Upland Restoration Monitoring, Williamson River Delta Preserve 2013 Results

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The Tulana project area of the Williamson River Delta Preserve contains about 775 acres of uplands that remained unflooded when sections of levee were removed to hydrologically reconnect the Delta to Upper Klamath and Agency Lakes in 2007. Within those upland areas 500 acres have been leased to a local farmer for agriculture production, while native revegetation has been implemented within the remaining 275 acres of uplands. Restoration has focused on establishing vegetation similar to adjacent reference areas and ecological sites (Elseroad 2005). From 2005 through 2008, various treatments were used to reduce weedy species establishment and to prepare the seedbed for revegetation. In the fall of 2009 about 180 acres were seeded with basin wildrye (*Leymus cinereus*), Idaho fescue (*Festuca idahoensis*), squirreltail (*Elymus elymoides ssp. brevifolius*) and Nuttall's alkaligrass (*Puccinellia nuttalliana*) in various combinations totaling approximately 9.5 PLS pounds/acre (figure 1). The basin wildrye and fescue were collected locally and then propagated/outgrown for seed by BFI Native Seeds in Moses Lake, Washington. The squirreltail and alkaligrass were purchased from Granite Seed Company in Lehi, Utah. The squirreltail is an unspecified variety with atypical characteristics; it looks similar to Canada wildrye, a large bunchgrass (Winter Damon, L&H Seeds, personal communication, 2014 Apr 30). Riverbend (64 ac.) and Searchlight (26 ac.) Fields were seeded with basin wildrye and Idaho fescue. Camp (37 ac.) and Strip (54 ac.) Fields were seeded with basin wildrye, squirreltail and Nuttall's alkaligrass.

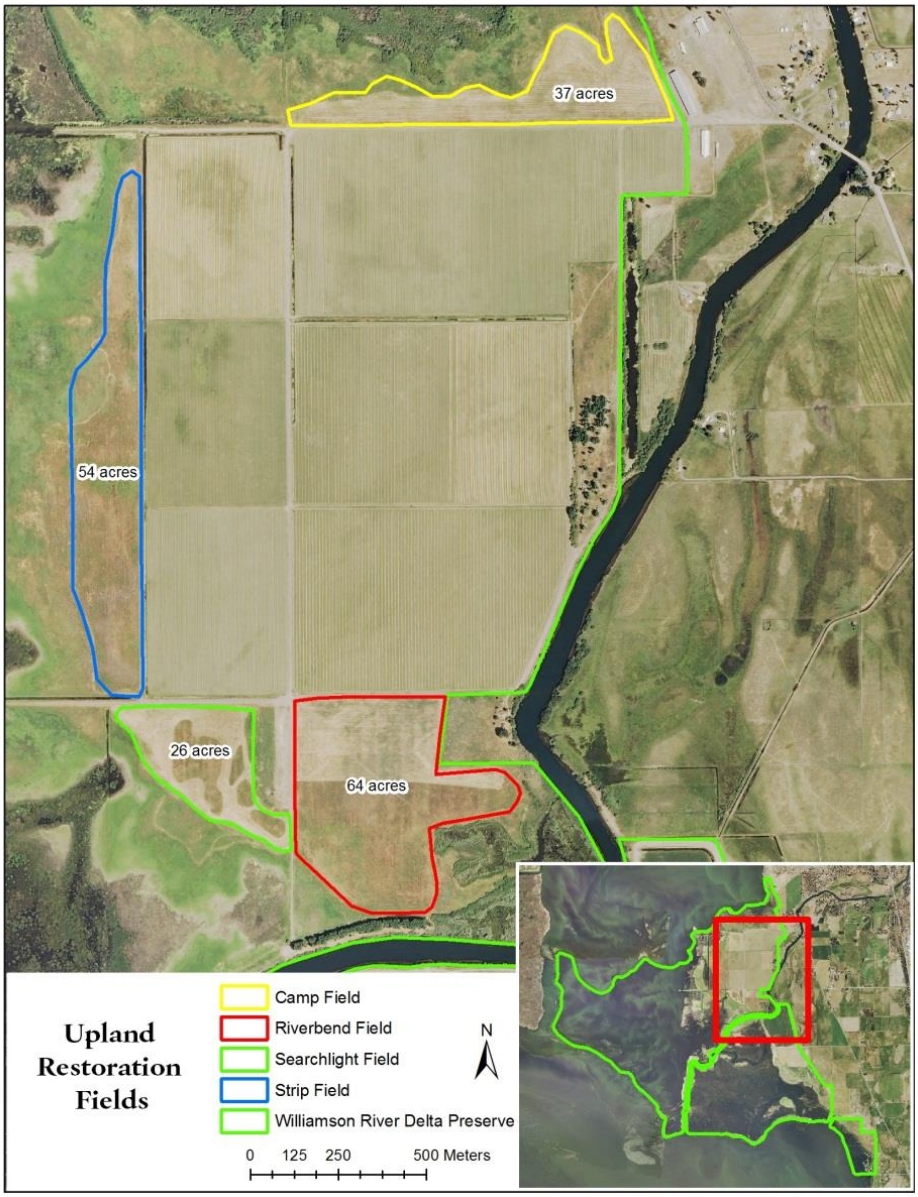


Figure 1. Upland restoration fields. Williamson River Delta Preserve, Upper Klamath Lake, Oregon.

Since revegetation in 2009, broadcast herbicide and mowing treatments have been implemented to reduce dominant exotic invasive species, primarily cheatgrass (*Bromus tectorum*), herb sophia (*Descurainia sophia*), prickly lettuce (*Lactuca serriola*) and tall tumblemustard (*Sisymbrium altissimum*), as well as dominant native weedy species common fiddleneck (*Amsinckia menziesii* var. *intermedia*) and stickwilly (*Galium aparine*).

Other exotic species that occur in all four fields but remain a minor component include lambsquarters (*Chenopodium album*), Canada thistle (*Cirsium arvense*) and shepard's purse (*Capsella bursa-pastoris*). Canada thistle occurs in the drier margins of the transition from riparian to upland habitat. In such places it is a dominant species; however it is unlikely to spread beyond currently populated areas. Bull thistle (*Cirsium vulgare*), poison hemlock (*Conium maculatum*) and Scotch cottonthistle (*Onopordum acanthium*) occur along the main levee roads adjacent to upland areas and have been treated with herbicide spot treatments, chopping, mowing and clipping annually since the mid-1990s.

In the summer of 2011, Camp and Strip Fields were mowed entirely, while only portions of Riverbend and Searchlight Fields were mowed (figure 2). Areas of Riverbend and Searchlight Fields with successful basin wildrye establishment were avoided in order to maintain those populations. Mowing was implemented as a management treatment in order to reduce weedy species populations, stimulate seeded grass and prepare fields for forb seeding.

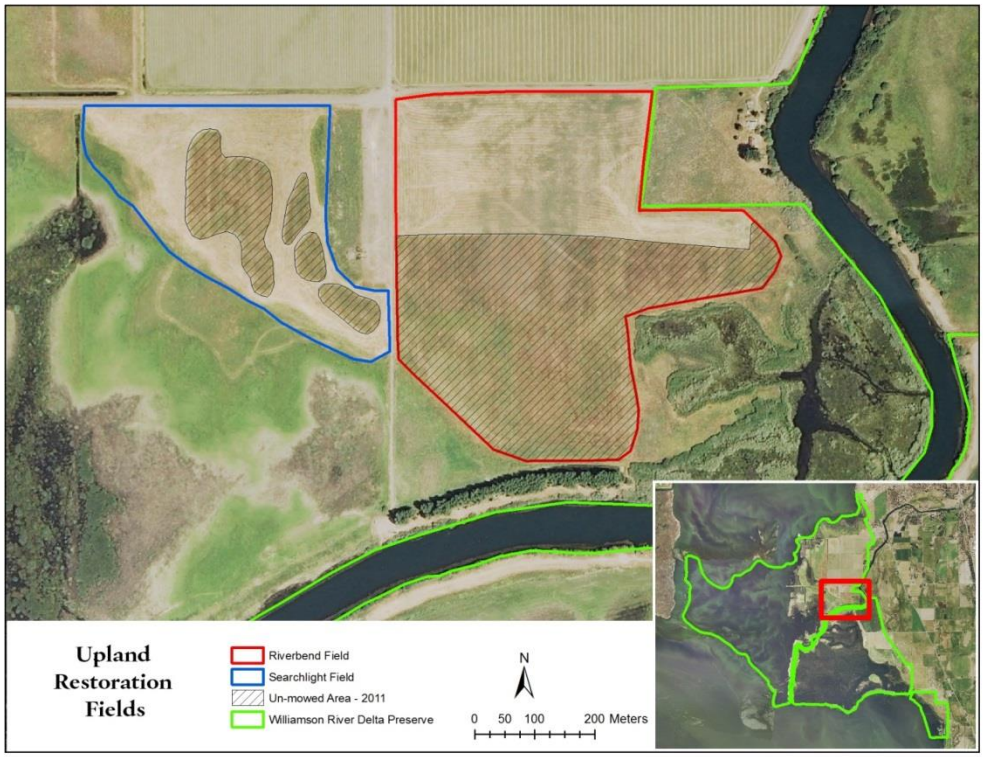


Figure 2. Mowed and unmowed areas of Riverbend and Searchlight Fields.

In the fall of 2011, all fields were hand-broadcast seeded with common yarrow (*Achillea millefolium*), Lewis flax (*Linum lewisii*), threadleaf fleabane (*Erigeron filifolius*) and parsnipflower buckwheat (*Eriogonum heracleoides*, also known as Wyeth's buckwheat). About 350 pounds of seed was purchased from BFI Native Seeds. Following seeding, the mowing treatment was repeated in order to improve seed to soil contact and provide mulch for seedlings. Also in fall 2011, four rubber rabbitbrush (*Ericameria nauseosa*) seedlings were planted in Camp Field in order to test planting methods.

Since 2010, revegetated areas have been monitored for success annually during the months of July and August (see Appendix A for species list). Twenty-five randomly selected $1m^2$ plots per field have been used to observe seeded species density, aerial cover of all plant species and percent bare ground/litter. Plots are re-randomized each year that monitoring occurs in order to increase the area sampled over time. In 2013, plot locations were randomly selected using the

XToolsPro extension "Create Random Sampling Points" tool in ESRI ARCMap 10.1. The objective of revegetation monitoring is to evaluate the success of management treatments.

Results

Preferred Native Species

Seeded native grass species initially were successful in 2010, with high density and low cover. A rapid decline in density occurred from 2010 to 2011 as seedlings failed to establish, however cover greatly increased through 2012. This trend followed the expected trend of early succession. Results from 2013 indicate density stabilization but a decline in cover. Average cover across all sites declined from 33% in 2012 to 25% (± 3%) in 2013. Strip Field had the lowest average cover with 8% (± 3%) of seeded native grass, while Riverbend Field had the highest cover with 37% (± 8%) (figure 3). The decline in cover is counterintuitive because density appears to have stabilized. Loss of native grass cover is likely due to drought conditions in 2012 and 2013 (Tipler 2013). Anecdotally, visual observation did not indicate such a severe decline in native grass cover within Strip Field. Native grasses have established in a mosaic pattern within Strip Field. Since the sampling design does not include stratification by habitat, more plots may have been randomly located in areas of poor establishment. Additionally, Strip Field appears to have soils with lower water holding capacity as compared to other fields, which would result in vegetation being more susceptible to drought conditions as compared to other areas, resulting in lower cover compared to other fields. Average densities of seeded native grass ranged from 2-4 plants/m^2, which was similar to densities observed in 2012 (3-4 plants/m^2). Searchlight Field had the lowest average density of seeded native grass with 2.4 plants/m^2 (± 0.2 plants/m^2), while Camp Field had the highest with 4.3 plants/m^2 (± 0.9 plants/m^2) (figure 4). Since an initial rapid decline in density from 2010 to 2011, native grass density appears to have stabilized as individuals have established within preferred habitat zones.

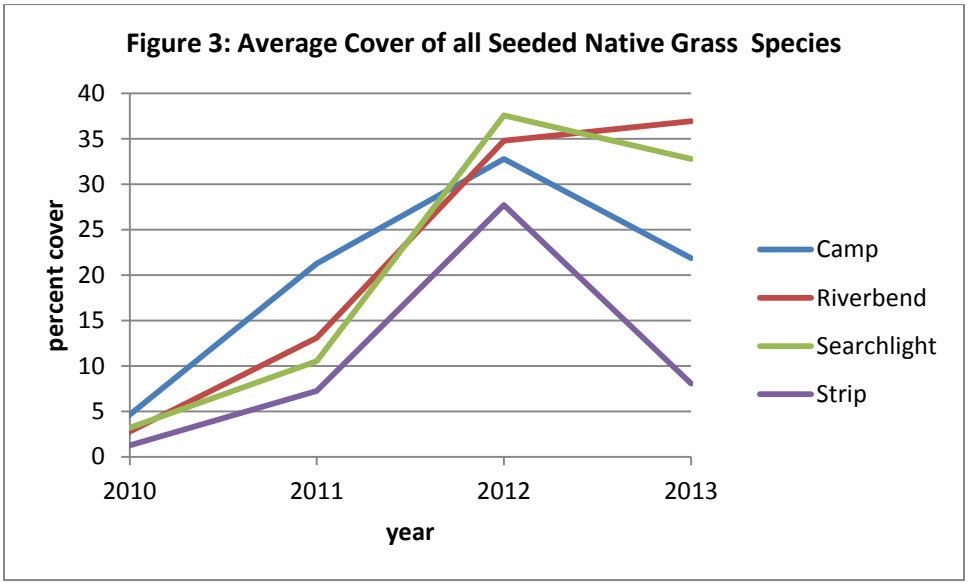


Figure 3. Comparison of seeded native grass species average percent cover by year.

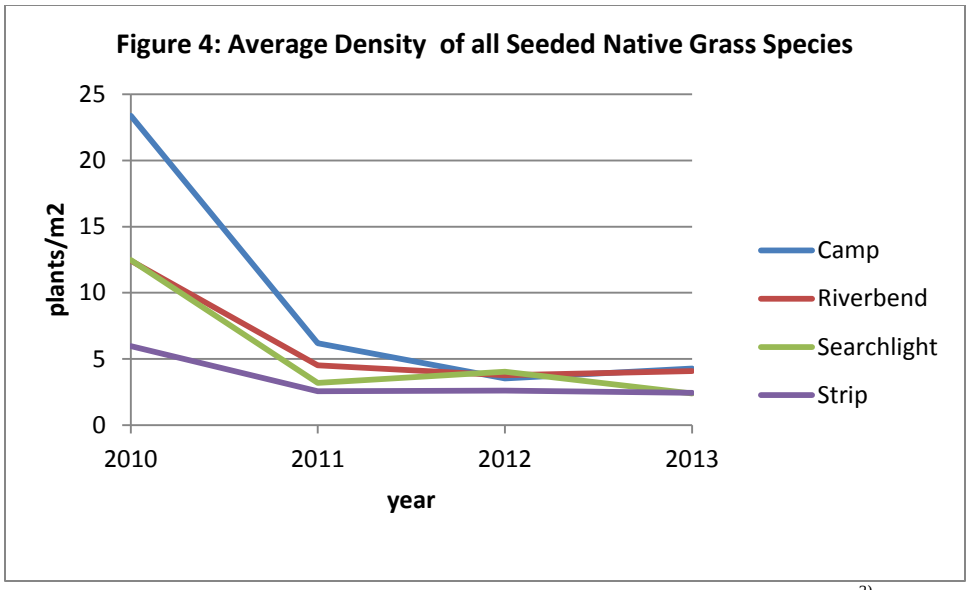


Figure 4. Comparison of seeded native grass species average density (plants/m$^{2)}$ by year.

Basin wildrye has successfully established in all four fields in a mosaic pattern indicating preferred habitat. As this species establishes it is expected that average density will decline as average cover increases because it is a very large bunchgrass. Density of basin wildrye increased in Camp and Riverbend Fields, while it decreased in Searchlight and Strip Fields, reversing the trends from the 2012 analysis (figure 5). In Camp Field squirreltail has continued to decrease in density since 2011 and has been somewhat successful in Strip Field (figure 6). However, squirreltail appears to be quite robust where it has established within preferred habitat, primarily interspersed with basin wildrye. Idaho fescue has not been successful; density decreased in Searchlight Field and it was not observed in Riverbend Field in 2013 (figure 7). The Nuttall's alkaligrass seeding failed; only one plant was observed in 2011 and it has not been observed since.

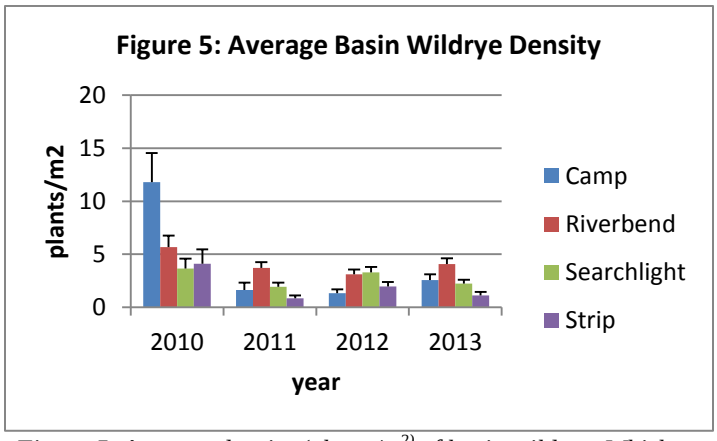


Figure 5. Average density (plants/m$^{2)}$ of basin wildrye. Whiskers indicate standard error.

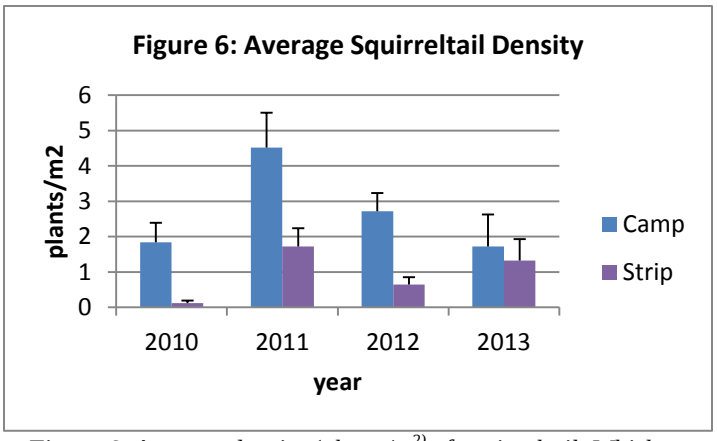


Figure 6. Average density (plants/m$^{2)}$ of squirreltail. Whiskers indicate standard error.

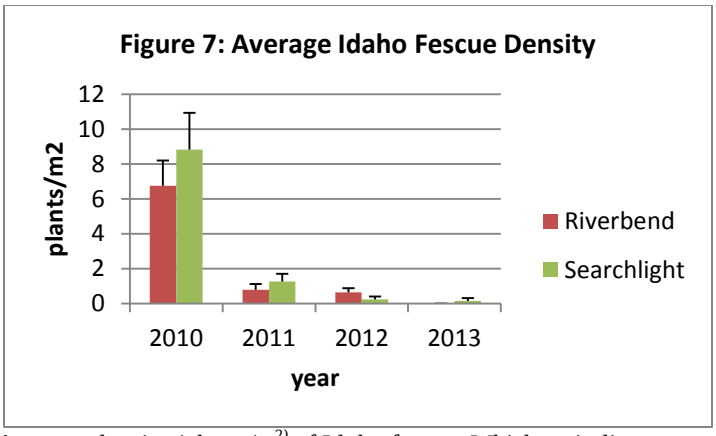
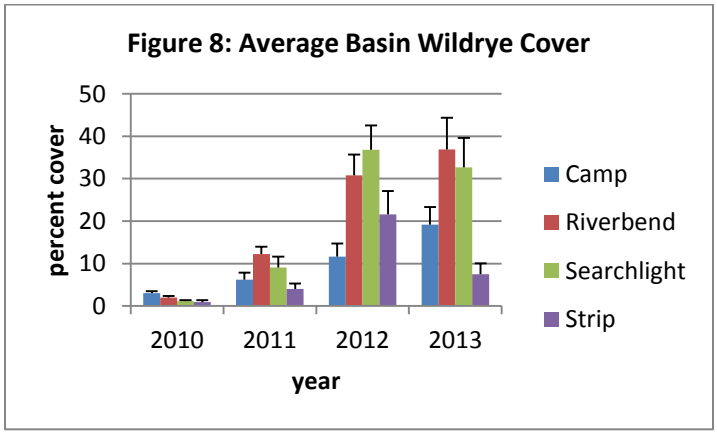
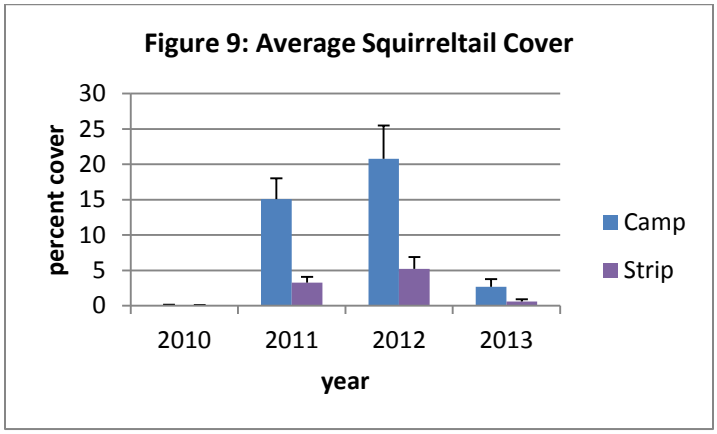
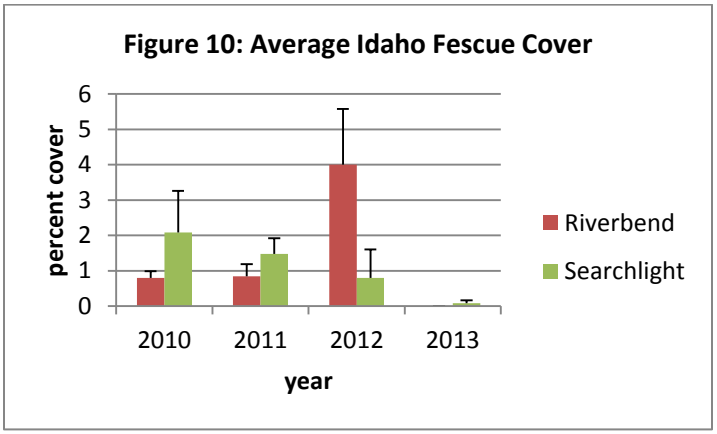


Figure 7. Average density (plants/m$^{2)}$ of Idaho fescue. Whiskers indicate standard error.

Following a steady increase in cover from 2010, in 2013 basin wildrye increased in cover in Camp and Riverbend Fields, while it declined in Searchlight and Strip Fields (figure 8). Both squirreltail and Idaho fescue declined in cover (figures 9 and 10). Though squirreltail cover has been reduced in Strip Field and declined greatly in Camp Field, it appears to be healthy where it has established within preferred habitat. Additionally, foxtail barley (*Hordeum jubatum*) was observed in Camp and Strip Fields, though it had low cover (0.4% ± 0.4% and 0.04% ± 0.04% respectively). Foxtail barley is a native species that has naturally begun colonizing the uplands; it was not observed in previous years' surveys.







Figures 8-10. Average percent cover of seeded native grass species. Whiskers indicate standard error.

Lewis flax and common yarrow have been minimally successful. In 2013, Lewis flax was observed in a single plot in Strip Field with a density of 0.2 plants/m^2 and common yarrow was not observed. Anecdotally, Lewis flax and common yarrow were observed occasionally throughout Strip and Camp Fields in 2013. In 2012, the density of Lewis flax was 0.8 plants/m^2 (± 0.6 plants/m^2) in Camp Field and 1.4 plants/m^2 (± 1.2 plants/m^2) in Strip Field. In 2012, the density of common yarrow was 0.6 plants/m^2 (± 0.4 plants/m^2) in Camp Field. Threadleaf fleabane and parsnipflower buckwheat have not been observed to date. The forb seeding treatment has not been successful. Drought conditions are likely greatly limiting success. Along with this, following the mowing treatment litter cover was quite dense during planting and seeds may not have been able to get the seed to soil contact necessary for dormancy and spring germination. Also, annual weeds are dominant in these fields and are currently outcompeting native forb establishment.

An unidentified *Nemophila* species was observed throughout Searchlight Field during the 2010 survey with average cover of 2.7% (± 0.8%). However, it was not observed in any other year. This native annual has likely been outcompeted by more aggressive weed species.

The rubber rabbitbrush plants were all individually GPS-located. The GPS points were relocated in 2013 and none of the plants were observed, therefore these plantings failed.

Weed Species

Cheatgrass occurred in all four fields, with high average cover in Riverbend, Searchlight and Strip Fields (figure 11). Riverbend Field increased to 37% (± 8%) from 20% (± 4%) in 2012. Searchlight Field remained stable (19% ± 5%); cover was 17% (± 5%) in 2012. Strip Field decreased from 43% (± 6%) in 2012 to 38% (± 6%) in 2013. Camp Field decreased from 49% (± 5%) in 2012 to 5% (± 2%) in 2013. Anecdotally visual observation did not indicate that average cheatgrass cover should have had such a strong decline in Camp Field. Camp Field does have a mosaic pattern of vegetation establishment, including patches dominated by cheatgrass. Since the sampling design does not include stratification by habitat, more plots may have been randomly located in areas of low cheatgrass cover. Along with this, stickwilly and common fiddleneck did increase in Camp Field, which would likely be a cause of some of the decline in cheatgrass cover. After a steady increase from 2010 to 2011, trends are variable as compared to the trends from the 2011 to 2012 growing seasons.

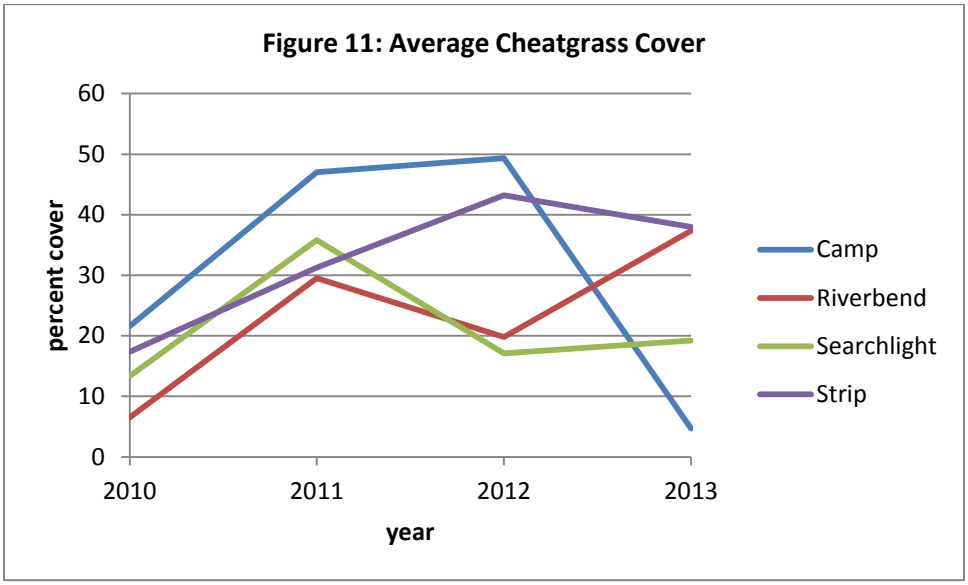


Figure 11. Average percent cover of cheatgrass.

Common fiddleneck, a weedy native species that occurred in all four fields, was the dominant weed species in Camp Field (15% ± 6%), as well as the dominant weedy forb in Riverbend Field (8% ± 4%). Strip Field had a decline in common fiddleneck, all other fields have had an increase (figure 12). Stickwilly was another weedy native species that occurred in

all four fields, and comprised 5% (± 2%) of Camp Field. Stickwilly has remained stable in all fields except Camp Field where it greatly increased from 2011 and then had a slight increase from 2012 to 2013 (figure 13). Other native weedy forbs identified were Canadian horseweed (*Conyza Canadensis*), tiny trumpet (*Collomia linearis*), tall annual willowherb (*Epilobium brachycarpum*), fringed willowherb (*Epilobium ciliatum* ssp. *watsonii*) and Norwegian cinquefoil (*Potentilla norvegica*). However, these species made up a small component of the restored lands.

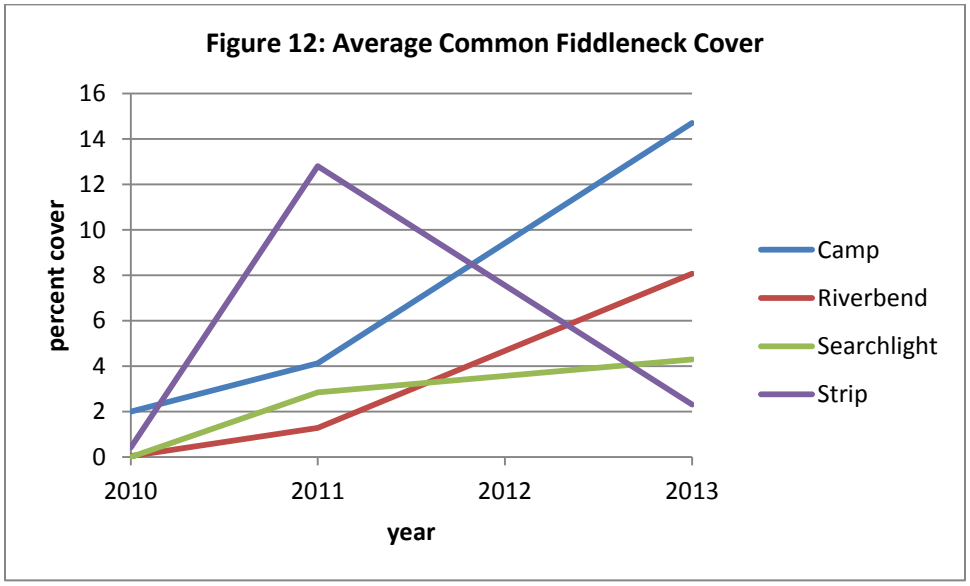


Figure 12. Average percent cover of common fiddleneck.

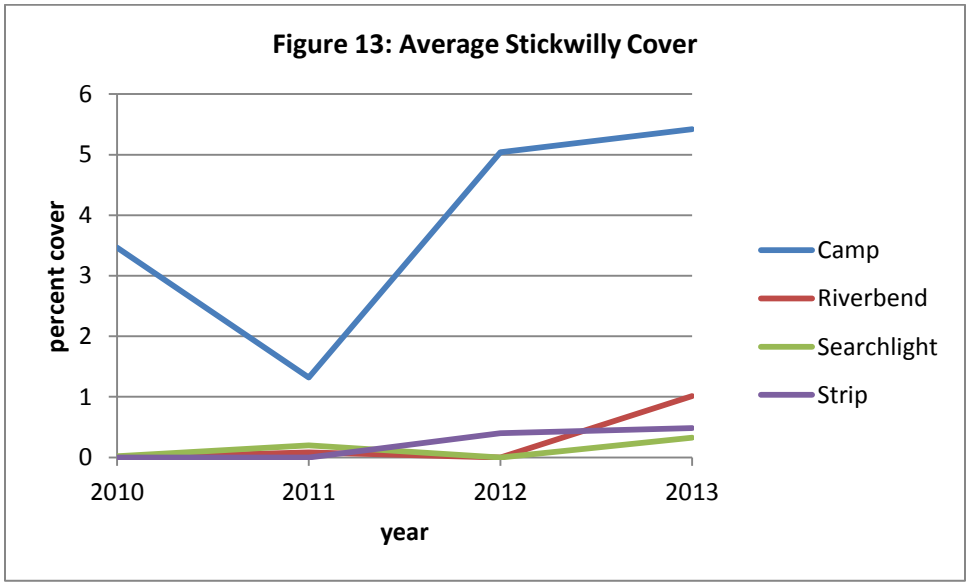


Figure 13. Average percent cover of stickwilly.

The non-native forbs herb sophia, prickly lettuce and tall tumblemustard occur across the entire project area, ranging up to 5% average cover in 2013 (figures 14-16). These plants were established throughout the project area prior to restoration and have remained a major component within restored areas. Canada thistle and lambsquarters also occur across the entire project area; however they remain a relatively small component of upland areas. Though Canada thistle has established and become a dominant species in preferred habitat zones, it is unlikely to spread beyond current established areas. Bull

thistle was infrequently observed in both Searchlight and Strip Fields in 2012, however it was not observed in any other years.

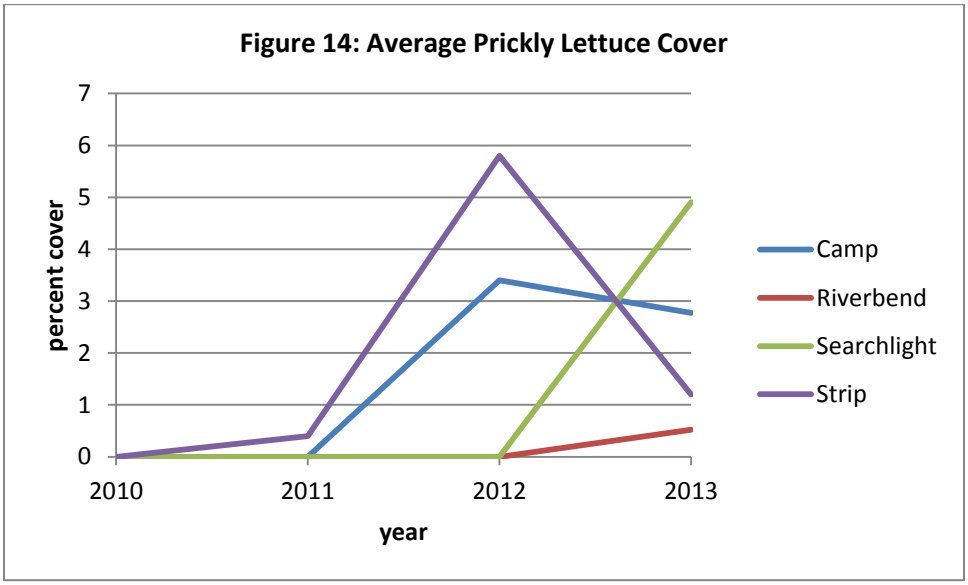


Figure 14. Average percent cover of prickly lettuce.

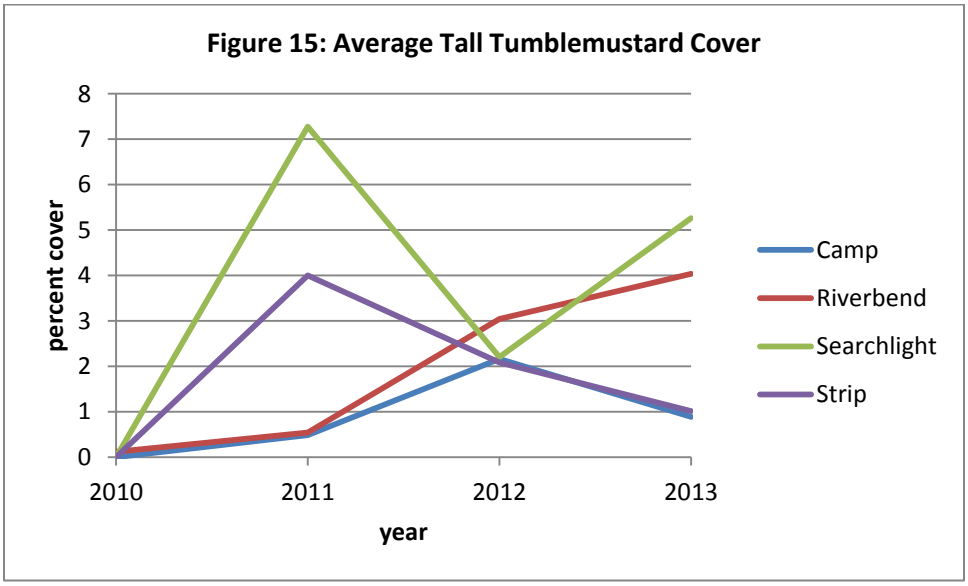


Figure 15. Average percent cover of tall tumblemustard.

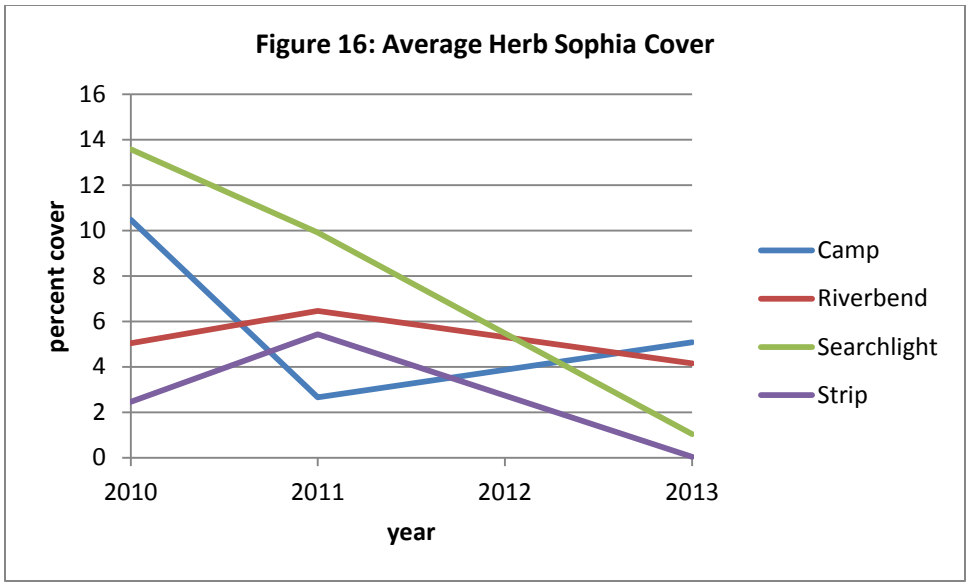


Figure 16. Average percent cover of herb sophia.

Ground Cover

Average bare ground has remained low since a steep decline from 2010 to 2011 (figure 17). Average litter cover greatly increased between 2012 and 2013 (figure 18). Between 2011 and 2012 a decline in litter indicates the mowing treatments; however the sharp increase in 2012 indicates recovery of annual species. These trends follow the expected succession of the dominant annual species.

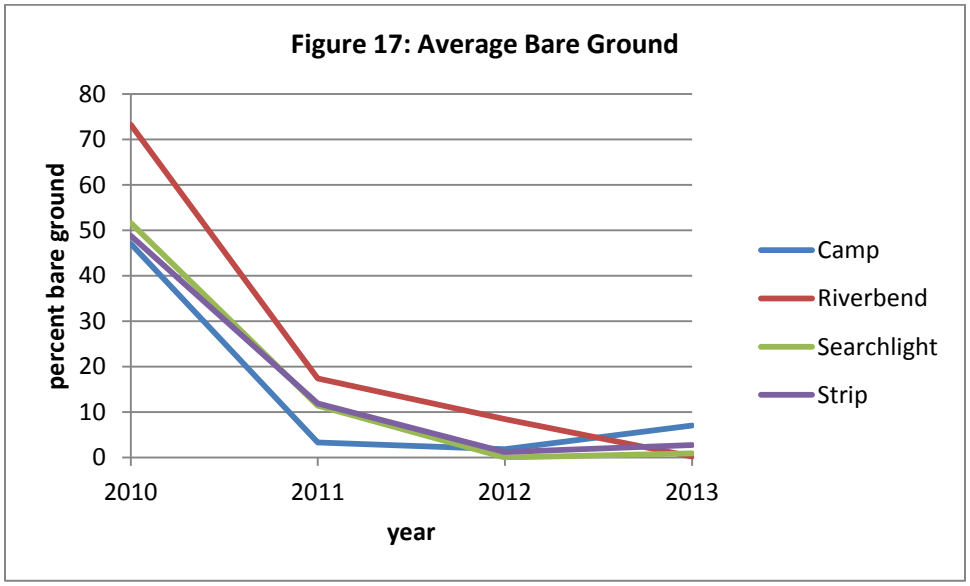


Figure 17. Average percent bare ground.

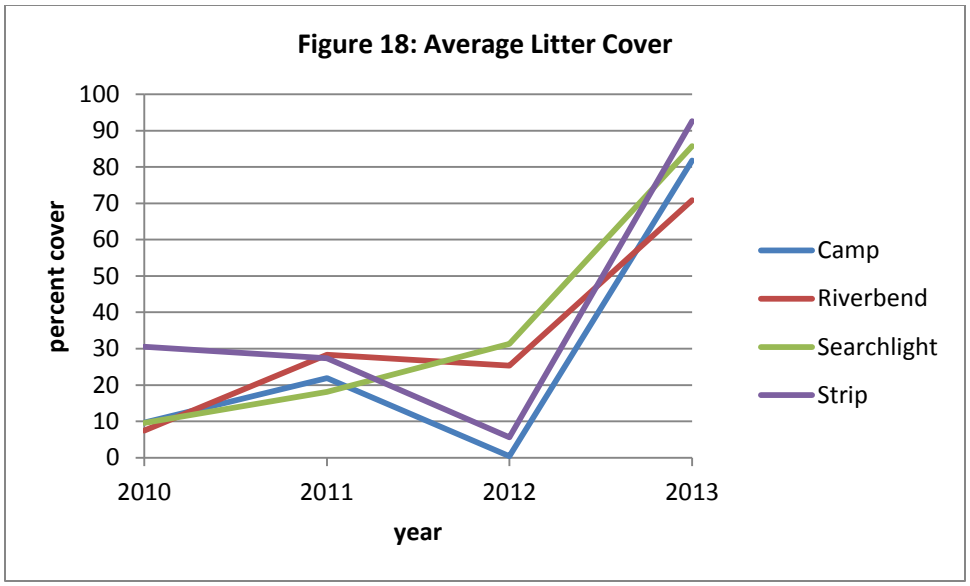


Figure 18. Average percent cover of litter.

Mowing Treatments

In 2011, Camp and Strip Fields were mowed entirely and areas of Riverbend and Searchlight Fields with poor basin wildrye establishment were mowed (figure 2). Mowing was implemented as a management treatment in order to reduce weedy species populations, stimulate seeded grass and prepare fields for forb seeding.

Basin wildrye was the only grass species seeded in all four fields and therefore is the only native species used for comparison of mowing treatments. In unmowed areas of Riverbend Field basin wildrye declined in density from 2012 to 2013, while mowed areas remained stable (figure 19). However, both unmowed and mowed areas of Searchlight Field declined in density. Percent cover trends of basin wildrye were variable by field in mowed areas, while unmowed areas increased in cover (figure 20). However, unmowed areas of both Riverbend and Searchlight Fields had successfully established populations and so were avoided in order to maintain those populations. Such areas would naturally have increased in percent cover as compared to areas of poor success. Therefore, there is no apparent trend for basin wildrye in relation to mowing treatments.

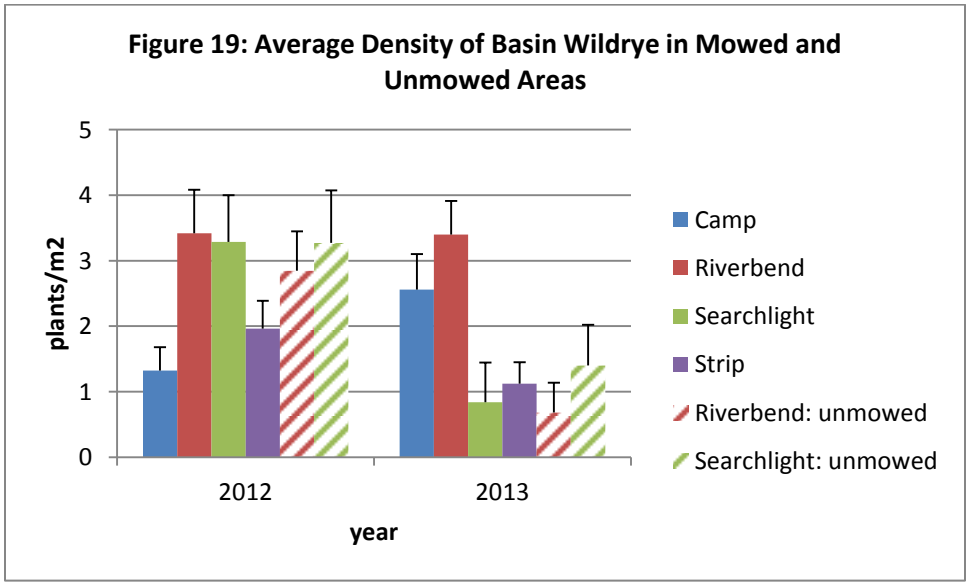


Figure 19. Average density of basin wildrye in mowed and unmowed areas.

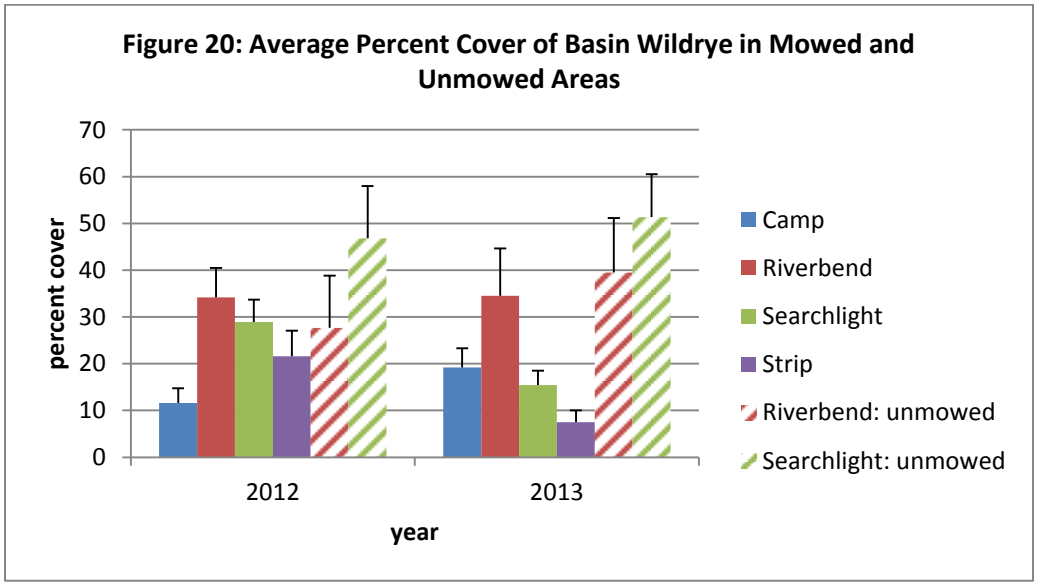


Figure 20. Average percent cover of basin wildrye in mowed and unmowed areas. Whiskers indicate standard error.

Though cheatgrass declined in average percent cover in Camp Field in mowed areas, mowing does not appear to have had an effect in any of the other fields (figure 21). Unmowed areas of Riverbend Field had a substantial increase in cheatgrass cover and to a lesser extent cheatgrass increased in Searchlight Field. Anecdotally, visual observation did not indicate such a strong disparity in mowed to unmowed areas of Riverbend Field. Additionally, visual observation did not indicate that average cheatgrass cover should have had such a decline in Camp Field. Both fields have strong mosaic patterns of vegetation establishment. Since the sampling design does not include stratification by habitat, more plots may have been randomly located in areas that did not represent the visual observational trends for those fields. Other than in Camp Field, it appears that though cheatgrass did not decline in most mowed areas, the mowing treatment may have resulted in stabilizing cheatgrass. Average percent litter cover increased substantially in all fields in both mowed and unmowed areas (figure 22). Along with this, unmowed areas had similar amounts of litter cover as compared to mowed areas; therefore it does not appear that mowing treatments had an effect on litter cover. The average percent bare ground was low in all fields and there was no apparent trend for percent bare ground between mowed and unmowed areas.

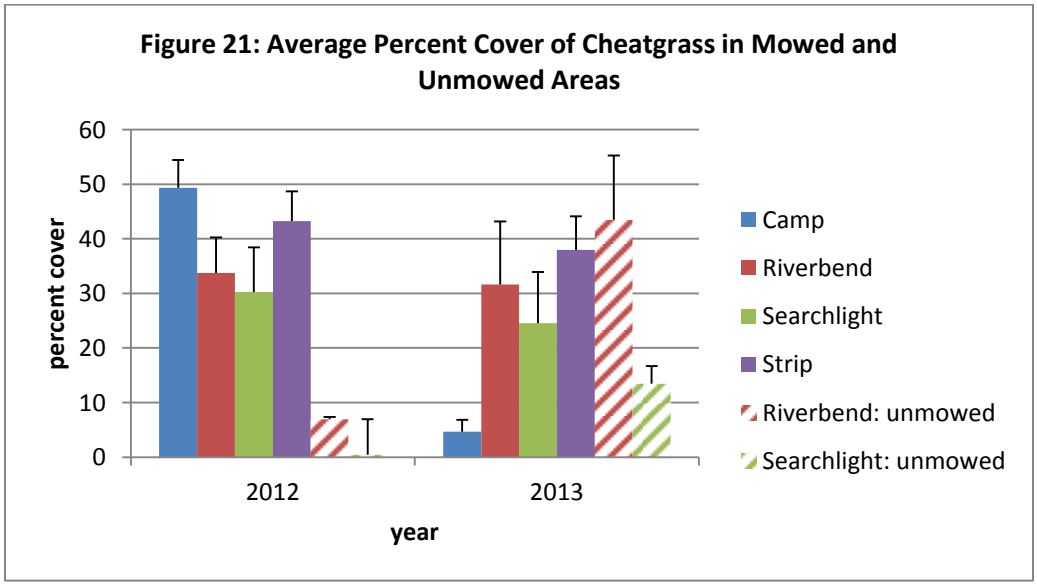


Figure 21. Average percent cover of cheatgrass in mowed and unmowed areas. Whiskers indicate standard error.

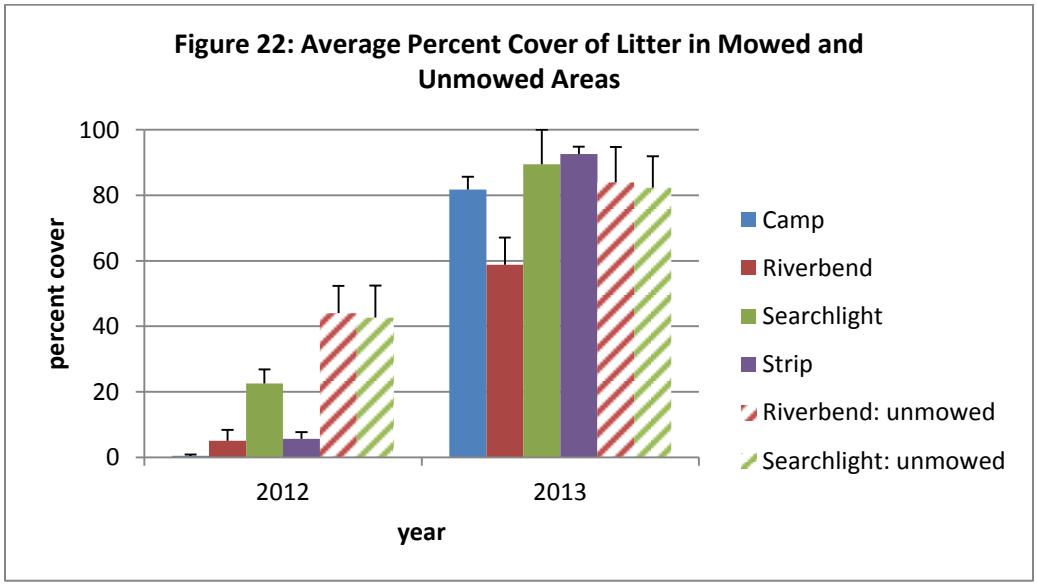


Figure 22. Average percent cover of litter in mowed and unmowed areas. Whiskers indicate standard error.

Discussion

Drought has been a limiting factor in successfully establishing native vegetation. In 2012 below normal precipitation resulted in the lowest lake elevation in Upper Klamath Lake ever recorded (Tipler 2013). 2013 was the driest year on record since 1994 (Tipler 2013). Such conditions are not conducive to germination or establishment of seedlings. Along with this, weedy species are typically better adapted to drought conditions allowing them to outcompete seeded species.

Basin wildrye and squirreltail have established well in areas of preferred habitat. Over the last few years, drought has limited cover; however established individuals appear robust. Because these two species are large dominant bunchgrasses they are very competitive against other native species and have formed a monoculture within preferred habitat zones. Augmenting these areas to increase diversity would be challenging and unnecessary. All other areas of the uplands are dominated by cheatgrass, common fiddleneck, herb sophia, prickly lettuce, stickwilly and tall tumblemustard. Such weed dominated areas require active restoration in order to suppress weeds and establish native species. Potential methods include a combination of mowing, burning, herbicide and reseeding treatments.

The sampling design has some inherent variability among results. Primarily, it appears that plots should be stratified by habitat type within each field because vegetation has re-established in a strong mosaic pattern. For example, within Strip Field the 2013 data shows a severe decline in native grass cover (figure 3) and Camp Field had a severe decline in cheatgrass cover (figure 11). Visual observation of these fields did not indicate either of those trends. Monitoring methods could be improved by delineating habitat boundaries and creating random sampling points by stratification. Such areas could also be visually observed for revegetation success and failure using a plotless ocular estimate of dominant species percent aerial cover, bare ground and litter. Along with this, cover estimates are known to be variable among observers which could be improved by incorporating a cover class system of measurement into the methods. Over time, as vegetation becomes established, monitoring methods and frequency could be scaled back to incorporate aerial imagery analysis with limited ground-truthing in order to improve efficiency of monitoring the Preserve.

References

Elseroad A. 2005. Upland restoration plant species lists for the Williamson River Delta Preserve. Unpublished Report. The Nature Conservancy.

Tipler S. 2013 Oct 29. BOR, Klamath Project reflect on water year. Herald and News. [accessed 2013 May 14]; http://www.heraldandnews.com/news/local_news/article_c17276e8-4056-11e3-b2c2-001a4bcf887a.html.

Appendix A: Species List

USDA Common name	Genus	Species	Family	Origin	Duration	Growth Habit	Synonym
baby blue eyes	Nemophila	sp.	Hydrophyllaceae	N	A	forb	
basin wildrye	Leymus	cinereus	Poaceae	N	P	graminoid	Elymus cinereus
bull thistle	Cirsium	vulgare	Asteraceae	I	B	forb	
burningbush	Bassia	scoparia	Chenopodiaceae	I	A	forb	kochia
Canada thistle	Cirsium	arvense	Asteraceae	I	B	forb	
Canadian horseweed	Conyza	canadensis	Asteraceae	N	A/B	forb	
cereal rye	Secal	cereal	Poaceae	I	A	graminoid	
cheatgrass	Bromus	tectorum	Poaceae	I	A	graminoid	
common fiddleneck	Amsinckia	menziesii var. intermedia	Boraginaceae	N	A	forb	
common mullein	Verbascum	thapsus	Scrophulariaceae	I	B	forb	
common oat	Avena	sativa	Poaceae	I	A	graminoid	
common yarrow	Achillea	millefolium	Asteraceae	N	P	forb	
curly dock	Rumex	crispus	Polygonaceae	I	P	forb	
dense silkybent	Apera	interrupta	Poaceae	I	A	graminoid	
foxtail barley	Hordeum	jubatum	Poaceae	N	P	graminoid	
fringed willowherb	Epilobium	ciliatum ssp. watsonii	Onagraceae	N	P	forb	
golden dock	Rumex	maritimus	Polygonaceae	N	A/B	forb	
herb sophia	Descurainia	sophia	Brassicaceae	I	A/B	forb	
Idaho fescue	Festuca	idahoensis	Poaceae	N	P	graminoid	
Kentucky bluegrass	Poa	pratensis	Poaceae	I	P	graminoid	
lambsquarters	Chenopodium	album	Chenopodiaceae	I	A	forb	
Lewis flax	Linum	lewisii	Linaceae	N	P	forb	
Lupine	Lupinus	sp.	Fabaceae	N	P	forb	
Norwegian cinquefoil	Potentilla	norvegica	Rosaceae	N	A/B/P	forb	
Nuttall's alkaligrass	Puccinellia	nuttalliana	Poaceae	N	P	graminoid	
parsnipflower buckwheat	Eriogonum	heracleoides	Polygonaceae	N	P	forb	Wyeth's buckwheat
poison hemlock	Conium	maculatum	Apiaceae	I	B	forb	
prickly lettuce	Lactuca	serriola	Asteraceae	I	B	forb	
prostrate knotweed	Polygonum	aviculare	Polygonaceae	I	A/P	forb	
pullup muhly	Muhlenbergia	filiformis	Poaceae	N	A	graminoid	
quackgrass	Elymus	repens	Poaceae	I	P	graminoid	
redstem stork's bill	Erodium	cicutarium	Geraniaceae	I	A/B	forb	
rubber rabbitbrush	Ericameria	nauseosa	Asteraceae	N	P	shrub	

USDA Common name	Genus	Species	Family	Origin	Duration	Growth Habit	Synonym
Scotch cottonthistle	Onopordum	acanthium	Asteraceae	I	B	forb	Scotch thistle
shepard's purse	Capsella	bursa-pastoris	Brassicaceae	I	A	forb	
squirreltail	Elymus	elymoides ssp. brevifolius	Poaceae	N	P	graminoid	
stickwilly	Galium	aparine	Rubiaceae	N	A	forb	common bedstraw
stinging nettle	Urtica	dioica	Urticaceae	I	P	forb	
tall annual willowherb	Epilobium	brachycarpum	Onagraceae	N	A	forb	Epilobium paniculatum
tall tumblemustard	Sisymbrium	altissimum	Brassicaceae	I	A/B	forb	
threadleaf fleabane	Erigeron	filifolius	Asteraceae	N	P	forb	
tiny trumpet	Collomia	linearis	Polemoniaceae	N	A	forb	
yellow salsify	Tragopogon	dubius	Asteraceae	I	A/B	forb	
green cells indicate seeded species							
purple cells indicate native species							