Clatsop Plains – Long Beach Peninsula Coastal Prairie Restoration

2017

Progress Report to the USDI, US Fish and Wildlife Service

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Institute for Applied Ecology

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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 2017, 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 grasses, 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 2017. The soil removal treatment had a relatively high ratio of native forbs to invasive forbs, and lower levels of invasive graminoid cover compared to the other treatments. The lower cover of invasive graminoids 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 graminoids 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 to invasive forbs and lower levels of invasive graminoid cover compared to the other treatments. While future monitoring will be important to note how this changes in invasive graminoid 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 2017 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 1). Both imazapyr and glyphosate are broad-spectrum herbicides and repeated applications are often required to achieve adequate control of invasive graminoid 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 2). 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 2). 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 3; 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 3). 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.

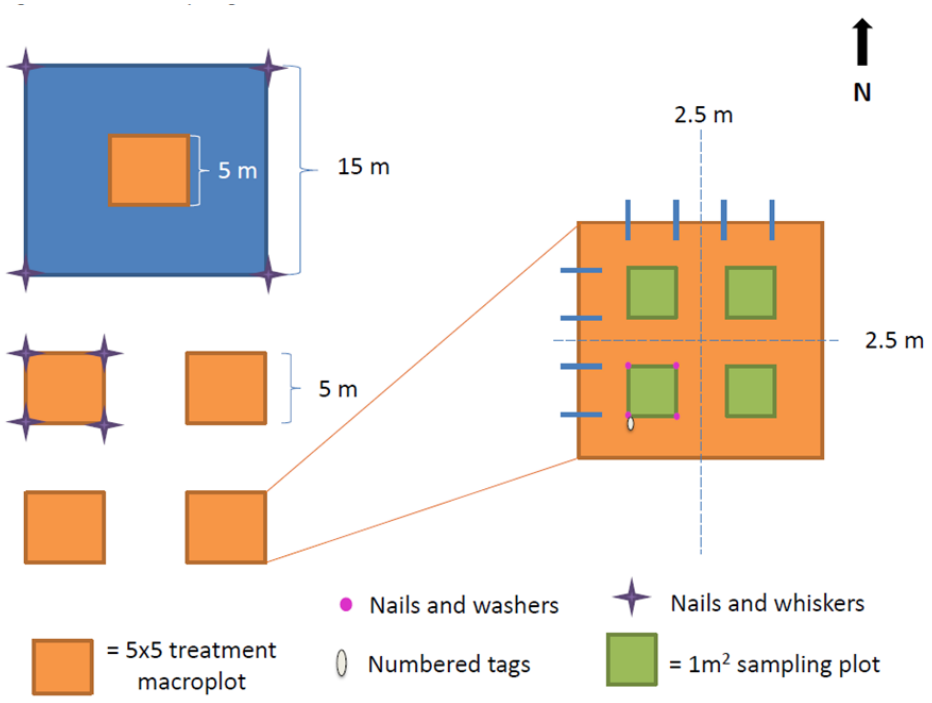

FIGURE 3. PLOT DESIGN AND SAMPLING PROTOCOL FOR COASTAL PRAIRIE RESTORATION STUDY.

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

5 x 5 meter plots 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

*Replaced *Lupinus littoralis* at Willapa site only.

RESULTS

North Coast Land Conservancy

Neacoxie Forest

SEEDED SPECIES

Seeded native forb cover was similar in 2017 to 2016, remaining <10% in all treatments (Figure 4). We recorded *Achillea millefolium*, *Lupinus littoralis*, and *Solidago canadensis* in seeded plots, but only *A. millefolium* averaged cover >1%. In control plots, there was <1% *A. millefolium* cover recorded and all treatments had significantly higher cover (Figure 4). *A. millefolium* ranged from 4-7% in treatment plots and did not vary significantly among treatments.

Festuca rubra was recorded in all treatments and ranged from <1-13% in 2017 (Figure 5). Herbicide treatments had significantly higher cover of *F. rubra* than control plots. *F. rubra* comprised most of the cover recorded for native graminoid species in herbicide treated plots (Figure 5).

FORB COVER

In 2017, native forb cover in the controls ranged from <1-25% (Figure 4). *A. millefolium* had the highest cover of native forb species in treatment plots, averaging from 4-7% in treatment plots. *Ranunculus occidentalis* had the highest native forb cover in control plots, averaging 5% (Figure 4).

In 2017, invasive forb cover in control plots ranged from <1-38% (Figure 4). Herbicide treatments had significantly higher invasive forb cover than all other treatments in 2015, 2016, and 2017 (Figure 4). In 2017, invasive forb cover in herbicide treatments ranged from 19-45%. Soil removal plots averaged <5% invasive forb cover in 2015-2017, and in 2017, ranged from 0-10%. *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 2017, and comprised most of the native graminoid cover in that treatment (Figure 5). Native graminoid cover was <15% in all treatments and remained less than half of the invasive graminoid cover in each treatment, except for the soil removal treatment, which had higher native graminoid cover than invasive graminoid cover in 2017 (Figure 5).

Invasive graminoid cover was significantly higher in control plots than all other treatments, exceeding 100% (Figure 5). Soil removal treatments had significantly lower cover of invasive graminoids than the soil inversion and herbicide treatments (Figure 5). While soil removal plots had lower invasive graminoid cover in 2017 than 2016, soil inversion and herbicide plots both had higher invasive graminoid cover in 2017 than 2016 (Figure 5). *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 (7%) than any other treatment in 2017, due to the presence of the native blackberry, *Rubus ursinus*.

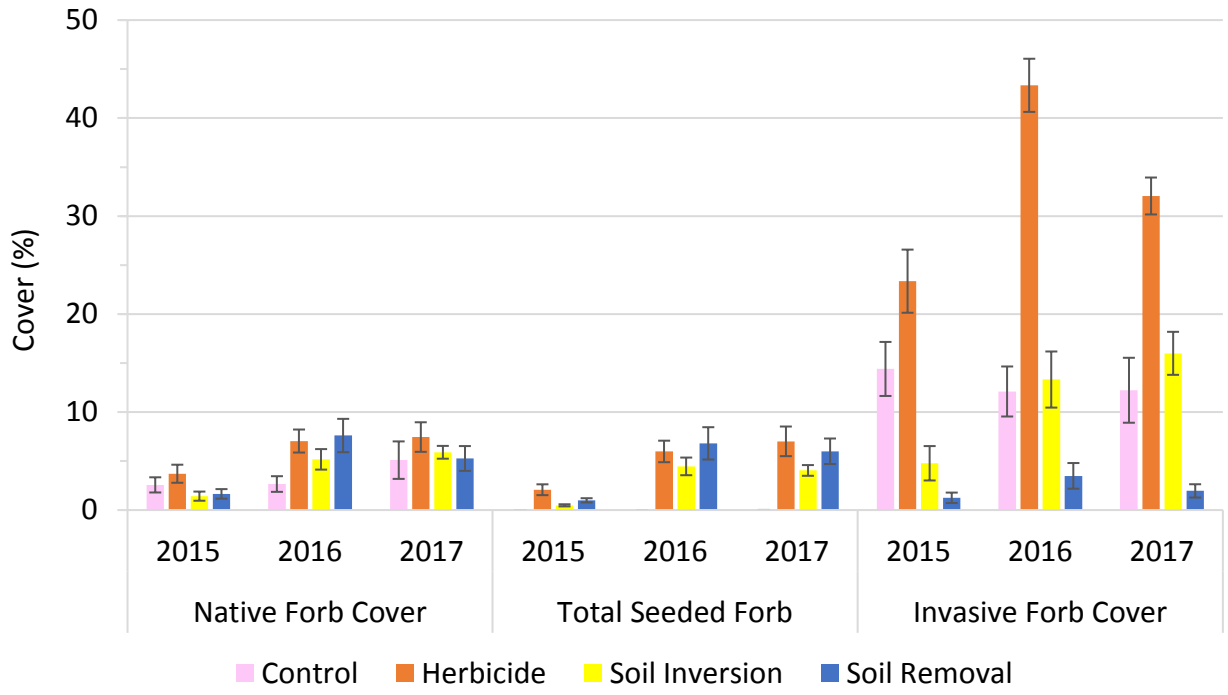

FIGURE 4. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS AT NEACOXIE FOREST IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES.

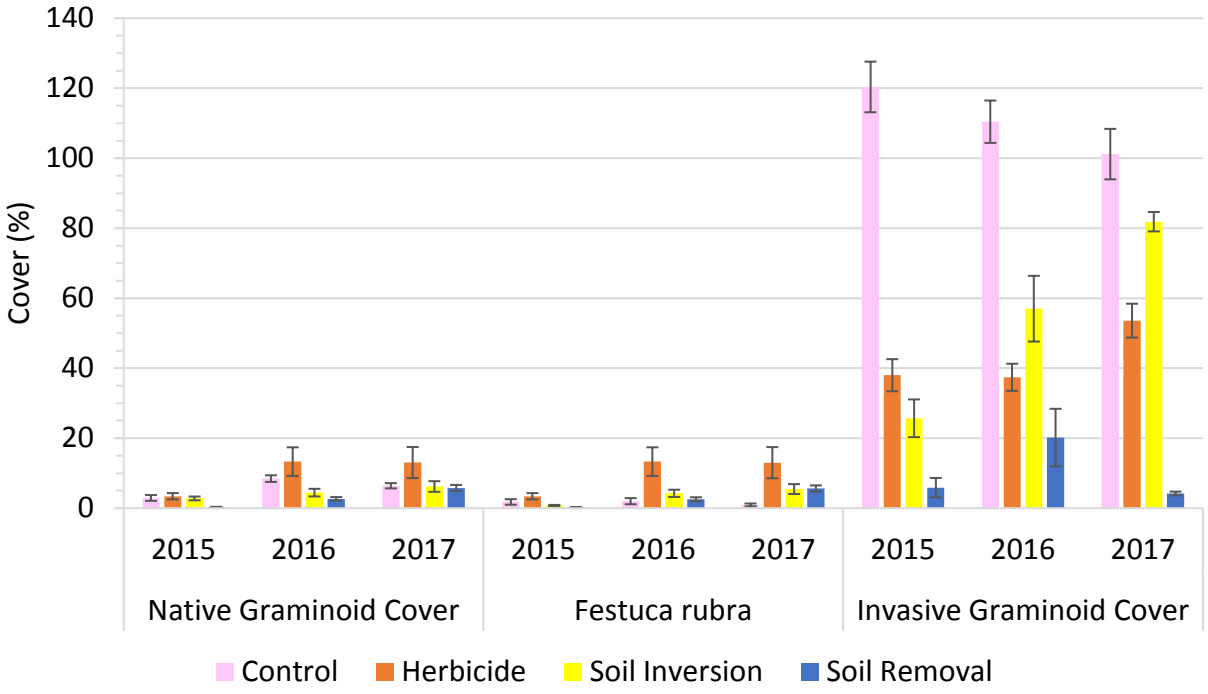

FIGURE 5. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT NEACOXIE FOREST IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).

Surf Pines

SEEDED SPECIES

Seeded native forb cover increased from 2015 to 2016, reaching nearly 20% cover in several treatments, but decreased slightly from 2016 to 2017 (Figure 6). We recorded *A. millefolium*, *L. littoralis*, and *Aster subspicatus* in seeded plots in 2017. *A. millefolium* cover ranged from 1-13%, and was highest in the herbicide treatment. *L. littoralis* cover ranged from <1-2%, and was highest in the soil removal treatment. *A. subspicatus* cover was <1% and was only recorded in the soil removal treatment.

F. rubra was recorded in all treatments and ranged from <1-6% in 2017 (Figure 7). *F. rubra* cover was significantly higher in soil removal plots than any other treatment (Figure 7).

FORB COVER

Native forb cover was significantly higher in the herbicide treatment than the control, soil inversion, or soil removal treatments (Figure 6). *A. millefolium* had the highest native forb cover among treatment plots (4-12%), while *A. millefolium* and *R. occidentalis* had similar cover in control plots (~1%).

Soil removal plots had significantly lower cover of invasive forbs, and was the only treatment with <10% cover in 2017 (Figure 6). In treated plots, invasive forb cover was as low as 5% in soil removal plots to as high as 32% in herbicide plots. Although herbicide plots had the highest native forb and seeded native forb cover, they also had the highest invasive forb cover (even higher than invasive forb cover in

controls) (Figure 6). *H. radicata* and *R. acetosella* comprised the majority of invasive forb cover recorded among all treatments.

GRAMINOID COVER

Native graminoid cover increased slightly in 2017, but remained <10% across treatments (Figure 7). Soil removal plots had the highest native graminoid and *F. rubra* cover in 2017 (Figure 7). *F. rubra* was the largest component of native graminoid cover in herbicide and soil removal treatment plots, while *Carex panza* was the largest component in soil inversion and control plots.

Invasive graminoid cover showed similar patterns in 2015, 2016, and 2017 (Figure 7). Soil removal plots and herbicide plots had significantly lower cover of invasive graminoids than the soil inversion or the control plots (Figure 7). *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

Herbicide plots had significantly higher shrub cover than any other treatment in 2017 (Figure 8). There was a dramatic increase in shrub cover in herbicide plots from 2016 to 2017 (Figure 8). *Cytisus scoparius* (Scotch broom) provides the majority of shrub cover at the site.

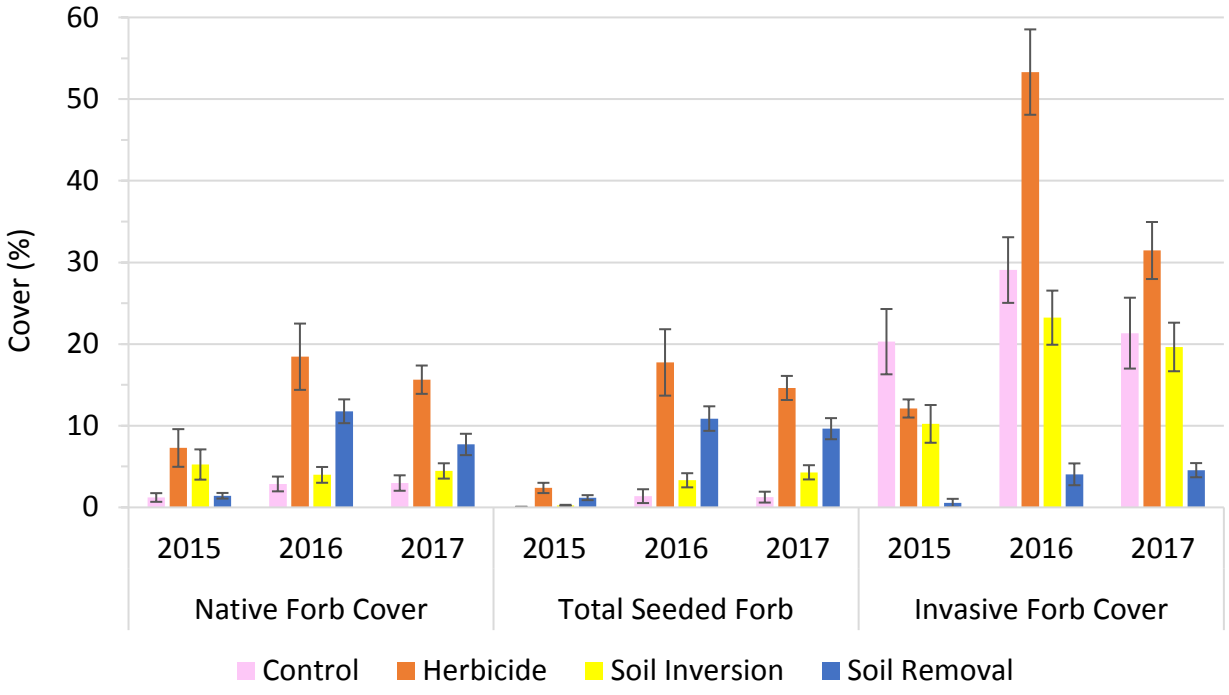

FIGURE 6. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS AT SURF PINES IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES.

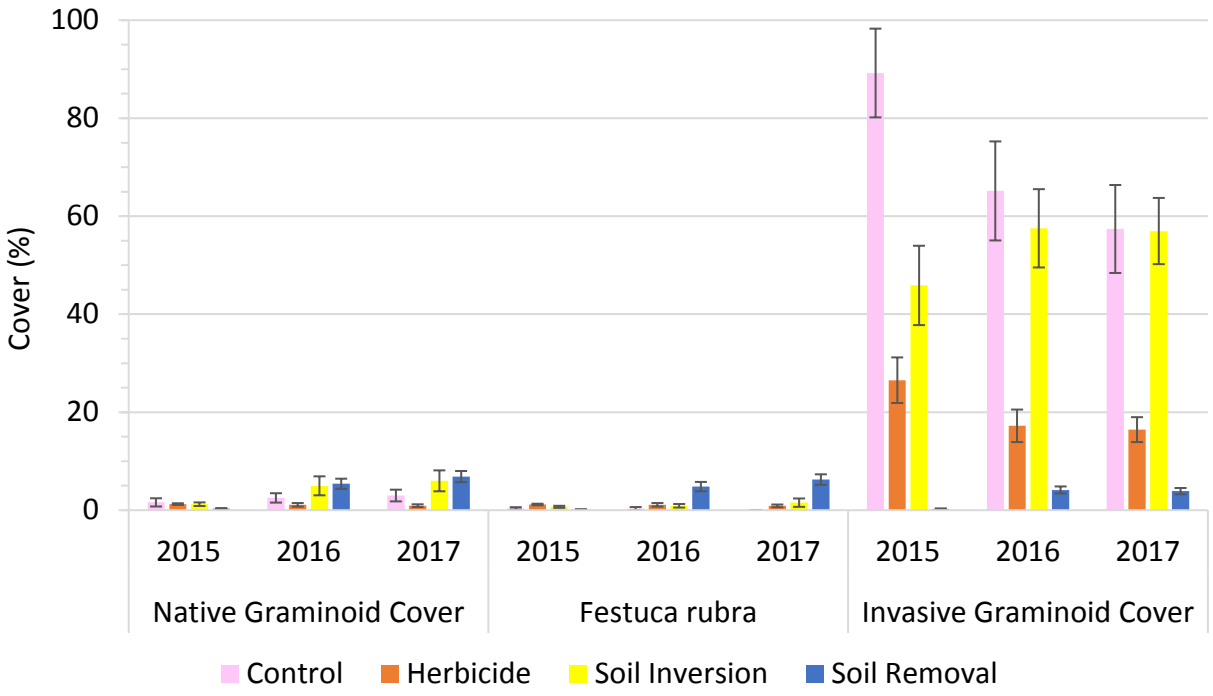

FIGURE 7. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT SURF PINES IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).

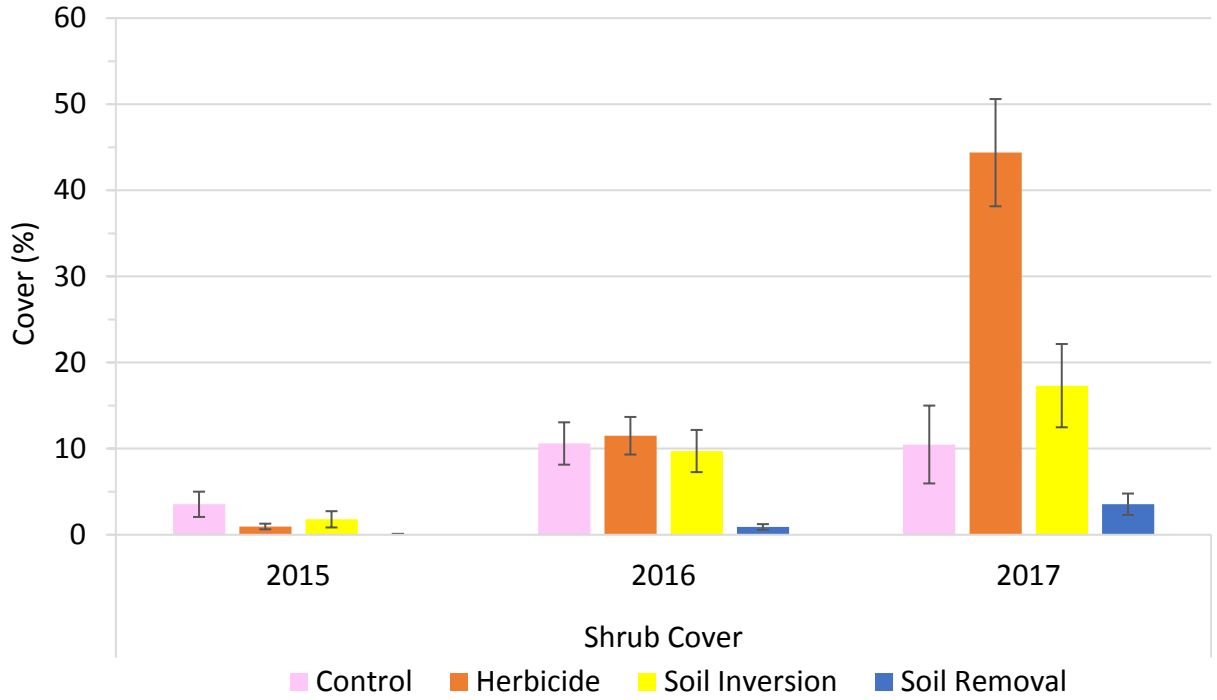

FIGURE 8. COVER OF SHRUBS AT SURF PINES IN 2015, 2016, AND 2017.

Reed Ranch

SEEDED SPECIES

Seeded native forb species decreased slightly from 2016 to 2017, remaining <10% in all treatments (Figure 9). We recorded *A. millefolium* and *L. littoralis* in seeded plots in 2017. *A. millefolium* cover ranged from <1-8%, and was highest in the herbicide treatment. *L. littoralis* cover ranged from <1-10%, and was highest in the soil removal treatment.

F. rubra was recorded in all treatments and ranged from <1-7% in 2017 (Figure 10). *F. rubra* cover did not vary significantly among treatments.

FORB COVER

Overall, there was low cover (<10%) of native forbs across all plots, with all treated plots averaging lower cover in 2017 than 2016 (Figure 9). Native forb cover was significantly higher in the herbicide treatment than the control and soil inversion treatment in 2017 (Figure 9). *A. millefolium* was the largest component of native forb cover in herbicide and soil inversion plots, while *L. littoralis* was the largest component in soil removal plots.

Soil removal plots had significantly lower cover of invasive forbs, and was the only treatment with <20% cover in 2017 (Figure 9). In treated plots, invasive forb cover was as low as 5% in soil removal plots to as high as 61% in herbicide plots (Figure 9). *H. radicata*, *R. acetosella*, and *Trifolium subterraneum* comprised the majority of invasive forb cover recorded among all treatments.

GRAMINOID COVER

Native graminoid cover increased slightly in 2017, but remained <10% across treatments (Figure 10). Soil inversion plots had the highest native graminoid and *F. rubra* cover in 2017 (Figure 10). *F. rubra* comprised the majority of native graminoid cover at the site and did not vary significantly among treatments (Figure 10).

Soil removal plots had <5% cover of invasive graminoids and was significantly lower than all other treatments (Figure 10). Invasive graminoid cover was >60% in the herbicide and soil inversion plots, and was >90% cover in control plots (Figure 10). *A. odoratum* was recorded in all plots and had the highest relative cover among treatments. *S. arundinaceus*, *Dactylis glomerata*, *Bromus hordeaceus*, and *A. alba* 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, 2016, and 2017.

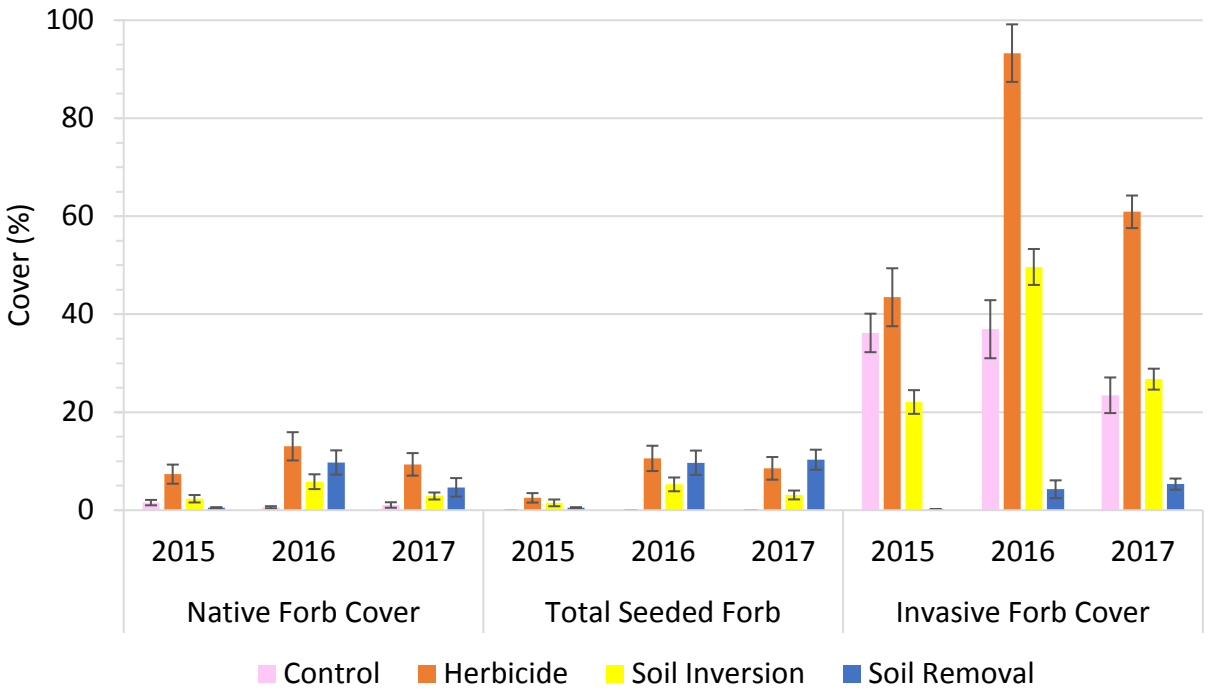

FIGURE 9. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS AT REED RANCH IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES.

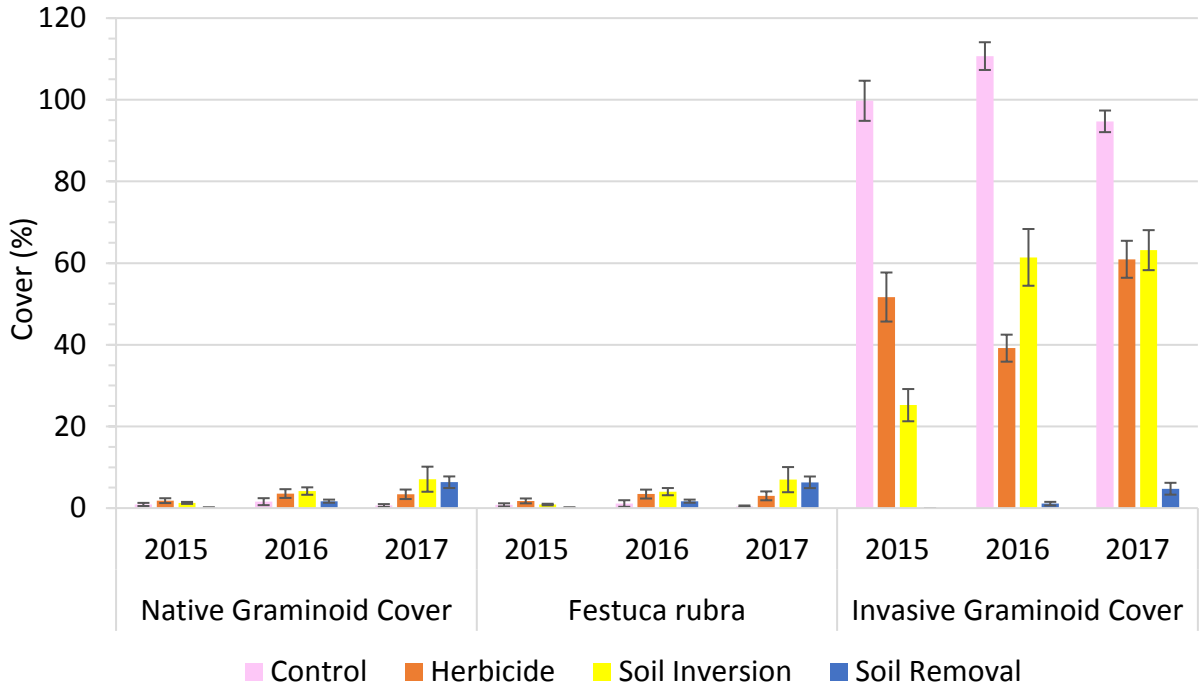

FIGURE 10. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT REED RANCH IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).

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).

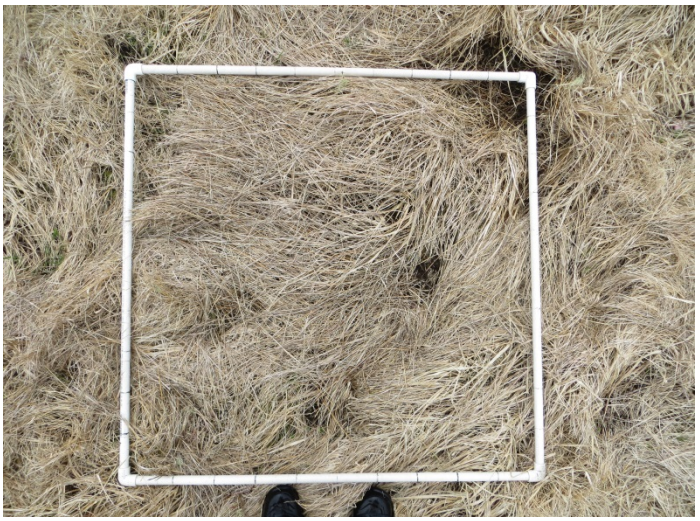

FIGURE 11. HERBICIDE TREATED PLOT SHOWING DENSE THATCH THAT MUST BE CONSIDERED WHEN PLANNING CONTROL AND RESEEDING EFFORTS.

SEEDED SPECIES

Cover of seeded native forb species decreased from 2016 to 2017, with cover remaining <5% (Figure 12). *A. millefolium* was found in all treatments, while *S. canadensis* was recorded in all treatments except for sand addition.

F. rubra was recorded in all treatments and ranged from <1-11% cover in 2017 (Figure 13). *F. rubra* cover was highest in soil inversion plots and lowest in the sand addition plots, but was not significantly different among treatments (Figure 13).

FORB COVER

Native forb cover was higher in treatment plots compared to the control, but did not vary significantly among treatments (Figure 12) and remained <5% in 2017. *A. millefolium* contributed the highest native forb cover across treatments.

Soil removal treatment had the lowest cover of invasive forbs, and was the only treatment with <10% cover in 2017 (Figure 12). In treated plots, invasive forb cover was as low as 3% in soil removal plots to as high as 57% 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 13).

Soil removal and sand addition plots had ≤10% cover of invasive graminoids and were significantly lower than other treatments (Figure 13). Invasive graminoid cover was ≥50% in the herbicide and soil inversion plots, but was less than control plots (79%; Figure 13). *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; there has been <1% shrub cover across all plots from 2015 to 2017.

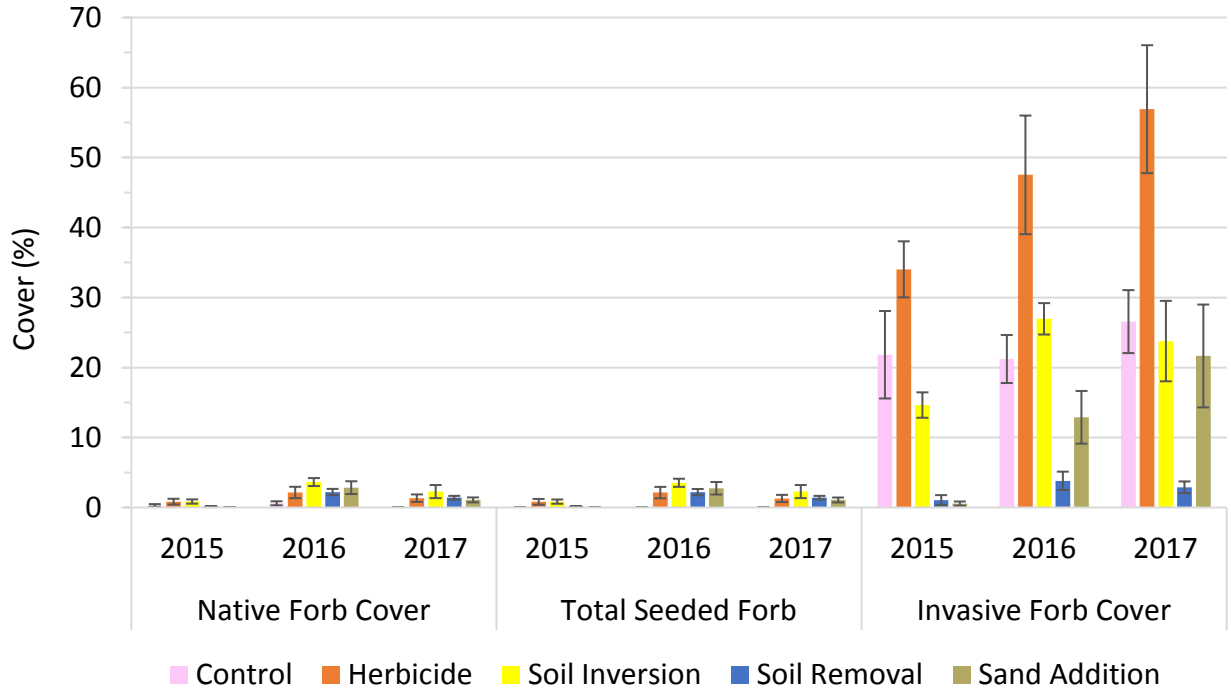

FIGURE 12. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS AT WILLAPA NWR IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES.

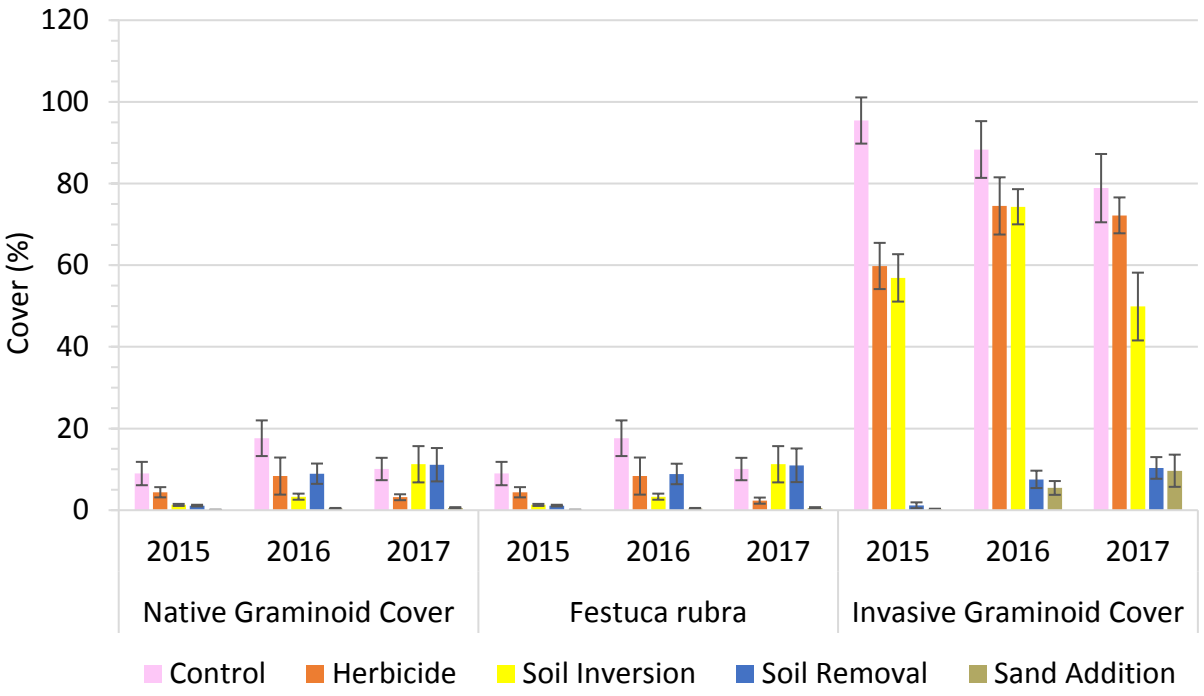

FIGURE 13. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT WILLAPA NWR IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).

National Park Service

Yeon

SEEDED SPECIES

Seeded native forb cover was generally low at this site (<5%; Figure 14). The soil removal treatment resulted in higher amounts of seeded forb cover than the control, but remained low after three growing seasons (Figure 14). *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 three growing seasons (Figure 15).

FORB COVER

Forb cover was generally low at this site in comparison to other sites (<16%; Figure 14). Native forb cover was <5% and did not show treatment effects (Figure 14). *A. millefolium* and *L. littoralis* were the only native forbs to average >1% cover in any of the treatments.

The soil removal treatment had lower invasive forb cover than the control and herbicide treatment (Figure 14). *H. radicata* comprised the majority of invasive forb cover, with *R. acetosella* and *Vicia sativa* also commonly recorded.

GRAMINOID COVER

Native graminoid cover was low across all treatments (<10%; Figure 15). *F. rubra* comprised the majority of the native graminoid cover recorded at the site in 2017.

Invasive graminoid cover increased in all treatments in 2017, and although significantly lower in soil removal plots, was >20% in all treatments (Figure 15). *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 in the treated plots at the Yeon site (<5%). However, shrub cover has increased in control plots from 2015 to 2017 and is now up to 16%, comprised mainly by C. *scoparius* (Scotch broom).

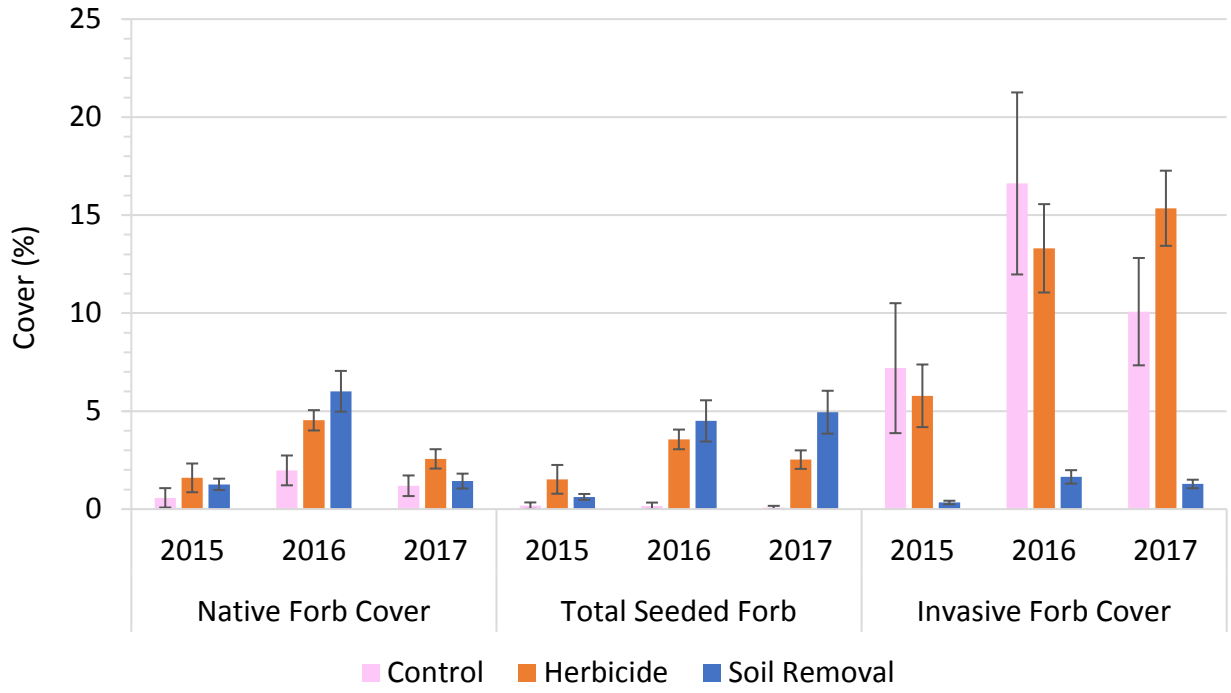

FIGURE 14. COVER OF NATIVE*, SEEDED, AND INVASIVE FORBS AT NPS YEON SITE IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES.

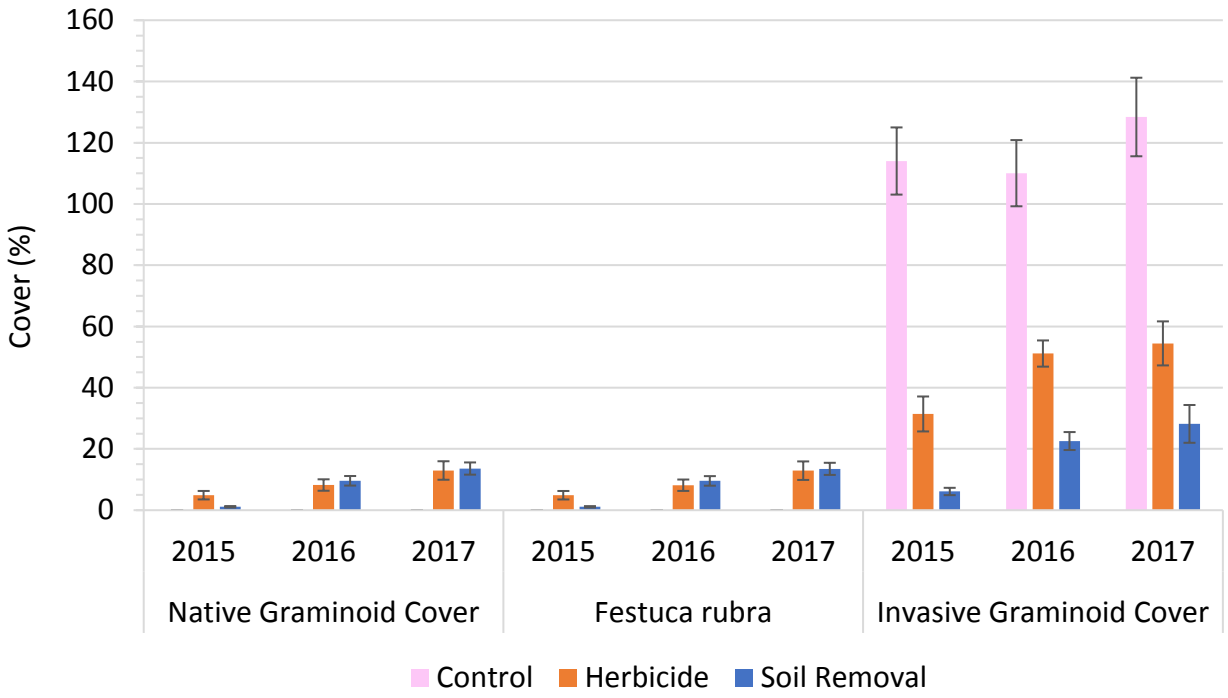

FIGURE 15. COVER OF NATIVE*, SEEDED (*FESTUCA RUBRA*), AND INVASIVE GRAMINOIDS AT NPS YEON SITE IN 2015, 2016, AND 2017. *NATIVE TOTALS INCLUDE SEEDED SPECIES (*FESTUCA RUBRA*).

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 three 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 (Silvernail 2017). Cover has remained low after three 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 2). 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 at Neacoxie Forest is currently invasive grasses, predominantly *A. alba*, *A. odoratum*, and *S. arundinaceus*. In 2016, 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). While invasive grass cover increased in the herbicide and soil inversion treatments from 2016 to 2017, it decreased in the soil removal treatment to <5% cover in 2017 (Figure 5).

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 herbicide treated plots had less invasive grass cover than controls, there was still nearly 40% cover in 2016, increasing to over 50% in 2017 (Figure 5). 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 since 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 resulted in cover values increasing in the second year, though they were able to be reduced by the third year (Figure 5). 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 at Surf Pines is currently invasive grasses, predominantly *A. alba*, *A. odoratum*, and *S. arundinaceus*. The soil inversion treatment had the highest cover of all treatments (57%) 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 16% 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, with only a slight reduction in the third year (Figure 7). 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*, with nearly 20% cover. Although at relatively low levels, due to past management efforts, this species should continue to be a target for management efforts. There was a dramatic increase in *C. scoparius* cover in herbicide plots from 2016 to

2017, with many plants that had been cut back starting to leaf out again. 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 concern at Reed Ranch is currently invasive grasses, predominantly *A. odoratum*, and invasive forbs, predominantly *H. radicata* and *R. acetosella*. Soil inversion and herbicide treatments had high cover of both invasive grasses and forbs (63% and 27%, and 61% and 61%, respectively) (Figure 9, Figure 10). The soil removal treatment had ≤5% of both invasive grasses and forbs (Figure 9, Figure 10). 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 and third year (Figure 10). 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 at Willapa NWR are currently invasive grasses, predominantly *A. alba*, 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 was statistically the same as the control plots, while both the soil removal and sand addition treatments were significantly lower with ≤10% invasive grass 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 and third year (Figure 13). 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 higher invasive forb cover (Figure 12). 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 at Yeon is currently 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 herbicide treated plots had less invasive grass cover than controls, invasive grass cover in herbicide plots has been steadily increasing from 2015 to 2017, and is now up to >50% cover (Figure 15). 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 often ineffective on these 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

Soil removal and sand addition plots can be hand-weeded. 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-pulling 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 2018 field season, and 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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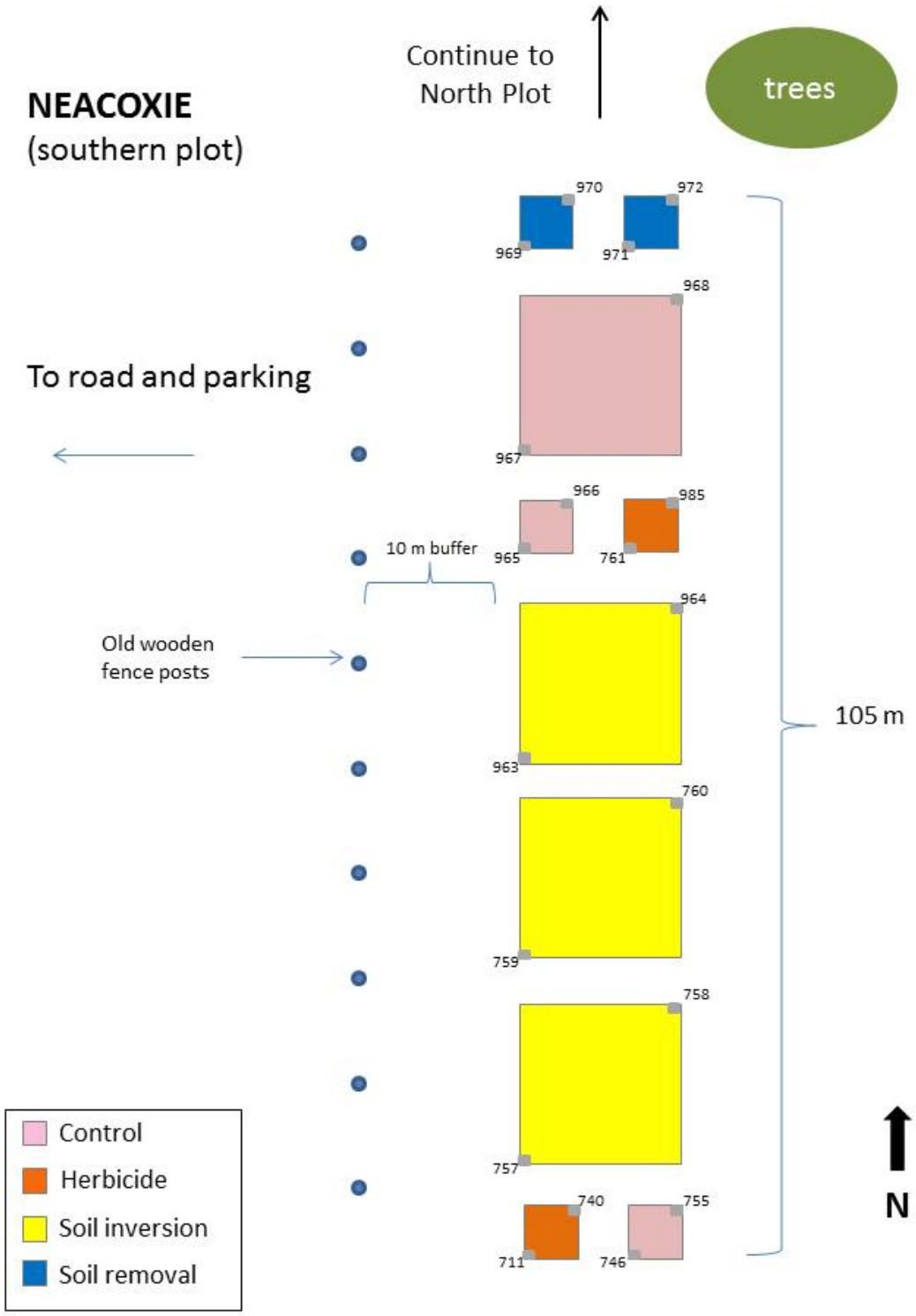
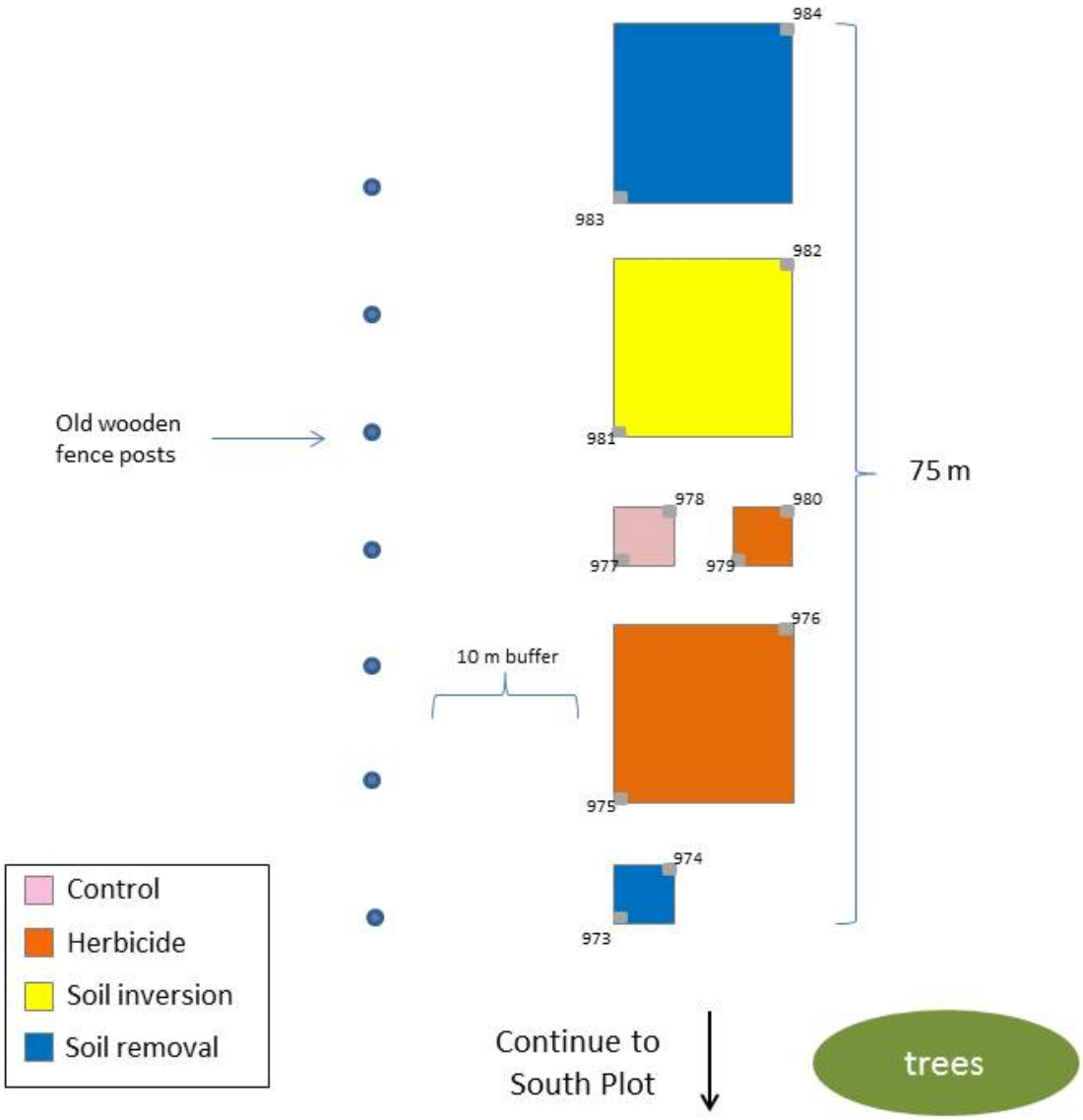
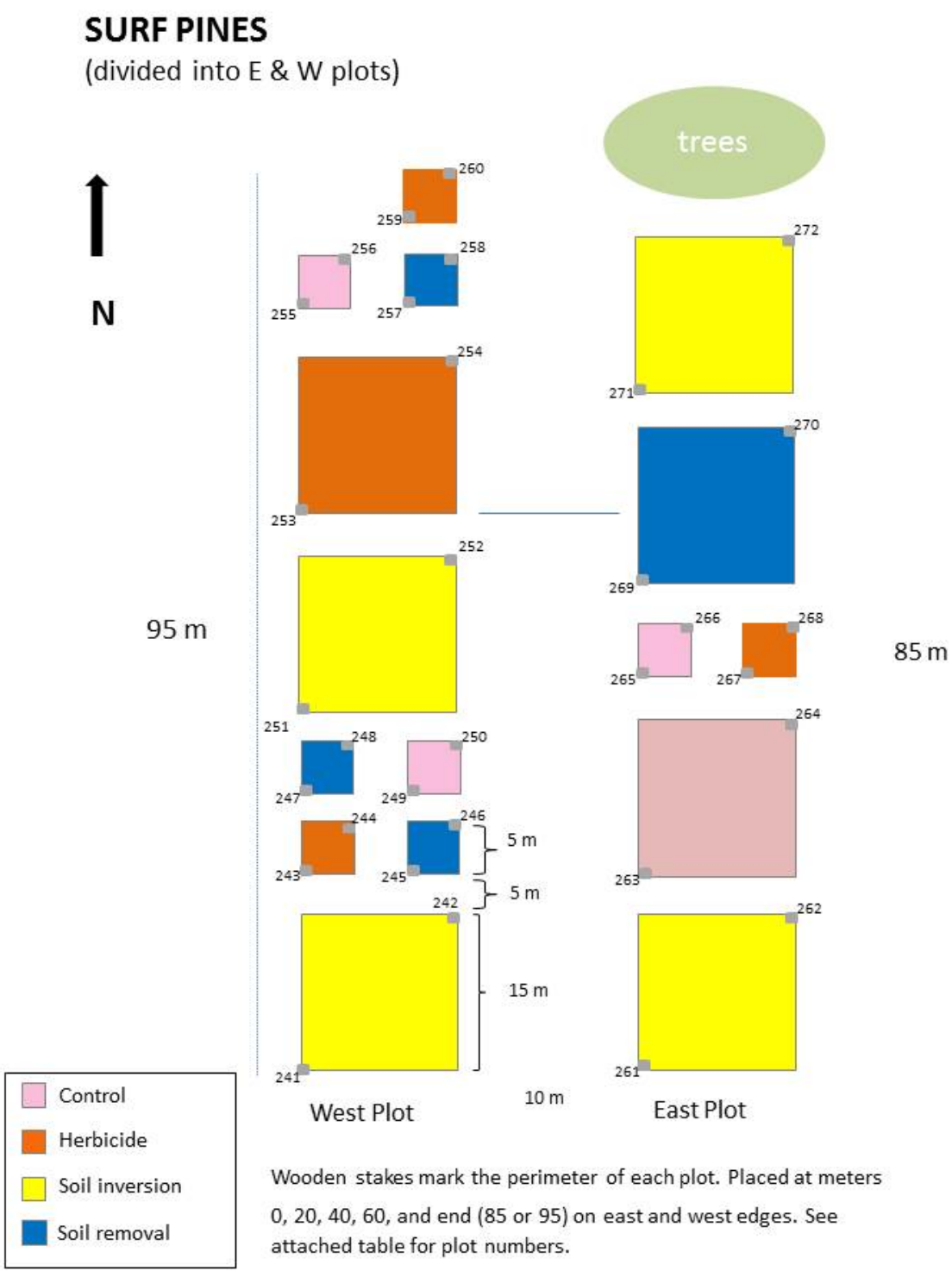
APPENDIX A. MAPS AND PLOT TAG NUMBERS FOR EACH OF THE CLATSOP PLAINS RESTORATION STUDY SITES.



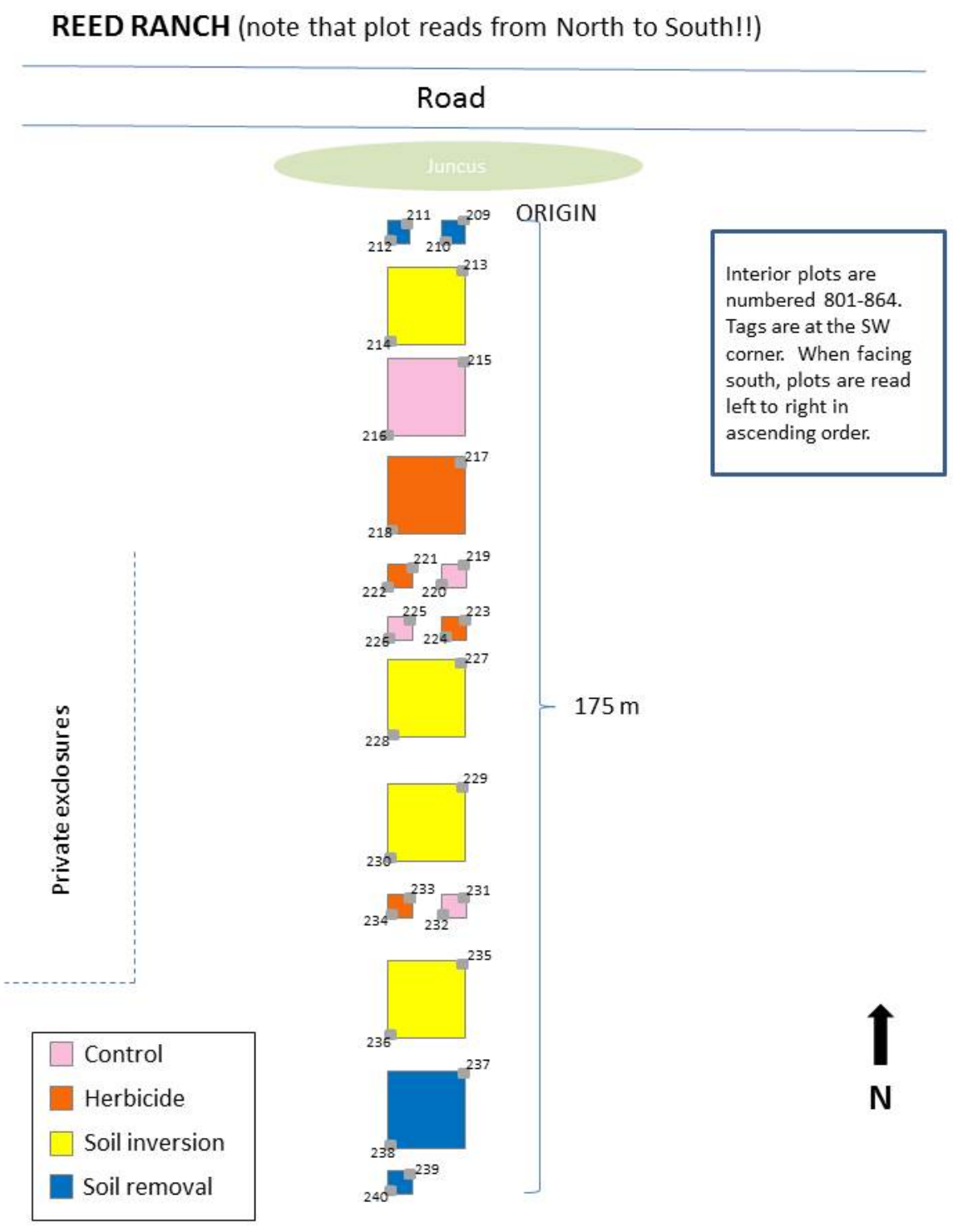
NEACOXIE
(northern plot)

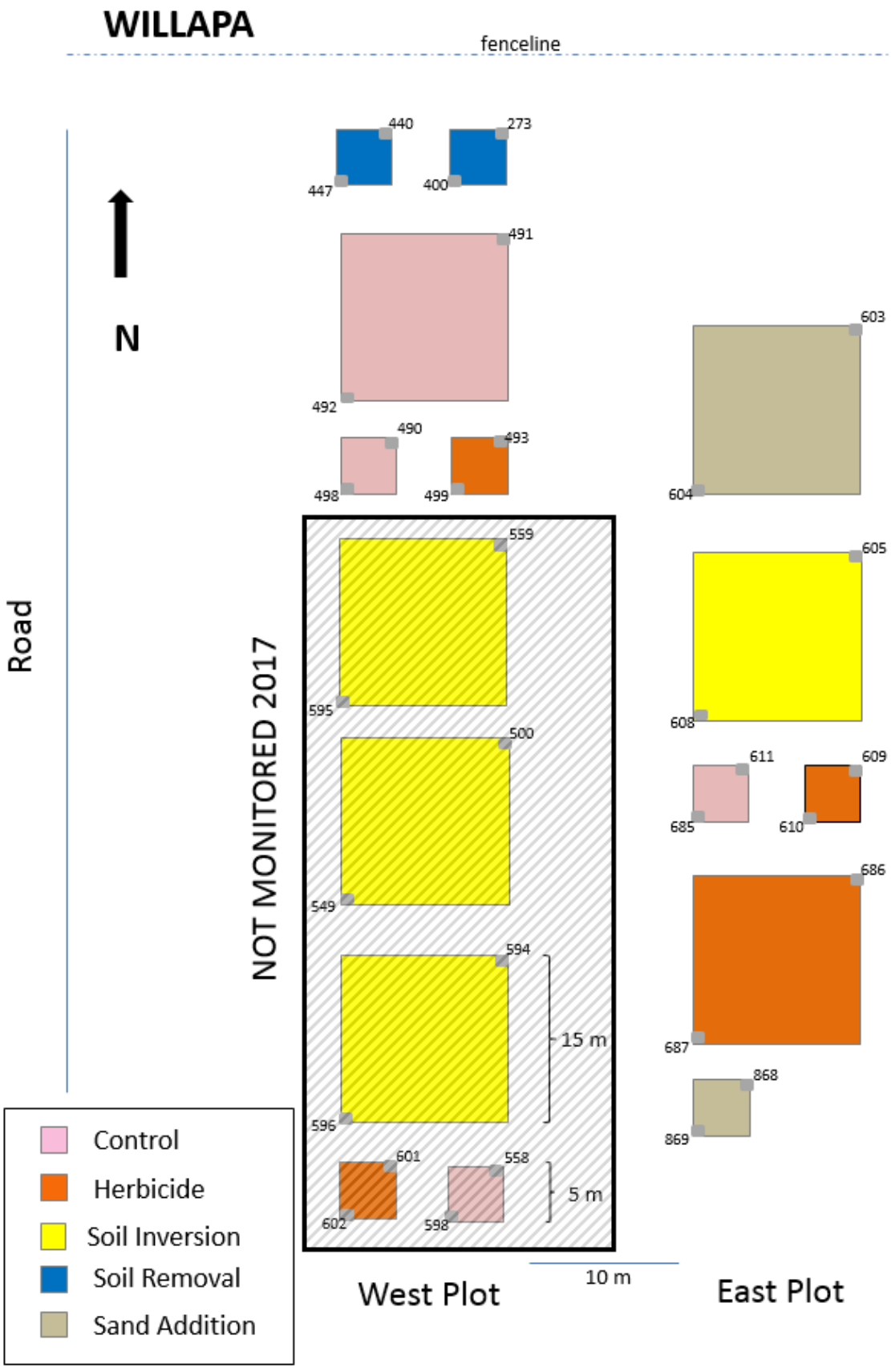
Wooden stakes mark the perimeter of each plot. They are placed at meters 0, 25, 50, 75, and 105 (south plot)



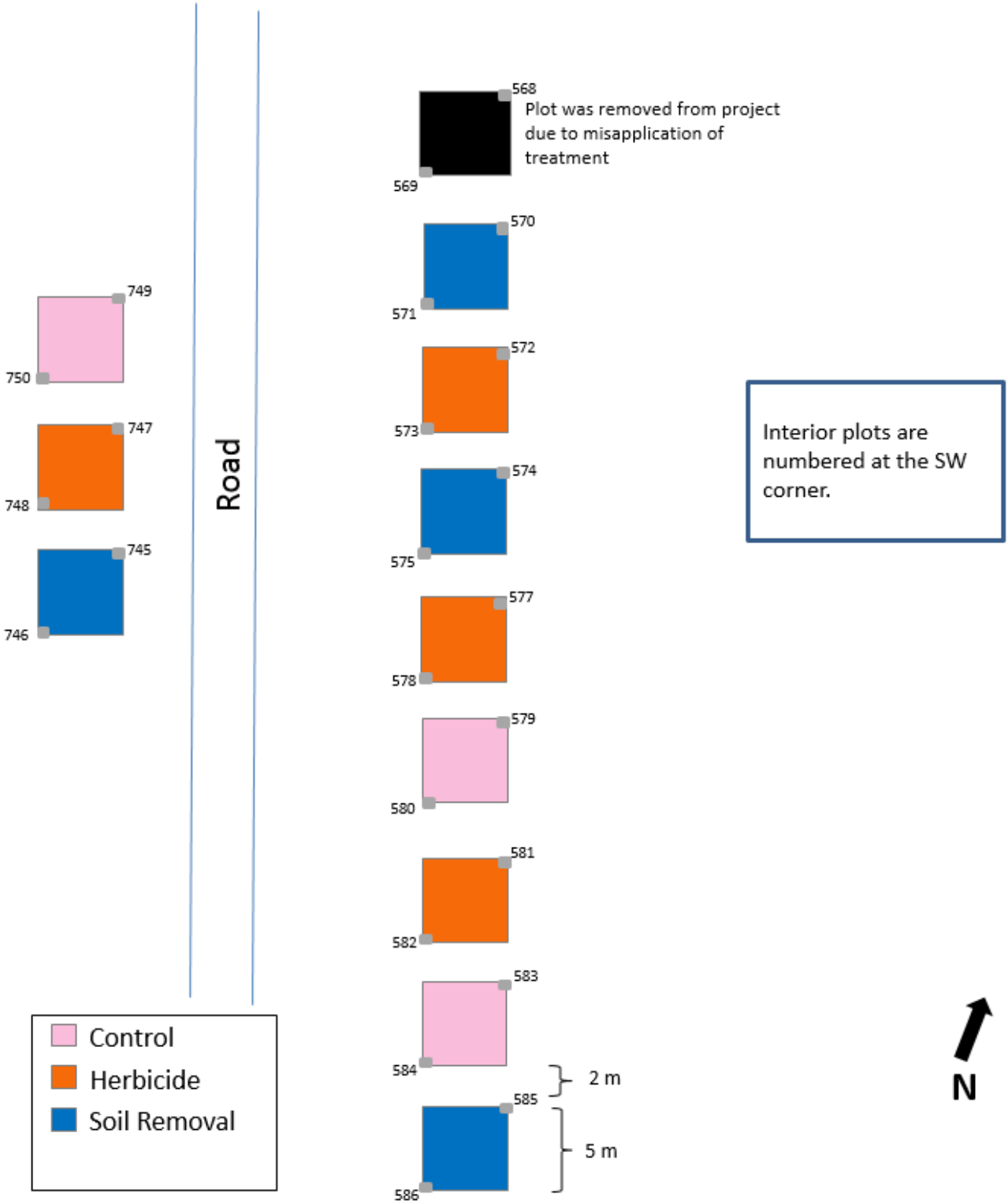


Wooden stakes mark the perimeter of each plot. Placed at meters 0, 20, 40, 60, and end (85 or 95) on east and west edges. See attached table for plot numbers.


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
NOT MONITORED 2017
440
447
273
400
491
492
490
498
493
499
559
595
500
549
594
596
601
602
558
598
15 m
5 m
10 m
West Plot
603
604
605
608
611
685
609
610
686
687
868
869
East Plot
Control
Herbicide
Soil Inversion
Soil Removal
Sand Addition

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



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

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

Neacoxie

	Control				Herbicide				Soil Inversion				Soil Removal			
	2013	**2015**	**2016**	**2017**	**2013**	**2015**	**2016**	**2017**	**2013**	**2015**	**2016**	**2017**	**2013**	**2015**	**2016**	**2017**
Bare	1.0	0.8	0.3	0.1	0.8	11.5	3.6	1.2	0.1	70.3	42.8	8.8	0.6	93.9	77.4	87.6
Moss/lichen	1.7	0.2	0.9	2.0	4.9	4.0	9.3	14.4	3.1	-	0.3	2.0	2.6	0.0	-	-
Litter	87.4	76.6	85.3	92.1	78.1	62.5	54.1	64.7	74.8	7.5	57.6	76.2	87.1	1.6	11.3	5.7
Forbs																
Achillea millefolium	0.0	-	-	0.0	-	2.0	5.7	6.5	-	0.4	3.8	3.9	-	0.5	6.3	4.5
Alchemilla occidentalis	-	-	0.6	0.2	-	0.4	0.7	0.4	-	0.1	0.2	1.1	-	0.0	0.3	-
Aster sp.	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-
Aster subspicatus	-	-	-	-	-	0.0	-	-	-	-	-	0.0	-	0.0	-	0.1
Brassica sp.	-	-	-	-	-	-	-	0.0	-	0.1	-	0.1	-	-	0.0	-
Cerastium arvense	0.0	-	0.0	0.1	-	0.4	3.3	1.0	-	0.4	1.0	2.3	-	-	0.2	0.1
Crepis setosa	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Daucus sp.	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-
Epilobium minutum	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-
Equisetum sp.	-	-	0.0	0.0	0.1	0.0	-	-	-	0.1	0.0	0.0	0.2	0.0	0.0	0.1
Galium aparine	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Geranium dissectum	0.1	0.0	0.1	0.0	0.1	0.2	1.5	0.2	0.2	0.2	2.2	0.9	0.0	0.0	-	0.0
Hypochaeris radicata	13.3	11.2	9.7	10.0	10.5	15.5	28.2	21.6	5.2	0.8	5.5	10.8	10.5	0.3	1.6	1.4
Leucanthemum vulgare	0.2	0.3	-	0.0	-	-	-	-	-	-	-	-	0.2	-	0.1	-
Lotus corniculatus	-	-	-	-	-	-	-	-	0.0	-	0.2	-	-	-	-	-
Lotus micranthus	-	-	-	-	-	-	0.0	0.1	-	-	-	-	-	-	-	-
Lupinus littoralis	-	-	-	-	-	0.1	0.3	0.4	-	0.1	0.6	0.2	-	0.1	0.3	0.9
Lupinus sp.	-	-	-	-	-	-	-	-	-	0.0	-	-	-	0.4	0.1	0.2
Matricaria discoidea	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-

Myosotis discolor	0.9	2.0	0.6	0.4	0.8	5.3	1.8	0.6	0.0	0.0	0.1	0.2	0.2	-	0.0	0.0
Parentucellia viscosa	-	0.0	-	-	-	0.0	-	-	-	0.0	-	-	-	0.0	-	-
Plantago lanceolata	0.1	0.1	0.1	0.0	-	-	-	-	-	-	0.0	-	0.1	-	-	-
Pteridium aquilinum	-	0.0	-	0.0	0.6	0.3	-	-	1.1	0.1	0.2	0.2	0.1	0.5	-	-
Ranunculus occidentalis	3.4	2.5	2.0	4.8	2.3	0.9	0.3	0.3	1.0	0.0	0.0	0.4	0.1	0.1	0.4	-
Rumex acetosella	1.1	0.4	1.0	1.0	0.3	0.2	4.8	3.5	1.5	3.2	4.0	1.5	1.7	0.9	1.4	0.3
Senecio jacobaea	0.2	0.0	0.0	0.1	-	0.8	2.4	1.1	0.1	0.0	0.1	0.1	-	0.0	-	-
Senecio vulgaris	-	-	-	-	-	0.3	1.6	0.1	-	-	-	-	-	-	-	-
Sisyrinchium sp.	-	0.0	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Solidago sp.	-	-	-	-	-	-	-	0.1	-	-	0.0	-	-	-	0.0	0.3
Sonchus asper	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Spergularia media	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.0	0.0	0.0
Stellaria media	-	-	0.0	-	-	0.0	0.1	-	-	0.7	0.3	0.3	-	-	-	0.0
Taraxacum officinale	0.3	0.1	0.1	0.1	-	-	-	-	0.1	-	-	-	0.2	-	-	-
Trifolium dubium	-	-	0.1	0.0	-	0.0	0.5	3.7	0.0	0.0	0.1	0.0	-	-	0.2	-
Trifolium repens	-	-	-	-	-	-	-	-	-	0.0	0.1	-	-	0.0	0.1	-
Trifolium subterraneum	-	-	-	-	-	-	0.1	-	-	-	-	0.0	-	-	0.0	-
Veronica americana	1.0	0.3	0.5	0.4	0.1	0.8	0.8	0.4	0.2	0.0	0.0	0.2	0.3	-	0.0	0.0
Vicia sativa	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Viola adunca	-	-	-	-	-	-	-	-	-	-	0.0	0.0	-	-	0.0	0.0
Graminoids																
Agrostis alba	48.1	64.1	38.2	38.7	50.6	7.9	12.8	16.3	53.1	7.3	5.8	17.7	57.2	2.5	3.7	0.5
Aira caryophylla	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aira praecox	-	-	-	0.0	-	-	-	0.0	-	-	-	0.8	-	-	-	0.4
Anthoxanthum odoratum	35.1	26.9	22.9	21.8	20.9	29.1	18.7	33.9	34.3	2.9	11.6	16.1	25.9	0.2	4.0	2.7
Bromus hordeaceus	1.5	-	0.6	0.8	5.5	-	0.3	0.3	0.0	-	-	0.1	7.5	-	-	-
Carex panza	0.1	0.3	0.9	1.0	0.0	-	-	-	-	-	0.0	-	0.0	-	0.0	0.0
Carex sp.	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomeratum	7.9	10.1	7.7	10.1	9.3	0.0	0.4	0.3	15.6	8.9	5.5	7.6	12.8	1.0	1.0	0.1

Danthonia californica	-	-	0.3	0.1	-	-	-	-	0.0	-	-	-	-	-	-	-
Elymus trachycaulus	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Festuca arundinacea	11.9	16.7	28.1	20.6	21.4	0.0	0.1	0.0	13.1	6.3	24.6	33.1	5.2	2.1	8.8	0.2
Festuca rubra	3.7	1.8	2.0	0.9	2.9	3.4	13.3	13.0	6.9	0.8	4.3	5.5	3.3	0.3	2.6	5.7
Holcus lanatus	0.2	0.6	0.4	0.2	0.1	0.9	5.1	2.8	0.3	0.0	4.6	3.5	0.4	-	0.6	0.5
Juncus bufonius	-	-	-	-	-	0.2	-	-	-	0.1	0.1	0.0	-	-	-	-
Juncus sp.	0.9	0.8	5.2	4.1	0.8	-	-	0.0	0.7	2.0	0.2	0.3	0.4	0.0	0.0	0.1
Luzula comosa	-	0.0	0.1	0.2	0.1	0.0	-	0.0	-	0.0	-	0.5	0.0	-	0.0	0.0
Poa compressa	-	2.0	12.5	9.0	-	0.0	-	-	-	0.3	4.9	3.1	-	0.0	2.0	-
Vulpia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-
Shrubs/Trees																
Acer sp.	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-
Cytisus scoparius	0.0	-	0.1	0.1	-	-	0.3	1.2	0.1	0.0	-	0.9	0.0	-	-	0.0
Rosa sp.	0.3	-	-	-	-	-	-	-	0.1	-	-	-	-	0.0	-	-
Rubus armeniacus	0.1	-	-	-	-	-	-	-	5.4	-	-	-	-	-	-	-
Rubus ursinus	-	-	-	-	-	0.0	-	-	-	1.9	5.3	6.6	-	-	-	-

Surf Pines

	Control				Herbicide				Soil Inversion				Soil Removal			
	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017
Bare	0.3	18.8	13.4	10.0	0.5	8.3	4.8	5.0	0.2	47.8	23.4	11.4	0.5	99.6	87.2	79.2
Moss/lichen	10.9	9.2	4.2	5.6	11.6	19.5	5.8	3.7	9.7	0.1	0.4	1.0	17.3	0.0	0.7	0.0
Litter	79.4	57.9	63.4	67.3	78.8	71.6	38.3	33.4	78.6	26.2	59.8	68.9	80.6	1.3	6.4	15.1
Forbs																
Achillea millefolium	-	0.0	1.0	1.3	-	2.2	12.2	13.4	-	0.2	2.7	3.7	-	0.1	8.1	7.1
Arenaria sp.	-	-	-	-	-	-	-	-	-	-	0.1	0.3	-	-	-	-
Aster sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-
Aster subspicatus	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	0.0
Brassica sp.	-	0.1	-	0.0	-	0.4	-	-	-	0.6	-	0.0	0.0	-	-	0.1
Cardamine oligosperma	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-
Centaurium erythraea	0.0	0.0	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Cerastium arvense	0.0	0.8	2.1	0.2	0.0	0.5	2.6	0.6	0.4	0.1	1.0	-	0.1	-	0.1	-
Cerastium fontanum	0.0	-	-	2.2	-	-	-	0.7	-	-	-	2.7	-	-	-	0.3
Cerastium glomeratum	0.1	-	-	-	0.1	0.0	-	-	0.1	-	-	-	0.0	-	-	-
Cirsium sp.	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-
Cirsium vulgare	-	-	-	-	-	0.1	-	-	-	0.1	0.6	-	0.6	-	-	-
Claytonia perfoliata	-	-	-	1.1	-	0.1	-	-	-	-	0.1	0.2	-	-	-	-
Crepis setosa	0.0	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-
Epilobium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
Equisetum sp.	0.0	0.1	0.2	0.4	0.0	-	-	0.1	0.2	0.0	0.5	0.3	0.0	0.1	0.9	0.6
Erodium cicutarium	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Galium aparine	-	-	-	-	0.0	-	-	-	0.0	-	-	-	0.0	-	-	-
Geranium dissectum	0.1	-	0.1	0.0	0.1	0.1	0.5	0.1	0.3	-	0.4	0.0	0.5	-	-	-
Hypochaeris radicata	16.1	16.7	15.6	13.7	15.4	5.1	26.9	23.4	15.8	4.8	12.4	13.3	14.8	0.0	1.4	2.4
Lotus micranthus	0.0	-	-	-	0.0	-	-	-	0.0	-	-	-	-	-	-	-
Lupinus littoralis	-	-	0.4	0.0	-	0.1	5.6	1.3	-	-	0.7	0.6	-	-	2.4	2.3
Lupinus sp.	-	0.0	-	-	-	0.1	-	-	-	0.1	-	-	-	1.1	0.3	-
Myosotis discolor	-	0.2	0.0	0.2	-	1.9	0.2	0.2	-	0.0	0.2	0.3	0.0	-	-	0.0
Plantago lanceolata	-	0.0	0.5	0.4	0.2	-	0.1	0.3	-	-	-	-	-	-	-	-

Ranunculus occidentalis	2.3	0.4	1.0	0.8	5.1	4.6	0.7	2.2	-	0.0	0.0	0.0	0.2	-	-	-
Rumex acetosella	0.6	1.7	8.3	3.4	0.5	1.3	18.5	3.4	1.9	4.5	6.7	1.8	0.2	0.5	2.4	1.5
Senecio jacobaea	-	0.3	0.4	0.5	0.0	0.5	1.2	0.2	-	-	-	0.1	-	-	-	-
Senecio vulgaris	-	-	0.0	0.3	-	0.1	1.3	-	-	-	2.2	0.5	-	-	0.0	-
Sisyrinchium sp.	0.0	0.1	0.2	0.1	-	-	-	0.0	-	-	-	0.0	-	-	-	-
Solidago canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
Solidago sp.	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-
Spergularia media	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-	0.1	0.0
Stellaria media	-	0.6	0.0	0.5	-	0.2	-	0.0	0.0	4.9	-	0.4	0.0	0.1	-	-
Taraxacum officinale	-	-	-	-	0.3	-	-	-	-	0.1	0.0	-	-	-	-	-
Trifolium dubium	0.3	0.1	0.5	-	0.3	0.1	2.2	0.9	0.1	-	0.6	0.3	-	-	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	0.7	-	-	0.8	0.0	-	-	-	0.0
Veronica americana	0.5	0.2	0.3	0.8	0.6	1.8	0.6	1.2	1.1	0.0	0.5	1.1	0.7	-	0.0	0.2
Vicia sativa	0.0	0.1	0.1	0.0	-	-	-	-	-	-	-	-	0.0	-	-	-
Viola adunca	-	0.0	0.1	0.0	-	-	-	-	-	-	-	-	-	-	0.0	0.0
Graminoids																
Agrostis alba	19.0	18.8	6.0	7.0	11.2	6.3	2.4	1.3	31.1	14.6	11.4	7.0	23.0	0.2	1.1	1.2
Aira caryophylla	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-
Aira praecox	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.4
Anthoxanthum odoratum	23.8	13.8	11.9	7.5	41.3	18.6	8.7	11.3	19.9	2.0	8.4	5.8	25.8	-	1.5	1.2
Bromus hordeaceus	0.6	-	0.9	0.3	-	-	0.1	-	1.3	-	-	0.0	-	-	0.0	0.0
Carex panza	0.0	1.0	1.4	2.3	0.1	0.0	-	-	0.3	0.1	2.9	4.4	0.0	-	-	-
Dactylis glomeratum	6.6	11.9	8.3	11.3	9.0	0.1	0.2	0.5	2.4	4.6	2.3	2.9	2.2	0.0	0.2	0.1
Festuca arundinacea	30.1	30.9	32.3	26.1	6.4	-	-	-	19.1	15.5	25.1	32.5	27.5	0.0	0.5	0.8
Festuca rubra	-	0.4	0.3	0.0	-	1.2	1.1	0.9	0.0	0.7	0.9	1.5	0.1	0.1	4.8	6.3
Holcus lanatus	0.6	0.9	1.2	2.1	0.4	1.7	5.8	3.4	0.5	1.4	3.2	7.5	0.3	-	0.8	0.3
Juncus bufonius	-	-	-	0.0	-	-	-	-	-	-	-	0.4	-	-	-	-
Juncus sp.	0.4	0.2	0.8	0.7	0.8	-	-	-	0.8	0.4	1.2	0.1	0.8	0.2	0.6	0.6
Luzula comosa	-	-	-	-	-	0.0	-	0.0	0.0	-	-	0.0	-	-	-	-
Poa compressa	-	13.0	4.5	3.1	-	-	-	-	-	7.8	6.9	1.3	-	-	0.0	0.0

Shrubs/Trees																
Cytisus scoparius	7.1	3.5	10.6	10.5	12.5	1.0	11.5	44.4	13.3	1.8	9.7	17.3	11.1	0.1	0.9	3.5
Rosa sp.	-	-	0.0	-	-	0.0	-	-	-	-	-	-	-	-	-	-
Rubus armeniacus	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-

Reed Ranch

	Control				Herbicide				Soil Inversion				Soil Removal			
	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017
Bare	0.8	0.4	0.2	0.4	0.4	10.9	0.6	0.7	0.3	63.8	26.2	10.4	0.1	100.0	98.6	84.9
Moss/lichen	0.3	0.0	0.6	0.2	0.5	2.1	16.4	4.4	0.3	0.0	0.3	4.0	0.3	0.0	-	0.0
Litter	87.8	79.1	87.9	89.2	85.6	36.3	38.8	41.6	83.8	6.0	45.6	62.7	79.4	0.3	0.8	7.4
Forbs																
Achillea millefolium	-	-	-	0.0	-	2.2	9.6	7.8	-	0.8	3.9	2.4	-	0.0	0.3	0.7
Alchemilla occidentalis	-	-	0.0	-	-	-	0.0	-	-	-	0.0	-	-	-	-	-
Allium sp.	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-
Aster subspicatus	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-
Brassica sp.	-	-	-	-	-	0.0	-	-	-	-	-	0.3	-	-	-	-
Cerastium arvense	0.1	1.1	0.0	-	0.3	2.0	0.1	-	0.0	0.0	0.1	-	0.1	-	-	-
Cerastium fontanum	-	-	-	0.2	-	-	-	0.4	0.0	-	-	0.6	-	-	-	0.1
Cirsium vulgare	-	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-
Crepis setosa	0.0	-	-	-	0.1	-	-	-	0.0	-	-	-	-	-	-	-
Equisetum sp.	0.1	-	0.1	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Erodium cicutarium	0.1	-	-	-	0.2	-	-	-	0.1	-	-	-	0.0	-	-	-
Galium aparine	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Geranium dissectum	4.4	2.6	5.6	0.9	5.4	9.6	1.6	1.1	5.7	0.3	2.4	0.4	4.0	0.0	0.0	-
Hypochaeris radicata	14.5	17.6	19.4	13.4	12.1	12.0	49.6	27.2	8.9	6.7	16.6	13.4	8.9	0.0	0.1	0.2
Lotus corniculatus	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-
Lotus micranthus	1.5	-	-	-	2.9	-	-	-	2.3	-	-	-	0.4	-	0.0	-
Lupinus littoralis	-	-	-	-	-	0.2	0.5	0.8	-	-	0.8	0.5	-	-	4.1	5.8
Lupinus sp.	-	-	-	-	-	0.1	0.5	0.0	-	0.7	0.6	0.2	-	0.5	5.3	3.9
Myosotis discolor	0.3	2.1	0.1	0.2	0.2	1.0	0.4	0.0	0.2	0.2	0.0	0.0	0.0	-	-	-
Parentucellia viscosa	0.0	0.1	0.1	0.0	0.0	1.8	0.7	0.3	-	-	-	-	-	-	-	-
Plantago lanceolata	0.2	0.5	1.3	1.1	0.9	0.0	0.3	0.5	1.5	0.4	0.9	0.4	0.9	0.0	0.6	-
Ranunculus occidentalis	1.9	0.7	0.5	0.9	0.4	0.1	0.4	0.4	1.7	0.7	0.1	0.0	0.0	-	-	-
Ranunculus repens	-	-	-	-	-	-	0.1	0.0	-	-	-	0.0	-	-	-	-
Rumex acetosella	1.0	2.1	3.5	0.5	1.9	2.1	22.4	6.0	5.8	10.3	10.3	2.8	1.7	0.1	2.7	4.0
Scleranthus annuus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0

Senecio jacobaea	-	-	-	-	-	-	0.1	0.1	-	-	-	-	2.3	0.0	0.8	0.9
Senecio vulgaris	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	0.0
Spergularia media	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-
Stellaria media	0.0	0.2	0.1	0.1	0.0	-	0.4	-	-	0.1	0.1	0.1	-	-	-	0.1
Taraxacum officinale	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium dubium	1.2	0.8	1.0	0.3	2.6	4.9	7.4	5.3	4.8	0.1	1.7	0.9	1.2	-	0.0	-
Trifolium repens	-	4.2	1.1	0.1	-	4.9	2.4	-	-	1.1	8.1	0.1	-	0.0	-	-
Trifolium sp.	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium subterraneum	-	-	3.5	3.2	-	-	4.6	16.0	-	-	6.0	5.0	-	-	0.1	0.0
Triphysaria pusilla	0.9	0.6	-	0.1	0.6	4.8	1.6	1.1	0.6	0.1	0.3	0.2	0.1	-	-	-
Veronica americana	1.2	2.0	0.4	0.7	1.2	0.8	1.1	0.6	1.6	0.2	0.8	0.8	6.8	-	0.0	0.1
Vicia hirsuta	-	1.0	2.7	1.6	-	0.2	0.3	2.5	-	0.0	0.4	0.0	-	-	-	-
Vicia sativa	6.5	3.0	1.1	2.8	4.0	4.3	2.5	3.4	3.8	2.8	2.3	2.1	6.5	-	0.0	0.0
Vicia tetrasperma	0.5	-	-	-	0.5	-	-	-	0.1	-	-	-	-	-	-	-
Viola adunca	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-	0.0	0.0
Graminoids																
Agrostis alba	3.7	9.4	7.2	7.9	2.4	1.8	6.9	4.1	3.8	4.2	8.7	14.4	2.6	-	0.1	2.8
Anthoxanthum odoratum	23.6	43.9	29.6	32.6	18.9	47.8	24.6	48.9	18.9	8.7	13.0	16.9	20.8	-	0.4	0.8
Arrhenatherum elatius	-	-	-	-	-	-	0.1	-	-	-	3.1	-	-	-	-	-
Bromus hordeaceus	37.2	1.4	11.5	3.1	41.9	0.0	0.4	0.7	21.1	0.4	3.5	6.0	31.9	-	0.1	0.2
Bromus sp. (perennial)	-	-	0.1	-	-	-	-	-	-	-	1.5	-	-	-	0.2	-
Carex panza	-	0.1	0.5	0.2	-	0.1	0.1	0.2	1.3	-	-	-	-	-	-	-
Carex scoparia	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-
Dactylis glomeratum	2.4	9.9	14.7	17.3	4.1	0.3	-	0.0	15.9	3.7	7.4	7.7	18.3	-	0.1	0.1
Danthonia californica	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-
Festuca arundinacea	12.0	27.5	39.6	32.2	7.5	0.0	-	-	12.6	7.1	21.6	15.9	8.1	-	-	0.1
Festuca rubra	1.3	0.8	1.1	0.4	0.6	1.8	3.4	3.0	2.2	0.9	4.0	7.0	-	0.1	1.7	6.3
Holcus lanatus	2.7	6.6	5.4	0.4	1.1	1.8	7.1	7.2	1.1	0.2	0.9	1.8	1.0	-	0.1	0.7
Juncus bufonius	-	-	-	-	-	-	-	-	-	-	0.3	0.1	-	-	-	-
Juncus sp.	-	-	-	-	0.0	-	-	-	1.5	0.4	0.0	0.0	0.7	-	-	0.0
Luzula comosa	-	0.0	-	-	0.1	-	-	0.2	0.0	-	0.1	0.1	-	-	-	-
Poa compressa	-	1.1	2.6	1.2	-	-	-	-	-	1.0	1.6	0.5	-	-	-	0.0
Vulpia sp.	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	0.1	-

Shrubs/Trees																
Cytisus scoparius	0.4	0.6	1.0	0.9	-	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.6	-	-	0.0
Rubus armeniacus	-	-	-	-	-	-	-	-	-	-	0.0	0.0	-	-	-	-

Willapa

	Control				Herbicide				Sand Addition				Soil Inversion				Soil Removal			
	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017
Bare	1.9	1.1	0.1	0.8	0.5	7.1	0.0	10.8	0.8	99.9	84.1	70.3	1.2	24.5	4.4	10.3	1.5	98.8	71.9	76.3
Moss/lichen	29.0	0.1	0.1	1.4	19.8	2.2	12.4	9.3	22.4	-	-	0.0	25.4	2.2	0.8	3.5	21.9	0.1	0.1	6.6
Litter	63.9	62.8	91.4	97.4	72.4	57.8	79.2	60.0	74.4	0.2	5.5	18.0	66.8	30.3	84.4	82.0	63.8	0.7	7.2	23.5
Forbs																				
Achillea millefolium	-	-	-	-	-	0.8	2.1	1.3	-	-	2.8	1.1	-	0.8	3.5	2.3	-	0.2	1.9	1.3
Alchemilla occidentalis	-	-	-	0.0	-	0.0	0.0	-	-	0.0	-	-	-	-	0.1	-	-	-	-	-
Cakile sp.	-	-	-	-	-	-	-	-	-	-	0.1	0.0	-	-	-	-	-	-	-	-
Cerastium arvense	-	0.0	-	0.1	-	0.0	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-
Cerastium glomeratum	0.1	-	-	-	-	-	-	-	0.0	-	-	-	0.0	-	-	-	-	-	-	-
Crepis setosa	-	-	-	-	-	-	-	-	0.0	-	-	-	0.1	-	-	-	-	-	-	-
Erodium cicutarium	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geranium dissectum	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-
Hypochaeris radicata	24.9	9.8	5.7	3.2	20.6	14.6	17.3	8.0	21.6	0.2	3.1	2.9	27.6	4.5	9.2	6.8	32.9	0.1	0.3	0.4
Lotus corniculatus	5.5	5.3	4.4	9.8	14.4	10.3	9.3	21.7	20.1	-	0.3	0.8	6.3	0.4	1.5	13.5	7.1	0.1	0.3	0.8
Lotus micranthus	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Lupinus littoralis	-	-	-	-	-	0.0	-	-	-	-	-	-	-	0.0	-	-	-	0.0	-	-
Matricaria discoidea	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-
Plantago lanceolata	4.8	2.6	3.7	5.8	4.0	1.9	3.0	3.9	0.6	0.0	0.3	0.1	12.1	0.8	3.1	-	6.3	0.3	0.9	0.3
Ranunculus occidentalis	1.9	0.3	0.6	-	0.1	0.0	0.0	-	0.0	-	-	-	-	0.0	-	-	-	-	-	-
Ranunculus repens	-	-	-	0.5	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
Rumex acetosella	1.6	2.1	1.9	2.9	0.8	3.4	2.3	0.5	0.4	0.3	0.8	0.1	1.3	7.9	5.3	3.4	2.9	0.6	2.2	1.4
Rumex crispus	-	-	-	-	-	-	0.1	0.3	-	-	-	-	-	-	-	-	-	-	-	-
Senecio vulgaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-
Solidago sp.	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	0.0	-	-	0.3	0.2
Spergularia media	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	0.0	0.1
Stellaria media	-	-	0.0	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-
Taraxacum officinale	-	-	0.1	0.3	0.5	1.4	0.5	-	0.3	-	-	-	0.7	0.1	0.2	-	-	-	-	-
Trifolium dubium	3.5	1.6	2.8	2.7	2.7	1.9	6.1	6.7	0.0	-	0.2	0.6	3.8	0.6	2.1	0.2	0.2	-	-	0.1

Trifolium repens	2.1	0.3	2.8	-	3.9	0.4	8.9	-	1.6	0.1	4.0	9.4	5.1	0.5	5.6	-	0.5	0.0	0.1	-
Trifolium subterraneum	-	-	-	1.2	-	-	-	15.7	-	-	4.3	7.8	-	-	-	-	-	-	-	-
Viola adunca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-
Graminoids																				
Agrostis alba	27.4	42.5	48.0	42.9	21.4	14.3	27.4	32.0	24.1	0.1	2.4	3.7	26.9	29.4	48.4	19.5	40.6	0.7	4.9	7.9
Ammophila breviligulata	-	-	-	-	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-
Anthoxanthum odoratum	31.1	40.8	18.3	28.8	31.4	31.9	23.0	33.5	27.1	0.2	2.3	4.0	32.1	25.1	14.3	10.1	46.9	0.5	2.3	2.3
Bromus hordeaceus	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex panza	-	-	-	-	0.0	-	-	-	0.2	-	-	-	0.4	-	-	-	-	-	0.1	0.1
Carex scoparia	-	-	-	-	0.0	-	-	-	1.6	-	-	-	-	-	-	-	-	-	-	-
Carex sp.	-	-	0.2	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomeratum	0.2	0.1	0.2	0.1	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-	-	-
Elymus trachycaulus	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Festuca arundinacea	0.6	0.5	0.3	1.3	0.3	-	-	-	-	-	-	0.1	0.0	-	-	-	-	-	-	-
Festuca rubra	17.7	9.0	17.6	10.1	14.1	4.4	8.4	2.3	14.4	0.1	0.4	0.6	8.6	1.3	3.3	11.3	7.8	1.1	8.9	11.0
Holcus lanatus	7.1	10.7	16.6	4.6	9.9	13.4	23.2	6.7	15.8	-	0.8	1.4	3.8	2.3	11.5	20.0	0.3	0.0	0.3	0.2
Juncus bufonius	-	-	-	-	-	-	-	-	-	-	0.6	0.0	-	-	0.3	-	-	-	0.0	-
Juncus sp.	-	-	-	-	0.4	-	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Lolium perenne	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poa compressa	-	0.9	4.9	1.2	-	0.3	0.9	-	-	-	-	0.0	-	0.1	0.1	0.3	-	-	-	-
Shrubs/Trees																				
Acer sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.0
Cytisus scoparius	-	0.1	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-
Rubus armeniacus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	-

Yeon

	Control				Herbicide				Soil Removal				Spoils Addition*		
	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016	2017	2013	2015	2016
Bare	-	0.1	0.1	0.2	-	3.7	2.7	2.3	-	97.5	66.9	61.6	-	38.8	12.0
Moss/lichen	-	1.3	3.4	9.0	10.6	3.8	8.2	23.1	3.3	0.1	0.0	3.1	-	0.6	7.8
Litter	6.4	85.8	90.5	92.7	0.3	77.8	70.2	56.1	0.6	2.3	20.2	38.9	-	41.3	81.3
Forbs															
Achillea millefolium	-	-	-	-	-	1.5	2.9	1.8	-	0.4	1.5	0.6	-	-	-
Alchemilla occidentalis	-	-	0.2	0.2	-	0.0	0.1	0.3	-	-	0.0	0.1	-	-	-
Arenaria sp.	-	-	0.0	-	-	-	-	-	-	-	0.0	-	-	-	-
Aster subspicatus	-	0.0	-	-	-	0.0	-	-	-	0.0	-	0.0	-	-	-
Brassica sp.	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-
Cerastium arvense	-	0.3	0.2	0.1	-	1.9	0.7	0.2	-	-	-	-	-	-	-
Equisetum sp.	0.7	0.4	1.6	1.0	0.8	0.1	0.9	0.4	0.6	0.6	1.4	0.5	-	-	-
Galium aparine	-	-	0.7	0.8	-	-	-	-	-	-	-	-	-	-	-
Hypochaeris radicata	2.5	4.9	8.2	7.2	4.9	0.9	8.1	12.7	2.6	0.2	0.7	0.5	3.8	6.0	5.8
Iris sp.	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
Lathyrus sp.	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Lupinus littoralis	-	-	0.2	0.1	-	-	0.7	0.7	0.3	-	2.7	4.1	-	-	0.8
Lupinus sp.	-	0.2	-	-	-	0.0	-	-	-	0.3	0.3	0.2	-	0.1	0.1
Plantago lanceolata	-	-	-	-	0.4	0.1	0.1	0.3	-	-	-	-	-	-	-
Polystichum munitum	-	0.0	-	-	-	-	-	-	0.3	-	-	-	-	-	-
Rumex acetosella	1.2	0.4	1.4	0.7	2.3	1.2	3.0	1.3	1.3	0.0	0.8	0.8	6.3	5.5	3.8
Senecio vulgaris	-	-	0.0	-	-	3.6	2.0	-	-	0.0	0.0	-	-	-	-
Solidago sp.	-	-	-	-	-	-	-	0.0	-	-	0.1	-	-	-	-
Spergularia media	-	-	-	-	-	-	-	-	-	0.1	0.0	0.0	-	-	-
Trifolium dubium	-	0.7	1.5	0.4	-	0.0	0.1	-	-	-	-	0.0	-	-	-
Triphysaria pusilla	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-
Veronica americana	-	0.0	-	0.0	-	0.3	0.3	0.2	-	-	0.0	-	-	-	-

Vicia hirsuta	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Vicia sativa	0.2	1.0	4.4	1.0	-	1.4	1.0	0.7	0.2	0.2	0.2	-	-	-	-
Viola adunca	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-
Graminoids															
Agrostis alba	49.8	22.2	8.4	9.8	32.1	2.0	2.4	2.2	24.8	0.9	0.7	0.7	13.8	8.8	1.8
Agrostis B	8.3	40.7	29.1	33.4	10.3	-	11.9	11.3	6.6	2.2	3.4	2.6	-	5.5	2.3
Agrostis sp.	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Aira caryophylla	-	0.1	-	-	-	0.8	3.9	4.4	-	-	0.9	0.9	-	-	0.4
Aira praecox	-	1.0	1.5	0.1	-	0.3	3.6	3.2	-	0.2	1.2	0.8	-	1.3	5.0
Ammophila arenaria	3.3	1.4	1.2	0.4	4.8	0.1	0.3	0.2	8.6	1.1	5.4	6.0	42.5	32.5	30.1
Ammophila breviligulata	22.3	6.8	38.6	52.9	27.5	0.8	11.6	15.7	30.6	1.4	8.5	12.0	14.0	8.3	13.0
Anthoxanthum odoratum	11.3	26.8	19.3	24.8	13.7	16.6	13.1	16.7	18.8	0.1	2.1	5.1	13.5	14.0	6.0
Arrhenatherum elatius	-	-	2.9	-	-	-	-	-	-	-	-	-	-	-	-
Bromus hordeaceus	-	-	0.0	-	-	-	0.1	0.2	-	-	0.0	-	-	-	0.0
Carex panza	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.3
Dactylis glomeratum	0.3	10.4	3.9	2.3	-	0.0	0.1	-	-	-	-	-	-	-	-
Festuca arundinacea	-	0.3	1.4	0.5	-	-	-	0.0	-	-	0.1	-	3.8	2.0	10.0
Festuca rubra	-	-	-	-	2.6	4.9	8.2	12.9	21.5	1.1	9.6	13.5	-	6.8	11.8
Holcus lanatus	6.5	2.8	0.7	1.2	8.0	11.0	3.2	0.7	1.9	0.3	0.3	0.0	8.5	3.0	1.8
Juncus bufonius	-	-	-	-	-	0.0	-	-	-	0.0	-	-	-	-	-
Luzula comosa	-	-	-	-	-	0.0	0.1	0.1	-	0.0	0.0	0.1	-	0.1	0.5
Poa compressa	-	1.5	3.0	3.0	-	-	0.1	-	-	-	-	0.1	-	-	0.2
Vulpia sp.	-	-	-	-	-	0.1	0.9	-	-	-	0.0	-	-	-	-
Shrubs/Trees															
Acer sp.	-	-	-	-	-	-	-	0.0	-	-	-	0.0	-	-	-
Cytisus scoparius	-	0.5	6.6	11.4	1.9	0.1	0.9	1.8	0.9	0.2	3.2	2.2	-	0.3	2.0
Rosa sp.	0.1	0.1	0.0	0.2	-	-	-	-	2.1	0.1	0.3	0.3	-	-	-
Rubus armeniacus	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus ursinus	0.3	-	0.5	0.1	0.4	-	-	-	-	-	-	-	-	-	-

*Not sampled in 2017 – see Appendix A.

APPENDIX C. TREATMENT AND IMPLEMENTATION SCHEDULES BY SITE THROUGH SPRING 2017.

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
2016	Spring	May	Monitor	Monitor	Monitor	Monitor
		June	Mow	Mow	Mow	Mow
2017	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[1]	Mow[1]	Mow[1]
2016	Spring	May	Monitor	Monitor	Monitor
		June	Mow[1]	Mow[1]	Mow[1]
2017	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.

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

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**[1]	Mow**[1]	Mow**[1]
2016	Spring	May	Monitor	Monitor	Monitor
		June	Mow[1]	Mow[1]	Mow[1]
2017	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.

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

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**[1]	Mow**[1]	Mow**[1]
	Fall	September	?	?	?
2016	Spring	May	Monitor	Monitor	Monitor
		June	Mow[1]	Mow[1]	Mow[1]
2017	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.

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

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	Monument	Monument	Monument
			Monitor	Monitor	Monitor	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]
2017	Spring	April-Aug	Mow[1]	Mow[1]	Mow[1]	Mow[1]
		May	Monitor	Monitor	Monitor	Monitor
		-	Weed/Trim	Weed/Trim	-	Weed/Trim

*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
2016	Spring	May	Monitor	Monitor
2017	Spring	May	Monitor	Monitor

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