# Clatsop Plains – Long Beach Peninsula Coastal Prairie Restoration

2016

## Progress Report to the USDI, US Fish and Wildlife Service

Report prepared by Matt A. Bahm

*Institute for Applied Ecology*

Institute for Applied Ecology

## PREFACE

This report is the result of an agreement between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization whose mission is conservation of native ecosystems through restoration, research and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.


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**Cover photograph**: Herbicide treated plot at North Coast Land Conservancy's Surf Pines property.

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# EXECUTIVE SUMMARY

In 2016, treatments varied by site and establishment of seeded species was low across sites. Overall, soil removal treatments showed the most promise across sites. Soil removal plots had lower cover of invasive grasses and forbs and offered more potential management action(s). Future monitoring will help to elucidate treatment effectiveness and aid in management recommendations.

**NCLC Sites**

Treatments did reduce cover of both exotic forbs and graminoids, in comparison to control plots. Invasive grass species continue to be a concern at all NCLC sites. Native species cover remained relatively low across treatments in 2016. The soil removal treatment had a relatively high ratio of native forbs to invasive forbs, and lower levels of invasive grass cover compared to the other treatments. The lower cover of invasive grasses and forbs in the soil removal treatment provides an opportunity for spot treatment that could reduce competition for seeded species.

**Willapa NWR**

Invasive grasses and forbs continue to be a management issue at the site. Although the treatments did reduce invasive graminoid cover compared to the controls, all maintained levels that will likely require intensive management. The soil removal and sand addition treatments show the most promise at Willapa NWR. The lack of cover of seeded species is a concern, but the low cover of invasive grasses and forbs is promising and provide opportunities for spot treatment that could reduce competition for seeded species.

**Yeon (National Park Service)**

This site was very different from the other sites in terms of soil substrate and existing vegetation. The soil removal treatment shows the most promise at Yeon, with higher ratio of native forbs to invasive forbs and lower levels of invasive grass cover compared to the other treatments. While future monitoring will be important to note how this changes in invasive grass cover over time, initial results indicate that current treatments may be excessive for the site and will likely need to be modified.

# Clatsop Plains – Long Beach Peninsula Coastal Prairie Restoration

**PROGRESS REPORT TO THE USDI, US FISH AND WILDLIFE SERVICE**

## INTRODUCTION

Current established techniques for restoring prairies have shown various results on a single- and multiple-treatment scale. Commonly employed restoration techniques generally aim either to reintroduce disturbance or to reduce non-native grasses, other graminoids, forbs, shrubs, and nitrogen-fixing legumes—or a combination of both techniques. Management techniques such as prescribed fire, mowing, herbicide application, solarization (e.g., heating the weed seed bank to lethal temperatures using clear plastic ground cloth), grazing, topsoil removal, and topsoil inversion have been used to mimic non-climatic natural disturbance processes, and to foster restoration of biodiversity of native plants and animals on managed sites (Van Dyke et al. 2004).

Studies conducted on coastal prairie habitat in central California and northwest Wales, UK, have shown promise in reintroducing the historic natural disturbance regime of blowing sand. Plant growth and establishment of coastal prairie species increased when combined with topsoil inversion or topsoil removal (Jones et al. 2010, Buisson et al. 2006).

The Nature Conservancy (TNC) and U.S. Fish and Wildlife Service (USFWS) have been most active in restoration efforts on the Clatsop Plains and Long Beach Peninsula. Following the designation of the Clatsop Plains in the Oregon Silverspot Butterfly Recovery Plan, various partners charged with managing coastal prairie habitat in this region gathered together to develop a comprehensive, ecologically-based planning document, facilitated by The Nature Conservancy's Conservation Action Planning (CAP) process, for the protection and restoration of the Clatsop Plains coastal corridor (Pickering 2005).

During 2002-2007, TNC tested various combinations of treatments to evaluate the best approach for maintaining and enhancing coastal prairie communities. Primary treatments included mowing, prescribed fire, and grazing, with overlain treatments of heat (infrared weed burner), soil impoverishment, and applications of organic herbicide. While several of these treatments reduced the abundance of specific groups of invasive plants or increased the abundance of native species, none of the treatment combinations was successful in meeting all of the restoration objectives. Restoration at Long Beach has similarly included various combinations of prescribed fire, herbicide application, mowing, hand removal, rototilling, seeding, and planting. To date, no treatment combination has been proven to be effective at maintaining coastal prairie habitat on the peninsula.

# METHODS

## Initial Site Conditions

### NCLC

The three sites managed by the North Coast Land Conservancy include Neacoxie Forest, Surf Pines and Reed Ranch. These three sites have high cover of exotic perennial grasses. At these three sites, the ratio of native to exotic forb and graminoid species was low (<1:10; Appendix B).

NEACOXIE FOREST
Exotic graminoid cover was very high, with average cover of exotic graminoid species >100%.

SURF PINES
This site has a small remnant population of *Viola adunca*. This site also has *Cytisus scoparius* present.

REED RANCH
In addition to the aforementioned suite of exotic perennial grasses, this site also has abundant *Cytisus scoparius*, which has been kept at bay with frequent mowing.

### USFWS, Willapa NWR, OSB Field 3

Unlike the remaining sites, the plant community at Willapa also includes *Lotus corniculatus*, and extremely low cover of native forb species. This site also contains higher cover of the perennial and mat-forming *Agrostis sp.* than other sites (Appendix B).

### National Park Service, Yeon Property

This site is a remnant dune with cover of beach grass and other dune species not found at other Clatsop Plains study sites, and higher initial cover of bareground (sand) than any other site. Soil Inversion was not considered as a treatment here, due to feasibility constraints (including site size and equipment restrictions). When soil removal occurred, one control plot was covered with spoils and was removed from the study (Appendix B).

## Experimental design

At each site, there were initially four replicates of each of four treatments (includes untreated control) (Appendix A). Modifications were made at several sites due to specific site conditions/issues and are documented in Appendix A. A complete schedule of treatments for each site through the Spring of 2016 is available in Appendix C. For the control, herbicide, and soil removal treatments, there are three, 5 x 5 meter plots and one 15 x 15 meter plot. For the soil inversion treatment, plot size was 15 x 15 meters for all four plots in order to accommodate the size of the equipment. Regardless of the treatment area, the sampling will occur at the 5 x 5 meter scale (see Figure 3).

### Treatments

The treatments tested for this study include: herbicide, soil removal, and soil inversion. Herbicide treatments including an initial application of imazapyr in Fall 2013, followed by application of

glyphosate in Spring and Fall 2014 (Figure 2). Both imazapyr and glyphosate are broad-spectrum herbicides and repeated applications are often required to achieve adequate control of invasive grass and forb species prior to initiation of restoration actions.

**FIGURE 1. HERBICIDE TREATED PLOT AT WILLAPA SITE.**

Soil inversion treatments were initiated in Fall 2014 (Figure 3). This treatment was intended to bury existing vegetation (and seedbank), and expose bare soil for planting. Soil removal plots were also initiated in Fall 2014 (Figure 3). The goal of this treatment was similar to the soil inversion in removing the existing vegetation and exposing bare soil, but topsoil was completely removed from the site(s).

**FIGURE 2. SOIL INVERSION AND SOIL REMOVAL PLOTS, RESPECTIVELY, AT THE WILLAPA SITE.**

### Seeding

In the fall/winter of 2014 five species were seeded into the 5 x 5 meter plots, while in the larger plots the area outside the 5 x 5 meter plots was seeded with *Festuca rubra* only (Figure 2; Table 1). All sites received the same species mix, with the exception of Willapa, which had *Cirsium brevistylum* substituted for *Lupinus littoralis* due to seed limitation (Table 1).

## Data collection and analysis

For each 5 x 5 meter plot, we established four 1m$^2$ sampling plots (Figure 2). Each meter square plot was set one meter from the edges and one meter from each other. Within each sampling plot, we estimated visual cover of each species present. Each species cover was estimated to the nearest 1%, except for those with <1%. Species with <1% cover were estimated at either 0.5%, or listed as "trace" to note occurrence, and assigned 0.01% for use in analysis.

Pretreatment data was collected in 2013 and is presented in Appendix B. The presence of both native and nonnative species was documented at all sites. The nonnative species documented had been noted by land managers prior to our sampling and will be monitored throughout the study to determine the treatment impacts. Post-treatment monitoring occurs annually mid- to late-May to document plant survival and natural regeneration of native and nonnative species.

Qualitative monitoring was conducted in 2014 due to budget constraints, and documented an initial reduction in vegetation cover in the herbicide treatment plots.

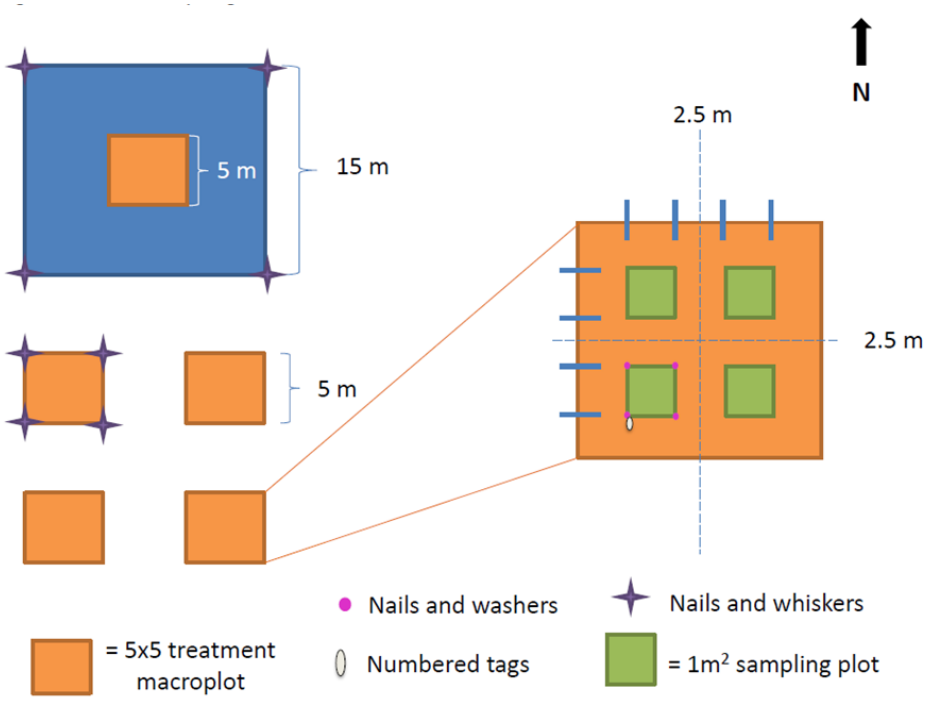


**FIGURE 3. PLOT DESIGN AND SAMPLING PROTOCOL FOR COASTAL PRAIRIE RESTORATION STUDY.**

**TABLE 1. SPECIES AND AMOUNTS SEEDED INTO COASTAL PRAIRIE RESTORATION RESEARCH PLOTS.**

| 5 x 5 meter plots<br>Species | Pure Live Seeds/ft$^2$ | Pure Live Seeds /m$^2$ | seeds/lb | g/m$^2$ | purity | germ |
|---|---|---|---|---|---|---|
| *Festuca rubra* | 30 | 323 | 400,000 | 0.37 | 90 | 80 |
| *Achillea millefolium* | 50 | 538 | 2,000,000 | 0.12 | 70 | 70 |
| *Solidago canadensis* | 50 | 538 | 2,000,000 | 0.12 | 50 | 50 |
| *Aster subspicatus* | 20 | 215 | 1,000,000 | 0.09 | 40 | 40 |
| *Lupinus littoralis* | 2 | 22 | 70,000 | 0.14 | 100 | 90 |
| *Cirsium brevistylum* | 36 | 385 | 175,000 | 0.95 | 95 | 90 |
| **Large plot area outside 5 x 5 meter plots** | | | | | | |
| *Festuca rubra* | 50 | 538 | 400,000 | 0.6 | 90 | 80 |

# RESULTS

## North Coast Land Conservancy

### Neacoxie Forest

SEEDED SPECIES

Seeded native forb species increased from 2015 to 2016, but remained <10% in all treatments (Figure 3). We recorded *Achillea millefolium*, *L. littoralis*, and *Solidago canadensis* in seeded plots, but only *A. millefolium* averaged cover >1%. In control plots, no *A. millefolium* cover was recorded and all treatments had significantly higher cover (Figure 3). *A. millefolium* ranged from 4-6% in treatment plots and did not vary significantly among treatments.

*F. rubra* was recorded in all treatments and ranged from 2-13% in 2016 (Figure 4). Herbicide treatments had significantly higher cover of *F. rubra* than all other treatments. *F. rubra* comprised all cover recorded for native graminoid species in herbicide treated plots (Figure 4).

FORB COVER

In 2016, native forb cover in the controls ranged forb cover from <1-9% (Figure 3). *A. millefolium* had the highest cover of native forb species in treatment plots, averaging from 4-6% in treatment plots. *Ranunculus occidentalis* had the highest native forb cover in control plots, averaging 2% (Figure 3).

Soil removal and inversion had lower cover of invasive forbs in both 2015 and 2016 (Figure 3). In 2016 control plots, invasive forb cover ranged from <1-32%. Herbicide treatments had significantly higher cover invasive forb cover in 2015 and 2016 (Figure 3). In 2016, invasive forb cover in herbicide treatments ranged from 30-64%. Soil removal plots averaged <5% invasive forb cover in 2015 and

2016, and in 2016, ranged from 0-15%. *Hypochaeris radicata* and *Rumex acetosella* comprised the majority of invasive forb cover recorded among all treatments.

### GRAMINOID COVER

Cover of *F. rubra* was significantly higher in the herbicide treatment during 2016, and comprised all of the native graminoid cover in that treatment (Figure 4). Native graminoid cover was <20% in all treatments and remained less than half of the invasive graminoid cover in each treatment (Figure 4).

Invasive graminoid cover was significantly higher in control plots than all other treatments, exceeding 100% (Figure 4). Soil removal treatments had significantly lower cover of invasive grasses than the soil inversion and herbicide treatments, but all were ≥20% in 2016 (Figure 4). *Agrostis alba*, *Anthoxanthum odoratum*, and *Schedonorus arundinaceus* comprised the majority of invasive graminoid cover.

### SHRUB COVER

There was no clear effect of treatments on shrub cover, likely due to low initial levels at the site (<2%). However, the soil inversion plots had significantly higher shrub cover (5%) than any other treatment in 2016, due to the presence of the native blackberry, *Rubus ursinus*.

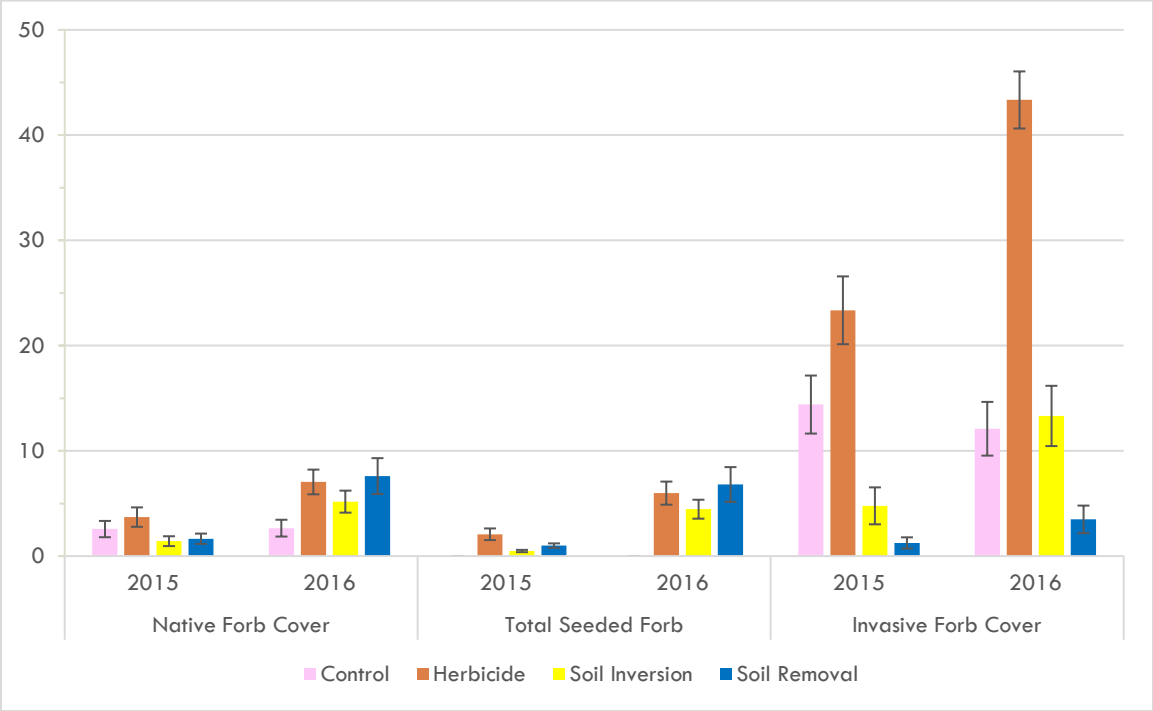


**FIGURE 4. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS, AT NEACOXIE FOREST IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES.**

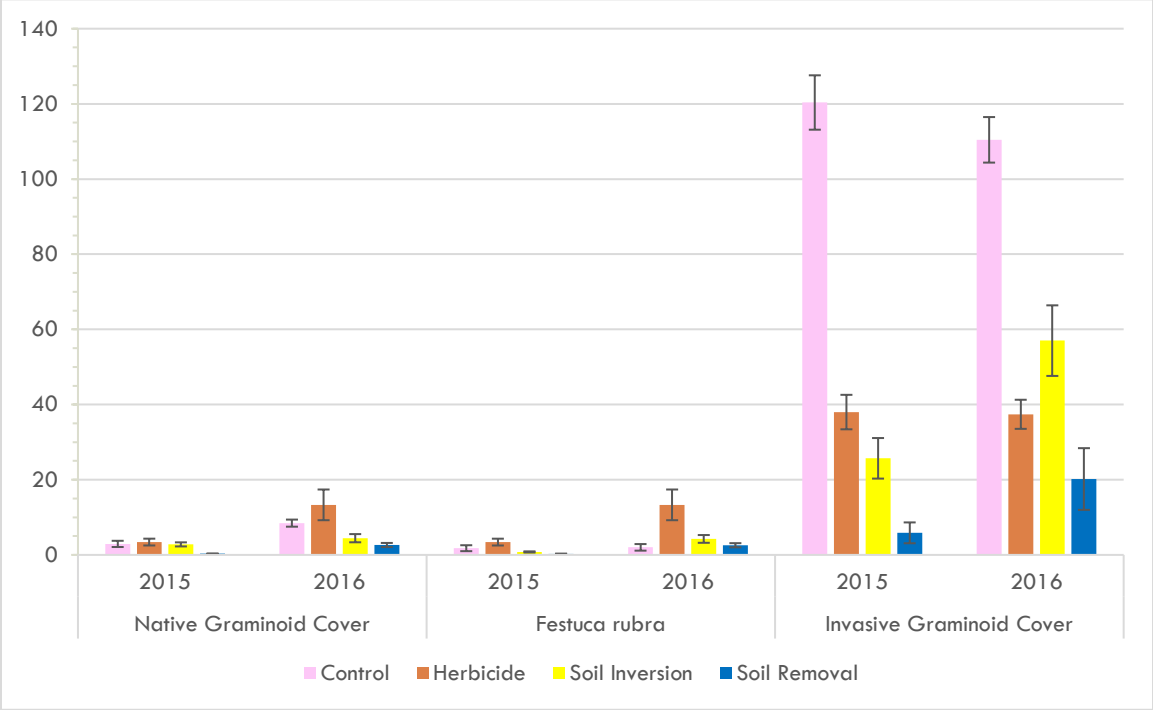


**FIGURE 5. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT NEACOXIE FOREST IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).**

## Surf Pines

### SEEDED SPECIES

Seeded native forb species increased from 2015 to 2016, reaching nearly 20% cover in several treatments (Figure 5). We recorded *A. millefolium* and *L. littoralis* in seeded plots in 2016. *A. millefolium* cover ranged from 1-12%, and was significantly higher in the herbicide and soil removal treatments. *L. littoralis* cover ranged from <1-6%, and was significantly higher in the herbicide treatment.

*F. rubra* was recorded in all treatments and ranged from <1-5% in 2016 (Figure 6), and was not statistically different among treatments.

### FORB COVER

Native forb cover was highest in the herbicide treatment (Figure 5). The herbicide and soil removal treatments had significantly higher native forb cover than the soil inversion and control treatment. *A. millefolium* had the highest native forb cover among treatment plots (3-12%), while *A. millefolium* and *R. occidentalis* had similar cover in control plots (1%).

Soil removal plots had significantly lower cover of invasive forbs (Figure 5), and was the only treatment with <10% cover in 2016. In treated plots, invasive forb cover was as low as 6% in soil removal plots to as high as 53% in herbicide plots. *H. radicata* and *R. acetosella* comprised the majority of invasive forb cover recorded among all treatments.

## GRAMINOID COVER

Native graminoid cover increased slightly in 2016, but remained ≤5% across treatments (Figure 6). *F. rubra* had the highest native graminoid cover in herbicide and soil removal treatment plots, while *Carex panza* had the highest cover in soil inversion and control plots.

Invasive graminoid cover showed similar patterns in 2015 and 2016 (Figure 6). Soil removal plots had significantly lower cover of invasive graminoids than all other treatments, while herbicide treatments had lower cover than the soil inversion or the control plots (Figure 6). *A. alba* and *A. odoratum* were found at relatively high cover values across treatments, while *S. arundinaceus* had high cover in control and soil inversion plots (>25%), but was not recorded in herbicide plots and was <1% in soil removal plots.

## SHRUB COVER

There was no clear effect of treatments on shrub cover in 2015, but the control, herbicide and soil inversion treatments had significantly higher cover than the soil removal treatment in 2016 (Figure 7). *Cytisus scoparius* (Scotch broom) provides the majority of shrub cover at the site.

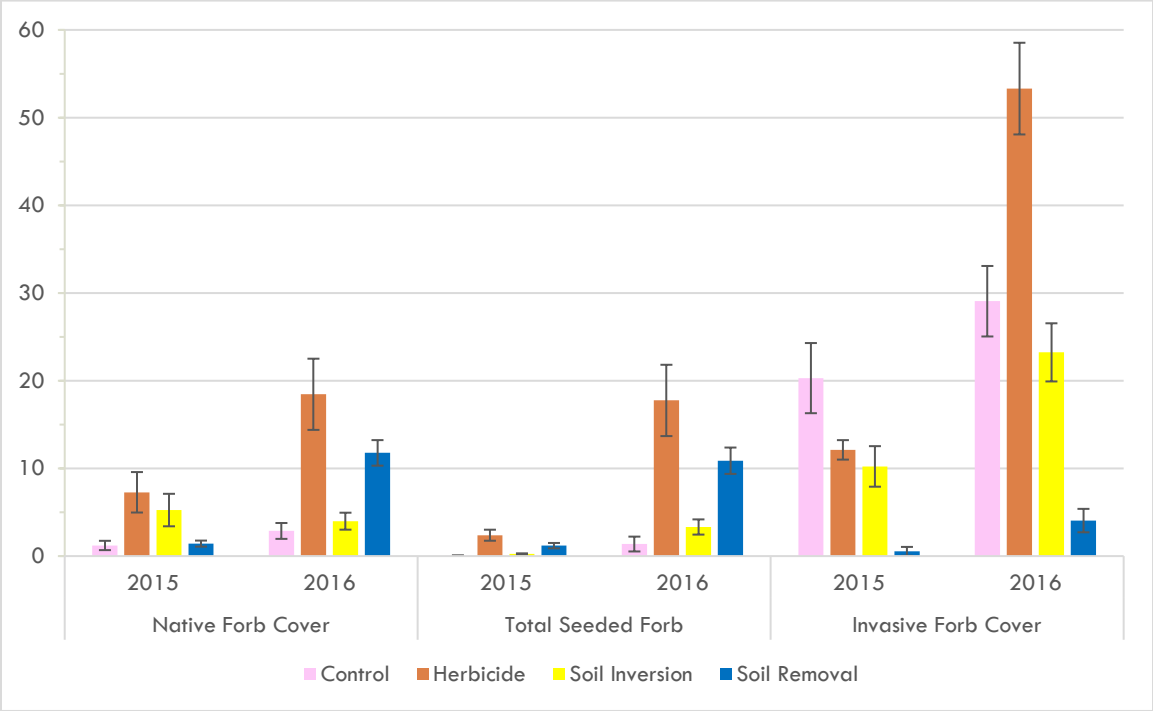


**FIGURE 6. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS, AT SURF PINES IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES.**

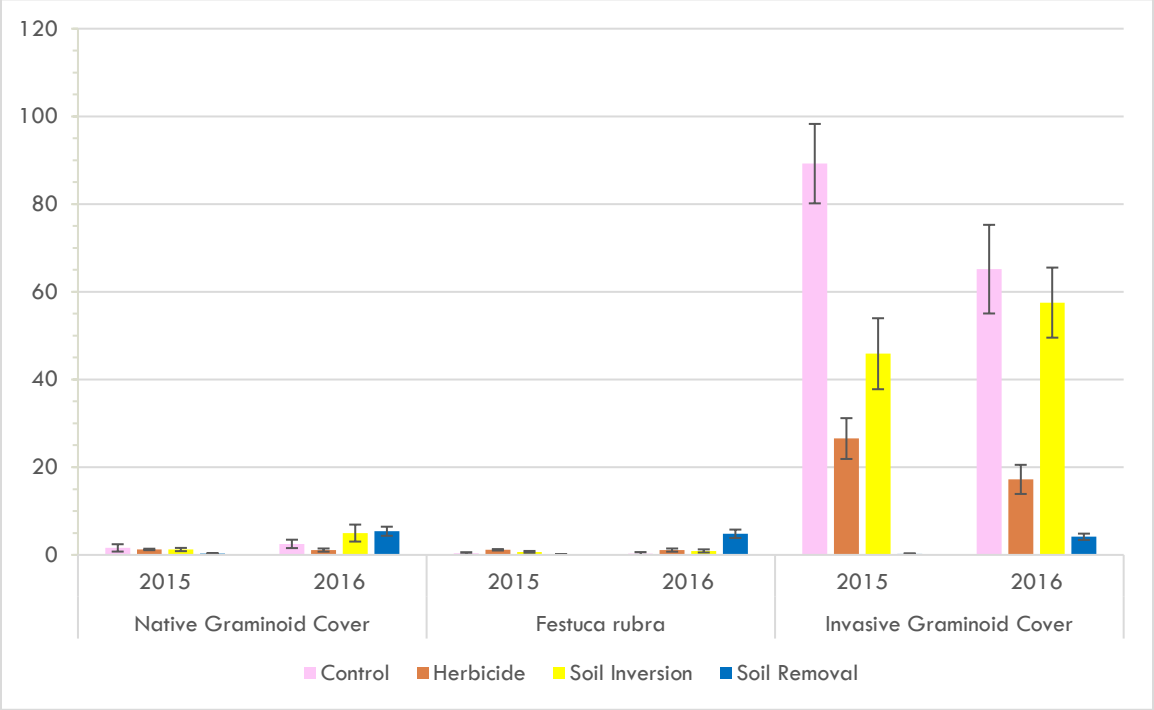


**FIGURE 7. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT SURF PINES IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).**

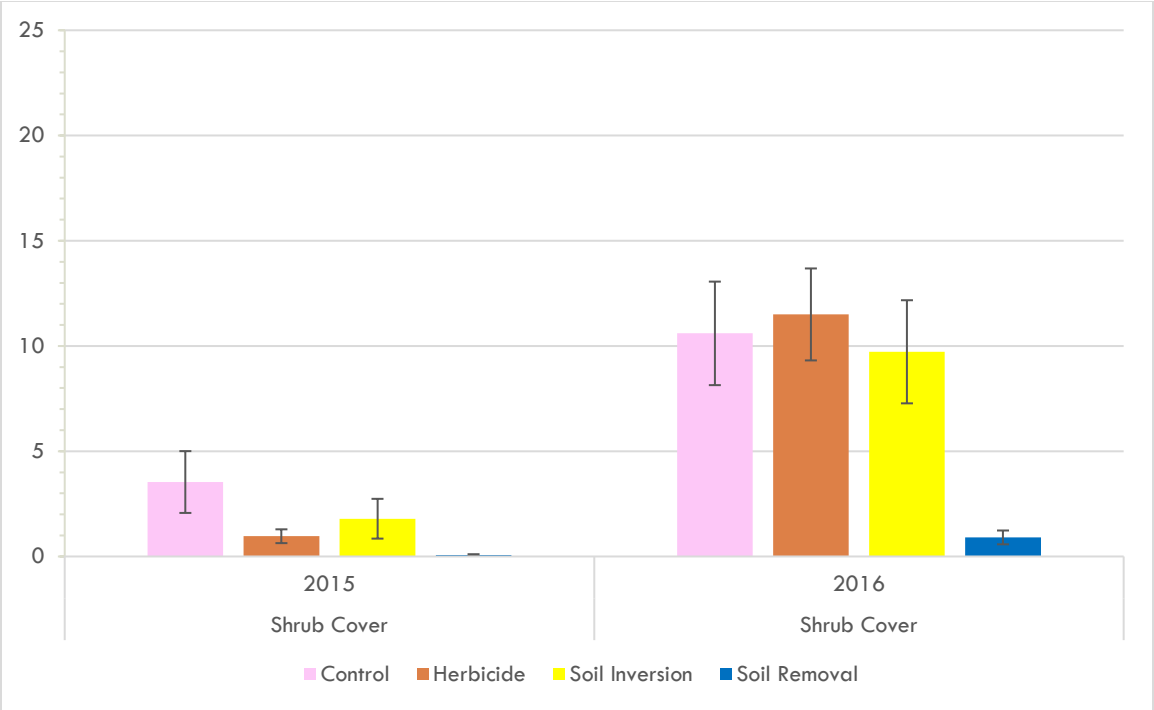


**FIGURE 8. COVER OF SHRUBS AT SURF PINES IN 2015 AND 2016.**

## Reed Ranch

### SEEDED SPECIES

Seeded native forb species increased from 2015 to 2016, but remained <10% in all treatments (Figure 8). We recorded *A. millefolium* and *L. littoralis* in seeded plots, with *A. millefolium* averaging <1-10% and *L. littoralis* averaging <1-5%. *A. millefolium* cover was significantly higher in herbicide treatment plots, while *L. littoralis* was significantly higher in soil removal plots.

*F. rubra* was recorded in all treatments and ranged from 1-4% in 2016 (Figure 9). *F. rubra* cover did not vary significantly among treatments.

### FORB COVER

Native forb cover was higher in treatment plots compared to the control, but did not vary significantly among treatments (Figure 8). *A. millefolium* had the highest native forb in herbicide and soil inversion plots, while *L. littoralis* had the highest native forb cover in soil removal plots.

Soil removal plots had significantly lower cover of invasive forbs (Figure 8), and was the only treatment with <30% cover in 2016. In treated plots, invasive forb cover was as low as 4% in soil removal plots to as high as 93% in herbicide plots. *H. radicata* and *R. acetosella* comprised the majority of invasive forb cover recorded among all treatments.

### GRAMINOID COVER

*F. rubra* comprised the majority of native graminoid cover and did not vary significantly among treatments (Figure 9).

Soil removal plots had <5% cover of invasive graminoids and was significantly lower than all other treatments (Figure 9). Invasive graminoid cover was >39% in the herbicide and soil inversion plots, and was >100% cover in control plots. *A. odoratum* was recorded in all plots and had the highest relative cover among treatments. *S. arundinaceus*, *Dactylis glomerata*, and *Bromus hordeaceus* had high cover values in the control and soil inversion plots.

### SHRUB COVER

Shrubs are uncommon in our study plots and cover was $\leq$1% in 2015 and 2016.

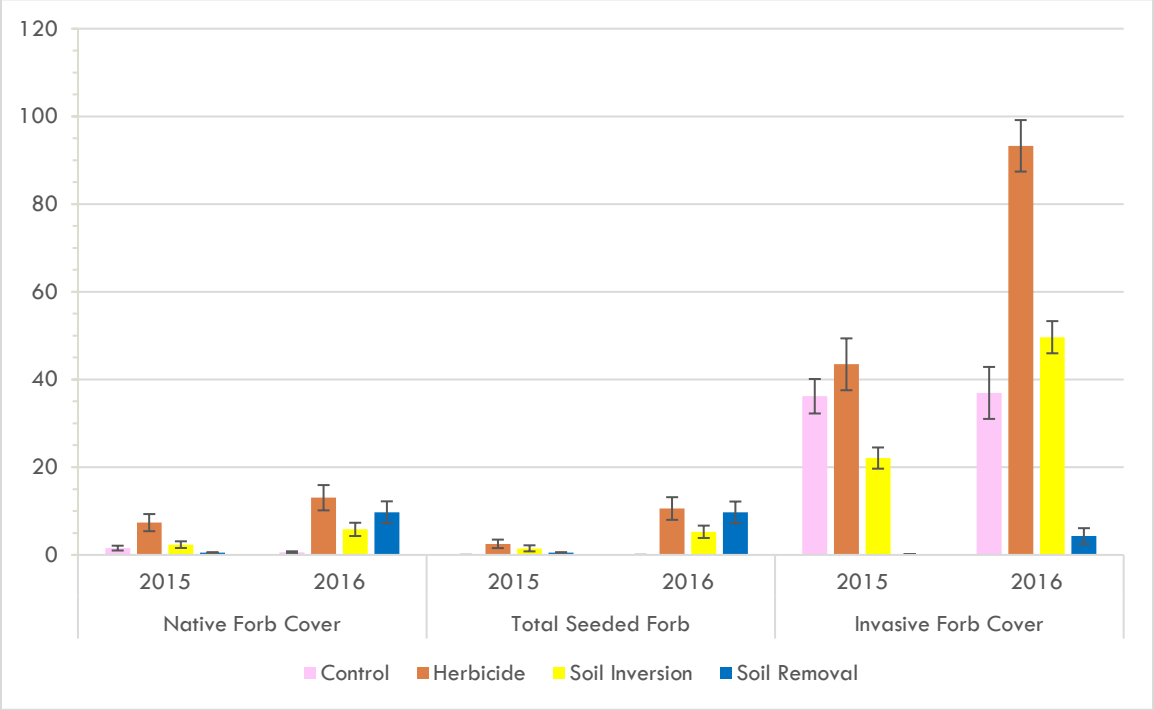


**FIGURE 9. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS, AT REED RANCH IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES.**

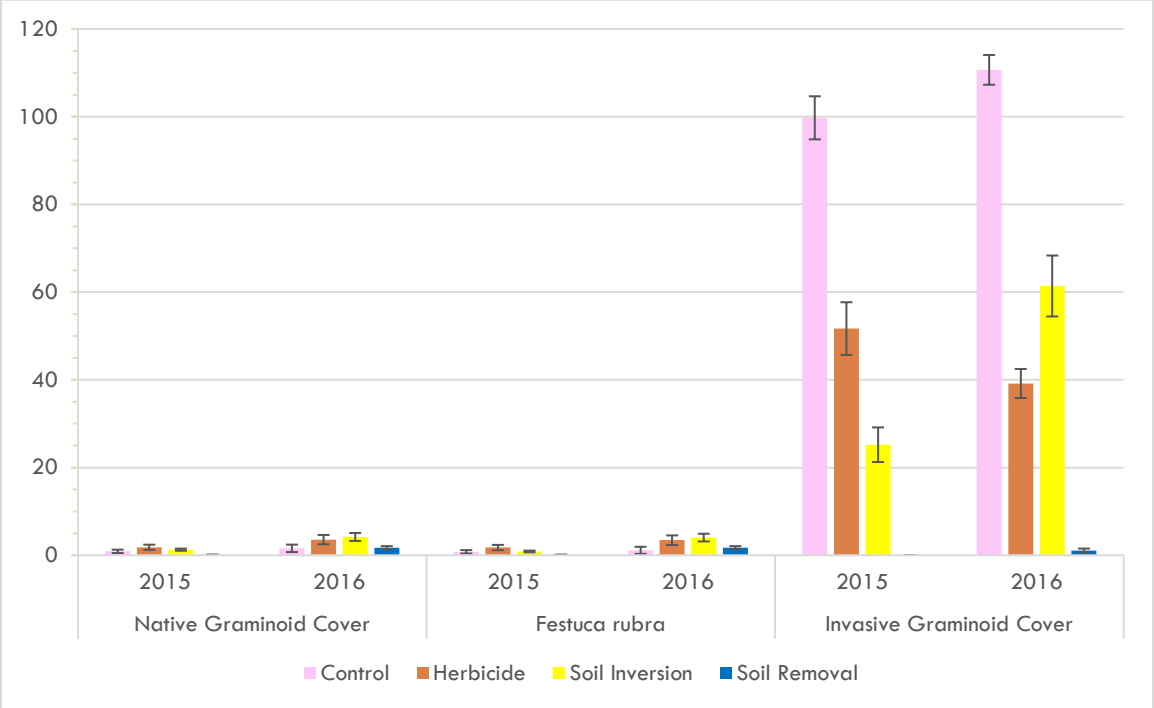


**FIGURE 10. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT REED RANCH IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).**

## US Fish and Wildlife Service

### Willapa NWR

At this site, two of the soil removal plots were dug sufficiently below the water table, such that water ponded in the plots during the rainy season: subsequently, the two easternmost soil removal plots were infilled with sand and these plots are considered as a separate treatment not included at other sites.

Herbicide applications were most patchy at this site, possibly due to large amounts of thatch impeding contact of chemicals with live plant materials (Figure 11).

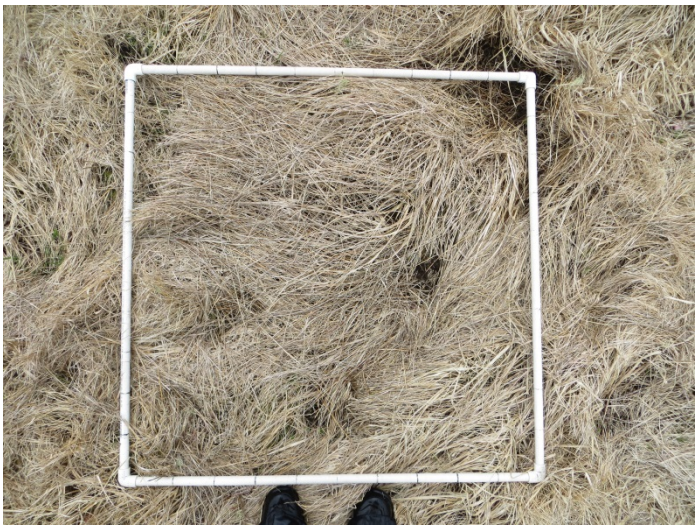

**FIGURE 11. . HERBICIDE TREATED PLOT SHOWING DENSE THATCH THAT MUST BE CONSIDERED WHEN PLANNING CONTROL AND RESEEDING EFFORTS.**

#### SEEDED SPECIES

Cover of seeded native forb species did increase from 2015 to 2016, but cover remained <5% (Figure 12). *A. millefolium* was found in all treatments, but *S. canadensis* was recorded only in soil removal plots.

*F. rubra* cover was highest in the control plots (Figure 13). This is not a result of seeding, but due to the presence of the species prior to initiation of our study (Appendix B). *F. rubra* cover was lowest in the sand addition plots, but not significantly different among the other treatments (Figure 13). Despite the differences, all plots had <10% cover after the second growing season.

#### FORB COVER

Native forb cover was higher in treatment plots compared to the control, but did not vary significantly among treatments (Figure 8) and remained <5% in 2016. *A. millefolium* contributed the highest native forb cover across treatments.

Soil removal plots had significantly lower cover of invasive forbs, and was the only treatment with <10% cover in 2016 (Figure 10). In treated plots, invasive forb cover was as low as 4% in soil removal plots to as high as 48% in herbicide plots. *H. radicata, R. acetosella*, *Lotus corniculatus*, and *Trifolium* spp. were commonly recorded and comprised the majority of invasive forb cover recorded among all treatments.

#### GRAMINOID COVER

*F. rubra* comprised the majority of native graminoid cover and did not vary significantly among treatments (Figure 11).

Soil removal and sand addition plots had <8% cover of invasive graminoids and were significantly lower than other treatments (Figure 11). Invasive graminoid cover was >74% in the herbicide and soil inversion plots, and was similar to the 88% cover in control plots. *Agrostis alba* was recorded in all plots and had

the highest relative cover among treatments. *A. odoratum* also had relatively high cover across treatments, while *Holcus lanatus* had high cover values in the control, herbicide, and soil inversion plots.

## SHRUB COVER

Shrubs are not common at the Willapa site.

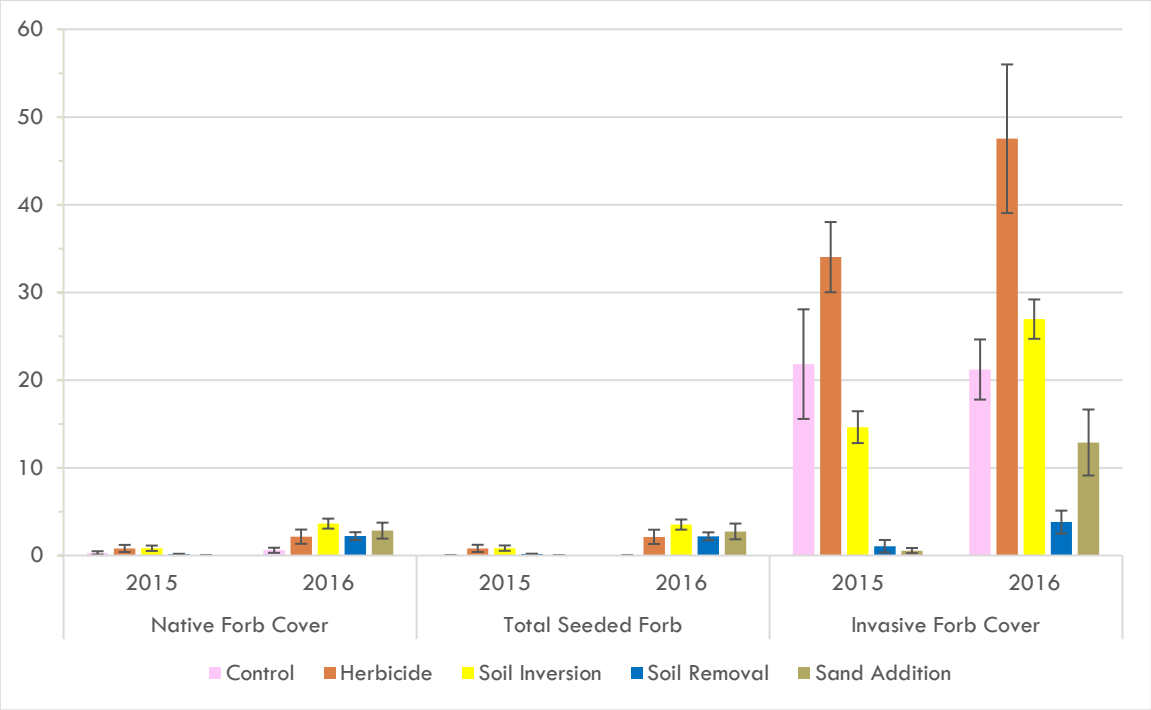


**FIGURE 12. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS AT WILLAPA NWR IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES.**

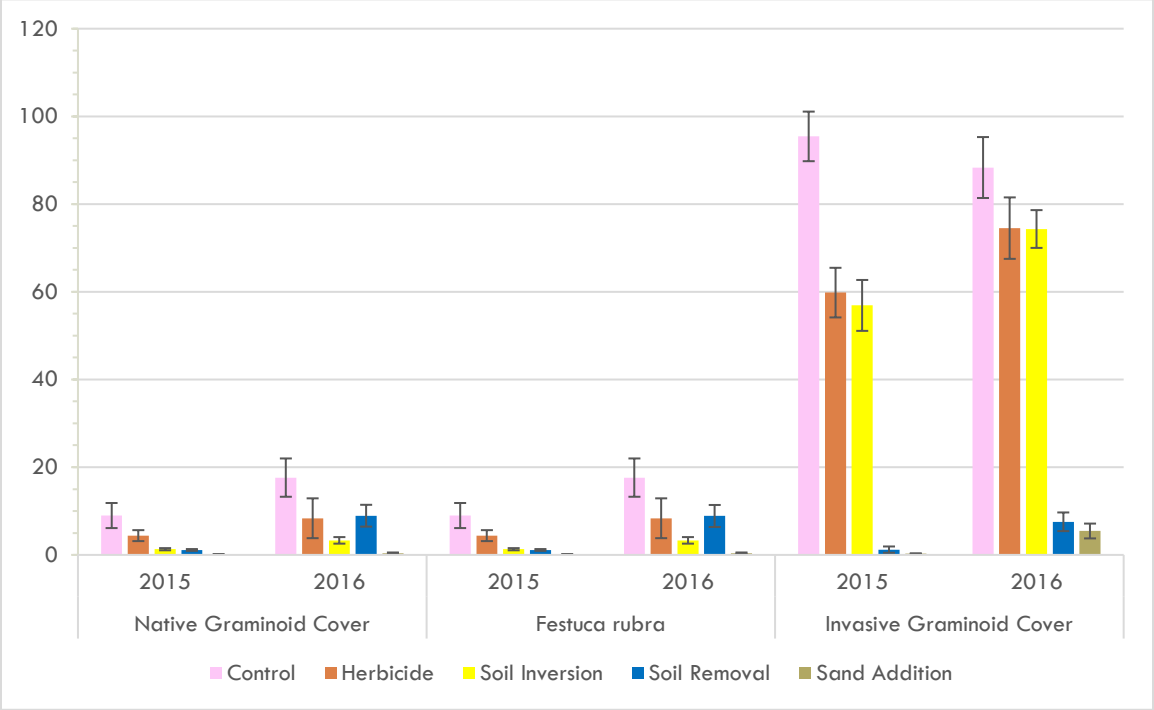


**FIGURE 13. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT WILLAPA NWR IIN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).**

## National Park Service

### Yeon

SEEDED SPECIES

Seeded native cover was generally low at this site (<5%; Figure 12). The soil inversion and soil removal treatments resulted in higher amounts of seeded forb cover than the control, but remained low after two growing seasons. *L. littoralis* was recorded in all treatments, *A. millefolium* was recorded only in herbicide and soil removal plots, and *S. canadensis* was recorded only in soil removal plots.

*F. rubra* cover was higher in herbicide and soil removal treatments than in the control, but was less than 15% after two growing seasons (Figure 13).

FORB COVER

Forb cover was generally low at this site in comparison to other sites (<17%; Figure 12). Native forb cover was <5% and did not show treatment effects. *A. millefolium* and *L. littoralis* were the only native forbs to average >1% cover in any of the treatments.

The herbicide treatment and the control had higher invasive forb cover than the soil removal treatments (Figure 12). *H. radicata* comprised the majority of invasive for cover, with *R. acetosella* and *Vicia sativa* also commonly recorded.

## GRAMINOID COVER

Native graminoid cover was low across all treatments (<10%; Figure 13). *F. rubra* comprised the majority of the native graminoid cover recorded at the site in 2016.

Invasive graminoid cover increased in all treatments in 2016, and although significantly lower in soil removal plots, was >20% in all treatments (Figure 13). *Ammophila breviligulata* (native to the eastern U.S.), *Agrostis* spp., and *A. odoratum* comprised the majority of invasive graminoid cover.

## SHRUB COVER

Shrubs are not common at the Yeon site.

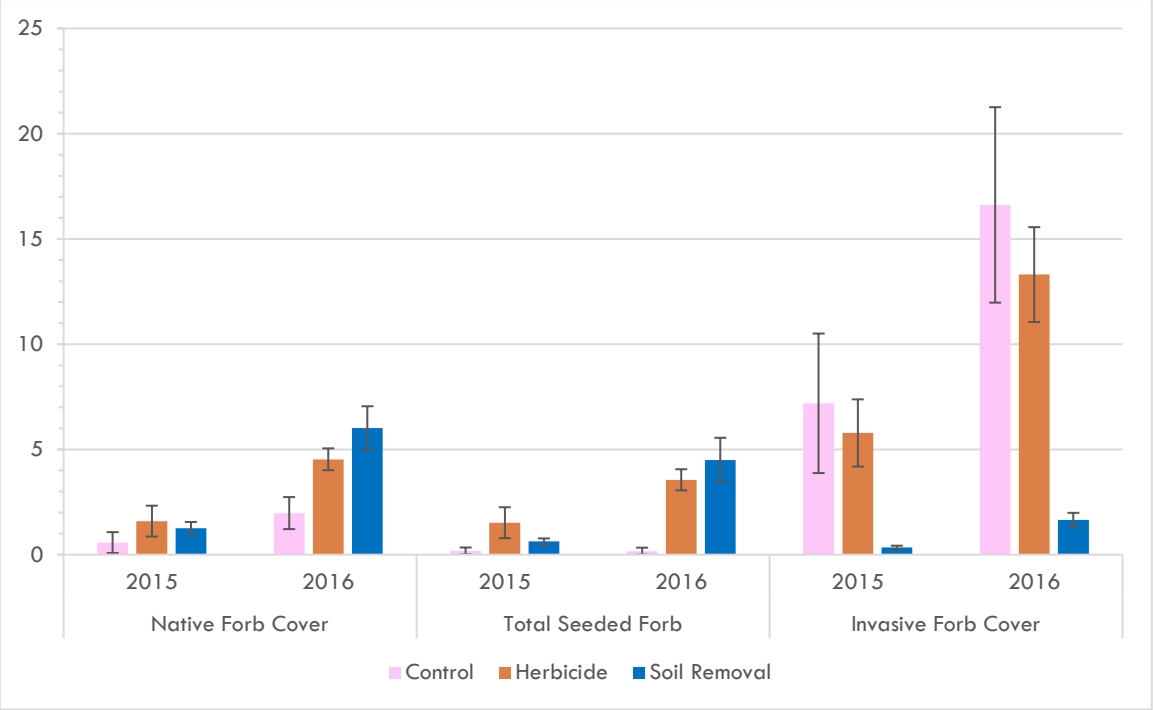


**FIGURE 14. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS AT NPS YEON SITE IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES.**

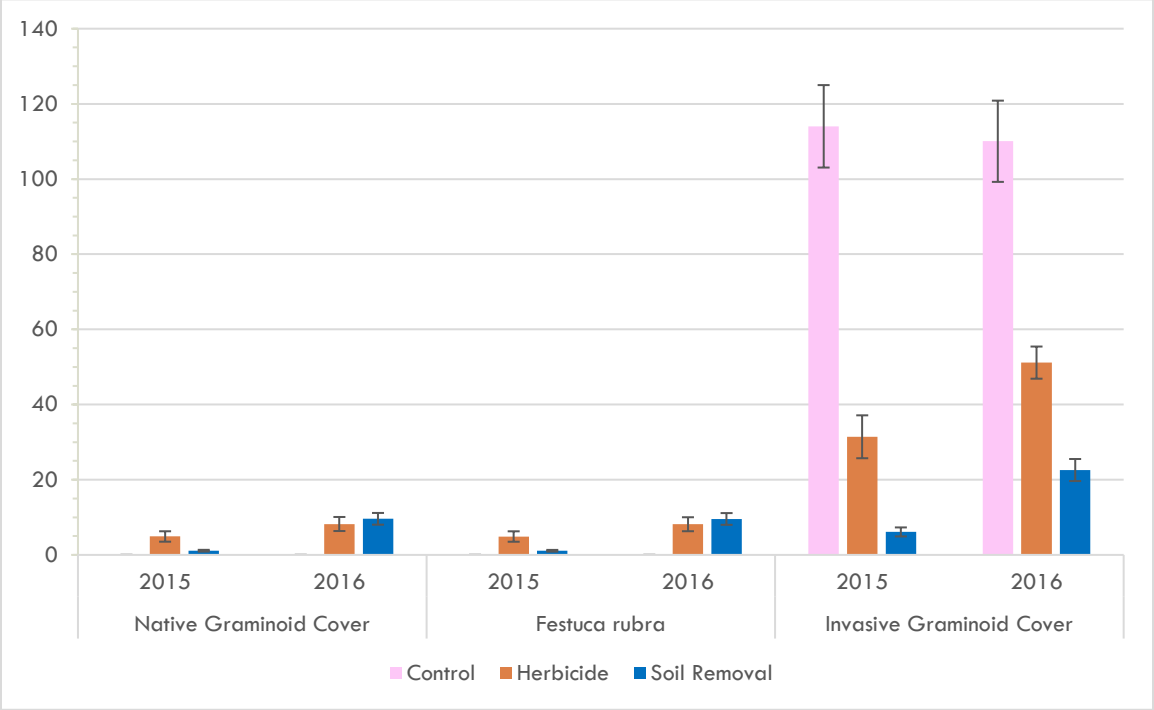


**FIGURE 15. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT NPS YEON SITE IN 2015 AND 2016. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).**

## MANAGEMENT IMPLICATIONS

In addition to site-level variables and initial vegetative community, historical land-use is an important consideration in restoration of functional ecosystems (Brudvig 2011). The variation we have recorded in treatments among the sites over the past two growing seasons is likely due to a combination of site history, soil types, existing vegetation, and climatic/topographic factors. Although these differences limit the general conclusions that can be drawn, the data collected at each site do allow for site specific recommendations to be made.

All sites would have benefited from more native seed being available. This limitation is not unique to this study, but is a known issue in coastal prairie restoration efforts. There are efforts underway to increase the amount of seed and number of species available for restoration, but these efforts are only in the early stages and will be several years before benefits are realized.

We intentionally limited the amount of *F. rubra* seed in the mix due to concerns with it being too dominant over the native forb species, as has been recorded during the Nestucca Bay NWR prairie restoration efforts (I. Silvernail, personal communication). Cover has remained low after two years, and future efforts should likely include higher seeding rates of *F. rubra*. The limited amount of native forb seed available for the project has likely limited establishment of selected native species, which have been unable to compete with the seedbank present at each site, resulting in dominance of several invasive forbs and grasses among most of the treatments.

The soil inversion technique was envisioned to completely "flip" the soil so that the existing vegetation would be buried and the soil profile would be exposed. The hypothesis was that this would result in killing the existing vegetation, while exposing soil for seeding with native species. In practice, this technique was difficult to implement for several reasons. First, equipment varied among the various partners involved in the study. The need for a plow capable of completely turning the soil with existing vegetation was important, as was the need for a tractor powerful enough to pull that equipment. At none of the sites did we have successful application of this technique, which resulted in incomplete soil turning and minimal harm to existing vegetation (Figure 14). If the technique were to be tested again, modification would have to be made to ensure proper equipment and likely need to include some form of preparation of the existing vegetation (mowing, herbicide, rototilling, etc.).

## North Coast Land Conservancy

### Neacoxie Forest

The major management concern currently are invasive grasses, predominantly *A. alba*, *A. odoratum*, and *S. arundinaceus*. All treatments had ≥20% cover of invasive grasses, with the highest levels recorded in the soil inversion treatments. This treatment did not achieve the objective of completely "flipping" the soil to cover the existing vegetation and reveal the soil underneath (see paragraph above for all sites).

The herbicides used during our study, imazapyr and glyphosate, are both broad-spectrum herbicides and would be expected to control these invasive grass species. Although the herbicide treatments did show a decrease compared to the control plots, there was still nearly 40% cover in 2016 (Figure 4). This amount of cover ensured that these species would continue to dominate the plots and limit establishment of seeded native species. The lack of complete control could be due to a variety of factors. Some possible factors could be the lack of thatch removal that could have limited herbicide contact with actively growing plant material, timing (i.e. cold weather limiting photosynthetic rate), and/or weather factors (i.e. rain fall too soon after application). Although not specifically researched for this study, removal of thatch could likely have provided better control by exposing more actively growing plant tissue to herbicide application. Future efforts could be focused at removal of thatch prior to application (i.e. haying, raking, etc.).

The soil removal treatment was the most effective technique for reducing cover of invasive grasses. This result was expected, because the existing vegetation was removed and likely portions of the existing seedbank as well. The spread of these invasive grasses from outside our research plot has resulted in cover values increasing in the second year (Figure 4). This treatment is likely still early enough to allow for spot treatment of invasive grasses with either herbicide or hand-pulling to limit the damage to seeded native species.

Although not as much of a concern compared to other sites, invasive forbs are present at the site and would require management to keep levels reduced. *H. radicata,* and *R. acetosella* were the most commonly recorded invasive forbs, in terms of cover. Both species will require management action, otherwise they will continue to increase. *H. radicata* can be treated by herbicide and/or hand-pulling. Only the soil removal treatment would likely be a candidate for hand-pulling, as the amount in the other treatments would require intense effort and cause larger scale soil disturbance. *R. acetosella* can spread

vegetatively, in addition to seed, and will likely require herbicide treatment to reduce/eliminate. Mowing is ineffective on these two species and would also likely harm the seeded native species.

Overall, the soil removal treatment shows the most promise at Neacoxie. The higher ratio of native forbs to invasive forbs is promising, as is the lower levels of invasive grass cover compared to the other treatments. Monitoring will be important to determine the success of seeded native species, especially if the suggested management action(s) are implemented, and will aid in making future management recommendations and improving restoration efforts.

### Surf Pines

The major management concern currently are invasive grasses, predominantly *A. alba*, *A. odoratum*, and *S. arundinaceus*. The soil inversion treatment had the highest cover of all treatments (58%) and had similar issues as those listed for all of the sites. The soil removal treatment had <5% cover of invasive grasses, while herbicide plots had 17% cover.

The herbicides used during our study, imazapyr and glyphosate, are both broad-spectrum herbicides and would be expected to control these invasive grass species. While we did see significant reductions compared to the control and soil inversion treatment, the amount of cover remaining would likely allow these species to dominate the plots and limit establishment of seeded native species into the future. The lack of complete control could be due to a variety of factors, similar to those mentioned for the Neacoxie site above. Levels are still low enough that spot treatment of invasive grasses could be effective in reduction/elimination.

The soil removal treatment was the most effective technique for reducing cover of invasive grasses. This result was expected, because the existing vegetation was removed and likely portions of the existing seedbank as well. The spread of these invasive grasses from outside our research plot has resulted in cover values increasing in the second year (Figure 4). This treatment is likely still early enough to allow for spot treatment of invasive grasses with either herbicide or hand-pulling to limit the damage to seeded native species.

Although not as much of a concern compared to other sites, invasive forbs are present at the site and would require management to keep levels reduced. *H. radicata,* and *R. acetosella* were the most commonly recorded invasive forbs, in terms of cover. Both species will require management action, otherwise they will continue to increase. *H. radicata* can be treated by herbicide and/or hand-pulling. Only the soil removal treatment would likely be a candidate for hand-pulling, as the amount in the other treatments would require intense effort and cause larger scale soil disturbance. *R. acetosella* can spread vegetatively, in addition to seed, and will likely require herbicide treatment to reduce/eliminate. Mowing is ineffective on these two species and would also likely harm the seeded native species.

This site also had the highest cover of the invasive shrub, *C. scoparius*. Although at relatively low levels, due to past management efforts, this species should continue to be a target for management efforts. Spot treatment with herbicide and hand-pulling are both effective for controlling *C. scoparius*.

Overall, the soil removal treatment shows the most promise at Surf Pines. The higher ratio of native forbs to invasive forbs is promising, as is the lower levels of invasive grass cover compared to the other treatments. The low cover of *F. rubra* was offset by the low cover of invasive grasses and provides an

opportunity for spot treatment that could reduce competition for seeded species. Soil removal also maintained low cover of C. *scoparius*, which would allow for spot treatment with herbicide and/or hand-pulling to eliminate. Monitoring will be important to determine the success of seeded native species, especially if the suggested management action(s) are implemented, and will aid in making future management recommendations and improving restoration efforts.

### Reed Ranch

The major management concerns currently are invasive grasses, predominantly *A. odoratum*, and invasive forbs, predominantly *H. radicata* and *R. acetosella*. Soil inversion treatments had ≥50% cover of invasive grasses (61%) and forbs (50%), and herbicide treatments had 39% cover of invasive grasses and 93% cover of invasive forbs. The soil removal treatment had <5% of both invasive grasses and forbs. The re-treatment of invasive grasses and forbs in these plots would likely require broadcast herbicide application and be detrimental to the seeded native species present.

The herbicides used during our study, imazapyr and glyphosate, are both broad-spectrum herbicides and would be expected to control these invasive grass and forb species. Although the herbicide treatments did show a decrease compared to the control plots, the amount of cover remaining ensured that these species would continue to dominate the plots and limit establishment of seeded native species. The lack of initial control could be due to a variety of factors, similar to those mentioned for the Neacoxie site above. The increase in invasive forb cover is also likely due to germination from the seed bank after the initial decrease in the existing vegetation.

The soil removal treatment was the most effective technique for reducing cover of invasive grasses and invasive forbs. This result was expected, because the existing vegetation was removed and likely portions of the existing seedbank as well. The spread of these invasive grasses from outside our research plot has resulted in cover values increasing in the second year (Figure 4). This treatment is likely still early enough to allow for spot treatment of invasive grasses with either herbicide or hand-pulling to limit the damage to seeded native species.

Overall, the soil removal treatment shows the most promise at Reed Ranch. The higher ratio of native forbs to invasive forbs is promising, as is the lower levels of invasive grass cover compared to the other treatments. The cover of native forbs in the soil removal treatment was similar to herbicide treatments, but did not have the high cover values of invasive forbs found in herbicide treatments. Monitoring will be important to determine the success of seeded native species, especially if the suggested management action(s) are implemented, and will aid in making future management recommendations and improving restoration efforts.

## US Fish and Wildlife Service

### Willapa NWR

The major management concerns currently are invasive grasses, predominantly *A. odoratum*, and invasive forbs, predominantly *H. radicata, R. acetosella*, *Lotus corniculatus*, and *Trifolium* spp. *A. odoratum* also had relatively high cover across treatments, while *H. lanatus* had high cover values in the control, herbicide, and soil inversion plots. Invasive grass cover in herbicide and soil inversion treatments were statistically the same as the control plots, while both the soil removal and sand addition treatments had

<8% cover. The herbicide treatment had significantly higher invasive forb cover than any other treatment, including the control. The re-treatment of invasive grasses and forbs in the herbicide and soil inversion treatments would likely require broadcast herbicide application, or other heavy management action, and be detrimental to the seeded native species present.

The herbicides used during our study, imazapyr and glyphosate, are both broad-spectrum herbicides and would be expected to control these invasive grass and forb species. Cover of invasive grasses and forbs in herbicide treatments are increasing and would require broadcast herbicide or some other heavy management action to eliminate. This amount of cover ensured that these species would continue to dominate the plots and limit establishment of seeded native species. The lack of complete control could be due to a variety of factors. Some possible factors could be the lack of thatch removal that could have limited herbicide contact with actively growing plant material, timing (i.e. cold weather limiting photosynthetic rate), and/or weather factors (i.e. rain fall too soon after application). Although not specifically researched for this study, removal of thatch could likely have provided better control by exposing more actively growing plant tissue to herbicide application. Future efforts could be focused at removal of thatch prior to application (i.e. haying, raking, etc.).

The soil removal treatment was the most effective technique for reducing cover of invasive grasses. This result was expected, because the existing vegetation was removed and likely portions of the existing seedbank as well. The spread of these invasive grasses from outside our research plot has resulted in cover values increasing in the second year (Figure 4). This treatment is likely still early enough to allow for spot treatment of invasive grasses and forbs with either herbicide or hand-pulling to limit the damage to seeded native species.

The sand addition treatment showed similar patterns to the soil removal treatment, except that it did have significantly higher invasive forb cover. The amount of cover is still relatively low compared to the herbicide and soil inversion treatments, and is likely still early enough to allow for spot treatment of invasive grasses and forbs with either herbicide or hand-pulling to limit the damage to seeded native species.

Overall, the soil removal and sand addition treatments show the most promise at Willapa NWR. The lack of cover of seeded species is a concern, but the low cover of invasive grasses and forbs is promising. Monitoring will be important to determine the success of seeded native species, especially if the suggested management action(s) are implemented, and will aid in making future management recommendations and improving restoration efforts.

## National Park Service

### Yeon

The major management concern currently are invasive grasses, predominantly *A. breviligulata*, *Agrostis* spp., and *A. odoratum*. All treatments had ≥20% cover of invasive grasses, with the highest levels recorded in the herbicide treatments.

The herbicides used during our study, imazapyr and glyphosate, are both broad-spectrum herbicides and would be expected to control these invasive grass species. Although the herbicide treatments did show a decrease compared to the control plots, cover was >50% in 2016 (Figure 12). This site has less soil

development compared to the other sites and is mostly sand, which could have impacted the efficacy of the herbicide application(s). Imazapyr does have residual soil activity, but it is likely that the sand caused it to dissipate through the soil profile.

The soil removal treatment was the most effective technique for reducing cover of invasive grasses. This result was expected, because the existing vegetation was removed and likely portions of the existing seedbank as well. This treatment is likely still early enough to allow for spot treatment of invasive grasses with either herbicide or hand-pulling to limit the damage to seeded native species.

Although not as much of a concern compared to other sites, invasive forbs are present at the site and would require management to keep levels reduced. *H. radicata, R. acetosella*, and *V. sativa* were the most commonly recorded invasive forbs, in terms of cover. All species will require management action, otherwise they will continue to increase. *H. radicata* and *V. sativa* can be treated by herbicide and/or hand-pulling. Only the soil removal treatment would likely be a candidate for hand-pulling, as the amount in the herbicide treatment would require intense effort and possibly cause soil disturbance. *R. acetosella* can spread vegetatively, in addition to seed, and will likely require herbicide treatment to reduce/eliminate. Mowing is ineffective on these two species and would also likely harm the seeded native species.

Overall, the soil removal treatment shows the most promise at Yeon. The higher ratio of native forbs to invasive forbs is promising, as is the lower levels of invasive grass cover compared to the other treatments. While future monitoring will be important to note how this changes in invasive grass cover over time, initial results indicate that current treatments may be excessive for the site and will likely need to be modified.

## NEXT STEPS

All of the soil removal and sand addition plots will be hand-weeded after consultation with IAE field staff. IAE field staff will work with partner agencies to help with identification and appropriate methods to reduce the impact of hand-pulling on establishing native plants. Hand-puilling is the recommended method, unless assurances are made that applicators have strong plant identification skills to differentiate native species from invasive, exotic species.

Herbicide and soil inversion plots could be retreated with a broad-spectrum herbicide (i.e. glyphosate) to attempt better control of established species (both grasses and forbs). Broadleaf herbicides (i.e. clopyralid) could be used to target invasive forb species, but caution would be required because native species are killed by these herbicides and many also have residual time in the soil that must be taken into account. Grass-specific herbicides (i.e. fluazifop-p-butyl) could be used to specifically target invasive grass species, but similar caution would need to be exercised.

Data collection will continue through the 2017 field season at all sites; results will be used to inform restoration efforts/management recommendations at these and similar sites in the Clatsop Plains managed by the NCLC and USFWS. We will be consulting with project partners to discuss the management actions listed above to determine adaptive management strategies for each site.

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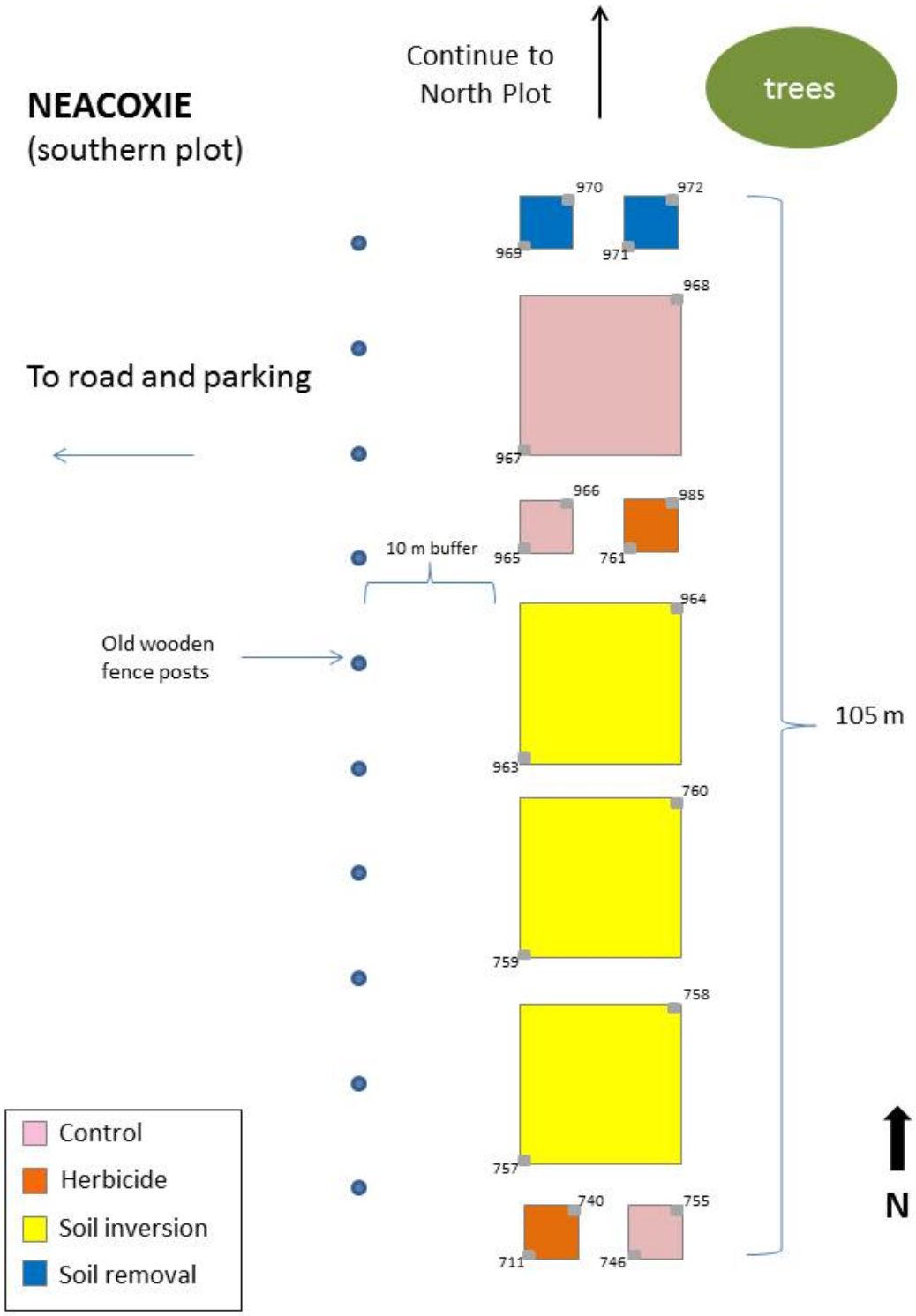
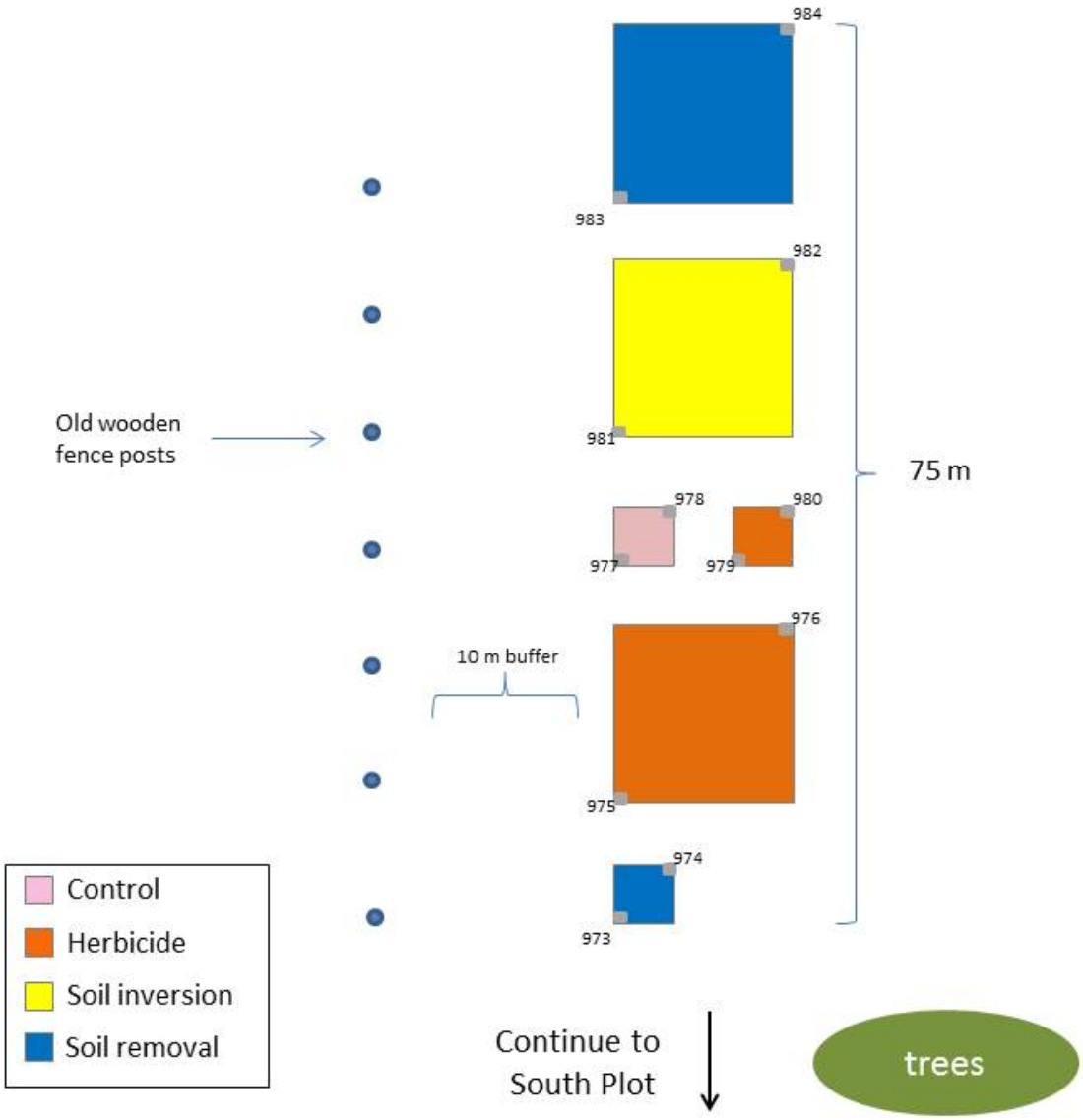
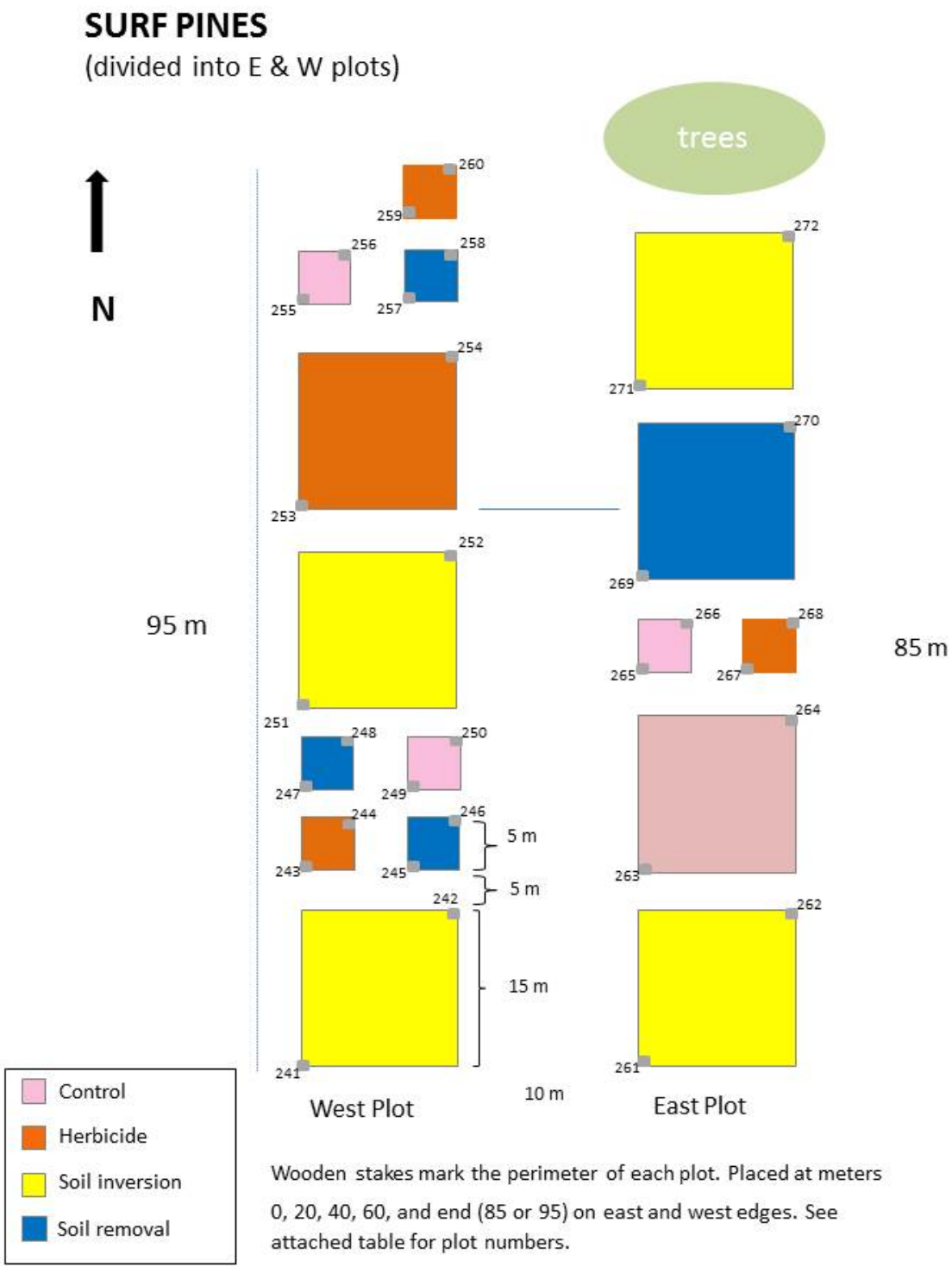
# APPENDIX A. MAPS AND PLOT TAG NUMBERS FOR EACH OF THE CLATSOP PLAINS RESTORATION STUDY SITES.



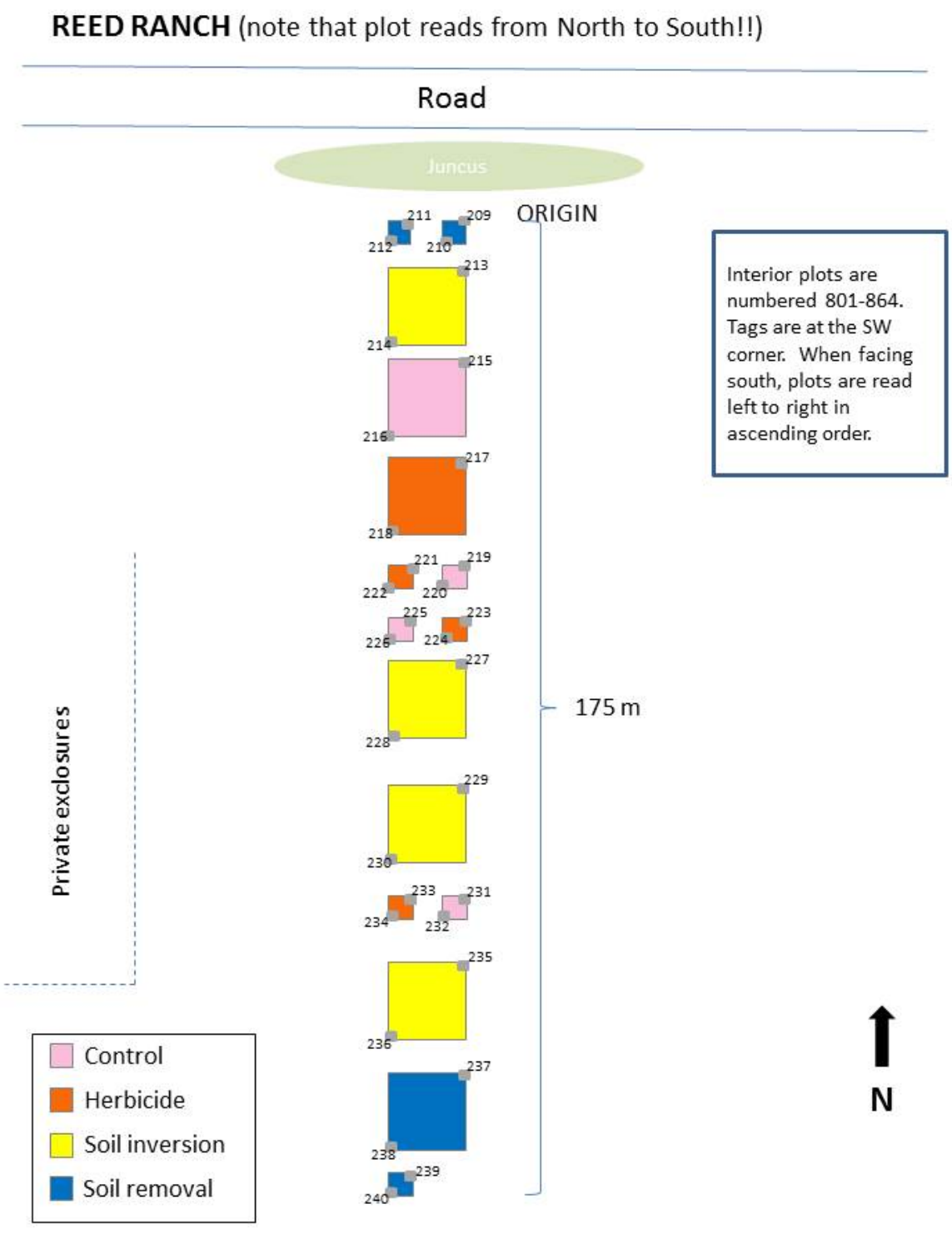
**NEACOXIE**
(northern plot)

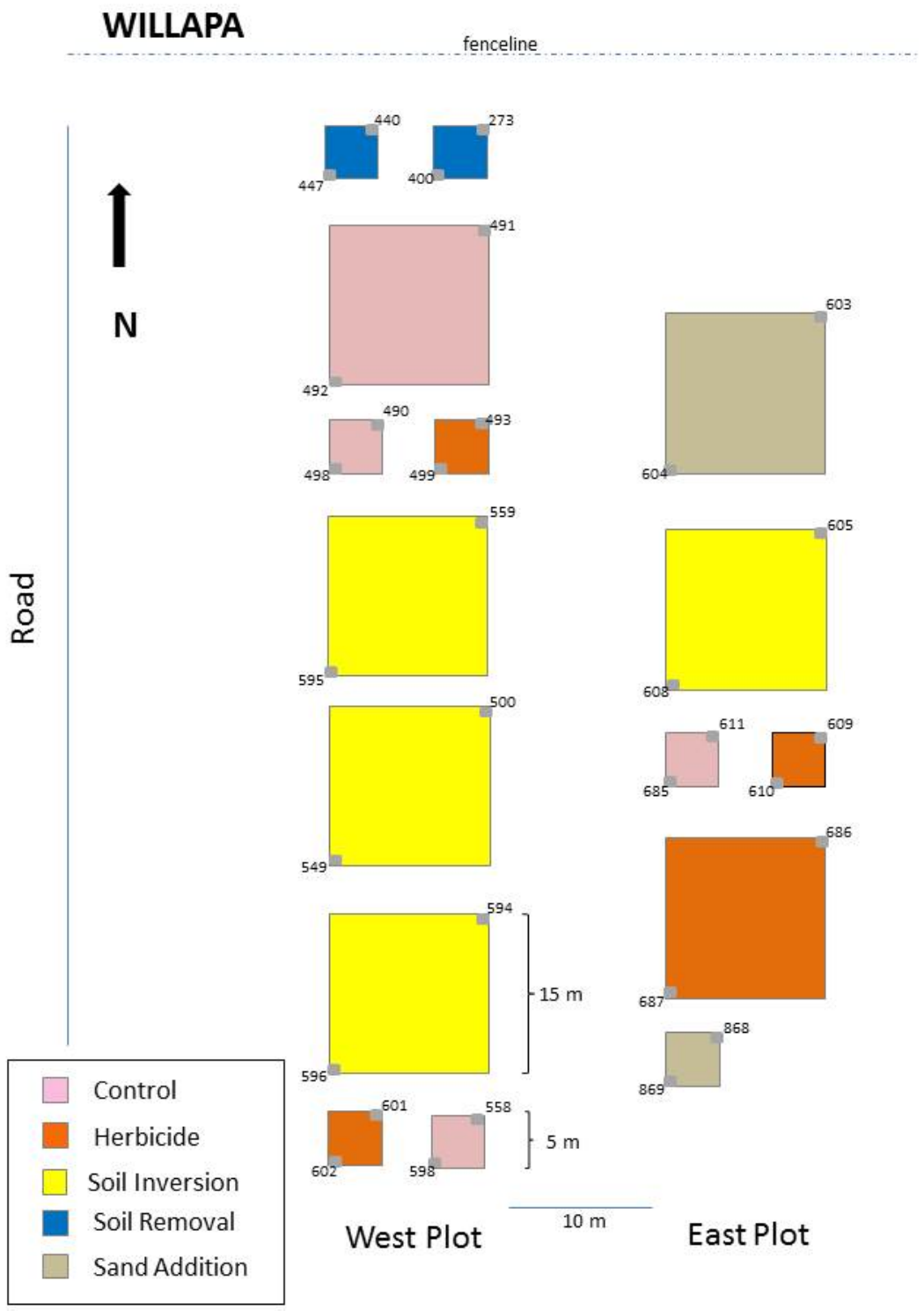
Wooden stakes mark the perimeter of each plot. They are placed at meters 0, 25, 50, 75, and 105 (south plot)



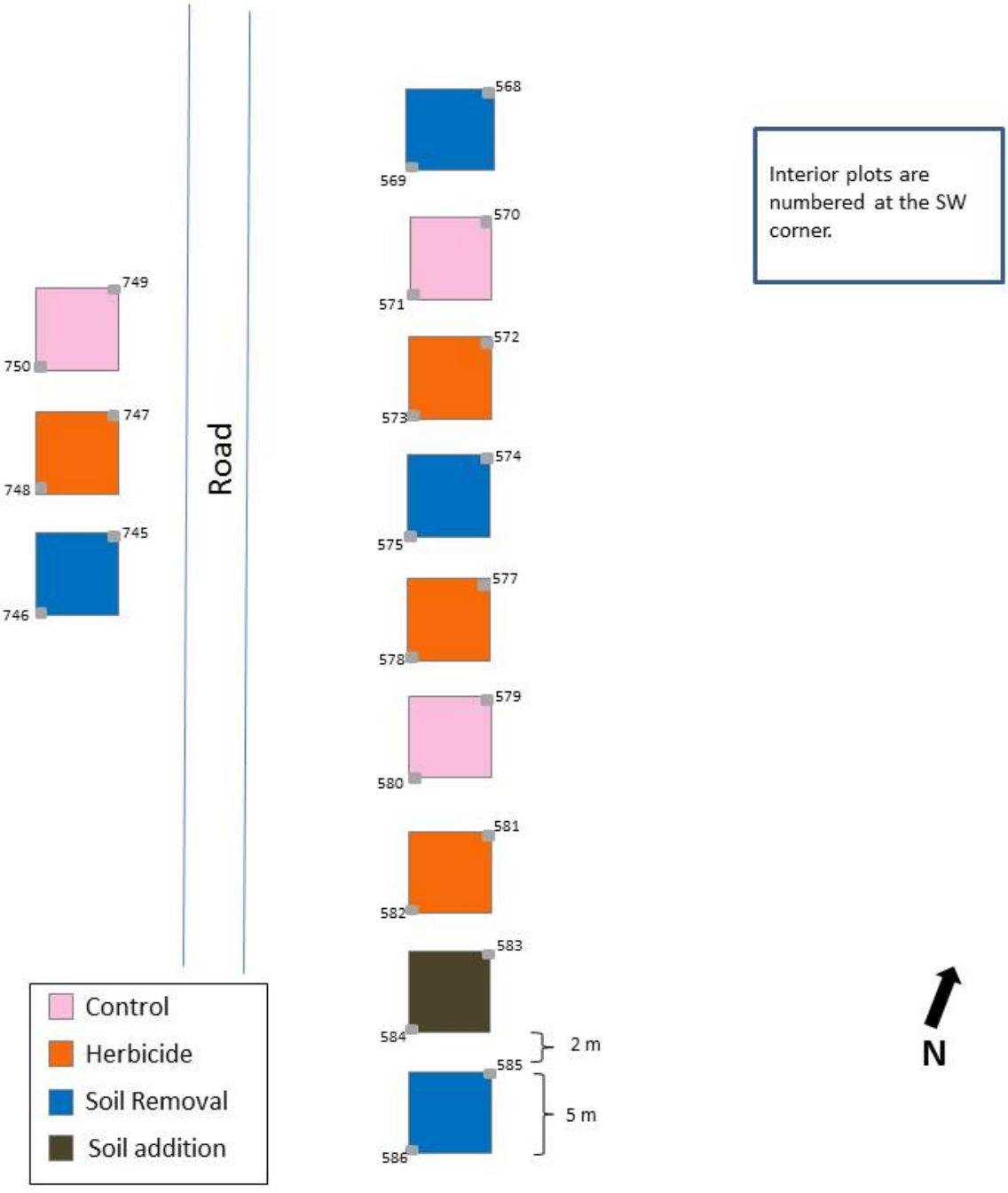



Wooden stakes mark the perimeter of each plot. Placed at meters 0, 20, 40, 60, and end (85 or 95) on east and west edges. See attached table for plot numbers.


REED RANCH (note that plot reads from North to South!!)
Road
Juncus
ORIGIN
211
209
212
210
213
214
215
216
217
218
221
219
222
220
225
223
226
224
227
228
229
230
233
231
234
232
235
236
237
238
239
240
175 m
Interior plots are numbered 801-864. Tags are at the SW corner. When facing south, plots are read left to right in ascending order.
Private exclosures
Control
Herbicide
Soil inversion
Soil removal
N


WILLAPA
fenceline
N
Road
440
273
447
400
491
492
603
604
490
493
498
499
559
595
605
608
500
549
611
609
685
610
686
687
594
596
15 m
868
869
601
558
602
598
5 m
10 m
West Plot
East Plot
Control
Herbicide
Soil Inversion
Soil Removal
Sand Addition

**Yeon Proerty** (note that plot reads from North to South!!)



# APPENDIX B. AVERAGE COVER OF ALL SPECIES OBSERVED AT COASTAL PRAIRIE RESTORATION SITES.

## Pretreatment

| | Surf Pines | Neacoxie | Reed Ranch | Willapa | Yeon |
|---|---|---|---|---|---|
| Bare | 0.4 | 0.6 | 0.4 | 1.2 | 0.0 |
| Moss/lichen | 12.4 | 3.0 | 0.4 | 24.1 | 15.9 |
| Litter | 79.3 | 81.9 | 84.1 | 68.0 | 20.0 |
| **Graminoids** | | | | | |
| *Agrostis alba* | 21.1 | 52.3 | 3.2 | 27.0 | 41.1 |
| *Ammophila arenaria* | 0.0 | 0.0 | 0.0 | 0.0 | 22.3 |
| *Ammophila breviligulata* | 0.0 | 0.0 | 0.0 | 0.0 | 32.2 |
| *Anthoxanthum odoratum* | 27.7 | 29.1 | 20.5 | 32.9 | 15.4 |
| *Bromus hordeaceus* | 0.5 | 3.6 | 33.0 | 0.0 | 0.0 |
| *Carex pansa* | 0.1 | 0.0 | 0.3 | 0.1 | 0.0 |
| *Carex scoparia* | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 |
| *Dactylis glomerata* | 5.1 | 11.4 | 10.2 | 0.1 | 1.3 |
| *Danthonia californica** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Festuca arundinacea* | 20.8 | 12.9 | 10.0 | 0.2 | 5.0 |
| *Festuca rubra* | 0.0 | 4.2 | 1.0 | 12.9 | 29.7 |
| *Holcus lanatus* | 0.4 | 0.3 | 1.5 | 7.2 | 12.3 |
| *Juncus* sp. | 0.7 | 0.7 | 0.6 | 0.1 | 0.0 |
| *Lotus micranthus* | 0.0 | 0.0 | 1.8 | 0.0 | 0.0 |
| *Luzula comosa** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Phleum pratense* * | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Vulpia* sp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Forbs** | | | | | |
| *Achillea millefolium* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Brassica sp. (slender sil.)* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Brassica sp. (rounder sil.)* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Cerastium arvense* | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 |
| *Cerastium fontanum** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Cerastium glomeratum* | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Centaurium* sp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Cirsium vulgare* | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Crepis setosa** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Erodium cicutarium* | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| *Equisetum* sp. | 0.1 | 0.1 | 0.0 | 0.0 | 1.8 |
| *Fragaria* sp. | 0.0 | 0.0 | 0.0 | 0.0 | 7.5 |
| *Galium aparine** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Geranium dissectum* | 0.2 | 0.1 | 4.9 | 0.0 | 0.0 |

| | | | | | |
|---|---|---|---|---|---|
| *Hypochaeris radicata* | 15.5 | 9.9 | 11.1 | 25.1 | 6.3 |
| *Leucanthemum vulgare* | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| *Lotus corniculatus* | 0.0 | 0.0 | 0.0 | 10.0 | 0.0 |
| *Lupinus* sp. | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 |
| *Myosotis discolor* | 0.0 | 0.5 | 0.2 | 0.0 | 0.0 |
| *Parentucellia viscosa** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Plantago lanceolata* | 0.0 | 0.0 | 0.9 | 6.1 | 3.5 |
| *Polystichum munitum* | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 |
| *Pteridium aquilinum* | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| *Ranunculus occidentalis* | 1.9 | 1.7 | 1.0 | 0.5 | 0.0 |
| *Rumex acetosella* | 0.8 | 1.2 | 2.6 | 1.3 | 5.4 |
| *Senecio jacobaea* | 0.0 | 0.1 | 0.6 | 0.0 | 0.0 |
| *Sisyrinchium* sp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Solidago* sp. * | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Stellaria* sp. * | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Tanacetum* sp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Taraxacum officinale* | 0.1 | 0.1 | 0.0 | 0.3 | 0.0 |
| *Trifolium dubium* | 0.2 | 0.0 | 2.5 | 2.5 | 0.0 |
| *Trifolium repens* | 0.0 | 0.0 | 0.0 | 3.1 | 0.0 |
| *Triphysaria pusilla* | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 |
| *Veronica americana* | 0.7 | 0.4 | 2.7 | 0.0 | 0.0 |
| *Vicia sativa* | 0.0 | 0.0 | 5.2 | 0.0 | 0.9 |
| *Vicia tetrasperma* | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |
| *Viola adunca* | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| **Shrubs** | | | | | |
| *Amelanchier* sp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Cytisus scoparius* | 11.0 | 0.0 | 0.3 | 0.0 | 3.8 |
| *Rosa* sp. | 0.0 | 0.1 | 0.0 | 0.0 | 8.8 |
| *Rubus armeniacus* | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 |
| *Rubus ursinus* | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 |

*Species present, but <0.1% cover

## Neacoxie

| | Control | | Herbicide | | Soil Inversion | | Soil Removal | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Bare | 0.8 | 0.3 | 11.5 | 3.6 | 70.3 | 42.8 | 93.9 | 77.4 |
| Moss/lichen | 0.2 | 0.9 | 4.0 | 9.3 | - | 0.3 | 0.0 | - |
| Litter | 76.6 | 85.3 | 62.5 | 54.1 | 7.5 | 57.6 | 1.6 | 11.3 |
| **Forbs:** | | | | | | | | |
| *Achillea millefolium* | - | - | 2.0 | 5.7 | 0.4 | 3.8 | 0.5 | 6.3 |
| *Alchemilla occidentalis* | - | 0.6 | 0.4 | 0.7 | 0.1 | 0.2 | 0.0 | 0.3 |
| *Aster* sp. | - | - | - | - | 0.0 | - | - | - |
| *Aster subspicatus* | - | - | 0.0 | - | - | - | 0.0 | - |
| *Cerastium arvense* | - | 0.0 | 0.4 | 3.3 | 0.4 | 1.0 | - | 0.2 |
| *Crepis setosa* | - | 0.0 | - | - | - | - | - | - |
| *Epilobium minutum* | - | - | 0.0 | - | - | - | - | - |
| *Equisetum* sp. | - | 0.0 | 0.0 | - | 0.1 | 0.0 | 0.0 | 0.0 |
| *Geranium dissectum* | 0.0 | 0.1 | 0.2 | 1.5 | 0.2 | 2.2 | 0.0 | - |
| *Hypochaeris radicata* | 11.2 | 9.7 | 15.5 | 28.2 | 0.8 | 5.5 | 0.3 | 1.6 |
| *Leucanthemum vulgare* | 0.3 | - | - | - | - | - | - | 0.1 |
| *Lotus corniculatus* | - | - | - | - | - | 0.2 | - | - |
| *Lotus micranthus* | - | - | - | 0.0 | - | - | - | - |
| *Lupinus littoralis* | - | - | 0.1 | 0.3 | 0.1 | 0.6 | 0.1 | 0.3 |
| *Lupinus* sp. | - | - | - | - | 0.0 | - | 0.4 | 0.1 |
| *Matricaria discoidea* | - | - | - | - | 0.1 | - | - | - |
| *Myosotis discolor* | 2.0 | 0.6 | 5.3 | 1.8 | 0.0 | 0.1 | - | 0.0 |
| *Parentucellia viscosa* | 0.0 | - | 0.0 | - | 0.0 | - | 0.0 | - |
| *Plantago lanceolata* | 0.1 | 0.1 | - | - | - | 0.0 | - | - |
| *Pteridium aquilinum* | 0.0 | - | 0.3 | - | 0.1 | 0.2 | 0.5 | - |
| *Ranunculus occidentalis* | 2.5 | 2.0 | 0.9 | 0.3 | 0.0 | 0.0 | 0.1 | 0.4 |
| *Rumex acetosella* | 0.4 | 1.0 | 0.2 | 4.8 | 3.2 | 4.0 | 0.9 | 1.4 |
| *Senecio jacobaea* | 0.0 | 0.0 | 0.8 | 2.4 | 0.0 | 0.1 | 0.0 | - |
| *Senecio vulgaris* | - | - | 0.3 | 1.6 | - | - | - | - |
| *Sisyrinchium* sp. | 0.0 | - | - | - | - | - | - | - |
| *Solidago* sp. | - | - | - | - | - | 0.0 | - | 0.0 |
| *Sonchus asper* | - | - | - | 0.1 | - | - | - | - |
| *Spergularia media* | - | - | - | 0.0 | - | - | 0.0 | 0.0 |
| *Stellaria media* | - | 0.0 | 0.0 | 0.1 | 0.7 | 0.3 | - | - |
| *Taraxacum officinale* | 0.1 | 0.1 | - | - | - | - | - | - |
| *Trifolium dubium* | - | 0.1 | 0.0 | 0.5 | 0.0 | 0.1 | - | 0.2 |
| *Trifolium repens* | - | - | - | - | 0.0 | 0.1 | 0.0 | 0.1 |
| *Trifolium subterraneum* | - | - | - | 0.1 | - | - | - | 0.0 |
| *Veronica americana* | 0.3 | 0.5 | 0.8 | 0.8 | 0.0 | 0.0 | - | 0.0 |
| *Viola adunca* | - | - | - | - | - | 0.0 | - | 0.0 |
| **Graminoids:** | | | | | | | | |
| *Agrostis alba* | 64.1 | 38.2 | 7.9 | 12.8 | 7.3 | 5.8 | 2.5 | 3.7 |
| *Aira caryophylla* | 0.0 | - | - | - | - | - | - | - |
| *Anthoxanthum odoratum* | 26.9 | 22.9 | 29.1 | 18.7 | 2.9 | 11.6 | 0.2 | 4.0 |
| *Bromus hordeaceus* | - | 0.6 | - | 0.3 | - | - | - | - |
| *Carex pansa* | 0.3 | 0.9 | - | - | - | 0.0 | - | 0.0 |
| *Dactylis glomerata* | 10.1 | 7.7 | 0.0 | 0.4 | 8.9 | 5.5 | 1.0 | 1.0 |
| *Danthonia californica* | - | 0.3 | - | - | - | - | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Festuca arundinacea* | 16.7 | 28.1 | 0.0 | 0.1 | 6.3 | 24.6 | 2.1 | 8.8 |
| *Festuca rubra* | 1.8 | 2.0 | 3.4 | 13.3 | 0.8 | 4.3 | 0.3 | 2.6 |
| *Holcus lanatus* | 0.6 | 0.4 | 0.9 | 5.1 | 0.0 | 4.6 | - | 0.6 |
| *Juncus bufonius* | - | - | 0.2 | - | 0.1 | 0.1 | - | - |
| *Juncus* sp. | 0.8 | 5.2 | - | - | 2.0 | 0.2 | 0.0 | 0.0 |
| *Luzula comosa* | 0.0 | 0.1 | 0.0 | - | 0.0 | - | - | 0.0 |
| *Poa compressa* | 2.0 | 12.5 | 0.0 | - | 0.3 | 4.9 | 0.0 | 2.0 |
| *Vulpia* sp. | - | - | - | - | - | - | - | 0.0 |
| **Shrubs/Trees:** | | | | | | | | |
| *Acer* sp. | - | - | - | 0.0 | - | - | - | - |
| *Cytisus scoparius* | - | 0.1 | - | 0.3 | 0.0 | - | - | - |
| *Rosa* sp. | - | - | - | - | - | - | 0.0 | - |
| *Rubus ursinus* | - | - | 0.0 | - | 1.9 | 5.3 | - | - |

**NOTE**: "0.0" values indicate the species was present but had low cover (average % cover < 0.1); "-" indicates the species was not present.

## Surf Pines

| | Control | | Herbicide | | Soil Inversion | | Soil Removal | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Bare | 18.8 | 13.4 | 8.3 | 4.8 | 47.8 | 23.4 | 99.6 | 87.2 |
| Moss/lichen | 9.2 | 4.2 | 19.5 | 5.8 | 0.1 | 0.4 | 0.0 | 0.7 |
| Litter | 57.9 | 63.4 | 71.6 | 38.3 | 26.2 | 59.8 | 1.3 | 6.4 |
| **Forbs:** | | | | | | | | |
| *Achillea millefolium* | 0.0 | 1.0 | 2.2 | 12.2 | 0.2 | 2.7 | 0.1 | 8.1 |
| *Arenaria* sp. | - | - | - | - | - | 0.1 | - | - |
| *Aster* sp. | - | - | - | - | - | - | 0.0 | - |
| *Aster subspicatus* | - | - | 0.0 | - | - | - | - | - |
| *Brassica* sp. | 0.1 | - | 0.4 | - | 0.6 | - | - | - |
| *Cardamine oligosperma* | - | - | - | - | 0.0 | - | - | - |
| *Centaurium erythraea* | 0.0 | 0.0 | - | - | - | - | - | - |
| *Cerastium arvense* | 0.8 | 2.1 | 0.5 | 2.6 | 0.1 | 1.0 | - | 0.1 |
| *Cerastium glomeratum* | - | - | 0.0 | - | - | - | - | - |
| *Cirsium* sp. | - | - | 0.1 | - | - | - | - | - |
| *Cirsium vulgare* | - | - | 0.1 | - | 0.1 | 0.6 | - | - |
| *Claytonia perfoliata* | - | - | 0.1 | - | - | 0.1 | - | - |
| *Epilobium* sp. | - | - | - | - | - | - | - | 0.1 |
| *Equisetum* sp. | 0.1 | 0.2 | - | - | 0.0 | 0.5 | 0.1 | 0.9 |
| *Geranium dissectum* | - | 0.1 | 0.1 | 0.5 | - | 0.4 | - | - |
| *Hypochaeris radicata* | 16.7 | 15.6 | 5.1 | 26.9 | 4.8 | 12.4 | 0.0 | 1.4 |
| *Lupinus littoralis* | - | 0.4 | 0.1 | 5.6 | - | 0.7 | - | 2.4 |
| *Lupinus* sp. | 0.0 | - | 0.1 | - | 0.1 | - | 1.1 | 0.3 |
| *Myosotis discolor* | 0.2 | 0.0 | 1.9 | 0.2 | 0.0 | 0.2 | - | - |
| *Plantago lanceolata* | 0.0 | 0.5 | - | 0.1 | - | - | - | - |
| *Ranunculus occidentalis* | 0.4 | 1.0 | 4.6 | 0.7 | 0.0 | 0.0 | - | - |
| *Rumex acetosella* | 1.7 | 8.3 | 1.3 | 18.5 | 4.5 | 6.7 | 0.5 | 2.4 |
| *Senecio jacobaea* | 0.3 | 0.4 | 0.5 | 1.2 | - | - | - | - |
| *Senecio vulgaris* | - | 0.0 | 0.1 | 1.3 | - | 2.2 | - | 0.0 |
| *Sisyrinchium* sp. | 0.1 | 0.2 | - | - | - | - | - | - |
| *Solidago* sp. | - | - | 0.0 | - | - | - | - | - |
| *Spergularia media* | - | - | - | - | 0.2 | - | - | 0.1 |
| *Stellaria media* | 0.6 | 0.0 | 0.2 | - | 4.9 | - | 0.1 | - |
| *Taraxacum officinale* | - | - | - | - | 0.1 | 0.0 | - | - |
| *Trifolium dubium* | 0.1 | 0.5 | 0.1 | 2.2 | - | 0.6 | - | 0.0 |
| *Trifolium repens* | 0.1 | 1.0 | 0.1 | - | 0.0 | 0.1 | 0.0 | - |
| *Trifolium* sp. | - | - | - | - | - | - | - | 0.1 |
| *Trifolium subterraneum* | - | 0.1 | - | 0.5 | - | 0.8 | - | - |
| *Veronica americana* | 0.2 | 0.3 | 1.8 | 0.6 | 0.0 | 0.5 | - | 0.0 |
| *Vicia sativa* | 0.1 | 0.1 | - | - | - | - | - | - |
| *Viola adunca* | 0.0 | 0.1 | - | - | - | - | - | 0.0 |
| **Graminoids:** | | | | | | | | |
| *Agrostis alba* | 18.8 | 6.0 | 6.3 | 2.4 | 14.6 | 11.4 | 0.2 | 1.1 |
| *Aira caryophylla* | - | - | - | - | - | 0.1 | - | - |
| *Aira praecox* | - | - | - | - | - | - | - | 0.0 |
| *Anthoxanthum odoratum* | 13.8 | 11.9 | 18.6 | 8.7 | 2.0 | 8.4 | - | 1.5 |
| *Bromus hordeaceus* | - | 0.9 | - | 0.1 | - | - | - | 0.0 |
| *Carex pansa* | 1.0 | 1.4 | 0.0 | - | 0.1 | 2.9 | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Dactylis glomerata* | 11.9 | 8.3 | 0.1 | 0.2 | 4.6 | 2.3 | 0.0 | 0.2 |
| *Festuca arundinacea* | 30.9 | 32.3 | - | - | 15.5 | 25.1 | 0.0 | 0.5 |
| *Festuca rubra* | 0.4 | 0.3 | 1.2 | 1.1 | 0.7 | 0.9 | 0.1 | 4.8 |
| *Holcus lanatus* | 0.9 | 1.2 | 1.7 | 5.8 | 1.4 | 3.2 | - | 0.8 |
| *Juncus* sp. | 0.2 | 0.8 | - | - | 0.4 | 1.2 | 0.2 | 0.6 |
| *Luzula comosa* | - | - | 0.0 | - | - | - | - | - |
| *Poa compressa* | 13.0 | 4.5 | - | - | 7.8 | 6.9 | - | 0.0 |
| **Shrubs/Trees:** | | | | | | | | |
| *Cytisus scoparius* | 3.5 | 10.6 | 1.0 | 11.5 | 1.8 | 9.7 | 0.1 | 0.9 |
| *Rosa* sp. | - | 0.0 | 0.0 | - | - | - | - | - |
| *Rubus armeniacus* | - | - | 0.0 | - | - | - | - | - |

**NOTE**: "0.0" values indicate the species was present but had low cover (average % cover < 0.1); "-" indicates the species was not present.

## Reed Ranch

| | Control | | Herbicide | | Soil Inversion | | Soil Removal | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Bare | 0.4 | 0.2 | 10.9 | 0.6 | 63.8 | 26.2 | 100.0 | 98.6 |
| Moss/lichen | 0.0 | 0.6 | 2.1 | 16.4 | 0.0 | 0.3 | 0.0 | - |
| Litter | 79.1 | 87.9 | 36.3 | 38.8 | 6.0 | 45.6 | 0.3 | 0.8 |
| **Forbs:** | | | | | | | | |
| *Achillea millefolium* | - | - | 2.2 | 9.6 | 0.8 | 3.9 | 0.0 | 0.3 |
| *Alchemilla occidentalis* | - | 0.0 | - | 0.0 | - | 0.0 | - | - |
| *Allium* sp. | - | - | - | - | - | 0.0 | - | - |
| *Aster subspicatus* | - | - | - | - | - | - | 0.0 | - |
| *Brassica* sp. | - | - | 0.0 | - | - | - | - | - |
| *Cerastium arvense* | 1.1 | 0.0 | 2.0 | 0.1 | 0.0 | 0.1 | - | - |
| *Cirsium vulgare* | - | - | - | - | - | 0.4 | - | - |
| *Equisetum* sp. | - | 0.1 | - | - | - | - | - | - |
| *Geranium dissectum* | 2.6 | 5.6 | 9.6 | 1.6 | 0.3 | 2.4 | 0.0 | 0.0 |
| *Hypochaeris radicata* | 17.6 | 19.4 | 12.0 | 49.6 | 6.7 | 16.6 | 0.0 | 0.1 |
| *Lotus corniculatus* | - | - | - | - | - | 0.0 | - | - |
| *Lotus micranthus* | - | - | - | - | - | - | - | 0.0 |
| *Lupinus littoralis* | - | - | 0.2 | 0.5 | - | 0.8 | - | 4.1 |
| *Lupinus* sp. | - | - | 0.1 | 0.5 | 0.7 | 0.6 | 0.5 | 5.3 |
| *Myosotis discolor* | 2.1 | 0.1 | 1.0 | 0.4 | 0.2 | 0.0 | - | - |
| *Parentucellia viscosa* | 0.1 | 0.1 | 1.8 | 0.7 | - | - | - | - |
| *Plantago lanceolata* | 0.5 | 1.3 | 0.0 | 0.3 | 0.4 | 0.9 | 0.0 | 0.6 |
| *Ranunculus occidentalis* | 0.7 | 0.5 | 0.1 | 0.4 | 0.7 | 0.1 | - | - |
| *Ranunculus repens* | - | - | - | 0.1 | - | - | - | - |
| *Rumex acetosella* | 2.1 | 3.5 | 2.1 | 22.4 | 10.3 | 10.3 | 0.1 | 2.7 |
| *Senecio jacobaea* | - | - | - | 0.1 | - | - | 0.0 | 0.8 |
| *Senecio vulgaris* | - | - | - | 0.0 | - | - | - | - |
| *Spergularia media* | - | - | - | - | 0.1 | - | - | - |
| *Stellaria media* | 0.2 | 0.1 | - | 0.4 | 0.1 | 0.1 | - | - |
| *Taraxacum officinale* | - | 0.0 | - | - | - | - | - | - |
| *Trifolium dubium* | 0.8 | 1.0 | 4.9 | 7.4 | 0.1 | 1.7 | - | 0.0 |
| *Trifolium repens* | 4.2 | 1.1 | 4.9 | 2.4 | 1.1 | 8.1 | 0.0 | - |
| *Trifolium subterraneum* | - | 3.5 | - | 4.6 | - | 6.0 | - | 0.1 |
| *Triphysaria pusilla* | 0.6 | - | 4.8 | 1.6 | 0.1 | 0.3 | - | - |
| *Veronica americana* | 2.0 | 0.4 | 0.8 | 1.1 | 0.2 | 0.8 | - | 0.0 |
| *Vicia hirsuta* | 1.0 | 2.7 | 0.2 | 0.3 | 0.0 | 0.4 | - | - |
| *Vicia sativa* | 3.0 | 1.1 | 4.3 | 2.5 | 2.8 | 2.3 | - | 0.0 |
| *Viola adunca* | - | - | - | - | - | - | - | 0.0 |
| **Graminoids:** | | | | | | | | |
| *Agrostis alba* | 9.4 | 7.2 | 1.8 | 6.9 | 4.2 | 8.7 | - | 0.1 |
| *Agrostis* sp. | - | - | - | - | - | - | - | 0.0 |
| *Anthoxanthum odoratum* | 43.9 | 29.6 | 47.8 | 24.6 | 8.7 | 13.0 | - | 0.4 |
| *Arrhenatherum elatius* | - | - | - | 0.1 | - | 3.1 | - | - |
| *Bromus hordeaceus* | 1.4 | 11.5 | 0.0 | 0.4 | 0.4 | 3.5 | - | 0.1 |
| *Bromus* sp. (perennial) | - | 0.1 | - | - | - | 1.5 | - | 0.2 |
| *Carex pansa* | 0.1 | 0.5 | 0.1 | 0.1 | - | - | - | - |
| *Dactylis glomerata* | 9.9 | 14.7 | 0.3 | - | 3.7 | 7.4 | - | 0.1 |
| *Festuca arundinacea* | 27.5 | 39.6 | 0.0 | - | 7.1 | 21.6 | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Festuca rubra* | 0.8 | 1.1 | 1.8 | 3.4 | 0.9 | 4.0 | 0.1 | 1.7 |
| *Holcus lanatus* | 6.6 | 5.4 | 1.8 | 7.1 | 0.2 | 0.9 | - | 0.1 |
| *Juncus bufonius* | - | - | - | - | - | 0.3 | - | - |
| *Juncus* sp. | - | - | - | - | 0.4 | 0.0 | - | - |
| *Luzula comosa* | 0.0 | - | - | - | - | 0.1 | - | - |
| *Poa compressa* | 1.1 | 2.6 | - | - | 1.0 | 1.6 | - | - |
| *Vulpia* sp. | - | - | - | - | - | - | - | 0.1 |
| **Shrubs/Trees:** | | | | | | | | |
| *Cytisus scoparius* | 0.6 | 1.0 | 0.0 | 0.0 | 0.0 | 0.1 | - | - |
| *Rubus armeniacus* | - | - | - | - | - | 0.0 | - | - |

**NOTE**: "0.0" values indicate the species was present but had low cover (average % cover < 0.1); "-" indicates the species was not present.

## Willapa

| | Control | | Herbicide | | Sand Addition | | Soil Inversion | | Soil Removal | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Bare | 1.1 | 0.1 | 7.1 | 0.0 | 99.9 | 84.1 | 24.5 | 4.4 | 98.8 | 71.9 |
| Moss/lichen | 0.1 | 0.1 | 2.2 | 12.4 | - | - | 2.2 | 0.8 | 0.1 | 0.1 |
| Litter | 62.8 | 91.4 | 57.8 | 79.2 | 0.2 | 5.5 | 30.3 | 84.4 | 0.7 | 7.2 |
| **Forbs:** | | | | | | | | | | |
| *Achillea millefolium* | - | - | 0.8 | 2.1 | - | 2.8 | 0.8 | 3.5 | 0.2 | 1.9 |
| *Alchemilla occidentalis* | - | - | 0.0 | 0.0 | 0.0 | - | - | 0.1 | - | - |
| *Cakile* sp. | - | - | - | - | - | 0.1 | - | - | - | - |
| *Cerastium arvense* | 0.0 | - | 0.0 | - | - | - | 0.0 | - | - | - |
| *Hypochaeris radicata* | 9.8 | 5.7 | 14.6 | 17.3 | 0.2 | 3.1 | 4.5 | 9.2 | 0.1 | 0.3 |
| *Lotus corniculatus* | 5.3 | 4.4 | 10.3 | 9.3 | - | 0.3 | 0.4 | 1.5 | 0.1 | 0.3 |
| *Lupinus littoralis* | - | - | 0.0 | - | - | - | 0.0 | - | 0.0 | - |
| *Matricaria discoidea* | - | - | - | - | 0.0 | - | - | - | - | - |
| *Plantago lanceolata* | 2.6 | 3.7 | 1.9 | 3.0 | 0.0 | 0.3 | 0.8 | 3.1 | 0.3 | 0.9 |
| *Ranunculus occidentalis* | 0.3 | 0.6 | 0.0 | 0.0 | - | - | 0.0 | - | - | - |
| *Rumex acetosella* | 2.1 | 1.9 | 3.4 | 2.3 | 0.3 | 0.8 | 7.9 | 5.3 | 0.6 | 2.2 |
| *Rumex crispus* | - | - | - | 0.1 | - | - | - | - | - | - |
| *Senecio vulgaris* | - | - | - | - | - | - | - | - | 0.0 | - |
| *Solidago* sp. | - | - | - | - | - | - | - | - | - | 0.3 |
| *Spergularia media* | - | - | - | 0.0 | - | - | - | - | - | 0.0 |
| *Stellaria media* | - | 0.0 | - | - | - | - | 0.0 | - | - | - |
| *Taraxacum officinale* | - | 0.1 | 1.4 | 0.5 | - | - | 0.1 | 0.2 | - | - |
| *Trifolium dubium* | 1.6 | 2.8 | 1.9 | 6.1 | - | 0.2 | 0.6 | 2.1 | - | - |
| *Trifolium repens* | 0.3 | 2.8 | 0.4 | 8.9 | 0.1 | 4.0 | 0.5 | 5.6 | 0.0 | 0.1 |
| *Trifolium subterraneum* | - | - | - | - | - | 4.3 | - | - | - | - |
| *Viola adunca* | - | - | - | - | - | - | - | - | - | 0.0 |
| **Graminoids:** | | | | | | | | | | |
| *Agrostis alba* | 42.5 | 48.0 | 14.3 | 27.4 | 0.1 | 2.4 | 29.4 | 48.4 | 0.7 | 4.9 |
| *Anthoxanthum odoratum* | 40.8 | 18.3 | 31.9 | 23.0 | 0.2 | 2.3 | 25.1 | 14.3 | 0.5 | 2.3 |
| *Bromus hordeaceus* | - | 0.0 | - | - | - | - | - | - | - | - |
| *Carex pansa* | - | - | - | - | - | - | - | - | - | 0.1 |
| *Carex* sp. | - | 0.1 | - | - | - | - | - | - | - | - |
| *Dactylis glomerata* | 0.1 | 0.2 | - | - | - | - | - | - | - | - |
| *Festuca arundinacea* | 0.5 | 0.3 | - | - | - | - | - | - | - | - |
| *Festuca rubra* | 9.0 | 17.6 | 4.4 | 8.4 | 0.1 | 0.4 | 1.3 | 3.3 | 1.1 | 8.9 |
| *Holcus lanatus* | 10.7 | 16.6 | 13.4 | 23.2 | - | 0.8 | 2.3 | 11.5 | 0.0 | 0.3 |
| *Juncus bufonius* | - | - | - | - | - | 0.6 | - | 0.3 | - | 0.0 |
| *Lolium perenne* | - | 0.0 | - | - | - | - | - | - | - | - |
| *Poa compressa* | 0.9 | 4.9 | 0.3 | 0.9 | - | - | 0.1 | 0.1 | - | - |
| **Shrubs/Trees:** | | | | | | | | | | |
| *Acer* sp. | - | - | - | - | - | - | - | - | - | 0.1 |
| *Cytisus scoparius* | 0.1 | - | - | - | - | - | 0.1 | - | - | - |
| *Rubus armeniacus* | - | - | - | - | - | - | - | - | 0.0 | 0.0 |

**NOTE**: "0.0" values indicate the species was present but had low cover (average % cover < 0.1); "-" indicates the species was not present.

## Yeon

| | Control | | Herbicide | | Soil Removal | | Spoils Addition | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Bare | 0.1 | 0.1 | 3.7 | 2.7 | 97.5 | 66.9 | 38.8 | 12.0 |
| Moss/lichen | 1.3 | 3.4 | 3.8 | 8.2 | 0.1 | 0.0 | 0.6 | 7.8 |
| Litter | 85.8 | 90.5 | 77.8 | 70.2 | 2.3 | 20.2 | 41.3 | 81.3 |
| **Forbs:** | | | | | | | | |
| *Achillea millefolium* | - | - | 1.5 | 2.9 | 0.4 | 1.5 | - | - |
| *Alchemilla occidentalis* | - | 0.2 | 0.0 | 0.1 | - | 0.0 | - | - |
| *Arenaria* sp. | - | 0.0 | - | - | - | 0.0 | - | - |
| *Aster subspicatus* | 0.0 | - | 0.0 | - | 0.0 | - | - | - |
| *Cerastium arvense* | 0.3 | 0.2 | 1.9 | 0.7 | - | - | - | - |
| *Equisetum* sp. | 0.4 | 1.6 | 0.1 | 0.9 | 0.6 | 1.4 | - | - |
| *Galium aparine* | - | 0.7 | - | - | - | - | - | - |
| *Hypochaeris radicata* | 4.9 | 8.2 | 0.9 | 8.1 | 0.2 | 0.7 | 6.0 | 5.8 |
| *Iris* sp. | - | 0.3 | - | - | - | - | - | - |
| *Lupinus littoralis* | - | 0.2 | - | 0.7 | - | 2.7 | - | 0.8 |
| *Lupinus* sp. | 0.2 | - | 0.0 | - | 0.3 | 0.3 | 0.1 | 0.1 |
| *Plantago lanceolata* | - | - | 0.1 | 0.1 | - | - | - | - |
| *Polystichum munitum* | 0.0 | - | - | - | - | - | - | - |
| *Rumex acetosella* | 0.4 | 1.4 | 1.2 | 3.0 | 0.0 | 0.8 | 5.5 | 3.8 |
| *Senecio vulgaris* | - | 0.0 | 3.6 | 2.0 | 0.0 | 0.0 | - | - |
| *Solidago* sp. | - | - | - | - | - | 0.1 | - | - |
| *Spergularia media* | - | - | - | - | 0.1 | 0.0 | - | - |
| *Trifolium dubium* | 0.7 | 1.5 | 0.0 | 0.1 | - | - | - | - |
| *Veronica americana* | 0.0 | - | 0.3 | 0.3 | - | 0.0 | - | - |
| *Vicia hirsuta* | - | 0.0 | - | - | - | - | - | - |
| *Vicia sativa* | 1.0 | 4.4 | 1.4 | 1.0 | 0.2 | 0.2 | - | - |
| *Viola adunca* | - | - | - | - | - | 0.1 | - | - |
| **Graminoids:** | | | | | | | | |
| *Agrostis alba* | 22.2 | 8.4 | 2.0 | 2.4 | 0.9 | 0.7 | 8.8 | 1.8 |
| *Agrostis* sp. | 40.7 | 29.1 | - | 11.9 | 2.2 | 3.4 | 5.5 | 2.3 |
| *Aira caryophylla* | 0.1 | - | 0.8 | 3.9 | - | 0.9 | - | 0.4 |
| *Aira praecox* | 1.0 | 1.5 | 0.3 | 3.6 | 0.2 | 1.2 | 1.3 | 5.0 |
| *Ammophila arenaria* | 1.4 | 1.2 | 0.1 | 0.3 | 1.1 | 5.4 | 32.5 | 30.1 |
| *Ammophila breviligulata* | 6.8 | 38.6 | 0.8 | 11.6 | 1.4 | 8.5 | 8.3 | 13.0 |
| *Anthoxanthum odoratum* | 26.8 | 19.3 | 16.6 | 13.1 | 0.1 | 2.1 | 14.0 | 6.0 |
| *Arrhenatherum elatius* | - | 2.9 | - | - | - | - | - | - |
| *Bromus hordeaceus* | - | 0.0 | - | 0.1 | - | 0.0 | - | 0.0 |
| *Carex pansa* | - | - | - | - | - | - | - | 3.3 |
| *Dactylis glomerata* | 10.4 | 3.9 | 0.0 | 0.1 | - | - | - | - |
| *Festuca arundinacea* | 0.3 | 1.4 | - | - | - | 0.1 | 2.0 | 10.0 |
| *Festuca rubra* | - | - | 4.9 | 8.2 | 1.1 | 9.6 | 6.8 | 11.8 |
| *Holcus lanatus* | 2.8 | 0.7 | 11.0 | 3.2 | 0.3 | 0.3 | 3.0 | 1.8 |
| *Juncus bufonius* | - | - | 0.0 | - | 0.0 | - | - | - |
| *Luzula comosa* | - | - | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.5 |
| *Poa compressa* | 1.5 | 3.0 | - | 0.1 | - | - | - | 0.2 |
| *Vulpia* sp. | - | - | 0.1 | 0.9 | - | 0.0 | - | - |
| **Shrubs/Trees:** | | | | | | | | |
| *Cytisus scoparius* | 0.5 | 6.6 | 0.1 | 0.9 | 0.2 | 3.2 | 0.3 | 2.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Rosa* sp. | 0.1 | 0.0 | - | - | 0.1 | 0.3 | - | - |
| *Rubus armeniacus* | 0.0 | - | - | - | - | - | - | - |
| *Rubus ursinus* | - | 0.5 | - | - | - | - | - | - |

**NOTE**: "0.0" values indicate the species was present but had low cover (average % cover < 0.1); "-" indicates the species was not present.

# APPENDIX C. TREATMENT AND IMPLEMENTATION SCHEDULES BY SITE THROUGH SPRING 2016.

## General Treatment Schedule for the Clatsop Plains Restoration Study

| | | | Treatment | | | |
|---|---|---|---|---|---|---|
| **Year** | **Season** | **Month** | **Herbicide*** | **Soil Inversion** | **Soil Removal** | **Sand Addition**** |
| 2013 | Spring | June | Mow | Mow | Mow | Mow |
| | | | Monument | Monument | Monument | Monument |
| | | | Monitor | Monitor | Monitor | Monitor |
| | Fall | September | Mow | Mow | Mow | Mow |
| | | October | Imazapyr | - | - | - |
| 2014 | Spring | April | Qualitative Monitor | Qualitative Monitor | Qualitative Monitor | Qualitative Monitor |
| | | May | Mow | Mow | Mow | Mow |
| | | May/June | Glyphosate | - | - | - |
| | Fall | September | Mow | Mow | Mow | Mow |
| | | September | - | Invert Soil | Remove soil | Remove Soil |
| | | October | Glyphosate | - | - | - |
| | | November | Seed | Seed | Seed | Seed |
| 2015 | Spring | April | - | - | - | Sand addition |
| | | May | Monitor | Monitor | Monitor | Monitor |
| | | June | Mow | Mow | Mow | Mow |
| | Fall | September | ? | ? | ? | ? |
| 2016 | Spring | May | Monitor | Monitor | Monitor | Monitor |

*Herbicide treatments were: Imazapyr (Fall 2013) + Glyphosate (Spring 2014) + Glyphosate (Fall 2014).

**Addition of dune sand to plots below water table in 2014 (Willapa NWR only).

## Neacoxie Forest (NCLC)

| | | | Treatment | | |
|---|---|---|---|---|---|
| **Year** | **Season** | **Month** | **Herbicide*** | **Soil Inversion** | **Soil Removal** |
| 2013 | Spring | May | Mow | Mow | Mow |
| | | | Monument | Monument | Monument |
| | | | Monitor | Monitor | Monitor |
| | Fall | September | Mow | Mow | Mow |
| | | October | Imazapyr | - | - |
| 2014 | Spring | April | Qualitative Monitor | Qualitative Monitor | Qualitative Monitor |
| | | May | Mow** | Mow** | Mow** |
| | | May/June | Glyphosate | - | - |
| | Fall | September | - | Invert Soil | Remove soil |
| | | October | Glyphosate | - | - |
| 2015 | Spring | May/June | Monitor | Monitor | Monitor |
| | | June | Mow | Mow | Mow |
| | Fall | September | ? | ? | ? |
| 2016 | Spring | May | Monitor | Monitor | Monitor |

*Herbicide treatments were: Imazapyr (Fall 2013) + Glyphosate (Spring 2014) + Glyphosate (Fall 2014).

**Site was only mowed a single time during season.

## Surf Pines (NCLC)

| | | | Treatment | | |
|---|---|---|---|---|---|
| **Year** | **Season** | **Month** | **Herbicide*** | **Soil Inversion** | **Soil Removal** |
| 2013 | Spring | May | Mow | Mow | Mow |
| | | | Monument | Monument | Monument |
| | | | Monitor | Monitor | Monitor |
| | Fall | September | Mow | Mow | Mow |
| | | October | Imazapyr | - | - |
| 2014 | Spring | April | - | - | - |
| | | April | Qualitative Monitor | Qualitative Monitor | Qualitative Monitor |
| | | May | Mow** | Mow** | Mow** |
| | | May/June | Glyphosate | - | - |
| | Fall | September | - | Invert Soil | Remove soil |
| | | October | Glyphosate | - | - |
| 2015 | Spring | May | Monitor | Monitor | Monitor |
| | | June | Mow** | Mow** | Mow** |
| | Fall | September | ? | ? | ? |
| 2016 | Spring | May | Monitor | Monitor | Monitor |

*Herbicide treatments were: Imazapyr (Fall 2013) + Glyphosate (Spring 2014) + Glyphosate (Fall 2014).

**Site was only mowed a single time during season.

## Reed Ranch (NCLC)

| | | | Treatment | | |
|---|---|---|---|---|---|
| **Year** | **Season** | **Month** | **Herbicide*** | **Soil Inversion** | **Soil Removal** |
| 2013 | Spring | May | Mow | Mow | Mow |
| | | | Monument | Monument | Monument |
| | | | Monitor | Monitor | Monitor |
| | Fall | September | Mow | Mow | Mow |
| | | October | Imazapyr | - | - |
| 2014 | Spring | April | - | - | - |
| | | April | Qualitative Monitor | Qualitative Monitor | Qualitative Monitor |
| | | May | Mow** | Mow** | Mow** |
| | | May/June | Glyphosate | - | - |
| | Fall | September | - | Invert Soil | Remove soil |
| | | October | Glyphosate | - | - |
| 2015 | Spring | May | Monitor | Monitor | Monitor |
| | | June | Mow** | Mow** | Mow** |
| | Fall | September | ? | ? | ? |
| 2016 | Spring | May | Monitor | Monitor | Monitor |

*Herbicide treatments were: Imazapyr (Fall 2013) + Glyphosate (Spring 2014) + Glyphosate (Fall 2014).

**Site was only mowed a single time during season.

## Willapa Wildlife Refuge, OSB Field 3

| | | | Treatment | | | |
|---|---|---|---|---|---|---|
| **Year** | **Season** | **Month** | **Herbicide*** | **Soil Inversion** | **Soil Removal** | **Sand Addition**** |
| 2013 | Spring | May | Mow | Mow | Mow | Mow |
| | | | Monument Monitor | Monument Monitor | Monument Monitor | Monument Monitor |
| | Fall | August | Mow | Mow | Mow | Mow |
| | | October | Imazapyr | - | - | - |
| 2014 | Spring | April | Qualitative Monitor | Qualitative Monitor | Qualitative Monitor | Qualitative Monitor |
| | | May | Mow | Mow | Mow | Mow |
| | | May/June | Glyphosate | - | - | - |
| | Fall | August | Mow | Mow | Mow | Mow |
| | | October | Glyphosate | - | - | - |
| | | November | - | Invert Soil | Remove soil | Remove Soil |
| | | Nov/Dec | Seed | Seed | Seed | Seed |
| 2015 | Spring | April | - | - | - | Sand addition |
| | | April | Mow[1] | Mow[1] | Mow[1] | Mow[1] |
| | | May | Monitor | Monitor | Monitor | Monitor |
| | | June | Mow[1,2] | Mow[1,2] | Mow[1,2] | Mow[1,2] |
| | Fall | September | Mow | Mow | Mow | Mow |
| 2016 | Spring | April-Aug | Mow[1] | Mow[1] | Mow[1] | Mow[1] |
| | | May | Monitor | Monitor | Monitor | Monitor |
| | | - | Weed/Trim | Weed/Trim | - | Weed/Trim |
| | Fall | Sept/Oct | Mow[1] | Mow[1] | Mow[1] | Mow[1] |

*Herbicide treatments were: Imazapyr (Fall 2013) + Glyphosate (Spring 2014) + Glyphosate (Fall 2014).

**Addition of dune sand to plots below water table in 2014 (Willapa NWR only).

[1]Mowing occurred adjacent to research plots, not within the plots.

[2]Plots were mowed twice in June.

## Yeon (NPS)

**Soil inversion (and addition) treatment(s) not included at this site.

| | | | Treatment | |
|---|---|---|---|---|
| **Year** | **Season** | **Month** | **Herbicide*** | **Soil Removal** |
| 2013 | Spring | June | Mow | Mow |
| | | | Monument | Monument |
| | | | Monitor | Monitor |
| | Fall | September | Mow | Mow |
| | | October | Imazapyr | - |
| 2014 | Spring | April | - | - |
| | | April | Qualitative Monitor | Qualitative Monitor |
| | | May | Mow | Mow |
| | | May/June | Glyphosate | - |
| | Fall | September | Mow | Mow |
| | | September | - | Remove Soil |
| | | October | Glyphosate | - |
| 2015 | Spring | May/June | Monitor | Monitor |
| | | June | Mow | Mow |
| | Fall | September | ? | ? |
| 2016 | Spring | May | Monitor | Monitor |

*Herbicide treatments were: Imazapyr (Fall 2013) + Glyphosate (Spring 2014) + Glyphosate (Fall 2014).