Effects of manual and mechanical removal of *Ammophila arenaria* on coastal plant communities and dune morphology

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Introduction:

European beachgrass (*Ammophila arenaria*) has invaded coastal sand dunes along the entire north coast of California, displacing native species. This invasive grass alters dune morphology by stabilizing the foredunes and hampering dune migration, which can cause a decline in native populations of flora and fauna [1]. For example, studies have shown that the endangered Western Snowy Plover (*Charadrius nivosus nivosus*) prefer nesting sites without *A. arenaria* [2]. Moreover, the lack of sand mobilization to the back dunes impacts native dune mat species [1] such as the rare and endangered pink sand verbena (*Abronia umbellata* var. *breviflora*), beach pea (*Lathyrus japonicus*), Humboldt Bay wallflower (*Erysimum menziesii*), and beach layia (*Layia carnosa*) [3].

Research Objective

1) Compare mechanical and manual removal treatments to see if one is more effective at lowering the *A. arenaria* population and increasing the native dune plants population over the long term.

Methods:

Study Sites

Three study sites were selected where mechanical and/or manual removal of *A. arenaria* had occurred (Figure 1):
(1) Gold Bluffs Beach in Prairie Creek Redwoods State Park (mechanical and manual removal);
(2) Little River State Beach (mechanical); and
(3) Tolowa Dunes State Park (manual removal).

Mechanical removal of *A. arenaria* used bulldozers to bury *A. arenaria* up to 2 meters under the sand, which occurred at Gold Bluffs Beach and Little River. In contrast, manual removal involved shovels to excavate the plant up to a depth of 0.6 meters, which was used at Gold Bluffs Beach and Tolowa Dunes. In 2009, mechanical removal began at Little River State Beach. Manual removal started at Tolowa Dunes in 2010. Gold Bluffs Beach underwent both treatments in 2013. All initial treatments, regardless of type, received additional manual removal at similar frequencies.

To measure the plant cover of nearshore dune vegetation in areas of mechanical and manual *A. arenaria* removal, we surveyed vegetation in established 25 m^2 plots. Adjacent invaded sites were also surveyed as controls. We recorded the percentage cover of all plant species found within fifteen 1 m^2 quadrats within each 25 m^2 plot (Figure 2 and 3).

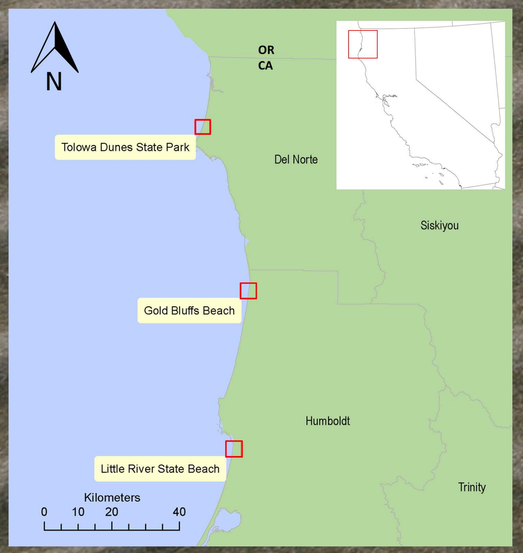

Figure 1. Map of study sites in Northern California

Figure 2. Field crew measuring vegetation cover at Tolowa Dunes in a control plot.

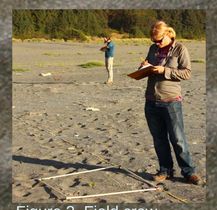

Figure 3. Field crew measuring vegetation cover at Gold Bluffs Beach in a mechanically treated plot.

Results:

The results of this study indicate that both treatment types lowered *A. arenaria* cover in restoration areas. A comparison of *A. arenaria* resprouts at Gold Bluffs Beach found that mechanical removal was slightly more effective compared to manual removal. This advantage is greater directly after removal and levels out over time. Tolowa Dunes had the lowest *A. arenaria* cover measured in manual removal plots. This could indicate that it is an overall more effective treatment, however, this could also be due to different invasion conditions at the sites. Gold Bluffs Beach, Little River, and Tolowa Dunes have significantly different percent cover between their treated areas and the adjacent controls (α=0.05). Removal of *A. arenaria* is effective at combating this invasive species.

The average control percent cover varied from site to site. Gold Bluffs Beach saw a lowering of *A. arenaria* cover in the control sites over time without treatment. Average percent cover at Little River started with a similar percent cover as the treated area before treatment. However measurements this year recorded an increase in percent cover in control plots. Tolowa Dunes also saw an increase in *A. arenaria* cover from spring to fall of this year, in both manual and control areas. This could be due to different environmental conditions at each site.

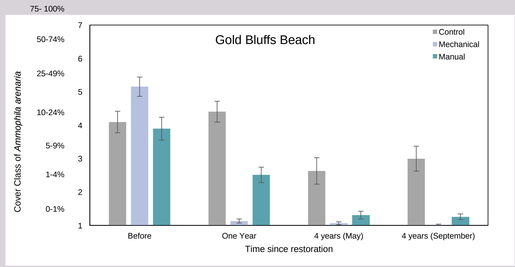

Figure 4. Average percentage cover of *Ammophila arenaria* with 95% confidence interval error bars (in a modified Braun-Blanquet cover class) at Gold Bluffs Beach in Prairie Creek Redwoods State Park before removal (July 2012), one year after removal (February 2014), and 4 years after removal (May and September 2017) in manual, mechanical and control plots.

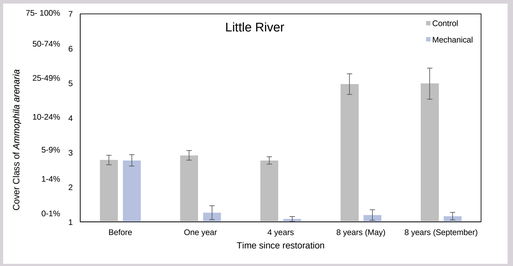

Figure 5. Average percentage cover of *Ammophila arenaria* with 95% confidence interval error bars (in a modified Braun-Blanquet cover class) at Little River State Beach before removal (2009), one year (2010), 4 years (2013), and 8 years (May and September 2017) after removal in mechanical and control plots.

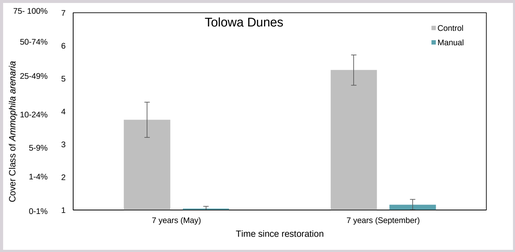

Figure 6. Average percentage cover of *Ammophila arenaria* with a 95% confidence interval error bars (in a modified Braun-Blanquet cover class) at Tolowa Dunes State Park 7 years (May and September 2017) after removal in manual and control plots.

Discussion:

Removal of *A. arenaria* by any treatment will lower the total cover within restoration areas compared to adjacent invaded areas. Changes in control percentage cover could be caused by weather and seasonal changes. However even with these variations the treated areas cover is lower at all three sites compared to invaded areas. At the site with both treatment types, Gold Bluff Beach, mechanical removal has afforded the lowest cover of *A. arenaria.*

Land managers prefer mechanical removal due to potentially lower cost. Mechanical removal, depending on access to the site, requires less time and smaller crew sizes. This treatment may also provide a shorter recovery time, which also lowers the cost of retreatment [3]. Our study supports this management choice.

However, to determine which management technique provides the best ecosystem response requires further analysis. Native plant cover, as well as other invasive and non-native plant cover, are important measures to take into account. Removal of *A. arenaria* may disturb the ecosystem and leave it vulnerable to other invaders. The foredune height can also play a role in the recovery of coastal sand dune ecosystems. A lower foredune can increase sand movement to the back dune system, and restore the dunes to pre-invasion conditions. Future steps would include these measurements.

Figure 6. Mechanical removal plot at Gold Bluffs Beach in Prairie Creek Redwoods State Park, Humboldt County, CA.

Figure 7. Foredune of control plot invaded with *Ammophila arenaria* Little River State Beach, Humboldt County, CA.

Citations:

[1] Wiedemann, A. M., & Pickart, A. 1996. The Ammophila Problem on the Northwest Coast of North America. *Landscape and Urban Planning, 34*: 287-299. [2] Zarnetske, P. L., Seabloom, E. W., & Hacker, S. D. 2010. Non-target Effects of Invasive Species Management: Beachgrass, Birds, and Bulldozers in Coastal Dunes. *Ecosphere, 1*(5): 1-20. [3] Mills, A. 2015. Evaluating the Effects of Mechanical and Manual Removal of Ammophila arenaria within Coastal Dunes of Humboldt County (Master's thesis). CSU Chico. http://hdl.handle.net/10211.3/145031 [4] Pickart, A.J. & Sawyer, J.O. 1988. *Ecology and Restoration of Northern California Coastal Dunes*. Sacramento, Calif.: California Native Plant Society.

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