Invasive Plants as a Threat in the San Francisco NWR Complex

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Introduction

Within the San Francisco NWR Complex, invasive plants are ranked as a very high threat. The following targets are under threat: tidal marsh and waterbirds at the San Pablo Bay and Don Edwards NWRs, vernal pools at Don Edwards NWR, marine island ecosystems at Farallon NWR, Pajaro Valley watershed at Ellicott Slough NWR, coastal dunes at Salinas NWR, riverine dunes at Antioch Dunes NWR, and estuarine island ecosystems at Marin Islands NWR. Nonnative species that cause environmental harm by reduction of biodiversity, degradation of habitats, alteration of native genetic diversity, and further threats to already endangered plants and animals are referred to as invasive species (USFWS 2005). Most invasive plants are introduced in the United States through human activity such as trade, travel, and horticulture (PROTECT 2008, Reichard et al. 2001). Plant seeds may also travel through water or through wildlife such as birds. Once invasive plants are established, they negatively impact biodiversity and plant composition of the invaded community (Hejda et al. 2009). These problems occur when invasive plants directly outcompete native plants, or when they indirectly impact native plants by altering fire, nutrient, water, and soil/sediment regimes (Brooks et al. 2004, Gaertner et al. 2014, Stromberg et al. 2007). Beyond affecting native plants, the effects of invasive plants on plant composition can then create stress on refuge wildlife who rely on native plants for food or habitat, or rely on lack of vegetation presence for habitat.

Tidal Marsh

In tidal marsh habitat at San Pablo Bay NWR and Don Edwards NWR, invasive plants are a high threat. Invasive plant species that are most problematic in tidal marsh tend to have one of the following effects: (1) displace and decrease the population size of native plants with their sheer abundance, (2) dominate areas by developing nearly single-species stands, (3) colonize habitats such as tidal flats naturally lacking in vascular plants, or (4) provide no escape cover during winter high tides because predators can see easily see through them (USFWS 2013). Two species, *Lepidium latifolium* (perennial pepperweed) and *Spartina*, play a large role in affecting native plant composition, invertebrate density and/or population, and soil-building properties of tidal marsh.

Several invasive *Spartina* species are found in San Francisco Bay. The most abundant is a hybrid formed between *Spartina alterniflora* (smooth cordgrass) and the native *Spartina foliosa*. If uncontrolled, this hybrid would be predicted to spread throughout the San Francisco Estuary and transform its tidal ecosystems (Zaremba et al. 2004). *S. alterniflora* is a perennial grass that spreads quickly due to annual re-sprouting from thick rhizomes underground in addition to reproducing from seed. An invasion at Willapa Bay in Washington demonstrated that extensive tidal mudflats could be converted to dense and continuous marsh composed only of *S. alterniflora* (Mumford et al. 1990). Since hybrid *Spartina* has the same tendency to spread

quickly, *S. foliosa* stigmas become swamped with hybrid pollen and *S. folisa* becomes crowded out by the hybrid (Daehler and Strong 1997). A genetic study found that later generations of the hybrid were two times more homozygous than early generation hybrids (Sloop et al. 2009). This discovery indicates that the hybrid likely evolved self-fertility, another explanation for the rapid spread of the hybrid in San Francisco Bay. As a result of the rapid spread, most remaining *Spartina* in California are the hybrid, not S. *alterniflora*. Efforts to control *Spartina* invasion at the refuges are already underway and close to completion.

Besides spreading quickly, hybrid *Spartina* density and biomass is six to seven times greater than native *S. foliosa* (Callaway 1992). This difference makes hybrids capable of higher rates of sediment trapping than usual, resulting in alteration of marsh habitat (USFWS 2013). Areas of mudflat and small tidal creeks may be converted to areas of solid marsh with few tidal creeks.

Invasive plants are recognized as a threat to several species in the USFWS Recovery Plan for tidal marsh. In high marsh areas, invasive plants are an immediate threat to endangered *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle) by interfering with regeneration of this low population plant. Another endangered plant affected by seedling regeneration is *Suaeda californica* (California sea-blite), which resides in a narrow zone in the upper edge of the marsh.

Plant composition influences Ridgway's rail, and lack of blocks of tidal marsh with suitable structure is the limiting factor for recovery (USFWS 2013). With narrow and fragmented patches, Ridgway's rail becomes more vulnerable to predation. Finding a solution for Ridgway's rail will be complicated because removal of invasive *Spartina* species will be necessary to improve plant composition, but hybrid *Spartina* currently provide habitat for the rail (USFWS 2013). However, the short-term benefit *Spartina* provides is thought to be outweighed by the long-term benefits to rail from improved ecosystem conditions.

Salt marsh harvest mouse is restricted to saline or subsaline tidal marsh habitat. Mouse populations rely on abundance of *Sarcocornia*, a dominant native plant species of tidal marsh, as well as being limited by distribution of high tide cover and escape habitat.

Waterbirds

The California least tern is listed as an endangered species and is under very high threat from invasive plants. Invasive *Spartina* species are a threat to the Alameda least tern colony located in San Francisco Bay. This Bay Area population is considered a critical population. The California Department of Fish and Game found the Alameda population to be the fourth best producer of fledglings, making this colony vital to statewide species recovery (Feeney 2000). Least terns require tracts of open sand or fine gravel substrate with sparse vegetation for nesting (Feeney 2000). *Spartina* grows densely and can become widespread, creating habitat loss for the least tern. When habitat is lost, least terns search for alternative sites without dense vegetation, leading them to nest at areas such as the Oakland Airport (Feeney 2000). At alternative sites,

they are susceptible to other factors like predation which results in nesting pairs to fail (Feeney 1996). Habitat loss must be prevented to stop least tern reproductive success from decreasing and allow the population size to increase. At Seal Beach NWR in southern California, vegetation management protocol was changed in the past to successfully have terns return to utilizing a site invaded by nonnative iceplant (*Carpobrotus edulis*) (USFWS 2006). This demonstrates that management can be effective in addressing the threat of invasive plants on least tern breeding success.

Vernal Pools

Invasive plants are a very high threat to vernal pool grasslands in Don Edwards NWR. Vernal pool plant species have declined due to introduction of non-native species (USFWS 2005). Competition for water, light, and nutrients has been a factor, affecting species such as *Chamaesyce hooveri* (Hoover's spurge) and *Orcuttia pilosa* (hairy orcutt grass). Altered disturbance regimes also play a role by facilitating establishment of invasives. In the past, unnatural disturbance resulted from urbanization, agricultural activities, and changes to fire and grazing frequency (Stylinski and Allen 1999). The invasive plants competing with *Orcuttia pilosa* are thought be a result of seeds being established after cattle carried seeds and created disturbance from trampling (Stone et al. 1988, Alexander and Schlising 1997). An eradication plan for the Sacramento Valley region was developed in response to invasive species occupying habitat previously home to native plants. One notable case that involved *Lepidium latifolium* (perennial pepperweed) and *Crypsis schoenoides* (swamp grass) invading vernal pool habitat previously occupied by *Tuctoria mucronata* and *Astragalus tener var. tener* inspired the creation of the eradication plan (USFWS 2006).

Vernal pool and grassland vegetation composition is important to two endangered species: the vernal pool tadpole shrimp (VPTS) and the California tiger salamander (CTS). The CTS is reliant on vernal pools for breeding. At an individual pond, the breeding population can drop to less than twenty adults, making a local population prone to extinction (USFWS 2005). Large vernal pool complexes containing multiple breeding ponds are required to improve breeding success of salamanders. Therefore, maintaining vernal pool vegetation structure and composition by controlling invasive plants is important to CTS breeding success.

Marine Islands

At Farallon NWR, breeding seabirds on the marine island ecosystem are under very high threat from invasive plants. Islands are one of the most vulnerable ecosystems based on studies of islands in the Atlanic, Caribbean, Mediterranean, Pacific, and Western Indian Ocean regions (Lloret et al. 2005, Kueffer et al. 2010). Seabirds on the Farallons could be affected through plants affecting nesting habitat availability, or through the effects of non-native plants on vegetation cover and composition. Studies in island ecosystems demonstrate that invasive plants on islands are correlated with a decline in habitat for seabirds. The spread of non-native *Malva arborea* on the Islands of Firth in Scotland were correlated to a decline in the Atlanic puffin

population (Harris et al. 2003). On Midway and Kure Atoll in the Hawaiian Islands, the invasive golden crownbeard (*Verbesina encelioides*) reduced available habitat for ground-nesting seabirds such as Laysan albatross, black footed albatross, Christmas shearwater, and wedge-tailed shearwater (Feenstra and Clements 2008). Direct effects on seabirds through toxicity are possible as shown by the toxic African boxthorn's impact on the short-tailed shearwater population on Allthorpe Island in southern Australia (Lawley et al. 2005).

On the Farallon Islands, a weed management plan was prepared in 2004 and updated in 2008, since non-native plants were recognized as a challenge towards successful seabird breeding. New Zealand spinach (*Tetragonia tetragonioides*) and cheeseweed (*Malva parviflora*) were identified as priorities for management. New Zealand spinach is difficult to remove and greatly affects vegetation composition, with NZ spinach detected on 13% of the surveyed area during Farallon Invasive Plant Inventory (USFWS 2016). Continued monitoring was recommended after the Inventory. Although there is greater prevention for non-natives to be brought in by humans, birds serve as vectors as well, making it necessary to prevent reintroduction of species after they are removed.

Pajaro Valley Watershed

Hydrology, California tiger salamanders, and Santa Cruz long-toed salamanders (SLTS) are impacted by invasive plants in Pajaro Valley watershed at the Ellicott Slough NWR, making invasives a very high threat there. Examples of invasive plants threatening native habitats are: eucalyptus (*Eucalyptus* spp.), pampas or jubata grasses (*Cortaderia* spp.), poison hemlock (*Conium maculatum*), New Zealand spinach (*Tetragonia tetragonioides*), and mustard (*Brassica* sp.) (USFWS 2010).

Invasive plants contribute to poor pond water quality and may affect pond water depth and hydroperiod. The invasive Curly dock (*Rumex crispus*) resides in ephemeral ponds, seasonal freshwater ponds that act as breeding sites for salamanders. Poor pond conditions lead to decreased food availability through effects on native pond invertebrates, which impact both salamander species. Additionally, the poor pond conditions affect aquatic vegetation, which impacts the SLTS population. Degradation and destruction of aquatic breeding habitat was the primary reason for listing SLTS as endangered.

Invasive plants affect salamander populations in other ways as well. CTS are known to travel up to 1 mile in search for a pond to breed. Invasive plant management is necessary to maintain habitat that can provide cover for salamanders to migrate safely.

Coastal Sand Dunes

Coastal sand dunes in Salinas NWR are under very high threat from invasive plants. Plants affect sand dune formation dynamics, which can have a variety of effects on organisms. [Placeholder] (Zarnestske et al. 2010).

Riverine Dunes

Antioch Dunes NWR is home to three endangered species: Lange's metalmark butterfly (*Apodemia mormo langei*), Contra Costa wallflower (*Erysimum capitatum angustatum*), and Antioch Dunes evening primrose (*Oenothera deltoides howellii*). Efforts are underway to restore and improve habitat negatively affected by invasive plants such as ripgut brome (*Bromus diandrus*), yellow starthistle (*Centaurea solstitialis*), vetch (*Vicia* spp.), and Russian thistle (*Salsola tragus*). When the refuge was established in 1980, invasive plants had already crowded the remaining native plants, and only a few acres of land supported the native plants. Due to the effects of invasive plants on the endangered species and the habitat they reside in, invasive plants are considered a very high threat at Antioch Dunes NWR.

[Placeholder for CC wallflower]

[Placeholder for AD evening primrose]

Invasive vetch likely plays a role in the extremely low population numbers of Lange's metalmark butterfly. Lange's population size dropped from a high of 2342 in 1999 to a population that has remained below 50 from 2009 onwards. Past trends from Antioch NWR show that a combination of fires, changing temperatures, and invasive plants likely caused the population decrease. Colonies are highly reliant on the host plant naked buckwheat (*Eriogonum nudum).* The host plant provides food and shelter for larvae, and butterflies use foliage on the lower half of the plant to deposit eggs (Powell and Parker 1993). Lange's colonies are limited to dense patches of naked buckwheat, as larvae require protection from overwintering (Arnold and Powell 1983). During the spring, invasive vetch outcompetes buckwheat, whose seedlings grow slowly in spring weather. Currently, efforts are made to control weeds. Without control of vetch, it is likely that Lange's could go extinct by losing its source of food and shelter.

Estuarine Island

The Marin Islands NWR Comprehensive Conservation Plan states: "Invasive species represent the single greatest threat to the Refuge System and the Service's wildlife conservation mission. East Marin Island's native plant assemblage is displaced by non-native vegetation." The Marin Islands NWR consists of two small islands: West Marin Island and East Marin Island. Although invasive plants are a great threat overall, invasive plants are a low threat on the western island because the island was not exposed to long-term human disturbance. The island will likely continue to avoid human disturbance in the long-term, since cliffs surround the island and make access difficult. West Marin Island contains significantly less non-native vegetation than its eastern counterpart (USFWS 2007). On the eastern island, invasive plants are a very high threat. Many species possess the potential to spread and displace native plants. Previous owners of the island planted non-native species, one factor which led to the spread of invasive plants on the eastern island. Lack of resources on the island makes removal of plants difficult.

While the vegetation management plan was being developed, it was suspected that native species richness would be reduced by long-term expansion of invasive vegetation in the long-

term (Baye 2005). Introduced overstory species dominate the East Marin Island. Examples include Monterey pine (*Pinus radiata*), blue gum (*Eucalyptus globulus*), and French broom (*Genista monspessulana*). The majority of Monterey pine and blue gum stands are mature while only patches of young stands exist, indicating that maintenance reduced the recruitment of pine and blue gum (USFWS 2007). Without maintenance, stand density would likely increase. French broom is a highly invasive nitrogen-fixing shrub which elevates nitrogen levels in soil (Baye 2005). It forms single-species stands that quickly spread through open habitat and under coast live oak canopies. On the island, French bloom consists of all age classes, and abundant persistent seed banks regenerate the population after adults are removed (Baye 2005). Additional examples of invasive plants abundant on the island are *Acacia* spp., Fennel, and Pride-of-Madiera (*Echium candicans*).

Invasive plants are difficult to remove in the Marin Islands. The refuge lacks electricity, requiring hand cutting or gas-powered chainsaws for removal of fennel, acacia, Scotch broom, and young Monterey Pine. Options are even more limited because the island soil is sandy and erosive, removing the possibility of using prescribed burns, digging, or uprooting vegetation (USFWS 2007).

Literature Cited

Alexander, D. G., & Schlising, R. A. (1997). Vernal pool ecology and vernal pool landscape management as illustrated by rare macroinvertebrates and vascular plants at Vina Plains Preserve, Tehama County, California. Unpublished report to the California Department of Fish and Game, Redding. 139 pages.

Arnold, R. A., & Powell, J. A. (1983). Apodemia mormo langei. *Ecological studies of endangered butterflies (Leipidoptera: Lycaenidae): island biogeography, patch dynamics, and the design of habitat preserves. University of California Publications in Entomology, 99*, 98-128.

Baye, Peter. 2005. Marin Islands National Wildlife Refuge and State Ecological Reserve Vegetation Management Plan.

Brooks, M. L., D'antonio, C. M., Richardson, D. M., Grace, J. B., Keeley, J. E., DiTomaso, J. M., ... & Pyke, D. (2004). Effects of invasive alien plants on fire regimes. BioScience, 54(7), 677-688.

Callaway, J. C., & Josselyn, M. N. (1992). The introduction and spread of smooth cordgrass (Spartina alterniflora) in South San Francisco Bay. *Estuaries and Coasts*, *15*(2), 218-226.

Daehler, C., & Strong, D. (1997). Hybridization between introduced smooth cordgrass (Spartina alterniflora; Poaceae) and native California cordgrass (S. foliosa) in San Francisco Bay, California, USA. *American Journal of Botany*, *84*(5), 607-607.

Feeney, L. R. (1996). California least tern breeding season at the Metropolitan Oakland International Airport- 1995. Report prepared for the Port of Oakland.

Feeney, L. R. (2000). California Least Tern. Species and, 359.

Feenstra, K. R., & Clements, D. R. (2008). Biology and Impacts of Pacific Island Invasive Species. 4. Verbesina encelioides, Golden Crownbeard (Magnoliopsida: Asteraceae) 1. Pacific Science, 62(2), 161-176.

Gaertner, M., Biggs, R., Te Beest, M., Hui, C., Molofsky, J., & Richardson, D. M. (2014). Invasive plants as drivers of regime shifts: identifying high-priority invaders that alter feedback relationships. Diversity and Distributions, 20(7), 733-744.

Harris, M. P., Wanless, S., Murray, S., Leitch, A., & Wilson, L. J. (2003). Counts of Atlantic puffins Fratercula arctica in the Firth of Forth, south-east Scotland in 2003. Atlantic seabirds, 5(3), 101-110.

Hejda, M., Pyšek, P., & Jarošík, V. (2009). Impact of invasive plants on the species richness, diversity and composition of invaded communities. Journal of Ecology, 97(3), 393-403.

Kueffer, C., Daehler, C. C., Torres-Santana, C. W., Lavergne, C., Meyer, J. Y., Otto, R., & Silva, L. (2010). A global comparison of plant invasions on oceanic islands. Perspectives in Plant Ecology, Evolution and Systematics, 12(2), 145-161.

Lloret, F., Médail, F., Brundu, G., Camarda, I., Moragues, E. V. A., Rita, J., ... & Hulme, P. E. (2005). Species attributes and invasion success by alien plants on Mediterranean islands. Journal of Ecology, 93(3), 512-520.

Powell, J. A., & Parker, M. W. (1993). Lange's metalmark: Apodemia mormo langei comstock. *Conservation biology of lycaenidae (butterflies)*, 116-19.

PROTECT, P. P. (2008). National Invasive Species Management Plan.

Reichard, S. H., & White, P. (2001). Horticulture as a pathway of invasive plant introductions in the United States: most invasive plants have been introduced for horticultural use by nurseries, botanical gardens, and individuals. BioScience, 51(2), 103-113.

Sloop, C. M., Ayres, D. R., & Strong, D. R. (2009). The rapid evolution of self-fertility in Spartina hybrids (Spartina alterniflora× foliosa) invading San Francisco Bay, CA. *Biological Invasions*, *11*(5), 1131-1144.

Stone, R. D., W. B. Davilla, D. W. Taylor, G. L. Clifton, and J. C. Stebbins (1988). Status survey of the grass tribe Orcuttieae and Chamaesyce hooveri (Euphorbiaceae) in the Central Valley of California. 2 volumes. U.S. Fish and Wildlife Service Technical Report, Sacramento, California. 124 pages.

Stromberg, J. C., Lite, S. J., Marler, R., Paradzick, C., Shafroth, P. B., Shorrock, D., ... & White, M. S. (2007). Altered stream-flow regimes and invasive plant species: the Tamarix case. Global Ecology and Biogeography, 16(3), 381-393.

Stylinski, C. D., & Allen, E. B. (1999). Lack of native species recovery following severe exotic disturbance in southern Californian shrublands. *Journal of Applied Ecology*, *36*(4), 544-554.

USFWS (2005). Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon.

USFWS (2006). California least tern 5-Year Review Summary and Evalution.

USFWS (2007). Marin Islands National Wildlife Refuge Comprehensive Conservation Plan.

USFWS (2010). Ellicott Slough National Wildlife Refuge Final Comprehensive Conservation Plan.

USFWS (2013). Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California.

USFWS (2016). Farallon Islands Invasive Plant Inventory.

Zaremba, K., McGowan, M., & Ayres, D. R. (2004, November). Spread of invasive Spartina in the San Francisco estuary. In Conference on Invasive Spartina.

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.