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Reversing Invasion of *Lupinus arboreus*, (Yellow Bush Lupine) an Invasive Species of Northern California Sand Dune Communities

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Figure 1. ***Lupinus arboreus***

(Courtesy of NPS 2000. http://www.nps.gov/redw-lupine.htm)

Summary

The invasion of *Lupinus arboreus* (Figure 1) in northern California sand dune communities, namely in Humboldt county, has become of increasing concern since its introduction in the early 1900s. Because of its rapid growth and long-lived, abundant seed bank, a successful eradication technique of *L.arboreus* is needed. To gain a better understand of this perennial, a description of biology, geography, and impacted systems of *L.arboreus* will be discussed throughout this paper. Four eradication techniques of *L.arboreus* removal will be briefly described and evaluated: manual, mechanical, granivory, and insect herbivory control. The importance of this woody shrub as a nitrogen fixer and its subsequent impacts upon sand dune communities is also important to consider in implementing control strategies. A strategy recommended involves the prevention of the further spread of *L .arboreus*, followed by manual removal techniques, as the entire plant needs to be removed in order to die, preventing further nutrient enrichment. Author comments and critiques can be found throughout, and conclusive remarks about future implications.

Biology and Geography

Native to the dry, warm areas of central and southern California, *Lupinus arboreus* (yellow bush lupine), (Figure 1) a fast-growing evergreen shrub, is found in areas close to the coast such as stable sand dunes, coastal bluffs and pine forests. As well as being present in the United States, *L. arboreus* is also native to Canada, France, and Argentina (ILDIS 1996).

Coastal prairie grasslands and dune communities foster seedling emergence with the onset of winter rains. This rapidly growing shrub begins to flower in its second spring, and rarely in its first summer (Maron 1998). Generally less than two meters tall, this perennial shrub produces spikes of bright yellow flowers, becoming fragrant in early summer. The sweet scented, pea shaped flowers make this species easy to recognize, and also give *L. arboreus* its familiar name, “yellow bush lupine”. The west coast of the United States contains fertile soil for *L. arboreus*, making it better known as one of the larger lupines, often called “tree lupine”. This shrub forms a long central taproot, occasionally producing a few large side roots (Maron 1998). *L.arboreus* is generally short-lived, few survive past seven years, with more frequent die-offs occurring after two to three years of growth (Maron et al. 1996). However, re-establishment is common due to an abundant and long-lived seed bank. The entire *Lupinus* genus consists of over 200 species varying in their colorful blooms, heights, uses, and distribution.

A member of the legume family (Fabaceae), *L. arboreus* fixes nitrogen and grows rapidly. It is this fact that makes *L.arboreus* a problem in northern California. Introduced to northern California in the early 1900's from southern California to stabilize coastal sand dunes near the Samoa Peninsula, *L.arboreus* aggressively invaded the cool, wet climate of the north coast (Figure 2). At one time deficient in nitrogen and shrub species, much of northern California sand dunes are now occupied by a dense canopy of *L. arboreus* and annual exotic weeds, which are attracted by the nitrogen enhanced soils (Pickart et al. 1998). This exotic depresses native communities by altering soil characteristics through its nitrogen fixing capabilities, and allows the spread of other nonnative species (BLM 2000).

Figure 2. Current range of *Lupinus arboreus.*

More specifically, several sources of disturbance facilitate the invasion of *L.arboreus*, such as the removal of the existing vegetation opening space for exotics to establish and rapidly colonize (Maron et al. 1996). Nutrient enrichment may also increase the likelihood of invasion by altering competitive factors, which allows the establishment of species that can use these nutrients for rapid growth.

Maron and Connors (1996) suggest the process of invasion begins in undisturbed, species-rich coastal prairie as *L.arboreus* seeds germinate in these nitrogen-poor areas. The seedlings surviving their first summer eventually grow into adult bushes with dense canopies that crowd and shade out native shade-intolerant species. *L.arboreus* then fixes large amount of nitrogen, much of which is transported to its leaves, which eventually drop to the ground first enriching the litter and duff layer, then the soil underneath the live plant. Once the plant dies, high levels of ammonium and nitrate are then available to invasive colonists, such as weedy grasses and forbs, namely *Bromus spp.* (brome), *Vulpia bromoides, Holcus lanatus* (velvet grass), *Aira spp.*(European hairgrass) (Pickart et al. 1998).

Ecosystem description

L.arboreus is generally found in dune communities. Coastal sand dune communities are fragile and ever-changing environments. The dunes are shaped by winds into curved ridges. Their contours constantly shift over time until coastal scrub plants root into the drifting sand and create the stable dune community. The influence of storm waves, wind and human disturbances can alter the dune habitat. The richer soils of the back dunes are occupied by *L.arboreus*. This location provides protection from salt spray and high winds. Dune communities exist throughout the west coast with over 27 dune fields in areas such as Monterey Bay, Nipome Dune Complex, Humboldt Bay, and San Diego Bay (CERES 1998).

An extensive area currently suffering from the spread of *L. arboreus* is the Humboldt Bay-Samoa region of northern California (Figure 2). *L.arboreus* crowds out native species through its formation of tall, dense shrubs followed by the spread of nonnative species colonizing below its limbs.

The remnant populations of local native lupines hybridize with those of *L.arboreus***.** For example, Redwood National Park contains hybrids between *L.arboreus* and *L.rivularis*. Hybridization is apparent at the south end of Redwood National Park in the Freshwater Lagoon area. The park's botanist, Leonel Arguello stated the 1994 Exotic Management Plan had identified these hybrids, but to his knowledge the hybrid populations have since been removed. Arguello knows of no current locations of hybrids within the park (NPS 2000, Davis 2000).

Wear (1998) documented hybridization in Humboldt County between *L.arboreus* and *L.littoralis* and between *L.arboreus* and *L. rivularis*. *L.littoralis*, a restricted coastal species, may face the threat of being genetically overwhelmed. In contrast, *L.rivularis*, a more ecologically generalized species, is presumed to be less threatened (Wear 1998). The focus of Wear's (1998) research was on hybridization of *L.arboreus* and *L.littoralis*. While the flowers of *L.arboreus* are large and yellow in color, the flowers of *L.littoralis* tend to be much smaller and purple in color. Hybrids are usually identifiable by their flower appearance as well, which is generally a mixture of purple, yellow, white. Wear (1988) also noted that the hybrids were usually intermediate in size, growth, form, and hairiness of leaves. Reproductive barriers between the two species are apparently weak; thus, *L.littoralis* could be in danger of existing as a distinct taxon. In addition, habitat disturbance reduces geographic separation that may have historically made hybridization unlikely (Wear 1998).

Wear (1998) mentioned the hybrids were removed in a majority of study sites. No follow up management is discussed, such as further manual eradication, or implementation of a buffer between sites where hybridization is most likely to occur. Further studies could be conducted to examine several control techniques of hybrids, and which type of habitats are most susceptible to hybridization.

Two endangered northern California native species are affected by the continued spread of *L.arboreus*: *Layia carnosa* (beach layia), and *Erysimum menziesii* (Menzies' wallflower). *Layia carnosa*, a member of the sunflower family (Asteraceae), is restricted to coastal sand dune areas, and has been listed endangered since 1991. *Erysimum menziesii*, a member of the mustard family (Brassicaceae), is also restricted to coastal sand dunes. Restoration projects managed by the Bureau of Land Management (BLM) in the Samoa Peninsula have been established to reduce the effect of *L. arboreus* (Chinn 2000) on these two native species. For example, 16-ha of *E. menziesii* habitat has been set aside by the BLM to reduce this threat. By fencing this area off to the public, restoration studies can be conducted as accurately as possible without further disturbance to the area.

Although *L.arboreus* is a major threat to the health of the sand dune communities, other exotics play a role in its degradation; namely, *Ammophila arenaria* (European beach grass), and *Carpobrotus edulis* (iceplant). The above exotics, as well as *L. arboreus*, are actively managed by the Arcata Field Office in the Humboldt Bay-Samoa region. *C.edulis*, is a member of the fig-marigold family. It is considered an invasive noxious weed. This species grows low to the ground and covers dunes with its expansive growth pattern (BLM 2000).

European beach grass, as its name suggests, is native to Europe as well as the U.S. East Coast. It is a coarse, perennial member of the grass family (Poaceae), and forms dense stands with deep, buried stems. A study conducted regarding the eradication of this grass was conducted by Pickart (1997). Control methods of this study could be used in cooperation with the methods for *L.arboreus*. Namely, chemical treatment of herbicides and the use of salt water as a chemical treatment as more cost effective eradication techniques. Although the use of salt water is highly contested because of its ecosystem level effects, namely its possible toxicity to native plant species, perhaps this method could be used only in highly invaded areas. It would be of interest to note how effective it would be in mortality of both species.

Control Techniques

Study sites, comparable to and including the 16-ha mentioned above, are varied in their application of treatment techniques and restoration methods. Four of these control techniques will be described and evaluated below. Manual, mechanical, granivory predation, and insect herbivory techniques are just a few of the ways *L.arboreus* invasion is controlled.

Manual control

Manual eradication is currently recommended by the National Park Service (NPS). They state hand pulling and weed wrenching as the most effective methods of *L.arboreus* eradication, as the complete root system of *L.arboreus* must be removed for plant mortality (NPS 1998).

Additional manual restoration techniques have been used in the 16-ha of land set aside for protection, research, and restoration previously mentioned in the Samoa Dunes Recreation Area (Figure 2). This area is an endangered plant protection area, and is closed to public use. Samoa Dunes Recreation Area provides many recreational opportunities, and is managed by the Bureau of Land Management (BLM) as a multiple-use recreation site. Recreational use of dunes in the park contribute to the destruction of the native habitat, necessitating the protection of the 16-ha site.

The emphasis of management at Samoa Dunes Recreation Area is on protection of *E. menziesii*. Its dune mat habitat and restricted low vegetation has currently become displaced due to the dense covering of *L. arboreus* on sand dune communities. Restoration efforts are centered on removal of *Ammophila arenaria*, *Carpobrotus edulis*, and *L.arboreus*. Interagency staff, community volunteers, and local non-profit groups comprise some of the people who provide hours of manual removal of these exotics (BLM 2000).

Pickart et al. (1998) conducted an extensive study in order to develop effective *L. arboreus* manual restoration techniques on the North Spit of Humboldt Bay. This team collected vegetation and soil data from five varying vegetation types located within the 16-ha site contained by the Samoa Dunes Recreation Area. There was a two-fold purpose to their study: (1) to record ecosystem effects of *Lupinus arboreus* by measuring its addition to available soil nitrogen and organic matter, and (2) once ecosystem effects were noted, to develop a restoration strategy designed to reverse the observed effects. Two restoration treatments were compared: (1) removal of *L.arboreus* only and (2) removal of all non-native vegetation and removal of litter and duff. After four years of monitoring with treatments applied annually, removal of all non-native vegetation, duff and litter was found to have a higher success rate, greatly reducing the emergence of nonnative grasses, such as *Vulpia bromoides*, *Holcus lanatus*, *Bromus* spp., and *Aira* spp. This technique was noted to be most appropriate for newly invaded sites.

Manual removal proved to be one of the most successful of the control techniques, based on the fact that high success was determined by removal of the entire root system. Considering community service programs such as 'sentence to serve', for physical labor in invaded areas, or similar programs, could provide needed labor for large-scale projects. Because this technique is most effective on newly invaded sites, volunteer hours could be spent preventing further spread of *L.arboreus* through continued management of these sites, with dispersal barriers set up around removal areas to reduce the seed bank over the years.

Mechanical control

Mechanical techniques were also studied for restoration success in late stage invasion by Pickart et al. (1998). Three restoration methods compared in this study were the removal of vegetation with a brush rake, removal of vegetation with a brush rake, followed by removal of litter and duff with a plough blade or bucket, and lastly removal of vegetation with tractor-pulled chokers.

Following this primary treatment, weedmats were placed over subplots for either one or two years. A weedmat allows for the passage of water, but hinders any plant emergence. The study mentioned the remaining debris from the primary treatment was cast to the side of the plots. The study indicated the second of the primary treatments, removal of vegetation with a brush rake, followed by removal of litter and duff with a plough blade or bucket, in combination with a two year weedmat was most successful. This technique was done on a flat, accessible area.

It would be interesting to see what types of mechanical techniques could be done on a more restricted area in the late stages of *L.arboreus* invasion. Results may have been improved had removal of the debris and subsequent burning taken place. A buffer could have been mowed around the study site to reduce future dispersal, as had been done in the study by Pickart et al (1998). Experiments could be conducted with varying buffer widths with analysis of the most effective. Perhaps tillage of the site and further removal could be considered to achieve removal of entire root system without the needed hours of volunteer work.

Granivory predation

Conducting the experiments using *Peromyscus maniculatus*, deer mouse, a primary consumer of dispersed *L.arboreus* seeds, Maron and Simms (1997) compared *P.maniculatus* predation of seeds in two communities, grasslands and dunes. Their study took place where *L.arboreus* is native, Sonoma County (Figure 2), on 147-ha at the Bodega Marine Reserve. The mice are common in these habitats where they nest under *L.arboreus* bushes for cover from predators (Maron and Simms 1997). Maron and Simms discovered greater success in the dune communities, where rodent granivory was 65% and 86% of seeds removed at the study site in two successive years. *P.maniculatus* predation was found to be 6% of seeds from plots in the grassland communities. It is interesting to note the grassland seed bank is 43-fold that of the dune community (Maron and Simms 1997). It is interesting to wonder whether whether granivory could be developed into a restoration strategy in conjunction with manual removal of seedlings.

Using fungi, bacteria and other pathogens could also possibly kill remaining *L.arboreus*, when used in combination with granivory predation. However, no research is known on this topic. Ongoing management would be less expensive than mechanical removal, as the seed bank was reduced over the years.

Insect herbivory and interspecific competition

Maron (1997) also conducted studies on insect herbivory and *L.arboreus* seedling survival. Competition for light and insect herbivory were jointly studied by Maron. A locally abundant caterpillar, *Orgyia vetusta* (western tussock moth) can defoliate leaves in early summer after grasses have died. Two sets of experiments were conducted. First, plots were exposed to or protected from *O.vetusta*. The second experiment dealt with competition in which Maron manipulated the density of grass surrounding *L.arboreus* seedlings. All the vegetation was removed surrounding some seedlings, and some seedling vegetation surrounding others was left intact. These experiments were combined to show higher seedling mortality. Fifty- percent mortality occurred for seedlings that had grown with competitors, and 53% mortality occurred for seedlings grown without competitors. Researchers could perhaps use this control technique in combination with the manual techniques. Revegetation with native shrub species could possibly shade out emergent *L.arboreus* seedlings, as *L.arboreus* is not a shade-tolerant species.

Conclusion

It is important to mention many restoration efforts do exist in the state of California, although typically on a small scale. *L.arboreus* will also likely continue to spread northward with the possibility of hybridization with other *Lupinus* species. First, current eradication methods need to focus on control of newly invaded sites. Then, experiments could be conducted on larger scale areas recently invaded. This could be applied to *L.arboreus* and hybrids. *L.arboreus* has been controlled for over 20 years in Humboldt County. This serves as a good example of continuing management and the dedication needed to control invasive species. In California, cooperative efforts between managing agencies have often resulted in a coordinated response to noxious weeds policy (ICE 2000). Further collaborations and education of the public must take place for successful eradication and adequate funding to ensure the success of these control techniques and further research. Only after these efforts, will the success of reversing the invasion of *L.arboreus* be feasible in northern California sand dune communities.

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