

Chapter 10

Dune Restoration Over Two Decades at the Lanphere and Ma-le'l Dunes in Northern California

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10.1 Introduction

Ecological restoration of coastal dunes on the west coast of North America had its beginnings in a relatively remote part of northern California. Although some earlier attempts had been made to revegetate disturbed dunes or stabilize moving dunes with native plants (Pickart 1988), the first documented efforts to restore dune processes as a component of restoration began at the Lanphere Dunes in the 1980s (Pickart and Sawyer 1998). In the ensuing decades, the region has become a model for dune restoration, and California has led the west coast in the development and implementation of restoration technologies. Most of this restoration has been carried out with the goal of restoring biodiversity through the removal of invasive plant species that have been shown to interrupt abiotic processes and reduce native diversity (Pickart and Barbour 2007). Many of these projects were sponsored by government agencies and NGOs with limited budgets, resulting in poor documentation and contributing to an under-appreciation of the progress made (Pickart and Barbour 2007). Even the “gray” literature vastly underreports restoration efforts because, unlike academics, restoration practitioners rely largely on a network of informal communication and information exchange (Baker 2005).

Historically, dune restoration success in California has been measured largely based on vegetation recovery as a proxy for ecosystem health. Much progress has been made in describing and classifying native vegetation types in California dunes, allowing managers to better evaluate restoration success in this context (Pickart and Barbour 2007; Sawyer et al. 2009). In other areas, such as New Zealand, monitoring has been driven more by physical processes, with the

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assumption that ecosystem recovery will follow (Hesp and Hilton, this volume). There is a need to better integrate the physical and biological components of restoration monitoring, particularly in the light of global climate change (Psuty and Silveira 2010).

This chapter presents a case study of the restoration at the Lanphere and Ma-le'l Dunes in Humboldt Bay National Wildlife Refuge, California, USA. These areas are managed with the goals of conserving and restoring globally rare dune habitats, supporting the recovery of endangered dune plants, and promoting long-term viability of ecosystems (USFWS 2009). Restoration goals for these projects were articulated in the context of ecosystem processes, with measurable objectives and monitoring focused on biotic variables such as vegetation cover, species diversity, and endangered plant recovery. Dune morphological terminology in this chapter follows Hesp (2000). Plant nomenclature follows the Flora of North America (FNAEC 1993).

10.2 Dune system

The Lanphere and adjoining Ma-le'l Dunes units encompass 327 ha located at 40.88°N on the upper end of the North Spit of Humboldt Bay in northern California (Fig. 10.1). Littoral drift is dominated by northern, storm-driven transport in the winter, and by southern, wind/wave-driven transport in the summer (Winkelman et al. 1999). Net northern transport occurs during the El Niño events of the Pacific Decadal Oscillation (Moffat and Nichol 2011). The majority of sediments feeding the system originate from the Eel River, 28 km to the south, which drains 9,540 km² and is estimated to deliver approximately 1.8 million m³ of sand annually (Patsch and Griggs 2007). The site is exposed to some of the most severe wave energy in the US, with predominant west–northwest swells from October through April (Costa and Glatzel 2002). The prevailing wind direction is north to northwest from spring through autumn, reversing to south to southeast in winter (Puffer 1998). Winds are strongest in April and May, reaching daily averages of 12.9 kph, and peak gusts up to 97 kph. An average of 96.7 cm of rainfall falls primarily between the months of October and May (Puffer 1998).

Surveyor charts from 1870 provide a record of the condition of the dune system prior to subsequent extensive modification of the area by EuroAmericans. The upper North Spit in 1870 consisted of two episodes of Holocene dune transgression, one older and stabilized by forest and a second overtaking the forest (Fig. 10.2). Reactivation of the forested dunes is hypothesized to be the result of the Cascadia subduction zone earthquake that occurred in 1700 (Atwater et al. 2005). Megaquakes along the subduction boundary occur at 100–1,000-year intervals and are tied to repeated dune activation at other dune sites in the Pacific Northwest (Wiedemann and Pickart 1996; Atwater et al. 1995). Relative sea level rise along the North Spit from 1977 to 2006 was 4.73 ± 1.58 mm per year, well above the global average (Moffat and Nichol 2011). Interseismic land level

Fig. 10.1 Location of the project site in California, USA



changes are a likely cause, but these changes are not consistent across Humboldt Bay (Moffat and Nichol 2011).

A record of topographic maps and aerial photographs has allowed documentation of the evolution of dune features in the more recent dune episode (Fig. 10.3). In 1939, the site consisted of a developing foredune–blowout–parabolic dune complex, with more developed features located upwind of discrete parabolic dunes, and more fragmented topography upwind of undifferentiated, transverse dune-dominated, transgressive dunefields. A decade later the less developed features had been eroded, and much of the southern portion of the site was unvegetated. The northern, more mature features supported vegetation now classified as the *Leymus mollis* herbaceous alliance on the foredune, and the *Abronia latifolia*–*Ambrosia chamissonis* herbaceous alliance on trailing ridges of parabolic dunes (Johnson 1963; Pickart and Barbour 2007; Sawyer et al. 2009). After 1970, *Ammophila arenaria* dispersed to the site from the south (Buell et al. 1995), resulting in the gradual development of an *Ammophila*-built foredune in the southern part of the site, and beginning the process of *Ammophila* invasion into the native vegetation to the north. By the 1980s, the Lanphere Dunes (consisting of the northern portion of the site) had been acquired and protected by The Nature Conservancy (later transferred to the US Fish and Wildlife Service), and this invasion was recognized as the primary threat to the preserve. *Ammophila* invasion results in steepening of the foredune, homogenization of vegetation, and suppression of the formation of new blowouts (Fig. 10.4). Although *Carpobrotus chilensis* had been present at the Lanphere Dunes at low densities since at least the 1960s (Johnson 1963), by the early 1990s the species was hybridizing with its invasive congener *Carpobrotus edulis*. These hybrids were observed to be

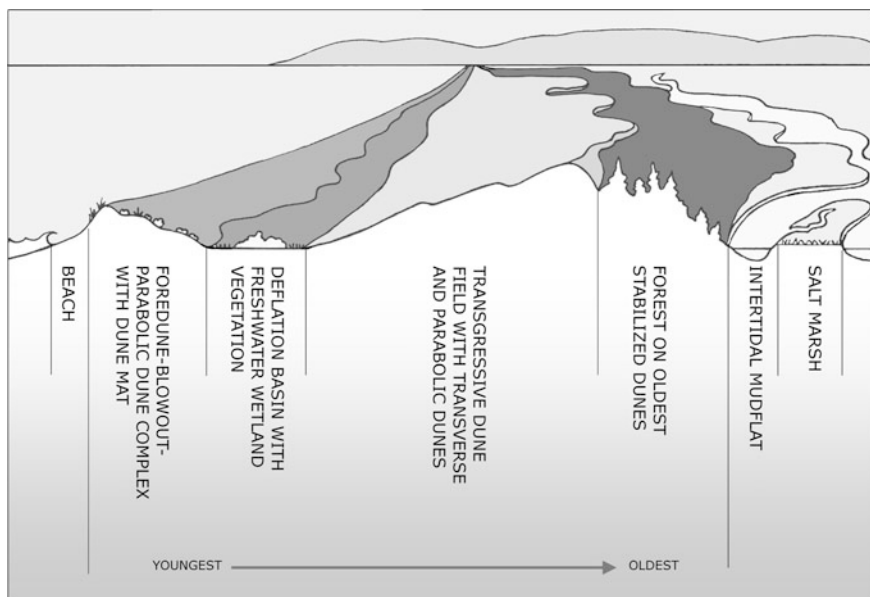


Fig. 10.2 A cross-section of the Lanphere and Ma-le'l Dunes system, showing the relationship between dune geomorphic forms and vegetation

spreading aggressively, especially on the erosional walls and depositional lobes of blowouts. Subsequent research confirmed that the population consisted of a hybrid swarm, with the potential for ecosystem-level impacts (Albert et al. 1998).

10.3 Methods

Successful methods to eradicate invasive plant species, and revegetate with native species, were developed during a series of research projects on the North Spit between 1982 and 1990 (Pickart and Sawyer 1998). Manual methods were chosen for the Lanphere and Ma-le'l Dunes based on their low impact to the extensive intact vegetation, including two federally listed endangered plants Humboldt Bay wallflower (*Erysimum menziesii* subsp. *eurekaense*) and beach layia (*Layia carnosa*). Restoration included the removal of invasive species and, to a lesser extent, the re-introduction of native species. The two invasive taxa *Ammophila arenaria* and *C. edulis* × *C. chilensis* were the primary target for eradication. The Lanphere restoration was carried out between 1992 and 1998, over an area of 11 ha in the foredune–blowout–parabolic dune complex. The Ma-le'l Dunes were added to the refuge in 2005 and 14 ha of dunes were restored from 2005 to 2010 in the foredune–blowout–parabolic dunes as well as in the deflation basin. In both projects, stands of *Ammophila* and other invasives were mapped and georeferenced prior to the start of restoration.

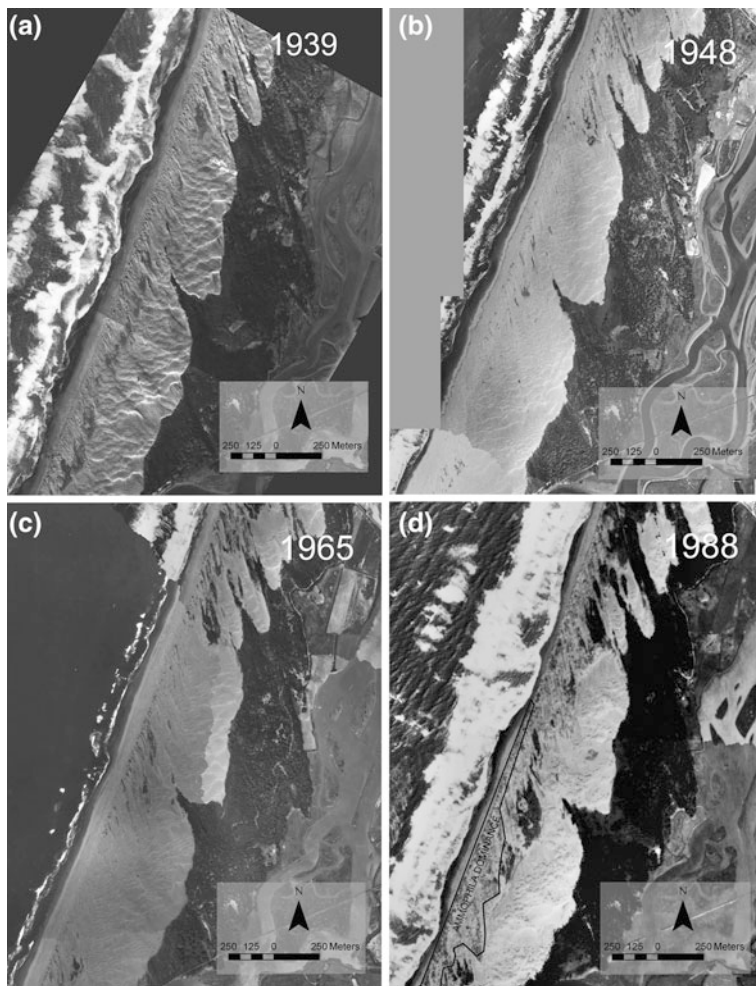


Fig. 10.3 Evolution of dune features at the Lanphere and Ma-le'l Dunes between 1939 and 1988. The *A. arenaria* invaded between 1965 and 1988, and was the dominant vegetation within the polygon in 1988

Ammophila was controlled through repeated digging/pulling, using a shovel to loosen or cut rhizomes below the surface (Fig. 10.5). Labor was provided by the California Conservation Corps, a state agency that provides a consistent labor source complete with crew supervisors and transportation. Digging commenced in February when carbohydrate reserves were low (plants had not yet broken dormancy), and continued through December. The greatest effort was required on the first dig, steeply diminishing thereafter. For the Lanphere project, treatments were applied over two growing seasons, with an average of eight treatments in the first



Fig. 10.4 *Ammophila arenaria*-built foredune at the Ma-le'l Dunes prior to restoration. The foredune to the left is transitioning from incipient to mature, and has few native species present, whereas the older, mature foredune to the right still retains some native plants. There are no blowouts along this stretch of invaded dunes; virtually all the sand is trapped in the foredune

Fig. 10.5 Members of the California Conservation Corps remove *A. arenaria* using a combination of pulling and digging at the Lanphere Dunes (1992)



year and seven in the second year. The Ma-le'l project employed fewer treatments per year over a 3-year period. Plants were piled up on site and burned after they had dried for a month or more.

In the earlier restoration at the Lanphere Dunes, a phased approach was employed to reduce the likelihood of reactivation of the dunes. *Ammophila* was removed in a patchwork fashion in three separate phases spaced 1–2 years apart, each receiving 2–3 years of treatment. Because the dead network of roots and rhizomes remained in the soil, the integrity of dune features was largely retained while native species recolonized from relict plants (Fig. 10.6). After initial deflation of several cm of sand, the dead stubble of the below-surface stems served to reduce wind speed and prevent further deflation of the surface. As a result, no revegetation was needed in the project.

At the Ma-le'l site, the restoration strategy for *Ammophila*-dominated dunes was altered somewhat. After observing the stabilizing effect of *Ammophila* stubble in the Lanphere restoration, this project was carried out without phasing it spatially

Fig. 10.6 The phased patchwork approach employed in the Lanphere restoration project prevented blowouts. Native species are already colonizing restored patches from the first phase, in the second year after initial removal (1994)



over time. However, after detecting less stability post-eradication compared with the Lanphere project, revegetation was added in the third year. Culms of the native dune grass *L. mollis* subsp. *mollis* with attached rhizomes or rhizome buds were harvested from a large nearby stand and planted during the winter months in 4-m² grids of 49 hills (two culms per hill) at spacings of 65 cm. The revegetated patches were distributed strategically along the foredune in areas of less stability and their position mapped with a GeoXT using ArcPad 7.1.

Carpobrotus control was also carried out using manual methods. The more aggressive hybrids form dense carpets that can be rolled up like a carpet. Shovels are used to sever rhizomes. When the plants are more scattered they are dug with a shovel and pulled, attempting to remove as much of the rhizome as possible. Several re-treatments are required to achieve complete mortality. As with *Ammophila*, the bulk of the labor is expended in the first treatment. *Carpobrotus* is difficult to burn owing to its high water content. Piles were dragged on tarps or in contractor bags to the beach and transported to a green-waste site by a four-wheel-drive truck.

Monitoring was carried out on both projects, including detailed labor tracking for the Lanphere project. Vegetation cover (total and by species) was sampled in 0.25-m² (Lanphere) or 1-m² (Ma-le'l) systematically placed plots. Sampling occurred at 1- to 2-year intervals through 2002 at Lanphere, and annually (still ongoing) at Ma-le'l, allowing documentation of progress toward the objectives of vegetation cover and species diversity. Surviving *Leymus* mounds were recorded in the summer following each planting. By the second summer, individual mounds could no longer be distinguished and the presence or absence of live *Leymus* in each grid was recorded.

In 2011 a new sampling design was implemented to estimate cover and species composition along a temporal gradient: the oldest vegetation that predated restoration and was never invaded, vegetation that originated as the result of restoration completed at the Lanphere Dunes in 1998, and the newly restored Ma-le'l Dunes

Fig. 10.7 *Leymus mollis* subsp. *mollis* planting areas at Ma-le'1 Dunes, beginning to merge after 2 years



completed in 2010. Percentage cover of perennial species was estimated in 10-m² plots systematically distributed among the three strata. Only plots with greater than 5 % cover were included to avoid sampling in blowouts.

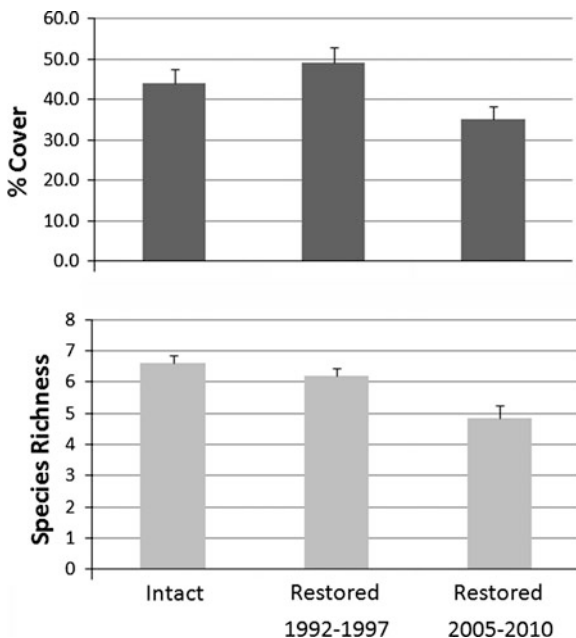
10.4 Results

In the Lanphere restoration, *Ammophila* was largely dead after 2 years of treatment, although there continued to be sparse resprouts requiring some treatment for a third year. After that, maintenance of the project was accomplished through annual “sweeps” for any remaining resprouts or new occurrences. Native species recovery was observed as early as the year after initial treatment, and the manual method allowed these plants to be avoided while treatments continued. *Ammophila* mortality took longer at Ma-le'1 due to the less intensive treatment application. However, by year 5, *Ammophila* cover was less than 1 %. In both projects, *Carpobrotus* cover was reduced to less than 1 % after 5 years. More so than *Ammophila*, *Carpobrotus* has continued to reinvade from adjacent sites, requiring re-treatment at an interval of 3–5 years.

Leymus mound survival was 61 % after 1 year. In the second year (2011), when the original mounds could no longer be distinguished, there were live plants in 100 % of the planting areas, but high variation in the density and cover of surviving *Leymus* (Fig. 10.7). In January 2012, additional *Leymus* planting was carried out.

By 2011 there were no significant difference between mean total cover values and species richness of the Lanphere restoration compared with intact vegetation ($p = 0.59$). Only 1 year post-completion (but 6 years after the start of the restoration), the restored vegetation at Ma-le'1 exhibited cover values not significantly different from intact vegetation ($p = 0.20$), but significantly and slightly lower than the Lanphere restoration ($p = 0.02$; Fig. 10.8). However, the Ma-le'1

Fig. 10.8 Differences in the mean percentage total cover and species richness (of perennial species) in intact dune mat vegetation, compared with restoration carried out from 1992 to 1998 (Lanphere Dunes) and from 2005 to 2010 (Ma-le'l Dunes). Error bars represent the standard error



vegetation exhibited significantly lower species richness than both the intact vegetation and the older restoration ($p < 0.01$). Changes in vegetation over time are illustrated in Figs. 10.9 (Lanphere) and 10.10 (Ma-le'l).

10.5 Costs

The labor component of *Ammophila* eradication was carefully tracked for the Lanphere project. Most of the actual digging time (78 %) was expended in the first dig. Almost half of total labor time was expended on walking to and from the remote site. Removing this site-specific variable, eradication required a total of 3,600 ph (person-hours)/ha in year 1, a total of 843 ph/ha in year 2, and 188 ph/ha in year 3. In 1998 this translated to a combined cost of \$54,590/ha (Pickart and Sawyer 1998). It is important to note that restoration managers use different approaches to quantifying costs. The approach employed at the Lanphere and Ma-le'l dunes based the costs not on the area of the total site, but rather on the area occupied by the invasive plants were they to occur in a contiguous fashion. Commonly, managers do not precisely map stands of invasive species, but simply use the area over which invasives are scattered. This is a valid approach in that the entire area benefits from the restored processes, but it makes costs difficult to compare among sites. When this second approach is used for the Lanphere and

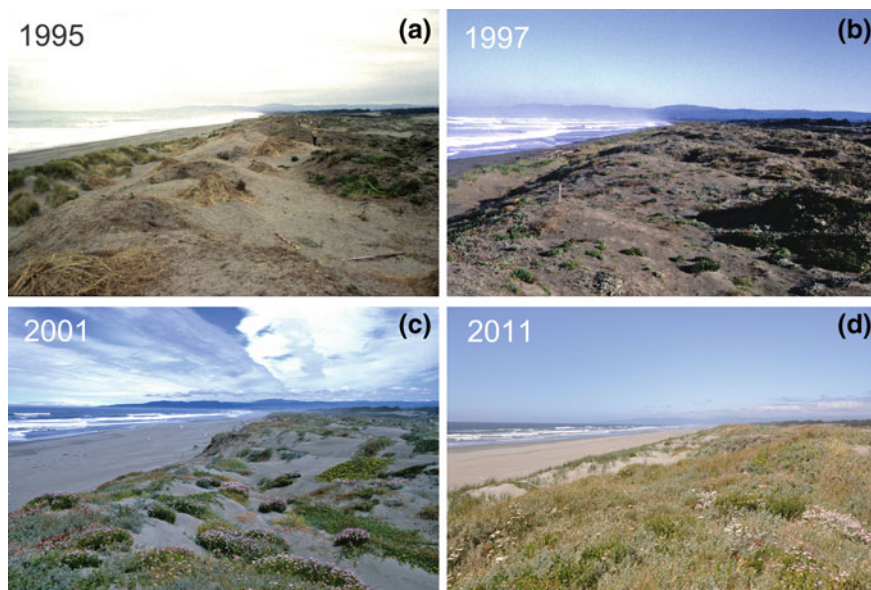


Fig. 10.9 Photographs of an area in which dense *A. arenaria* was removed from the Lanphere foredune. The initial photograph shows piles of *Ammophila* waiting to be burned. An incipient foredune to the east was also treated. By 1997 native plants had volunteered at low densities, and the incipient foredune was eroding. Four years later, in 2001, native species, including the early successional *A. latifolia* and *Erigeron glaucus*, were present with abundant open sand between individual plants. By 2011, cover was much higher, and species composition had shifted in favor of *Poa macrantha* and *Lathyrus littoralis* in the foredune. A new incipient dune was forming, built by native *Leymus mollis* subsp. *mollis*

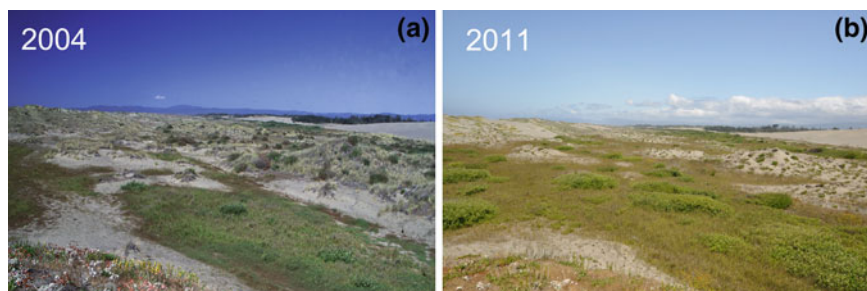


Fig. 10.10 Two photographs of the Ma-le'l Dunes, depicting the foredune (*left*), deflation basin (*center*), and parabolic trailing ridges (*right*). *Ammophila arenaria*-dominated vegetation has been replaced by native species. Behind the foredune, renewed sand movement allowed the deflation basin wetland to expand

Ma-le'l project, the cost of restoration over the entire affected area is reduced by almost two-thirds.

Using manual methods to remove *Ammophila* and other invasives is initially expensive, but carries many benefits that result in longer-term efficiency. Heavy equipment has been used successfully in northern California and elsewhere to eradicate *Ammophila*, but only where it achieves dominance over large areas. In an early-stage invasion into intact vegetation the impacts from heavy equipment on vegetation (including endangered species) would be too great, and this alternative would most likely not be permissible in the area under existing coastal laws and regulations. In addition, there is cause for concern at some sites that use of heavy equipment can reactivate dunes, slowing or preventing recovery of native vegetation. In contrast, manual methods can be targeted precisely, allowing the retention of interspersed native species. These surviving plants become a source of natural recolonization, reducing or even eliminating the need for revegetation. An effective herbicide treatment for *Ammophila* was not developed until the mid-1990s (Aptekar 2000), but more importantly, there was a strong community ethic opposing the use of herbicides. The restoration philosophy underpinning this effort embraced the support of the community, and this was perhaps one of the earliest community-based restoration projects (Jordan 1991; Pickart and Sawyer 1998). Over the past two decades, community support has crystallized in the form of an impressive volunteer labor force overseen by the NGO Friends of the Dunes, which supports restoration on lands throughout the Humboldt Bay region. Volunteer labor is ideal for maintaining restoration over the long term. *Ammophila* and other invasive species are able to reinvade at low rates from surrounding, unrestored areas. Given the extent of the regional *Ammophila* invasion as well as the constraints of private ownership, true eradication of *Ammophila* from the area is not currently feasible. However, continued management requires minimal resources if applied on a regular basis (in this case annually). The level of labor required to prevent reinvansion is suitable for volunteers who remain committed to this effort through a sense of investment. The support of the community adds to the likelihood of continued management even during periods of fiscal constraint for managing entities.

10.6 Conclusions

The manual methods employed in these two projects have resulted in the return of natural processes regulating the formation of foredunes, blowouts, and parabolic dunes, and the recovery of diverse native vegetation. Both projects were carried out over a 5- to 6-year period. The projects could have been accelerated given additional funding and resources, but the longer duration was ideal to allow a gradual transition from overstable dunes characterized by an almost monospecific stand of exotic vegetation to a more natural morphology without causing a level of instability precluding native species recovery.

Although both projects were relatively limited in area (together comprising a 2.5-km stretch of shoreline), the Lanphere project was the first of its kind in California, and gave rise to many other restoration projects in the region and beyond. As of 2011, a total of 12 km of coastline in the Humboldt and Del Norte counties have been cleared of *Ammophila* and other invasive species by a number of government agencies and NGOs. Methods have included both manual and mechanical (heavy equipment). Restoration has also been carried out, or is in progress, in a number of dune systems along the California coastline, including the Guadalupe-Nipomo Dunes, Morro Bay Dunes, San Francisco Bay Dunes, Point Reyes National Seashore, Bodega Bay, and MacKerricher State Park.

Acknowledgments The restoration projects described in this chapter are the result of much collaboration among many partners over a long period of time. I would like to acknowledge Linda Miller, Patricia Clifford, Trevor Goodman, and Kyle Wear, all of whom played critical roles in the planning, implementation, monitoring, and/or maintenance of these projects. Field work for new results presented in this chapter was carried out by Laurel Goldsmith and Kira Hawk. Funding for the projects was from a number of sources, including The Nature Conservancy, US Fish and Wildlife Service, National Fish and Wildlife Foundation, and the California Department of Corrections and Rehabilitation. Labor was provided by the California Conservation Corps., California Department of Forestry and Fire Protection, Sheriff's Work Alternative Program, Friends of the Dunes volunteers, and the staff of Humboldt Bay National Wildlife Refuge. Special thanks to Patrick Hesp for support, encouragement, and review of the manuscript.

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