is related to their ease of propagation. If the species is easy to germinate and has aggressive growth patterns, it is likely a good candidate for direct seeding. This would include taxa such as Idaho fescue, Oregon sunshine (*Eriophyllum lanatum*), and showy fleabane (*Erigeron speciosus*)—all easy, fast growers. In addition, there are some species that are likely much easier to direct seed than to propagate and transplant. Lupines are such species. Even though lupines can be propagated in the greenhouse, they are susceptible to diseases. In contrast, direct seeding has proven successful for a variety of lupines in other ecosystems, and is likely true for South Puget Sound prairie species too.

Direct Seeding of Idaho Fescue

The trials for direct seeding of Idaho fescue at Mortar Point 10 involved overseeding in the spring onto bare soil. The seeds were then raked into the top 2 cm of soil. These seeds germinated readily and produced seedlings within three weeks. Survivorship of these seedlings was not at the same success level as the transplanted Idaho fescue, but even with this mortality, densities of up to 72 individuals/meter^2 were produced. The mean density of seedlings in the direct-seeding trials was slightly greater than the medium-density transplanting in the remainder of the trials (29.33/m^2 seeded vs. 20/m^2 planted, SD seeded = 20.01).

The seedlings were not spaced evenly throughout the experimental plots. Many seedlings seemed to occur in small microsite niches. These sites often occurred on the north side of small rocks, almost pebbles. These sites could have ameliorated conditions for the seedlings, or the seeds could have been entrapped preferentially in these sites. Due to this distribution, seedlings were more variable in their final dispersion patterns than the transplanted Idaho fescue seedlings. Seedlings ranged in densities from 0 to the previously mentioned 72 individuals/m^2.

Growth of the direct seeded plants was slow in comparison with the transplanted plugs of Idaho fescue. The seeded individuals should have been only a single growing season behind the transplanted plugs. This was not the case. Most seeded plants did not flower till their third year, and even at this stage they were smaller and less robust than the transplants were at the end of their second season.

Although, this slower growth is a severe handicap in competition with invasive plants, it is compensated by the fact that a denser distribution of Idaho fescue can be created in the first cohort of seeded plants. In essence, direct seeding may eliminate the need for the transplanted plugs to quickly fill interspaces with individuals produced from seed. Unfortunately, the densities of seeded plants did not reach the normal density of high quality prairies and abundant seed production did not occur until the third year. The seeded plots are therefore quickly invaded by pest plants and growth is likely to be further reduced.

Trials with direct seeding Idaho fescue at Rocky Prairie NAP show similar results as those at Mortar Point 10. Germination was quick, some mortality occurred after germination and growth was slow compared to transplanted plugs (Davenport 1997, personal communication)

Direct Seeding of Prairie Forbs

Direct seeding of prairie forbs has been tested at Rocky Prairie NAP (Davenport, 1997). Five species were overseeded into plots with a single plot per species, though two species, camus and death camus, were seeded into a single plot. Each of the species germinated and produced seedlings, though growth was variable after this point (Table 18, Davenport, personal communication).

Table 18. *Summary of direct seeding capabilities for selected prairie forbs.*

Species	Germination	Growth	Comments
Camassia quamash	Good	Good	Vigorous, overall very good success
Erigeron speciosus	Good	Good	Good overall
Lomatium utriculatum	Good	Slower	Herbivory was prevalent on seedlings
Microseris laciniata	Good	Good	Good overall, easier than transplants
Zigadenus venenosus	Good	Unknown	Sown in *Camassia* plot; hard to distinguish

Application Techniques

Direct seeding in South Puget Sound prairie restorations has been limited to small trials. Seed has been applied by hand and mixed into the upper soil layer. These trials focused on whether direct seeding is feasible, not on refining application techniques.

Direct seeding techniques have been more refined in other prairie situations. Several seeding techniques, such as hand or mechanical broadcasting, native seed drills, and hydroseeding, can be used. Many of these are summarized in "The Tallgrass Restoration Handbook" (Packard and Mutel, 1997). Two specific techniques have been discussed for large-scale direct seeding in South Puget Sound Prairies: seed drilling and hydroseeding.

Seed drills are tractor-mounted booms that open a furrow in the soil, place specific amounts of seed at determined depths and distances and then refill the furrow. Native-seed drills are basically variations on agricultural seeders. Because of their heritage, seed drills work best on sites that are well prepared. In the Midwest, this typically involves plowing and roller packing. These prepared fields then easily accept the furrows and the planted seeds. This also means that these sites are generally devoid of vegetation prior to seed drilling.

Whether the gravel outwash soils of South Puget Sound prairies are amenable to using a seed drill without damage needs to be determined. This suitability may also differ between specific locations, since sites have different soil profiles, and the disturbance history may create conditions favoring or disfavoring seed drill use. Trials with no-till seed drills, which do not cut furrows, should also be undertaken.

The advantage of using a seed drill is its efficient use of seed. Typically about one-half as much seed is needed with a seed drill as with broadcast spreading (Morgan, 1997). This dramatically reduces the amount of seed that needs to be collected or produced.

Hydroseeding involves mixing seed in a water-mulch mix and then spraying it onto the site. Widely used by landscapers to establish fast-growing cultivars on lawns and other landscape elements, hydroseeding is also used to establish erosion control species on steep slopes and road cuts. Trials are needed to determine if this application technique is practical with our prairie species.

One potential problem with hydroseeding is generating good seed-to-soil contact, since the seed is sprayed in a matrix on top of the soil. This may reduce germination and result in a patchy distribution of prairie species. In addition, hydroseeding (as opposed to seed drills) is not an efficient use of seed. In typical lawn and roadcut application, hydroseeding can require hundreds of pounds of seed per acre. Even with reduced seed density, hydroseeding may require upwards of 40 pounds of Idaho fescue per acre. Using this amount of seed, even over relatively small areas, would require producing seed in managed seed plots.

Restoration of Oregon White Oak Woodlands

Oregon white oak habitats are critical components of the regional biodiversity of the South Puget Sound region. These oak woodlands and savannas harbored a unique assemblage of plant and animal species, including a range of species now considered rare or threatened with extinction.

These rare species include mammals such as the western gray squirrel and Mazama pocket gopher; two rare plants, *Aster curtus* and *Trillium parviflorum;* neotropical migrant birds; and invertebrates such as the Dusky propertius butterfly.

Unfortunately, much of the oak habitats in the South Puget Sound region have been eliminated or degraded. Since European settlement, over half of all oak habitat has been eliminated. The major causes for this elimination, land conversion and development, continue in the present day.

Degraded oak habitats are often missing key ecological processes, especially frequent and regular fire, and oak regeneration. Individual stands of oak are often isolated from other oak habitats, limiting the chance for organisms to move between stands. Many oak habitats are degraded by human uses such as firewood cutting, livestock grazing, or military training.

Restoration and management of Oregon white oak habitats is necessary to reverse degradation and to prevent rare species from becoming extinct. Oak restoration and management must aim to not only restore healthy plant communities, but also create specific habitats for the animals that rely on those communities.

Target Habitat Types and Major Threats

Several different Oregon white oak habitats occur in the South Puget Sound region. Three distinct habitats types occurred historically: oak savanna and woodlands, riparian oak, and wetland oak. Changes in management and other actions have created four additional habitat types (Figure 19). Each of these habitat types have different characteristics and can support different rare and critical species (Figure 20, Hanna and Dunn, 1996).

Oak savanna and open woodlands were common historically, but are almost entirely absent today. Only small patches of these habitats remain, not the large, continuous stands described historically. Original oak savanna and open woodlands contained large, mature, widely spaced oaks with single trunks and broad, spreading crowns. The understory was a single herbaceous layer of native bunchgrasses and forbs. Frequent and regular fires helped shape these communities.

With fire suppression, grazing, or disturbance, oak savanna and open woodlands can become any of the altered oak habitats: mixed oak/conifer woodlands, dense oak woodlands, range oak woodlands or clumped oak (Figure 19).

Riparian oak woodland, another historical oak habitat, occurs along mesic areas near streams and creeks. These areas are less affected by fire and express composition and structure quite different from oak woodlands shaped by fire. Riparian oak woodland can have variable

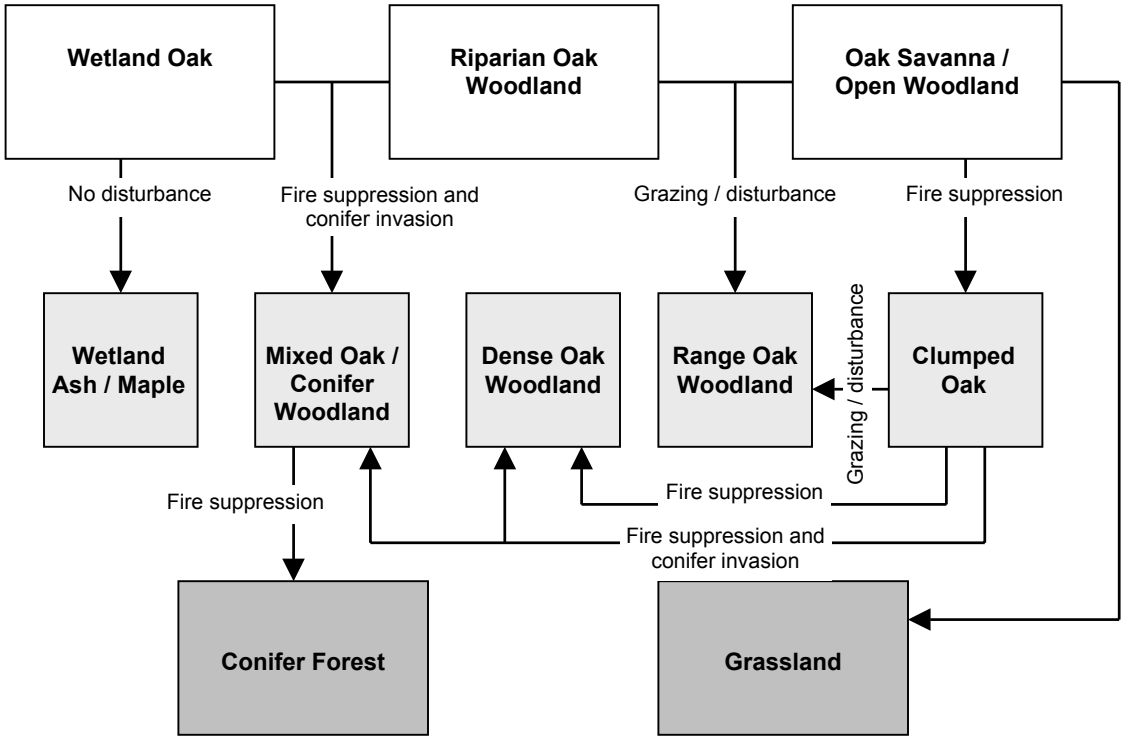


Figure 19. *A conceptual model of disturbances within Oregon white oak habitat types in the South Puget Sound. White boxes indicate historic oak habitat types; light gray boxes indicate altered oak habitat types; dark gray boxes indicate non-oak habitat types.*

structures, but most often forms linear bands between grassland and seasonal or year-round watercourses. Typical overstory structure consists of thin, tall oaks that form a closed canopy upland from more moisture-tolerant trees such as cottonwood and ash. The age classes and densities of oaks are wide ranging within riparian oak woodlands. The understory consists of diverse shrub and herb layers, with a much greater occurrence of mosses, ferns, and coarse woody debris than in savannas and open woodlands.

Riparian oak woodlands have been altered by conifer invasion to form mixed oak/conifer woodland and by grazing to form range oak woodlands.

Finally, wetland oak occur on consistently mesic soils in proximity to wetland edges. These oak habitats are typically small in area and contain unique species composition, which distinguishes them from riparian oak woodlands. Similar to riparian oak woodlands, wetland oaks grow tall and thin and form a generally closed canopy. However, shrub diversity and coverage are much higher than in riparian oak woodlands. The herb layer, therefore, consists of primarily shade-tolerant species, such as small-flowered trillium and sword fern (*Polystichum munitum*).

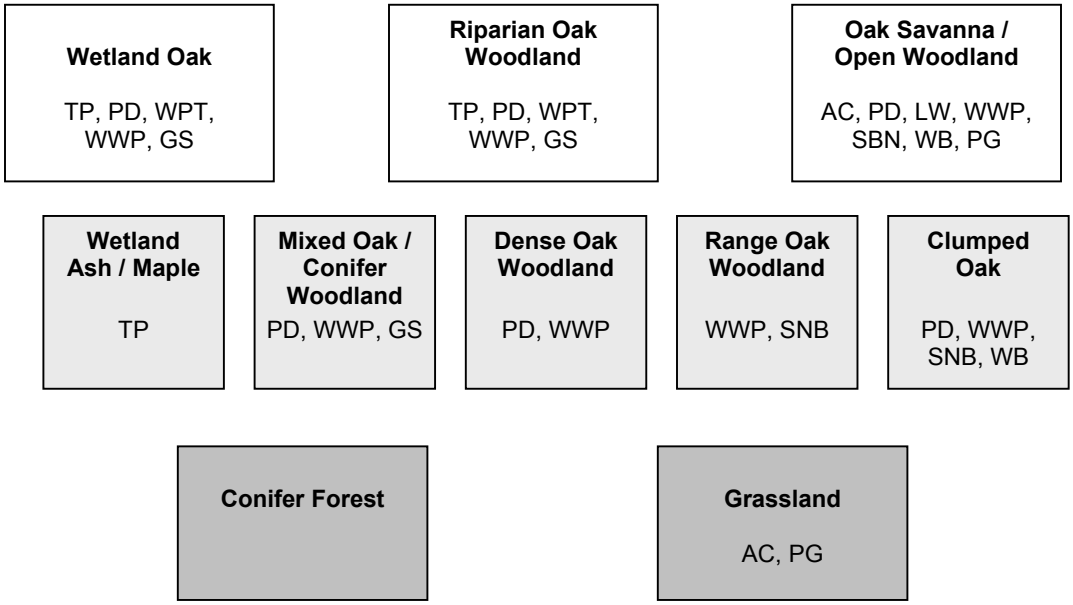


Figure 20. *A conceptual model of priority species usage within Oregon white oak habitat types in the South Puget Sound. White boxes indicate historic oak habitat types; light gray boxes indicate altered oak habitat types; dark gray boxes indicate non-oak habitat types.*

AC: White-top aster; TP: Trillium parviflorum; PD: Propertius' duskywing; WPT: Northwestern pond turtle; LW: Lewis' woodpecker; WWP: Western wood-peewee; SBN: Slender-billed nuthatch; WB: Western bluebird; GS: Western gray squirrel; and PG: Mazama pocket gopher.

** indicates possible species usage or usage under specific conditions (see Table 2).*

The ecological character of wetland oak has changed little. Surrounding communities are often subject to succession by conifers, but due to the mesic soils that exclude most conifers, oaks can persist in this habitat type for long periods.

Many of the threats to grassland communities are also significant in oak communities. Suppression of fire leads to the invasion of woody pest species, including Scotch broom and Douglas-fir. Scotch broom is not as severe a threat in closed-canopy oak woodlands as it is in more open habitats. Yet, Scotch broom has managed to impact negatively many acres of oak woodland and savanna understory. Douglas-fir is a severe pest in oak woodlands, overtopping and killing mature oaks, which leads to the conversion of the woodland to dense Douglas-fir forest. Controlling Douglas-fir is a major task for oak woodland restoration in South Puget Sound.

PLANTING OAKS

The slow growth typical of Oregon white oak increases the importance of individual trees. The loss of mature trees in a woodland can be a significant event and the replacement of these individuals is a priority for restoration (Figure 21). Transplantation of oak seedlings is a proven method for establishing new individuals.

The main problem in planting seedling Oregon white oaks for restoration is ensuring adequate survival and growth with minimal aftercare. In general, planting trials for Oregon white oak have focused on ameliorating the effects of summer droughts on the transplants. Shading, reducing competition, and irrigation have all been effective methods for a variety of oak species.

Trials in the South Puget Sound area focused on irrigation and shading. Several additional factors such as whether transplants were salvaged seedlings or acorn-grown seedlings, and planting date were also tested (Bell and Papanikolas, 1997).

Irrigation was found not to be necessary to ensure survivorship of transplanted Oregon white oak at the Montlake Fill in Seattle. Survival of both irrigated and unirrigated individuals was extremely good (100%, in six of eight plots). The irrigated individuals were generally larger than the unirrigated ones (Figure 22), though variability in the results reduced the statistical significance of the difference ($0.05<p<0.1$).

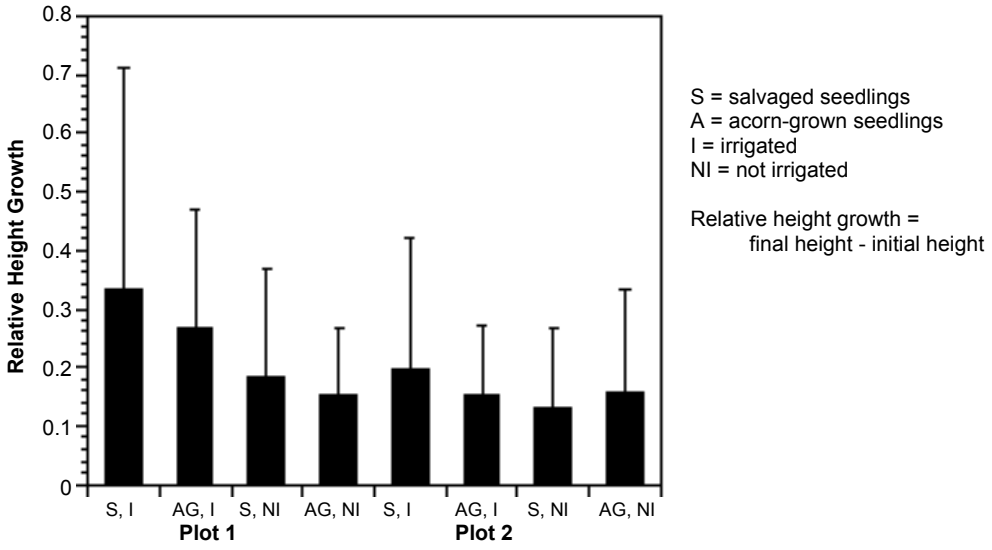


Figure 22. *Relative growth in height of transplanted Oregon white oak at Montlake Fill in Seattle. Both acorn-raised and salvaged seedlings were tested. From Bell and Papanikolas, 1997.*

Figure 21. *Single individuals of large Oregon white oak are important components of the community. Even individuals of this size are threatened by Douglas-fir encroachment. The establishment of individual oaks to replace trees such as this one is a restoration priority.*

Shading of Oregon white oak transplanted at Fort Lewis was beneficial (Papanikolas, 1997a). Nearly 89% of shaded oak transplants survived during the first year in the field. In contrast, 85% of the unshaded oak transplants had dead above-ground shoots. Some of these individuals with dead above-ground shoots may have been able to resprout. Even with this consideration, the death of above-ground shoots gave a good indication of overall stress for each unshaded transplant.

Shaded individuals grew significantly larger in biomass than the unshaded transplants (Table 19). Much of this growth occurred in the root biomass of the transplants, an investment characteristic of Oregon white oak seedlings (Hibbs and Yoder, 1993). Both the survivorship and growth data match nonquantitative field observations in the South Puget Sound, where most Oregon white oak seedlings and saplings are associated with shade, especially the shading of conifers and mature oaks.

Table 19. *Growth and biomass measurements (mean / std. err.) of Oregon white oak transplanted in the sun and shade. * = significant differences at p<0.05, #= significant differences at p<0.07. Modified from Papanikolas, 1997.*

	Stem Length * (cm)	Leaf Number *	Root Biomass * (g)	Total Biomass # (g)
Planted in Shade	11.64 / 0.52	13.07 / 0.57	3.80 / 2.0	5.11 / 2.6
Planted in Sun	12.63 / 0.49	15.55 / 0.65	3.09 / 1.7	4.37 / 2.3

The timing of transplantation of Oregon white oak seedlings does not seem to be important. Successful transplantations occurred in September, November, January, and March on Fort Lewis, though September was the least successful transplantation period. Individuals transplanted in September grew significantly less than the other transplantation dates (Papanikolas, 1997a).

Trials at Fort Lewis of planting Oregon white oak acorns were not successful. Acorn predation was high, with only 20% of the pre-germinated acorns producing seedlings (Papanikolas, 1997b). In addition, drought stress was also a severe limitation, resulting in the failure of all the emerged seedlings within the first growing season. To be successful, acorn planting may have to be combined with treatments to reduce predation and to ameliorate water stress through shading and irrigation.

CONTROLLING DOUGLAS-FIR

Douglas-fir can be a significant pest in Oregon white oak woodlands. Invasion of woodlands by Douglas-fir typically results in the overtopping of the oak, the oaks' subsequent death, and conversion of the area to Douglas-fir forest. This type of conversion is evident in a variety of stands, but is most notable when walking from prairies, through woodlands and into forest. Within the woodland, larger Douglas-fir overtop oaks, creating blankets of shade and thickets of younger Douglas-fir. On the edge of the Douglas-fir forest are large oak snags, sometimes with only a single branch system alive, sometimes completely dead. And finally, further into the forest are oak snags in various stages of decay, old skeletons of a former oak woodland.

Controlling Douglas-fir within oak woodlands is similar to controlling them in prairies. Selecting specific methodology for control relates to the amount of damage allowable on the site. In oak woodlands this is pertinent for both the canopy and understory, and can lead to unique combinations of methodologies.

When a closed or partially closed oak canopy occurs on the restoration site, cutting mature Douglas-fir is a critical step. Tremendous damage can occur to the oak canopy if indiscriminate felling of Douglas-fir occurs. Recovery from this type of damage is a slow process, as evident by oaks damaged by logging along the eastern edge of Johnson Prairie on Fort Lewis. These oaks are still distinguishable as "stripped bean poles" nearly a decade after initial removal of Douglas-fir from the stand (P. Dunn, personal observation).

Several different techniques can alleviate this problem. The basic idea is to ensure that the fellers take into consideration the effects on the oak canopy of dropping each tree. This could involve specific instructions, direct oversight, and applying financial incentives to protecting oak. At Fort Lewis a separate felling crew was contracted with specific financial incentives designed to limit the damage to oaks. Similar benefits can be gained by contracting a complete restoration project, rather than solely the timber removal actions.

Additional special requirements for Douglas-fir control within oak woodlands relate to yarding, slash removal, and the control of pre-commercial sized trees (Table 20). Each of these activities can potentially damage current resources or create conditions that make future restoration difficult. Controlling each of these tasks is critical to overall success.

Table 20. *Potential special requirements for controlling Douglas-fir within Oregon white oak woodlands.*

Task	Example Techniques
Felling commercial-sized trees	Mark the most difficult trees to be killed and leave as wildlife trees or snags. Hire crew specifically to fell trees. Increase on-site supervision. Contract entire restoration project and link canopy condition to payment.
Skidding and yarding	Use rubber tire skidders. Designate specific skidding roads and yarding locations. Minimize movement of weed seeds by designating quarantine actions.
Slash removal	Use a wide-area prescribed burn to remove slash. Leave some woody debris to form habitat for reptiles and amphibians. Mechanically chip slash and remove from site.
Pre-commercial thinning	Allow public firewood cutting of downed trees only. Mechanically chip slash and remove from site.

One difficulty with Douglas-fir control is selecting which trees will be left in or next to Oregon white oak woodlands. Douglas-fir is an integral component of the prairie landscape, but when its reproduction is left unchecked by fire or management, it become a pest. Unfortunately, there are few quantitative parameters that help dictate how many or which Douglas-fir should be left within the oak woodland. Large "lone wolf" trees, isolated from oaks are obvious candidates for leaving (Figure 23). So are sets of trees that extend from a forest and into a prairie. Each of these situations requires independent consideration and needs to be based on the final goal of the restoration and the experience of the restorationist.

Restoring Oak Woodland and Savanna Understory

In many situations, the desired endpoint of oak woodland and savanna understory is similar in composition and structure to open grasslands. Additionally, many of the threats and degraded conditions are also similar to those in open grasslands. In these cases, understory restoration techniques are similar to those discussed for open grasslands.

Application of these techniques has not occurred within the oak woodlands of the South Puget Sound region.

Figure 23. *A large, "lone wolf" Douglas-fir, isolated from Oregon white oak woodlands, is a candidate for leaving in the prairie landscape.*

Improving Prairie Management

Persistence and Alternatives in Management and Restoration

One of the most important aspects of natural area management and restoration is the persistent working of a comprehensive action plan. Much of the restoration and management actions discussed here differ from engineering tasks in that outcomes are not assured. Even with the highest probability restoration tasks, there is a possibility of failure or conditions that are inadequate to implement a planned task. For instance, drought may kill transplanted plants or weather conditions may never meet those required by a fire prescription.

The consequences of this variability are two. First, alternatives to tasks must be evaluated and planned. This is most important in the control of invasive species, where lack of action allows the invasion of pest species and degradation of native prairies. Planning for alternatives when controlling Scotch broom is especially important. For instance, if a second round of control is not implemented prior to plant maturation and the production of seed, then additional control will likely be needed. If the primary control effort is based on prescribed burning, then planning for an alternative control method is needed when weather or fuel conditions are not met. The implementation of these alternative control actions should be initiated consistently, and with persistence, whenever the primary task cannot be completed.

The second consequence of restoration's unpredictable nature is that plans should incorporate multiple actions to accomplish a single goal. An important example is to plan on transplanting native species over several years rather than only a single time. Unplanned conditions can minimize the success of any single transplantation, while multiple transplantations reduce the chances that negative conditions will occur for each of these transplantations.

Several examples of this have occurred at Fort Lewis. The most dramatic example did not occur in the prairie, but relates to establishing riparian vegetation. Here, the cuttings and bare root stock successfully planted in the spring along Muck Creek were washed away during 100-year flooding the following winter. If this was the only planned transplantation at Muck Creek, then much of the area would not have been restored. Planting in successive years has filled many of the holes that the flooding produced in the transplanted stock.

Another perspective on this consequence is to remember how invasive species so successfully expand their ranges. They produce seed each year, and although in many years no or few individuals are established, propagules are present when correct conditions do occur. A persistent and repeated effort in transplantation of native plants or controlling invasive species mirrors this successful biological strategy.

REGIONAL RESTORATION ACTIONS

Prairie restoration and research is being implemented throughout the South Puget Sound region. Many of these actions are parallel between prairie locations. The continuing collaboration between managers and researchers at all prairie sites should be a priority. Collaboration reduces overlap between projects, refines common management actions, and increases the rate that restoration techniques are improved. In addition, collaboration may reduce costs when common goals are identified and costs shared by multiple agencies (Dunn, 1997).

This type of collaboration has been initiated through the South Puget Sound Prairie Landscape Working Group. Yet support for this group needs to be widespread and continuing if it is to maintain its functions at optimal levels. Active participation in the group by managers and restorationists from all prairie locations will help ensure that the resources applied to prairie management and restoration in the South Puget Sound are put to their best possible use.

RESEARCH PRIORITIES

A similar concern exists with research in the South Puget Sound prairie landscape. Although all types of prairie research are to be encouraged, the development of a set of priorities will help advance prairie restoration and conservation more quickly and effectively. These priorities will help focus efforts on the most pertinent questions, form a list of potential projects for researchers, and help generate interest and funding from sources outside the immediate prairie managers and agencies.

A proven technique for developing research priorities brings researchers, land managers, conservation groups, and other interested parties together to jointly develop specific priorities (Hawaii Conservation Biology Initiative, unpublished report). Each of the participants have differing perspectives and knowledge. Joining these together helps to establish common research priorities and has proven practical and effective. South Puget Sound prairies would likely benefit from such an approach.

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