Control of European Beachgrass (Ammophila arenaria) on the West Coast of the United States

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European beachgrass *(Ammophila arenaria)* is the most pervasive exotic plant species currently threatening coastal dunes on the west coast of the U.S. *Ammophila* is invasive in every major dune system from Santa Barbara County, CA, to the northernmost dunes of Washington. Active management of this species is on the rise, in part because of the Federal listing under the Endangered Species Act in 1993 of the western snowy plover.

Although interest in controlling *Ammophila* began about 1980, real success was not encountered until 1990, and implementation of control efforts on a large scale is still new and undergoing refinement. In 1997 management of *Ammophila* was carried out by a total of seven agencies on eight different dune systems in Oregon and California at a total cost of $131,000 (Table 1). Currently in use are manual, mechanical, and chemical methods of control, used alone or in combination. The goals of these efforts have differed, as have their success.

Ammophila is now so widespread on the west coast of the U. S. that its eradication is not practical unless a more economic means of control is found.

Species Biology

Ammophila is a perennial, rhizomatous grass native to coastal dunes in Europe between the latitudes of 30° and 63° N. It spreads primarily by rhizomes, although viable seeds are produced. Long distance dispersal is usually by marine transport of dormant rhizomes, which can withstand submersion for long periods (Baye 1990).

Once established, *Ammophila* develops vigorous root and rhizome systems. Active sand burial stimulates the production of rhizomes (Gemmell et al. 1953, Greig-Smith 1961). This growth pattern results in dense clusters of shoots and in part accounts for *Ammophila's* dense growth habit and "phalanx-like" spread (Fig. 1). *Ammophila* can tolerate more sand burial than the native dunegrass *(Leymus mollis)*, but has a lower salt tolerance. Without fresh sand burial, *Ammophila* declines in vigor. This phenomenon has been attributed to a variety of factors, including exposure to pathogens that reduce the formation of new tillers (van der Putten et al. 1988). Fresh sand accumulation allows *Ammophila* to escape build-up of these organisms.

Introduction History

Planting of *Ammophila* on west coast dunes was common in the first half of the twentieth century. First introduced at Golden Gate Park, San Francisco, in the late 1800s (Lamson-Scribner 1895), the species was heralded as a desirable sand stabilizer and was eventually embraced by U. S. Soil Conservation Service and other agencies. Thousands of acres of west coast sand dunes were stabilized during this period (Reckendorf et al. 1987), the majority located along the Oregon coast. As a result, the Oregon and Washington coastlines are now largely lacking intact native foredune plant communities.

The introduction and spread of *Ammophila* has been closely traced for the North Spit of the Humboldt Bay dunes, providing a good illustration of its patterns of invasiveness. Buell et al. (1995) documented the extent of *Ammophila* on the spit at intervals between 1901 (its first introduction) and 1989. After 1939 it expanded exponentially, increasing over 600% in area. Despite multiple introduction dates and interactions with other competing non-native species like yellow bush lupine *(Lupinus arboreus)*, the rate of spread has been consistent with invasion models (Hengeveld 1989, van den Bosch et al. 1992). The pattern of spread has been bimodal, as described by Baker (1986) and Hengeveld (1989). Movement along foredunes has been via continuous "wavefronts" while more inland areas have been characterized by "broken-up fronts" of independently propagating foci.

Table 1. Total Ammophila acreage in California dunes and in the Oregon Dunes National Recreation Area, and the amount expended on control in 1997.

Dune system	Ttl. Acres Ammo	Managing agency	Site/Project	Cost in 1997
Oregon Dunes	9,000	U.S. Forest Service	Oregon Dunes N.R.A.	$38,000
(Reedsport to Florence)		U.S. Bureau of Land Mgt.	Coos Bay Shorelands	$30,000
Lake Earl Dunes	1,300	Calif. Dept. of Parks & Rec.	Lake Earl State Park	No control
		Calif. Dept. of Fish and Game	Lake Earl Wildlife Area	No control
Gold Bluffs Beach	200	National Park Service/Calif. Dept. of Parks & Rec.	GoldBluffs Beach/Redwood National & State Parks	No control
Freshwater Lagoon	3	U.S. Park Service/ Calif. Dept. of Parks & Rec.	Freshwater Lagoon / Redwood	No control
Big, Dry. & Stone Lagoons	10	Calif. Dept. of Parks & Rec.	Humboldt Lagoons State Park	No control
Humboldt Bay Dunes	1,026	The Nature Conservancy	Lanphere-Christensen Dunes	$10,000
		U.S. Bureau of Land Mgt.	Manila Dunes ACEC/ONA	$20,000+
			Samoa Dunes NRA	volunteer
		Center for Natural Lands Mgt.	Manila Beach & Dunes/	$5,000+
			Eureka Dunes Protected Area	volunteer
		Humboldt County	Mad River & Clam Beach	No control
			County Parks	
		Calif. Dept. of Parks & Rec.	Little River State Beach	No control
		Calif. Dept. of Fish & Game	Eeel Rivei Wildlife Area	No control
Ten Mile Dunes	125	Calif. Dept. of Parks & Rec.	MacKerricher State Park & Inglenook Fen-Ten Mile Dunes Preserve	$15.000
Manchester Dunes	520	Calif. Dept. of Parks & Rec.	Manchester State Beach	No control
Bodega Bay	860	Calif. Dept. of Parks & Rec.	Sonoma Coast State Beach	No control
		Univ. of Calif. Reserves	Bodega Marine Reserve	No control
Point Reyes	1,600	National Park Service	Abbott's Lagoon, Point Reyes National Seashore	volunteer
San Francisco Bay	11	National Park Service	Golden Gate NRA	volunteer
Monterey Coast Dunes	80	Calif. Dept. of Parks & Rec.	Zmudowski, Marina, Salinas	$3,000
			River, & Moss Landing	
			State Beaches, Ft. Ord	
Monterey Peninsular Dunes	7	Calif. Dept. of Parks & Rec.	Asiloma State Park	volunteer
Morro Bay Dunes	55	Calif. Dept. of Parks & Rec.	Montana de Oro State Park & Morro Strand State Beach	No control
Guadalupe-Nipomo Dunes	275	The Nature Conservancy	Mobil Coastal Preserve	$1.000
		Calif. Dept. of Parks & Rec.	Pismo Dunes State Reserve, Oceano Dunes State Vehicular Rec. Area, & Oso Flaco Lake Natural Areas	No control
San Antonio Terrace Dunes	80	U.S. Air Force	Vandenburg Air Force Base	$12,000

Fig. 1. The dense shoot pattern of Ammophila causes its phalanx-like spread.

Ecological Impacts

Ammophila has had a devastating impact on the inherently restricted dune resources of the west coast. *Ammophila* is a better sand accumulator than the native dunegrass, and creates a higher, steeper foredune, decreasing sand flow to interior dunes (Wiedemann and Pickart 1996). Although cyclic stabilization of dunes is a naturally occurring phenomenon in the Pacific Northwest regulated by tectonic events (Clark and Carver 1992, Komar and Shih 1993), the presence of *Ammophila* shortens the time for stabilization, and in addition, drastically alters natural succession (Wiedemann and Pickart 1996).

Perhaps the most significant impact of *Ammophila* is its ability to displace entire native plant communities with its phalanx-like mode of spread. The native dunegrass series (Sawyer and Keeler-Wolf 1995) is restricted to the primary or first parallel foredune along the coast. Once occurring along most major dune systems of the west coast north of Monterey, CA, this community is now restricted to only two location, at Point Reyes and Humboldt Bay (Pickart and Sawyer, in press). The relatively more extensive sand verbena-beach bursage series, which once occurred on semi-stable dunes along the entire coast, has also been tremendously impacted by the spread of *Ammophila*. In a number of dune systems, especially those where *Ammophila* was deliberately planted and cultivated, this community is near extirpation.

Ammophila currently or potentially impacts six Federally listed endangered plants that occur on coastal dunes of California: *Chorizanthe howelld, C. pungens* var. *pungens, Erysimum menziesii, Gilia tenuiflora* ssp. *arenaria, Layia camosa,* and *Lupinus fidestromii (U.S.* Fish and Wildlife Service 1997). The species is also detrimental to the threatened western snowy plover, a shorebird that nests in open areas on the strand. Dense stands of *Ammophila* directly displace nesting sites, and enhance cover for predators, thus decreasing nesting success (U.S. Fish and Wildlife Service 1995).

Control

Ammophila, with its extensive underground rhizome network, is extremely tenacious and its eradication has proven to be a continuing challenge to managers. It has required a decade of research and experimental trials to develop effective eradication techniques, and when applied on a large scale these methods show variable success (Pickart and Sawyer, in press). The arsenal of known techniques now includes manual, mechanical, and chemical alternatives, but refinements and other methods are still being sought.

Manual Removal

Manual removal has been used with great success, but at great expense, at the The Nature Conservancy's (TNC) Lanphere-Christensen Dunes Preserve in Humboldt Bay dunes. The method was first tested and found to be successful over a two-year period in small isolated stands (Pickart et al. 1990). Between 1992 and 1997, a ten-acre area of *Ammophila* was subjected to repeated manual digging using California Conservation Corps labor (Miller 1994). The area was divided into three sub-areas, each of which was initiated in a different year. A patchwork of small stands comprised each sub-area to reduce erosion, but it was found that this was unnecessary since dead *Ammophila* stubble provided sufficient stabilization. In fact, the use of small stands increased edge and therefore cost.

The first removal was carried out in March, as plants emerged from dormancy. A shovel was used to sever rhizomes at a depth of about eight inches, since the majority of active rhizomes were found to be in this region. Grass was piled and later burned. Resprouting occurred throughout the season, more vigorously at first. Crews returned to pull and/or dig resprouts an average of eight times over the first season, and seven times the second season. By the end of the second season plants were largely eradicated. Some of the stands were scattered in remote areas and did not receive systematic treatment; these areas will require additional follow-up.

Ammophila often hides small, relict native plants. After the *Ammophila* was removed, these plants flourished, eliminating the need for revegetation. This is a significant benefit realized by the manual method, as it is possible to selectively retain native plants. The elimination of revegetation work saves on costs and should be considered in the choice of eradication method. By 1997, at the TNC site, native plant cover had reached 45% of the cover found in sites not invaded by *Ammophila* (Fig. 2).

Fig. 2. Native plants colonizing an area formerly covered with *Ammophila* the The Nature Conservancy's Lanphere-Christensen Dunes Preserve.

The amount of labor required to dig, pile, and burn beachgrass was 1,858 person-hours/acre. An additional 1,093 person-hours/acre were required for the time it took to transport CCC crews from the CCC center to the site (90 minutes roundtrip) and to walk from the trailhead to the restoration area (90 minutes roundtnp). At the current local CCC rate of $11.75/hour, the cost of removal was $21,831/acre and the cost of transportation was $12,843/acre, for a total of $34,674/acre. This per-acre cost covers removal of a continuous beachgrass cover; in actuality, beachgrass is often spread out over a larger area or mixed with native vegetation. The cost would be significantly lower for a less remote site.

The most labor-intensive part of manual control is the first dig, due to the large biomass, density of stems, and the difficulty of severing rhizomes. To determine whether this first dig could be replaced with a labor-

saving controlled burn, the Center for Natural Lands Management recently established an experiment at the Manila Beach and Dunes in Humboldt Bay dunes. Burning is known to stimulate growth in *Ammophila* (Van Hook 1983), and will presumably increase resprout vigor or density. However, it is hypothesized that the increased labor required to remove resprouts after a burn may still represent a time savings over the initial dig.

Mechanical Removal

Heavy equipment has been used extensively to control *Ammophila* at Oregon Dunes National Recreation Area (NRA). The NRA has approximately 6,000 acres of *Ammophila*, with few remaining examples of intact native plant communities. The U.S. Forest Service is primarily managing the beachgrass for western snowy plower habitat, although restoration of native plant communities is a stated goal (Segotta 1995). Heavy equipment is used in combination with manual and chemical control.

Over the past 3 years, the Forest Service has treated a total of 45 acres of *Ammophila* with a D-8 Caterpillar. *Ammophila* is excavated and theoretically buried to a depth of 3 feet, although in actuality the depth of burial is inconsistent and is often less than 3 feet, reducing the effectiveness of the treatment. Moderate resprouting has occurred in these areas (Fig. 3), and requires manual follow-up. A single follow-up dig has been effective, although insufficient for complete eradication. The use of herbicide as a follow-up to mechanical is not effective because of the limited surface area exposed to the herbicide.

Fig. 3. Resprouts; of *Ammophila* in an area previously treated using heavy equipment at Oregon Dunes National Recreation Area.

At the nearby Coos Bay Shorelands, the U.S. Bureau of Land Management used a different mechanical treatment on 50 acres of Ammophila adjacent to a snowy plover nesting site (Rittenhouse, pers. comm.). In the summer of 1996, the grass had been unsuccessfully treated with salt water. In fall 1996 a D-8 Caterpillar with a wing ripper was used to "subsoil" or "rip" rhizomes 3 feet below the surface. In early March 1997 this treatment was followed by a single manual pulling treatment. Plants were easily pulled by hand. This combination of treatments appeared to be very effective (Fig. 4); however separating out the effects of earlier treatments (disking, salt water) was not possible.

Obviously, mechanical removal is only suitable for sites that are easily accessible, relatively flat, and without significant numbers of native plant. The cost of this treatment has not been estimated, and varies depending on whether equipment and operators are available to the managing agency. Compared with manual removal, the method is more impact-intensive, detrimental to invertebrates and vestigial native plants. If the goal

is to establish native plant communities, revegetation will be necessary. However, for a large area, and if done with sufficient quality control, it should be more cost-effective than manual removal.

Fig. 4. Only a few resprouts have returned in an area formerly dominated by Ammophila at Coos Bay Shorelands in Oregon. The site was treated unsuccessfully with salt water irrigation in summer 1996, "ripped" with a wing-ripper in fall 1996, and subjected to one hand-pull of resprouts in March 1997. The photograph was taken in August 1997.

Chemical Control

Glyphosate (Roundup and Rodeo) has been used with some success on Ammophila, although its effectiveness is dependent on consistency and thoroughness. A label recommendation of 8% Rodeo plus 0.5 to 1.5%nonionic surfactant (spray-to-wet) was developed for Oregon, Washington, and California following trials by the California Department of Parks and Recreation, the Oregon Department of Fish and Wildlife, and the Monsanto Company. Rodeo, a form of glyphosate without surfactant, was preferred in Oregon because of concerns about groundwater contamination. Rodeo is approved for aquatic use because it lacks the polyethoxylated tallowarnine present in the surfactant in Roundup. The label also recommends wiper applications for selective control, using a 33% solution plus 1.0 to 2.5% nonionic surfactant and avoiding contact with desirable vegetation. For either method, plants should be treated during periods of active growth.

The use of Roundup to control Ammophila was tested extensively by the California Department of Parks and Recreation and the University of California Davis at several California dune systems. Although results have not been published, the investigator reports good success using a 10% solution with added surfactant (0.5%) (Aptekar, pers. comm.). Since these experiments were carried out, the surfactant in Roundup has been reformulated by Monsanto, which recommends no additional surfactant be added to Roundup-Pro or Roundup-Ultra (McColly, pers. comm.).

Herbicides have been used on Ammophila most extensively at the Oregon Dunes National Recreation Area. In 1996-1997 about 60 acres of Ammophila were sprayed with an 8% solution of Rodeo (with surfactant) at Tahkenitch and Ten Mile dunes. In the first year only one application was used. Results were inconsistent, with some areas clearly missed. However, overall density and cover was significantly reduced (Segotta, pers. comm). In the second year (1997), missed areas were resprayed, and new areas were given two applications, but results are not yet available.

Chemical treatment of *Animophila* is likely to be the most cost-effective method of those used to date. There are, however, problems with this method. Herbicides have biological impacts and may be politically

unacceptable in a given area or for a particular agency (for example, the Bureau of Land Management is under an injunction prohibiting the use of herbicides on non-noxious weeds). When native plants are present, selective spraying may be difficult or impossible. After spraying, dead biomass must be removed if revegetation is to occur. If only a small amount of *Ammophila* regeneration occurs, it is infeasible to treat it with herbicide since surface area will be insufficient. If complete eradication is desired, manual follow-up may still be required at an additional cost, and the cost of revegetation must be added.

The use of salt water as a method of chemical control was attempted over a 25-acre stand of *Ammophila* in Coos Bay Shorelands by the U.S. Army Corps of Engineers (U.S. Army Corps of Engineers 1996). A six-cylinder diesel pump was used to supply by water to a sprinkler system. Sprinkler guns were moved along lateral lines and operated for 24-hour periods, resulting in the deposition of about 12 inches of salt water. Three 12-inch applications were made between June and September, and were expected to raise soil salinity to at least 2% to a depth of 3 feet (the salt tolerance of *Animophila* is 1 to 1.5%). Although the treatment resulted in initial browning, observations on the site indicated that salt water did not penetrate below the top 5 inches of the soil.

There is still some interest in using salt water to control *Ammophila*. One drawback of this method is the broad nature of its impacts. Although *Ammophila's* tolerance to salt water is lower than for some native plants, the salt is likely to be toxic to some desirable plant species and to other organisms, including beneficial soil microbes.

The Need for a Regional Control Strategy

Given the enormous extent of the *Ammophila* invasion on west coast dunes, and the high costs associated with control, prioritization of efforts is essential. Funds should be expended on projects with the greatest ecological return. As with other exotic plant infestations, prevention of expansion into any new, pristine areas is critical. This principle is applicable at both local and regional scales. Region-wide (for the west coast, or a given state), efforts should concentrate on dune systems that have only incipient populations of *Ammophila*. One example of this situation is the Ten Mile dunes in Mendocino County. Although the nearby Manchester dunes were targeted by early dune stabilizers, Ten Mile dunes somehow escaped this plight. *Ammophila* is a relatively recent invader and occupies less than 125 acres of the 1,400-acre dune system. It is now spreading rapidly, and the chance for early intervention is nearly past. A window of opportunity for control of this species will be gone within half a decade. With scarce resources, the recognition of a priority like this at a regional level will help to focus the efforts of the managing agency (in this case, State Parks).

Near the southern limit of the range of *Ammophila,* it is tempting to ignore the species in favor of other more visible exotics such as iceplant *(Carpobrotus edulis*) and veldt grass *(Ehrharta calycina).* The prevailing perception is that *Ammophila* spreads less aggressively south of San Francisco than to the north. However, at the Guadalupe-Nipomo dunes system, (one of the southernmost sites), *Ammophila* now occupies a total of 275 acres and is spreading exponentially through native vegetation, posing a serious threat to rare plants and nesting snowy plovers (Chestnut 1997).

In many California dune systems, multiple landowners and managers, make prioritization difficult. At Humboldt Bay, dune agencies have formed an alliance known as the Dunes Forum in order to set regional restoration priorities and to cooperate in fulfilling them. The Coastal Dunes Guild of the California Chapter, Society of Ecological Restoration, has established an objective to inventory California dune resources carefully, as the first step in setting state-wide priorities. However, funding sources to fulfill this objective have yet to be identified. Until such priorities are set, competition within regions and within agencies for limited resources, as well as inefficient expenditures will continue. Alternatively, with priorities in place, agencies can work together to increase efficiency.

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