Surveying Diversity and Distribution of Non-native Plants at the Albany Bulb

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Abstract Many mechanisms that facilitate the spread and establishment of non-native plant species are varied and complex. In this study, I explored the influence of individual plant characteristics and environmental factors on the distribution and dispersal of non-native perennial forbs and grasses at Albany Bulb, a park that was redeveloped two decades ago. No previous study has attempted to survey the Albany Bulb's diverse plant life and analyze the extent of non-native invasion and I hoped to answer the question: What is the extent of invasive plant species spread on Albany Bulb and are these invasive species dominating the native flora? To determine the distribution of native and non-native perennial plants on the Albany Bulb, I conducted an observational field study to identify and map dominant perennial plant communities using GIS. I also used field data to examine the possibility of a correlation between non-native species abundance measured by plant cover and distance from paths. In this three month, January to March 2009, survey, I found that the Albany Bulb is increasingly becoming home to more non-native herbaceous plants and grasses. Yet, results from this study regarding correlation of distance from paths remain inconclusive. Understanding the role that various environmental and individual plant factors play in the dispersal of invasive non-native species is crucial in preventing their spread and seeing the overall non-native plant dispersal and distribution in response to human and natural disturbances can provide valuable information for future management for the preservation of native species in urban parks.

Introduction

Non-native plants or animals can displace native species, disrupting ecosystems, and damage many commercial, agricultural and recreational resources (Harrison *et al.* 2002). Without naturalized predators or competitors, these non-native species can become invasive, spreading rapidly and aggressively, displacing whole native communities to become dominant (Dobson et *al* 2006). Invasions by non-native species can threaten entire ecosystems but mechanisms determining why and what impacts they have are still being determined (Seabloom *et al.* 2003). Non-native species do not naturally occur in a particular ecosystem but invasive non-native species aggressively establish themselves at the expense of already existing native species. According to the US Environmental Protection Agency (2008), invasive non-native species such as the zebra mussel (*Dreissena polymorpha*), gypsy moth (*Lymantria dispar*), and the sea lamprey (*Petromyzon marinus*) have caused massive economic and ecological losses in new locations because no controls on population were in place, disrupting entire food webs and causing damages that can be expressed in monetary terms, are estimated as high as $138 billion per year. It is also important to recognize that humans play a major role in facilitating the spread of these invasive species. Controlling and managing these non-native species can be difficult because the mechanisms that allow for establishment are varied.

Factors such as plant traits, abiotic factors, and disturbance, facilitate non-native plant establishment and there is still more inquiry needed into these conditions, beginning with individual plant characteristics (Kilnger *et al.* 2006). Non-native invasive plants, spread by either deliberate or accidental vectors, are settling in foreign habitats, spreading across landscapes and threatening native species diversity as humans themselves enter and expand across new territories (Henderson *et al* 2006). Establishment success of many non-native exotic plants varies widely but appears to be influenced by a number of plant traits related to growth rate, nutrient use efficiency, stress tolerance, and methods of seed dispersal (Ricklefs *et al.* 2008). Important factors relating to the dispersal and distribution of many non-native species include whether plants are annuals or perennials, or have larger or smaller seeds. With much of the California's native plant life threatened by the spread of non-native plants (Seabloom *et al.* 2003), it is crucial to understand the factors that facilitate non-native plant dispersal and distribution.

Environmental abiotic factors also play a role in degree of invasion; non-native species composition, richness, and cover are strongly affected by soil type, resource availability, and topography (Klinger et al 2006) (Maskell *et al*. 2006). Because of soil and substrate heterogeneity, the distribution and abundance of non-native species are likely to vary greatly along gradients of vegetation and soil characteristics (Kilnger et al 2006). In fact, physical site factors related to soils and topography must first be favorable for a non-native plant before it can establish itself (Gelbard and Belnap 2003) because growth is related to the plant's tolerance of the existing ecological conditions (Ricklefs *et al.* 2008). In an urban city setting, environmental conditions are heterogeneous and resource availability varies greatly (Stapanian *et al.* 1997). For example, soil quality can be high or poor in nutrients (e.g. close to fertilized areas), toxicity may be present or absent, and habitats can be anything from very dry to wet depending on climate. These extreme abiotic site conditions are important selection factor for the establishment of many plant species- while limiting resources can be a stress factor for some, others may thrive (Begon et al, 1990).

Human and natural disturbances also are important contributors to non-native invasive plant dispersal. According to Pickett and White (1985), a disturbance is a relatively discrete event, which suddenly disrupts the structure of an ecosystem, community, or population. Disturbances create open space and opportunities for colonization both by native and non-native species. In urban settings such as a park, human disturbance, from park walkers, pet owners, or even vehicles, can act as vectors for seed dispersal or make conditions easier for non-natives to establish themselves (Chytry *et al.* 2008). Harrison *et al.* (2002) noted that roads act as disturbances that promote invasive species and act as corridors for dispersal into new landscapes. Differences in the distribution of native and exotic richness are due in part to how native and exotic plants respond to human disturbance (Dobson *et al.* 2006). These disturbances may allow non-natives to gain an upper hand because the faster growing, short-lived herbaceous exotic species equilibrate more rapidly with the environment than longer-lived species (Dobson *et al.* 2006). Because of the complexities, I will be narrowing my focus to the interactions of disturbance on both native and non-native perennial grasses and herbaceous plants

In the process of colonization leading to succession "directed changes of a species composition over time" (Rebele 1994), newly created habitats are settled or sites are re-settled after a disturbance. Primary successions can occur in an urban setting when natural soil is excavated or a substrate is spread that did not have any plant growth (Crawley 1986). In cities, the settlement of primary habitats by plants is often rapid, since there are usually large numbers of colonizing species nearby (McDonnell and Stiles 1983). Secondary successions occur on sites that already have vegetation cover or a seedbank that are disturbed. According to Rebele (1994), the vegetation on landfills in cities usually has the character of some mixed form of secondary and primary succession because organic matter previously enriched the soil. However, as land is redeveloped in mixed urban settings, succession and the distribution of colonizing plants is unclear.

Little is known about plant succession on an established urban setting that is frequented by humans. The Albany Bulb in the San Francisco Bay area was created after the shoreline was filled with debris from construction and highway projects and used as a landfill for twenty-three years. In 1986, the state declared the land a public trust and prevented any further dumping and proceeded to covered over the dump with the debris used previously in the construction projects. Therefore, succession was able to take place because of this new substrate. Yet, as stated by Rebele (1994) earlier, this previous landfill can also exhibit some secondary succession because of the nitrogen-enriched substrate underneath from the prior existence of plants. Furthermore, the Albany Bulb has become a urban park, with visitors who frequent its many paths. The effects of human disturbance on plant succession and community establishment by various non-native and native plants during primary and secondary succession can be seen in redeveloped urban areas such as Albany Bulb (Chytry *et al.* 2008). Because the flora of Albany Bulb has never been extensively surveyed or catalogued since 1994, it will be interesting to see if differences in species composition exist 15 years later.

By identifying both plant characteristics such as vegetation cover, species concentration and dominance, and site characteristics such as spatial patterns in relation to walking paths and shoreline, I can describe the species diversity and dominance, as well as overall distribution of both native and non-native plants. I concentrated on a specific location, in this case, (Fig.1 in Appendix).

After human activities facilitate the initial invasion by exotic plants, exotics spread ahead into areas where there could be high numbers of threatened native plants (Dobson et al. 2006). In multiple settings, there were declines in the presence of exotic species that correlate with distance from roads (Gelbard and Belnap 2003). Therefore, near well-travelled paths we would expect a higher concentration of non-native plants, and with this focus, we can determine how the species spreads into the peninsula, which is a valuable setting because it provides discrete, bounded areas into which paths can act as corridors (Harrison et al. 2002) . The shoreline is similarly a site of disturbance and a corridor for invasion by non-native species because windborne or waterborne seeds can easily be spread along the shoreline or carried by vectors inland. Distance from the shoreline also influences plant growth because shoreline plants must be able to tolerate wind, salinity, and spray. Proximity to the sea and salt concentrations will limit the growth of native and non-native plants alike unless there is a species that is particularly tolerant. Therefore, I expect to see a greater distribution of non-native plant species along the shore and subsequently, less inland. By measuring distance from shoreline and paths, I expect to see correlations between distance from these areas of disturbance and colonization and concentration of non-native species.

I intend to look for patterns in invasion of non-native plants and answer the questions; what is the extent of invasive non-native plant species cover on Albany Bulb and are these non-native species more widespread than the native flora? Is there a correlation between non-native plant abundance and distance from paths?

To determine the distribution of native and non-native perennial plants on the Albany Bulb, I will be conducting an observational field study to identify and map dominant perennial plant communities using GIS. I will also be using field data to examine the possibility of a correlation between non-native species abundance measured by plant cover and distance from paths. My hypothesis is that the majority of the Albany Bulb is comprised of non-native invasive plant species and that these non-native species are more abundant, more widely distributed, and have more cover and percent cover than compared to the native plants.

Methods

This survey of native and non-native plants will take place on the Albany Bulb, a landfill converted into a recreational park on the San Francisco Bay shoreline, composed of heterogeneous concrete substrate 23 years prior and has been re-colonized. It has a mild climate, with an average temperature of 64.9° F, and is relatively moist due to its proximity to the bay, making it suitable for plant growth if plants are able to tolerate a summer drought. Proximity to the sea and salt concentrations will limit the growth of native and non-native plants alike unless there is a species that is particularly tolerant. The Albany Bulb is home to a wide range of native and non-native species of differing characteristics, all of which are spread throughout the Bulb and easily accessible for sampling. The study site is regularly exposed to disturbance from park visitors and their pets, making it an ideal site to look for any correlations between distance from paths and non-native plant species richness.

I determined species composition by first collecting plant specimens for classification and then estimating plant cover using visual estimates of percent cover within quadrats . I used a stratified sampling strategy where the study site was divided into 13 sections, in which five five-meter square quadrats were sampled to ensure equal coverage of the entire area. In these plots, markers maintained the border of the area of interest and guided the comparisons of cover height. Cover, the percentage of ground surface covered by live vegetation, is thought to be ecologically significant and an estimate of how much a plant dominates an ecosystem because it is more highly related to biomass than density or frequency and also reflects the resources and light the plant can access (Dobson *et al.* 2006).

To identify species, in every quadrat I collected two specimens of every plant; one sample, consisting of leaves, flower and/or seeds, was kept for future reference. When I was unable to identify using field manuals and Dr. Barbara Ertter's previous survey (1994), the samples were sent to the UC Jepson Herbaria for identification.

I will also record the distance from the center of the plant to the nearby path. Full vegetation sampling will take place January to March of 2009. Weekly trips to the study site will be taken by car with the help of assistants to collect samples.

Using GPS to record exact locations and preliminary mapping with GIS will allow me to take into consideration distance from paths and shoreline because I will be able to determine the exact distances from the paths using GPS with scale approximations and use these measurements for comparison post collection. With the data, a simple linear regression test, using R, will be employed to determine correlation between distance from paths/shoreline and cover of non-native species in the quadrats with the independent variable as the number of non-native perennial individuals in the quadrats and the dependent variable as the distance from path.

Results

Fig. 1- 65 square quadrats, determined by stratified random sampling, with centers marked on map of the Albany Bulb, CA.

From the sample of 65 quadrats randomly selected, non-native species made up on average 65.25% of the overall percent cover while native species made up 34.75% of the percent cover. Of the 36 species indentified, 27 of the species collected were classified as non-native species. Three species of plants, one native (*Salicornia virginica*) and two non-native (*Centaurea solstitialis* and *Foeniculum vulgare),* individually had over 10% plant cover in all quadrats. An a priori t-test power analysis was used to determine if the sample size was appropriate ($t= 1.96$, $df=64$, $P <0.005$). There was also a noticeable difference between the means of percent cover of non-native (65.2 ± 4.1) versus native species (35.7 ± 3.8) within each quadrat.

Table 1- Native species and non-native species (n=36) indentified with overall percent cover as determined from quadrats. Samples were taken during January to March 2009 at the Albany Bulb, CA.

Species	Native/Non-Native	Common Name	Type	% Cover
Ambrosia chamissonis	Native	Beach-bur	Forb	0.5
Euthamia occidentalis	Native	Western goldenrod	Forb	1.5
Heterotheca grandiflora	Native	Telegraph weed	Forb	2.25

Madia sp.	Native	Tarweed	Forb	0.5
Salicomia virginica	Native	Pickleweed	Forb	11
Xanthium strumarium	Native	Cocklebur	Forb	4.25
Distichlis spicata	Native	Saltgrass	Grass	5
Juncus patens	Native	Rush	Grass	3.25
Phrazmites australis	Native	Common Reed	Grass	6.5
Carduus pycnocephalus	Non-Native	Italian thistle	Forb	0.5
Carpobrotus edulis	Non-Native	Ice plant	Forb	3.5
Centaurea solstitialis	Non-Native	Yellow star-thistle	Forb	10.5
Centranthus ruber	Non-Native	Red valerian	Forb	0.25
Chenopodium multifidum	Non-Native		Forb	0.5
Convolvulus arvensis	Non-Native	Bindweed	Forb	1
Euphorbia characias	Non-Native	Spurge	Forb	1.5
Foeniculum vulgare	Non-Native	Fennel	Forb	12.25
Gnaphalium sp.	Non-Native	Cudweed	Forb	1
Lobularia maritime	Non-Native	Sweet Alyssum	Forb	1.5
Lotus comiculatus	Non-Native	Birdfoot Trefoil	Forb	0.5
Malva nicaeensis	Non-Native	Bull Mallow	Forb	1
Medicago polymorpha	Non-Native	California burclover	Forb	3
Melilotus alba	Non-Native	White sweetclover	Forb	0.25
Melilotus indica	Non-Native	Sourclover	Forb	2
Picris echioides	Non-Native	Ox-tongue	Forb	1
Plantago lanceolata	Non-Native	Plantain	Forb	0.5
Rumex pulcher	Non-Native	Fiddle docks	Forb	0.25
Avena barbara	Non-Native	Wild Oat	Grass	2
Bromus diandrus	Non-Native	Ripgut Brome	Grass	0.5
Bromus hordeaceus	Non-Native	Soft Chess	Grass	1.5
Cortaderi ajubata	Non-Native	Pampas Grass	Grass	8
Cynodon dactylon	Non-Native	Bermuda grass	Grass	0.25
Lolium multilflorum	Non-Native	Italian ryegrass	Grass	3.25
Phalaris aquatica	Non-Native	Harding grass	Grass	5.5
Piptatherum miliaceum	Non-Native	Smilo Grass	Grass	1
Polypogon monspeliensis	Non-Native	Rabbitfoot grass	Grass	2.25

Several non-native species (*Centaurea solstitialis, Foeniculum vulgare, Cortaderia jubata, and Phalaris aquatica)* but also native *Distichlis spicata* were found to be more prevalent in closer proximities to paths. There was no strong significant overall effect of distance from roads on non-native plant cover (r^2=0.0576, p=0.170).

Discussion

While non-native plants are much more abundant and diverse on the Albany Bulb, non-native plant distribution is not influenced by distance from areas of disturbance, mainly walking paths throughout the park.There were three times more species of non-native grasses and herbaceous plants sampled than native species (27 versus 9, respectively) with small patches of native plant islands clustered together more inland. The Albany Bulb is largely a heterogeneous composition of a variety of different non-native and some native colonizers.

While I hypothesized that as distance from paths increased, the percent plant cover of non-native species would decrease (Gelbard 2003), I did not observe this pattern. Native and non-native populations were found regardless of distance from paths, probably because the of the small sample size of the study site. In many cases, there were only one or two populations observed, of which no correlations would be made.

Sampling prior to the growth season in a dry year could have been a confounding factor, making a pattern among populations difficult to determine. Because samples were taken right before the annual rainy season and each of the species has different germination periods, there might have been greater differences if collected later in the season. It would be interesting to see how different the species composition would be if researched as conducted right before summer, after springs rains allow for germination of dormant species and before summer drought conditions set in. This is especially the case when considering the effect of competition from annuals and biannuals. As conditions change, the ability to detect which species are present and composition change as well.

Having better identification manuals and more plant classification experience to identify plant species would have provided much more accurate accounts of what plots really contained and would have been valuable to the experiment. Some plant species, in particular the grasses, may have been inaccurately classified and would have changed the differences among composition.

One reason there may not have been a statistical correlation between distance from paths and abundance of non-native species is that these paths, while occasionally travelled by park goers, are not maintained. Gelbard (2003) found that roads had an effect on plant cover and richness due to factors associated with construction, maintenance, and heavy traffic, which are not present in footpaths and not a characteristic of the study site. The same study also pointed out that native species and non-native species both experienced greatest cover along roadsides because along these corridors, native cover was not enough to limit the establishment of introduced species (Gelbard 2003). This indicates that the presence of paths creates opportunities for overall plant establishment and does not give a preference to native or non-native species. The species that is able to colonize or spread is based on individual site conditions. Other studies concluded that the ability of any non-native species to spread from a roadside or path depends on the soil characteristics of adjacent communities (Williamson and Harrison 2002); if the conditions at a particular area are favorable, then establishment will probably occur. This is particularly important for future study at the Albany Bulb because roadside communities are heterogeneous and different throughout the area. Future studies should discover which paths are most frequented by park visitors to see if these paths have the most plant cover associated with them.

Environmental variation such as soil type and compactness in inland communities might have had a significant contribution to the weak relationship between distance and abundance. Individual plant characteristics such as seed dispersal mechanisms and tolerance to disturbances such as trampling should be analyzed next time since relationships between native and non-native species richness are may correspond to different environmental variables (Levine 2000). The Levine study suggests that roads act as overall corridors of invasion because frequent disturbance by visitors makes the biological soil crust more vulnerable, and therefore easier for non-natives to establish. It is also noted that despite available entry points, the soil and topography may not be favorable because substrate of Albany Bulb is heterogeneous and in many ways, man made (Gelbard 2003).

This urban, shore side state park in the San Francisco Bay is a site that is increasingly becoming home to more non-native herbaceous plants and grasses than native. Yet, despite many trends found in past studies indicating that non-native species are more capable of establishing themselves than native species already adapted to these disturbed sites, results from this study regarding the correlation of distance remain inconclusive. With more inquiry to take into account seasonality to understand mechanisms for non-native plant establishment, we will learn to control and manage these often times harmfully invasive species and understand the role humans play in their spread.

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Appendix

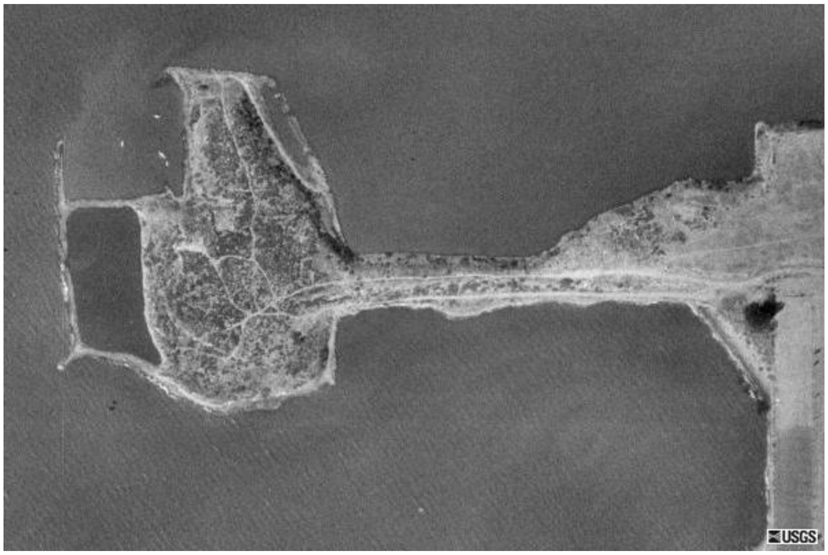

Figure 1: Aerial photograph of the Albany Bulb
http://socrates.berkeley.edu/~dkrasne/photos/Berkeley/albany_bulb/