Implications for Restoration by Seed Bank at Fort Funston, California

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Abstract This paper investigates the potential for restoration by seed bank recruitment in a coastal dune scrub ecosystem. I characterized the seed bank at Fort Funston, where for 45 years before restoration, invasive *Carpobrotus edulis*, commonly known as iceplant, was the primary vegetation. I sampled six locations with nine replicates, taking a total of 54 samples. Using a seedling emergence method, I examined the sand to measure the density and diversity of the seed bank in sites restored at different dates from 0 to 9 years ago. The method of seed bank analysis including greenhouse conditions highly influences the types and numbers of species found, making predictions at the species level impossible. The trends found in this study are as follows: 1.) Of 153 species found at Fort Funston 37 germinated, where 24 were native and 13 were not. 2.) Seed density increases exponentially with time since restoration. 3.) Diversity of non-native seeds decreases with time since restoration. Richness of species and evenness of some species suggest that trends in site diversity over time may exist.

Introduction

California's varied topography, geology, and climates have helped give rise to extraordinary native biological diversity and high levels of endemism, however, these varied conditions also provide suitable habitat for a wide variety of non-native plants that alter ecosystem function (Randall and Hoshovsky 2000). Native vegetation maintains diversity and self replication and has been declining in biomass in California since settlement in 1769 (Randall and Hoshovsky 2000). With European settlement many plants not endemic to California communities but adapted to the Mediterranean climate were introduced and established. These invasive plants have vastly altered ecological landscapes, outcompeting and excluding native plants and animals (Randall and Hoshovsky 2000). Many plant invasions can be slowed or halted, and even badly infested areas can be restored to relatively healthy communities dominated by native plants (Randall and Hoshovsky 2000).

Recognition of the deterioration caused by non-native plants has rapidly expanded the technology and practice of restoration, especially in the last thirty years (Pickart and Sawyer 1998), and invasive species control and restoration of native vegetation are now regarded as essential in many wildlands across the world (Randall and Hoshovsky 2000). The reintroduction of native plants to a restoration site has traditionally been referred to as restoration by revegetation, and increasingly restorationists are departing from traditional agricultural and landscape architecture revegetative techniques in favor of more ecologically based methods (Pickart and Sawyer 1998). Examples include using mycorrhizal inoculations to reduce the need for fertilizer and irrigation and exploiting seed reservoirs of historic vegetation (Pickart and Sawyer 1998).

As restoration work is often performed with limited budgets, and the cost of restoration is sometimes orders of magnitude higher than the cost of land acquisition, it is important that restoration projects be efficient (Pickart and Sawyer 1998). Regeneration by relict natives can significantly reduce the need for revegetation efforts, offsetting the high cost of restoration and increasing its success (Pickart and Sawyer 1998). Low materials cost, low intensity of labor, and low impact to land and rare species present make restoration by seed bank exploitation essential (Pickart and Sawyer 1998).

Knowledge of the seed bank at restoration sites is essential for managing for seed bank species (Strykstra et al 1998, van der Valk and Pederson 1989). Because seed banks relict from historical vegetation or donated from adjacent areas can be used in reestablishing vegetation, seed bank information can help predict resultant vegetation composition (van der Valk and Pederson 1989).

Many coastal ecosystems have been invaded by a South African succulent, *Carpobrotus edulis* (Alpert 2000). Commonly known as iceplant, invasion can cause a decline in biomass, life span, and reproductive output of native seedlings and shrubs because of its rapid spread and success in outcompetition (Alpert 2000, Pickart and Sawyer 1998). Invasion by iceplant also results in further invasion by non-native plants that would not be able to establish in sandy soils by contributing organic matter (Alpert 2000). Removal of ice plant is done manually, by chemical control, and mechanically, and afterwards requires revegetation to change species composition back to the relict natives (Alpert 2000). Planting may be desirable to decrease erosion, influence species composition, accelerate colonization and reduce the probability of invasion by other non natives but if adjacent native vegetation is present native plants may colonize a site without revegetation by planting (Pickart and Sawyer 1998). In California coastal dune scrub ecosystems, restoration projects including recruitment from the seed bank are in place, but the seed bank is presently unstudied (Setty pers comm, 2001).

Restoration is underway at Fort Funston National Recreation Area in San Francisco where *C. edulis* is outcompeting native vegetation. Because the seed bank in California's dune scrub ecosystem is presently unstudied and it is an important source for restoration after the invasion *of Carpobrotus edulis,* this study aims to analyze the seed bank at Fort Funston and discuss its implications for restoration of dune scrub ecosystems.

Specifically, this study will characterize the seed bank to: (1.) simplify revegetation efforts by better predicting what species are present below ground; and (2.) investigate the correlation between time since restoration and measures of the seed bank such as density, diversity and the relative occurrences of native and non-native individuals found.

I expect to find an exponential increase in seed density as the length of time since restoration increases due to deposition of seeds by planted species. I expect to see density of primarily iceplant and other non-native species in sites that have not begun restoration because of dispersal of iceplant seeds and the opportunity that iceplant allows for further invasions. I expect to see a trend in species diversity, with a peak in the region of intermediate disturbance, and more native species and individuals present relative to non-natives as time since restoration increases.

Site Description Fort Funston is located along the coastal region of the northern San Francisco penninsula, in San Francisco, California (37º43'N and 122º30'W, figure1). It spans approximately 230 acres sitting atop a sandstone bluff and it is home to rare and endangered species including cliff swallows and the San Francisco spineflower. The native vegetation is shrubby, adapted to nutrient poor sand and coastal fog and sea spray, and is part of a coastal dune scrub ecosystem.

Fort Funston is a converted military fort which discontinued use in 1963. It became part of the Golden Gate National Recreation Area in 1974. During military use in the 1930s an extensive system of coastal defense batteries was built and much of the native plant community at Fort Funston was destroyed. Following construction the army planted iceplant to stabilize the sand around the batteries. By the mid 1960s much of the present park was covered with non-native invasive plants such as iceplant and acacia (O'Niel 2000). Restoration began in 1976, by removing iceplant and revegetation with propagules collected from Fort Funston's watershed. To date, iceplant has been removed from the part of the park, both by volunteer hand pulling and mechanically. Sites sampled, Entrance Site (1), HRT Ridge and Scout Bowl (3), Merced Bowl (4), and the Nursery Hillside (6) had the majority of their restoration done in 1998, 1992, 1996, and 1994, respectively, and the Ropes Course (site 2) and the Battery Davis Erosion Control Area (site 5) have not been restored to date (see figure1) (Setty 2000).

Methods

Field Sampling The sampling sites were chosen from past and future restoration projects. Within each site I performed stratified random sampling to account for spatial variation in the seed bank. I divided each site into nine fractions by pacing and dividing the largest rectangle that fit into the site. I sampled at coordinates from a random number table within each fraction. I removed sand from the ground using a 15x25cm flat ended shovel targeting a depth of five centimeters and organic matter as suggested in a previous study (Staniforth et al 1998).

I collected samples on February 21st and 25th 2001, attempting to discard seedlings scooped with sand, and I stored them in sealed quart size, plastic Glad brand bags out of doors on nursery grounds until transfer to the greenhouse on February 26th. They were protected from rodents and rain under tarp in a wire cage during storage.

Greenhouse Treatment To simulate maximum germination I spread each sample in a shallow 26cm square tray on top of two centimeters of Sunshine aggregate mix 4, containing 55-65% sphagnum peat moss, to avoid desiccation and kept them in a random arrangement in the Oxford Research Facility greenhouse in Berkeley, California. I simulated optimal germinating conditions by lighting artificially from 6-8am and 6-8pm, watering twice daily, spraying pesticide once weekly, and heating the air temperature to 24° C. After two weeks of growth germination results were collected for five weeks. Upon weekly identification of germinants seedlings were removed from the trays to reduce competition. Unknown species were potted and tagged until identification was possible.

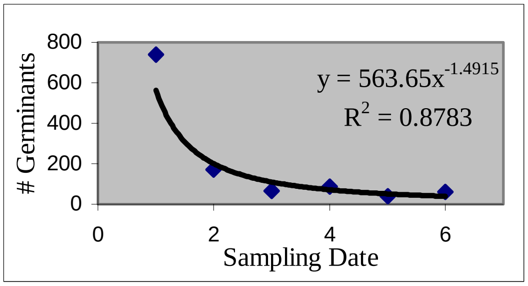
Data Collection In the initial two weeks of growth grass seedlings appeared *enmasse*, showing the presence of exceedingly mature seedlings. Although these grasses are assumed to be germinants at the time of sampling, rather than from seeds in the seed bank, neglecting the inclusion of the grasses in the study became appropriate. Grasses were removed upon germination but not recorded. I recorded the remaining germination results by tallying the quantity of each species germinating in each tray on each inspection date.

Stastical Analysis I used Microsoft Excel to perform simple regressions between time since restoration and the Shannon Weiner index of species diversity (Zar 1999) and other measurements used to quantify the seed bank. Excel also fit trend lines to graphs to explain variation between samples.

Results

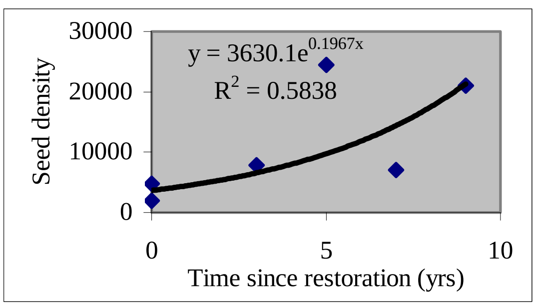
Germination of seed bank seeds provided valuable insight into the abundance of viable seeds present. We were unable to identify fourteen germinants from 10 different species, <1% of the total yield, thus, the remaining unknowns were not included in these results. Sprouting individuals were generally identified to species although some were grouped by genus. Neglecting unknown germinants and all grasses, 37 of the 153 species at Fort Funston (as recorded California Native Plant Society, appendix1), germinated in this experiment. For the benefit of restoration managers and future studies, a list of the species which germinated and their densities at each site is recorded (appendix 2). Neglecting *Crassula connata,* which accounts for more than half of the number of germinants and showed no trend over time (p=.46), the number of germinants found weekly decreased exponentially, p=0.09, (chart 1).

Chart 1: Total Germinants over Time



Density: A test for regression of seed density per site over time gives a less significant trend, p=0.11 (chart 2). The average density of the seed bank at Fort Funston was shown to be about 11000 seeds/m^2, where at restored sites the range is 7800seeds/m^2 to 24,000seeds/m^2 and at non-restored sites seed density averaged 3300seeds/m^2.

Chart 2: Seed Density over Time



Diversity: The Shannon Weiner Index of diversity showed no trend over time since restoration, although its two components, the number of individuals per species and the number of species present, show slight trends. A test for regression of individuals per species present at 4 or more sites showed with at least 90% confidence trends over time in *Carpobrotus edulis*, p=0.07 (chart 3) and *Lotus sp.*, p=0.04 (chart 4). A regression of the number of species per site shows a strong correlation with time since restoration, p<0.01 (chart 5). The number of individuals germinating from samples at each site increases exponentially with time since restoration, p=0.11. The diversity of native plants also suggests no trend (p=0.46).

Chart 3: Density of *Carpobrotus edulis* over Time

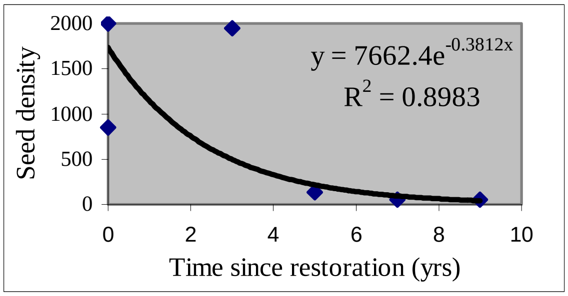


Chart 4: Density of *Lotus sp.* over Time

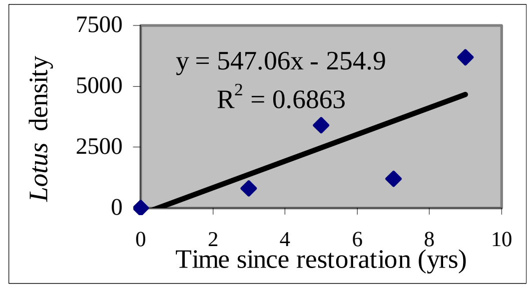
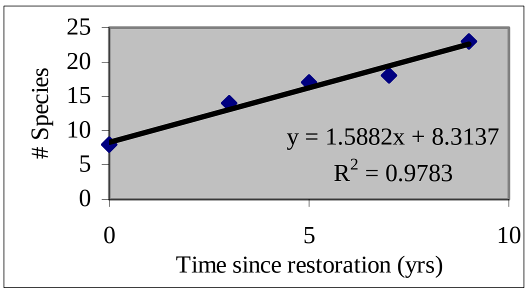


Chart 5: Number of Species over Time



Proportions of Natives and Non-Natives: Of the 37 species germinating, 24 were native and 13 were not. The number of species per site ranged from 8 to 23, of which natives ranged from 6 to 12 and non-natives from 4 to 11. Relationships were found in both the number of native and non-native species relative to the total number of species found at each site, $p= 0.16$ and $p=0.06$ respectively (charts 6 and 7). Relationships also appear in both the number of native and non-native individuals relative to the number of individuals at each site, $p=.12$ and $p=.11$ respectively (charts 8 and 9).

Chart 6: Relative # of Native Species over Time

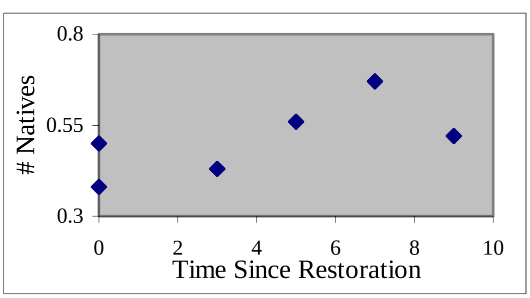


Chart 7: Relative # of Non-native Species over Time

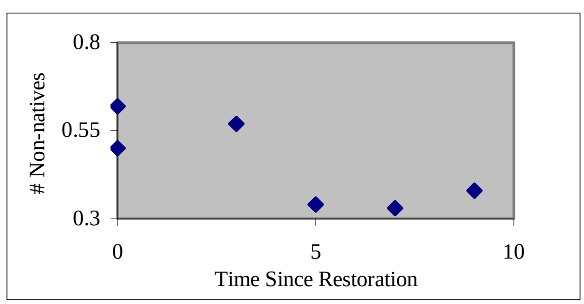


Chart 8: Relative # Native Individuals over Time

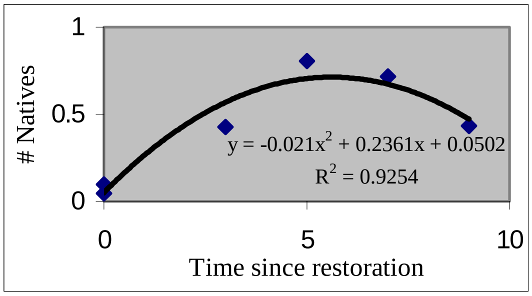
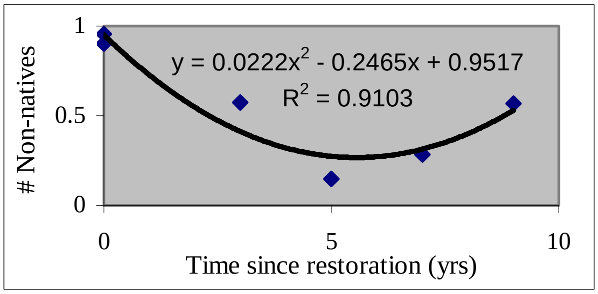


Chart 9: Relative # Non-native individuals over Time



Control trays: One germination occurred in the series of 8 control trays. This plant was *Crassula* and accounts for <<0.01% of total germination.

Discussion

This study examined the seed bank to find the common species occurring and to note trends. The density of the seed bank seems to increase exponentially with time since restoration and that trends in diversity are mostly inconclusive at this time. The number of non-native species present decreases with time since restoration.

Several species were seen at all sites sampled and some species were only seen in specific sites, but we can infer only general patterns from this data. It is impossible to make site-specific predictions from sites with variable histories (Conn et al 1984) and more information regarding each species is needed to make predictions about specific species, especially about seed dispersal, longevity, and germination requirements (Strykstra et al 1998, ter Heert et al 1999).

The primary goal of the study was to analyze the seed bank by determining the types and abundances of seeds present. It is important to realize that the method of analysis biases the types and abundances of seeds found, as does the greenhouse conditions and the seasonality of experimentation (Gross 1990, ter Heert et al 1999a and 1999b, Holl 2000). Two groups of methods are generally used to estimate seed bank composition, namely seed separation methods and seedling emergence methods (ter Heert et al 1996). Seed separation methods require further testing to determine viability, are very time consuming, and are ineffective in small-seeded species methods (ter Heert et al 1996). A preliminary study confirmed that seed separation was too laborious and that seeds of this ecosystem were too small for this method to be used in my research.

Seedling emergence methods are simple but have some disadvantages. Species differ greatly in germination requirements, therefore greenhouse conditions are not always suitable for the germination of all species (ter Heert et al 1996). It is also clear that seeds in a state of dormancy will not germinate (ter Heert et al 1996), such as chaparral shrubs that are adapted to fire (Holl et al 2000) or *Lupinus sp.* seeds that require scarification to germinate (Setty 2001). Another disadvantage of this seedling emergence method is that the soil samples must be kept in the greenhouse for a considerable time, and a period of 2 years has been suggested as reasonable (ter Heert et al 1996). In this study, both the abundances and species present may be underestimated to the method of analysis and germination conditions, and longevity of study. The steep decline in germinants after the first week of monitoring suggests that under the conditions given all significant germination happened (chart 1).

Density of seeds seemed to increase with increasing lengths of time since restoration, with 89% confidence implying that confounding factors may be present. The average seed density at Fort Funston was shown to be about 11000 seeds/m^2, where at restored sites the range is 7800seeds/m^2 to 24,000seeds/m^2 and at non-restored sites seed density averaged 3300seeds/m^2. These numbers are consistent with other studies. Less frequently disturbed sites are said to have higher seed densities than less frequently disturbed areas and the intermediate stage has the smallest overall density (Pierce and Cowling 1991). In this study the sites of lowest disturbance are undoubtedly the sites covered in *Carpobrotus edulis* and the sites with the longest time since restoration. Low diversity at intermediate disturbances is a confounding factor in predicting a trend in seed bank density over time.

The low density of seeds as seen in the non-restored sites indicates poor dispersal between sites or other adjacent re-vegetated areas, and little viable relict seed present. These results suggest that the existing seed bank is unlikely to lead to significant increases in re-vegetation and species diversity after the removal of *Carpobrotus edulis* and they are consistent with other studies (Baptista and Shumway 1998 and Holl et al 2000). Planting is essential in accelerating recovery from degradation, both at this site and others (Parker and Kelly 1989, Strykstra et al 1998, and Holl et al 2000).

Diversity of seedlings at each site showed no trend over time, nor was a trend present in the density of native plants at each site. In non-native plants diversity showes a slight trend of linear decrease over time ($p=0.14$, $R^2=0.45$), encouraging further examination of this issue. Although

Shannon Wiener's diversity index showed no trend, the two components of the calculation showed trends over time. Species richness, the number of species present in each site, showed a sharp linear increase over time. Species evenness, the abundance of each individual at each site, showed a trend in *Carpobrotus edulis*, with 90% confidence, and *Lotus sp.* with 95% confidence. Although the Shannon Wiener diversity index shown no trend over time, some implications can be made by further inspection into the basis of that test. The diversity of non-native seeds in this study seemed to decrease with time since restoration consistent with the characteristic of non-native plants to allow further invasion by non-natives (Randall and Hoshovsky 2000). Species richness increases sharply as restoration projects age. The abundance of invasive individuals such as *Carpobrotus edulis* decreases over time and natives, such as *Lotus sp.* may increase over time.

Since disturbance is known to result in exotic species invasion (McDonald 1996) the declining number of non-native species over time, with 94% confidence, is consistent with previous studies. Finding no correlation between the number of native species and the number of native and non-native individuals at each site may be influenced by incomplete characterization of the seed bank as discussed above.

This study examined the seed bank to find trends in density, diversity, and relative numbers of natives and non-natives. Many confounding factors arose weakening the significance of trends. Considering confounding factors such as the limitations of the method of analysis and the differences between sites, and the small number of samples taken, trends that appear slightly weak may indeed be stronger than suggested. This study has shown 1) that the density of the seed bank seems to increase with time since restoration, 2) that trends in the evenness of some species' are apparent and species richness increases sharply with increasing time since restoration, implying some trend in species diversity may exist and 3) that the abundance of non-native species decreases with increasing length of restoration projects.

Acknowledgements

I thank Asha Setty, Fort Funston's nursery manager, with her assistance in project implementation and germinant identification, Cheryl Lee for help in the field and writing critique. I also thank John Latto and Matt Orr, for help with the project's design and statistics and writing critique, and the College of Natural Resources for funding the greenhouse study.

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Appendix 1: Fort Funston Modified Plant List, May 2001 Nomenclature: Jepson 1993 & CNPS

FORT FUNSTON NATIVE PLANT LIST
modified for seed bank study.
Grasses removed and some spcies reduced to genus only.

SCIENTIFIC NAME	COMMON NAME	NATIVE
Abronia latifolia	Yellow Sand Verbena	yes
*Abronia umbellata **	Pink Sand, Beach Verbena	yes
Aceana pinnatifida var. californica	Aceana	yes
***Achillea millefolium*	Yarrow	yes
Agoseris apargioides var. apargioides	Coast Dandelion	yes
Agoseris apargioides var. eastwoodiae	Coast Dandelion	yes
Ambrosia chamissonis	Beach Bur, Silver Beach Weed	yes
Amsinckia sp.	Fiddleneck	yes
Anaphalis margaritacea	Pearly Everlasting	yes
*Angelica hendersonii **	Coast Angelica	yes
***Aphanes occidentalis **	Western Lady's Mantle	yes
Armeria maritima ssp. californica	Sea Thrift, Sea Pink	yes
***Artemisia pycnocephala*	Coastal, Beach Sagewort	yes
Astragalus nuttalli var.virgatus	Locoweed	yes
Atriplex leucophylla	Beach Salt Bush	yes
***Baccharis pilularis*	Coyote Bush	yes
Calystegia purpurata ssp. purpurata	Morning Glory	yes
Camissonia cheiranthifolia ssp. cheiranthifolio	Beach Evening Primrose	yes
Camissonia contorta	Contorted Primrose	yes
Camissonia micrantha	Small Primrose	yes
***Cardamine oligosperma*	Bitter-cress	yes
***Cardionema ramossissimum*	Sand -mat	yes
*Castilleja latifolia**	Seaside Paintbrush	yes
*Castilleja subinclusa ssp. franciscana *(?)*	Franciscan Paintbrush	yes
Castilleja wightii	Wight's Indian Paintbrush	yes
Chlorogalum pomeridianum var. divaricatum	Soap Plant, Amole	yes
***Chorizanthe cuspidata ssp. cuspidata (var. villosa?)*	San Francisco Spineflower	yes
Circium occidentale var. occidentale	Cobweb(by) Thistle	yes
Clarkia rubicunda (? keyed once, but still uncertain)	Farewell-to-Spring	yes
***Claytonia perfoliata ssp. perfoliata*	Miner's Lettuce	yes
***Crassula connata*	Sand Pygmy-weed	yes
*Croton californicus **	California Croton	yes
Cryptantha leiocarpa	Popcorn Flower	yes
Daucus pusillus	Rattlesnake Weed	yes

Dichelostemma capitatum ssp. Capitatum	Blue Dicks, Wild Hyacinth	yes
Dudleya farinosa	Live-forever, Sea Lettuce/	yes
Epilobium brachycarpum *	Panicled Willowherb	yes
Epilobium ciliatum ssp. watsonii	Willow-herb	yes
Equisetum telmateia ssp. braunii *	Giant Horsetail	yes
Ericameria ericoides	Mock heather	yes
Erigeron glaucus	Seaside daisy	yes
***Eriogonum latifolium*	Coast Buckwheat	yes
***Eriophyllum staechadifolium*	Lizard-tail, Seaside wooly sunflower	yes
Erysimum franciscanum	San Francisco Wall Flower	yes
Eschscholzia californica *	California Poppy	yes
Festuca rubra	Red Fescue	yes
Fragaria chiloensis	Beach Dune Strawberry	yes
Galium aparine	Bed Straw, Cleavers	yes
Gilia capitata ssp. chamissonis *	Blue Field Gilia, Dune Gilia (?)	yes
Gnaphalium purpureum	Purple Cudweed	yes
Grindelia hirsutula var. maritima *	San Francisco Gum Plant	yes
Heracleum lanatum	Cow Parsnip	yes
Hesperocnide tenella	Western Nettle	yes
Juncus balticus/lesuesrii(?)	Rush	yes
Koeleria macrantha	Koeleria,June Grass	yes
Lathyrus littoralis	Beach Pea	yes
Linaria canadensis	Canadian, Blue Toadflax	yes
Lonicera hispidula var. vacillans	California Honeysuckle	yes
Lotus heermannii var. orbicularis	Southern Lotus	yes
***Lotus sp*	Deer Weed	yes
***Lupinus sp.*	Lupine	yes
Madia sativa	Coastal Tarweed, Headland Tarweed	yes
Marah fabaceus	Man-root, Wild cucumber	yes
Melica imperfecta	Small-Flowered Melica	yes
Microseris bigelovii	Coast Dandelion, Coast Microseris	yes
***Mimulus auranticus*	Bush, Sticky Monkey Flower	yes
Monardella villosa ssp. franciscana *	Western Pennyroyal	yes
Myrica californica *	Wax Myrtle	yes
Navarretia squarrosa *	Skunkweed	yes
Oemleria cerasiformis	Oso Berry	yes
***Oenothera elata ssp. hookeri* *	Evening Primrose	yes
Paronychia franciscana *	California Whitlow-wort	yes
Phacelia californica	Phacelia	yes
Phacelia distans *	Wild Heliotrope	yes
Piperia elegans	Green Rein-orchid	yes
Plantago erecta *	Dwarf Plantain	yes

Plantago maritima *	Pacific Seaside Plantain	yes
***Polygonum paronychia*	Dune Knotweed	yes
Polypodium californicum	California Polypody	yes
***Pteridium aquilinum var. pubescens*	Western Bracken Fern	yes
Pterostegia drymarioides	Pterostegia	yes
Rhamnus californica ssp. californica	California Coffeeberry	yes
Rosa californica	California Wild Rose	yes
Rubus ursinus	California Blackberry	yes
***Rumex salicifolius var. crassus (?)*	Willow leaved Dock	yes
Salix lasiolepis (?)	Yellow, Arroyo Willow	yes
Satureja douglasii *	Yerba Buena	yes
***Scrophularia californica ssp.californica*	Bee Plant, California Figwort	yes
Sidalcea malvaeflora ssp.?	Checker Bloom, Wild Holly	yes
***Solanum nodiflorum=Solanum americanum (?)*	Small Flowered Nightshade	yes
*Solidago spathulata (ssp. spathulata)**	Dune, Coast Goldenrod	yes
*Spergularia macrothea (var. macrothe)**	Large Flowered Sand Spurry	yes
Tanacetum camphoratum	Dune Tansy	yes
Toxicodendron diversilobum	Poison Oak	yes
Trifolium willdenovii	Cow, Tomcat Clover	yes
Triteleia laxa	Ithuriel's Spear	yes
Uropappus lindleyi	Silver Puffs	yes
SCIENTIFIC NAME	COMMON NAME	NATIVE
Acacia longifolia	Golden Wattle	no
Albizia lophantha	Stink Bean	no
Ammophila arenaria	European Beach Grass	no
Anagallis arvensis	Scarlet Pimpernel	no
***Anthriscus caucalis*	Bur-Chervil	no
*Avena barbata**	Slim Oat	no
Avena fatua	Wild Oat	no
Brassica rapa	Field Mustard	no
***Cakile maritima*	Sea Rocket	no
Capsella bursa-pastoris	Shepherd's Purse	no
Carpobrotus chilensis *	Iceplant, Sea Fig	no
***Carpobrotus edulis*	Hottentot Fig/ Iceplant	no
Cardus pycnocephala	Italian Thistle	no
Centaurea melitensis	Napa Thistle	no
Chamomilla suaveolens	Pineapple weed	no
***Chenopodium sp.*	Chenopod	no
Cirsium vulgare	Bull Thistle	no
Conicosia pugioniformis	Narrow-Leaf Iceplant	no
Conium maculatum	Poison Hemlock	no
***Conyza bonariensis*	Horseweed	no
Cupressus macrocarpa	Monterey Cypress	no

Drosanthemum Floribundum	Ice plant	no
Erodium botrys	Broad leaf Filaree	no
Erodium cicutarium	Red Stemmes Filaree	no
***Erodium sp.*	Filaree	no
Eucalyptus globulus	Blue Gum	no
Foeniculum vulgare	Sweet Fennel	no
Fumaria parviflora	Fumitory	no
Geranium dissectum	Cut leaved Geranium	no
***Gnaphalium sp.*	Cudweed	no
Hedypnois cretica	Hedypnois	no
Hypochaeris glabra	Smooth Cat's-Ear	no
Lactuca saligna	Lettuce	no
Lavatera cretica	Tree-mallow	no
Leptospermum laevigatum	Tea Tree	no
Lotus corniculatus	Birdsfoot Lotus	no
Malva parviflora	Cheese Weed	no
Medicago polymorpha	Bur Clover	no
Melilotus indica	Sweet Clover	no
Myoporum laetum	Lollypop Tree	no
***Oxalis sp.*	Oxalis	no
*Paronychia franciscana**	Nailwort, something Whittlewort?	no
*Pinus radiata **	Monterey Pine	no
Plantago coronopus	Cut-leaved Plantain	no
Polycarpon tetraphyllum	Four-leaved polycarp	no
*Raphanus sativus **	Wild Radish	no
Rumex acetosella	Sheep Sorrel	no
Senecio elegans	Purple Ragwort	no
Senecio mikanioides= Delairia odorata	Cape Ivy / German Ivy	no
***Senecio vulgaris*	Common Groundsel	no
***Solanum furcatum*	Forked Nightshade	no
***Sonchus oleraceus*	Sow Thistle	no
Spergularia rubra	Purple Sand Spurrey	no
***Stellaria sp.*	Common Chickweed	no
***Tetragonia teragonoides*	New Zealand Spinach	no
Vicia sativa	Common Vetch	no
Vicia villosa	Wooly Vetch	no
Zantedeschia aethiopica	Calla Lily, Common Calla	no

** Species found in this study
* These species were not seen in the in the field for the compilation of this list,
but were carried over from previous year's lists.

Appendix2: Deed Bank Density Data by Site

Apendix 1: Table 2. Density by site of germinants in a sample of Fort Funston's seedbank.

Scientific Name	Native?	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Achillea millefolium	yes	-	-	-	-	-	400
Aphanes occidentalis	yes	-	400	-	-	-	-
Artemisia pycnocephala	yes	-	-	2800	-	-	-
Baccharis pilularis	yes	-	200	-	400	-	400
Camissonia cheiranthifolia	yes	1800	-	5200	800	1200	1600
Cardimine oligosperma	yes	-	-	200	200	-	1400
Cardionema ramossissimum	yes	-	-	-	-	-	200
Chorizanthe cuspidata ssp. cuspidata	yes	-	-	6000	5400	-	200
Claytonia perfoliata spp. Perfoliata	yes	-	-	4600	2000	-	200
Crassula connata	yes	17200	600	37200	143000	200	37000
Dudleya farinosa	yes	-	-	4000	-	-	200
Ergonium latifolium	yes	-	-	1200	600	-	600
Eriophyllum staechadifolium	yes	3000	-	-	-	-	-
Lotus scoparius	yes	800	-	6200	2200	-	1000
Lotus strigosis	yes	-	-	-	1200	-	200
Lupinus arboreus	yes	-	-	-	-	200	-
Mimulus auranticus	yes	600	-	-	-	-	-
Oenothera elata ssp. hookeri	yes	-	-	600	-	-	-
Polygonium californicum	yes	-	200	-	-	-	-
Pterostedia drymarioides	yes	-	-	-	200	-	-
Rumex ursinus	yes	-	-	-	-	-	1800
Scrophularia califonrica	yes	1600	-	-	-	-	-
Anthriscus caucalis	no	400	-	600	-	-	-
Cakile maritima	no	-	-	800	-	-	-
Carpobrotus edulis	no	14600	6400	400	1000	15000	400
Chenopodium sp.	no	400	-	200	400	200	2200
Conyza bonariensis	no	600	-	200	400	-	-
Erodium sp.	no	-	-	200	-	-	-
Gnapthalium sp.	no	12000	6000	9400	24000	5800	12200
Oxalis sp.	no	400		-	-	-	-
Senecio vulgaris	no	-	-	-	200	-	-
Solanum furcatum	no	-	-	200	200	-	1000
Sonchus oleraceus	no	4200	200	1000	200	2000	200
Stellaria sp.	no	1000	400	76600	800	-	2000
Tetragonia teragonoides	no	-	-	-	-	11000	-