DRAFT WRITTEN FINDINGS OF
THE WASHINGTON STATE NOXIOUS WEED CONTROL BOARD

SCIENTIFIC NAME: *Ammophila breviligulata, Ammophila arenaria, A. breviligulata x A. arenaria*

SYNONYMS: *Calamagrostis breviligulata, Calamagrostis arenaria, Ammophila arenaria var. Breviligulata, Ammophila arenaria subsp. Breviligulata (Global Biodiversity Information Facility)*

COMMON NAMES: American beach grass, European beach grass, and beach grass hybrid. North American and European marram grasses (Huiskes 1977).

FAMILY: Grass family, Poaceae

LEGAL STATUS: Considered together for one Class C listing.

DESCRIPTION AND VARIATION:

Both *Ammophila* species are perennial, clonal, C3 grasses that act as pioneer species on temperate dunes of ocean and lake coasts (Maun, 1984; Pickart, 2021).

A. breviligulata photo from NOAA.

OVERALL HABIT:

A. breviligulata grows taller at higher latitudes, and generally shows a plastic response to climate (Emery and Rudgers, 2014).

A. arenaria grows up to 120 cm, upright, and is sturdy. The shoots mostly grow from the vertical rhizomes, and form dense tussocks (Huiskes, 1979).

Hybrid individuals' morphology and functional traits overlap and can exceed both parent *Ammophila* species. Generally, they grow taller than *A. breviligulata* and closer in height to *A. arenaria,* though still taller (Askerooth, 2023). Shoot height correlates with sand accumulation, resulting in the hybrid generally accumulating more sand than either parent species. This sand accretion results in forming tussocks (Pickart, 2021).

STEMS:

The stems of *A. arenaria* will elongate and become vertical rhizomes when buried in sand (Huiskes, 1979).

LEAVES:

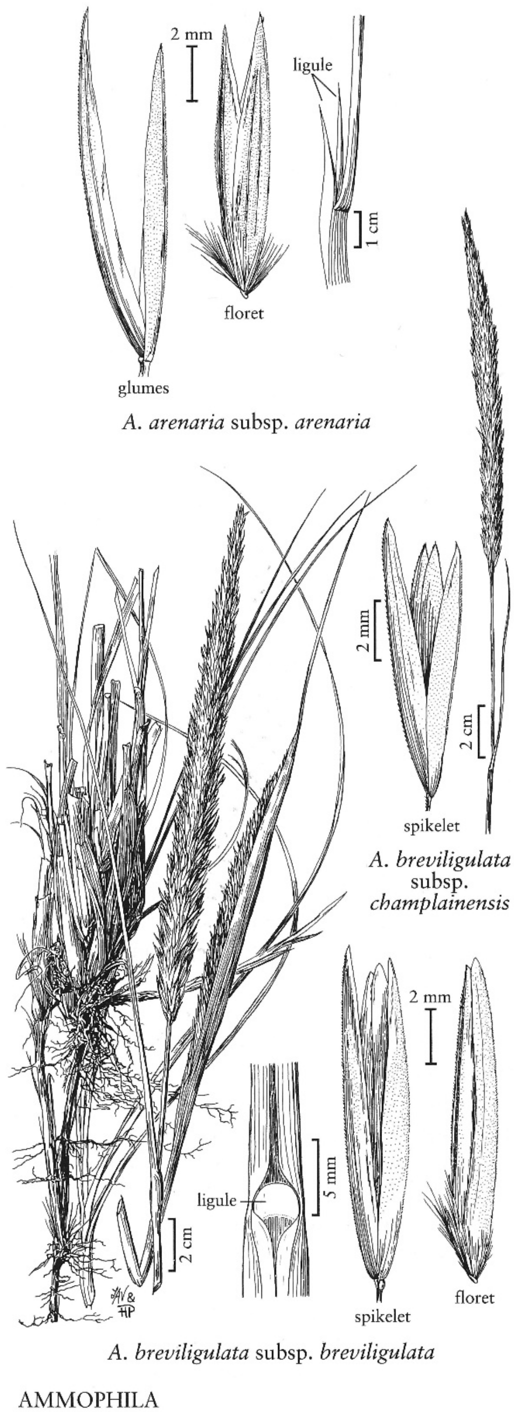
A. arenaria's leaves can be 6mm wide and usually 60cm long, though can grow as long as 90cm. Their tips are pointed and sharp. They roll inward, lengthwise, especially during dry conditions. Leaf undersides are grey-green and don't have distinct ribs. The top side of the leaf is glaucous green, with dense ribs, which are densely covered in very small hairs. The ligule can be up to 2.5cm long, and usually tears as the leaf ages (Huiskes, 1979).

A. breviligulata has a short ligule, which has squared off edges, but is otherwise very similar to *A. arenaria* (Huiskes, 1979). In the winter, leaves usually die back into flattened mats, and are buried by sand (Seabloom and Wiedemann 1994).

FLOWERS:

A. breviligulata does not make inflorescences most of the time, only in locations where sand accumulates at a regular rate (Maun and Lapierre, 1984).

The panicle of *A. arenaria* is 7-15 long, stout, spike-like, dense, and oblong in shape. It tapers upwards, with white-ish erect branches. The spikelets are 10-16mm long, narrowly oblong, and compressed, though they open when they dry. There is only one floret per spikelet. The glumes are slightly different in size (the upper glume is 3 nerved, and the lower glume is 1 nerved,) lightly pointed, and exceed the lemma and palea. The lemma is 8-12mm long, with a 1mm awn between two points at the end of the keeled lemma. The base of the lemma is surrounded by many fine hairs that are around 1/3 the length of the lemma. The palea is also keeled. The lodicules are tapering and 1mm long. There are 3 stamens, which are 4-7mm long, and hang outside of the floret, mature before the styles, though many are shriveled and do not produce any pollen.



Ammonia species illustrations from University of Utah

Left: *A. breviligulata* flowering parts from MinnesotaWildflowers.info

Right: *A. arenaria* in flower by Steve Matson (2016)

The styles are short. The ovaries are smooth. Inflorescences are often not present once a plant has been established for more than a few years. (Huiskes, 1979).

FRUITS/SEEDS:

The grains of *A. arenaria* are brown, oval shaped, and fall off the grass when still enclosed by hard lemma and palea, though plants produce very few seeds compared to the number of florets. Seeds are mostly spread by wind. (Huiskes, 1979).

ROOTS:

In *A. breviligulata*'s native range, plants put 30% of their biomass belowground, with 8% being rhizomes that have dormant buds. Only a small amount of these buds will produce vegetative shoots. These rhizomes radiate down and out from the base of the grass (Maun, 1984). The internodes of these rhizomes are hollow and vary in length. The nodes each have buds that can form shoots or more rhizomes when triggered to do so. Fragmentation stimulates these buds out of dormancy (Konlechner *et al*., 2016).

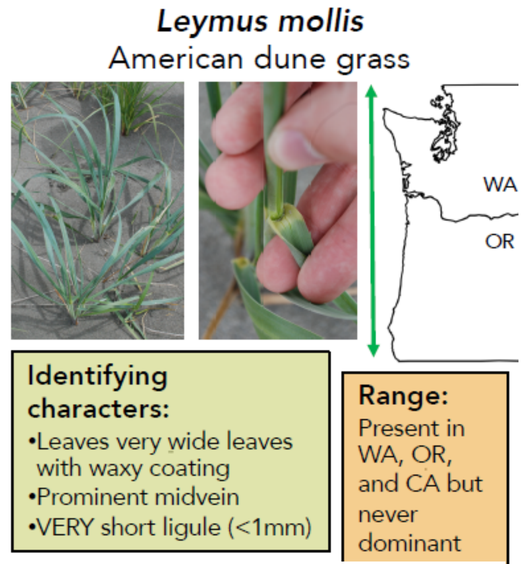
The rhizomes of *A. arenaria* grow vertically down as well as horizontally. They start out white to yellowish white and fleshy, and age to yellow-brown with a wiry texture (Huiskes, 1979). Like *A. breviligulata, A. arenaria* also have a large number of dormant buds on their rhizomes (Maun, 1984).

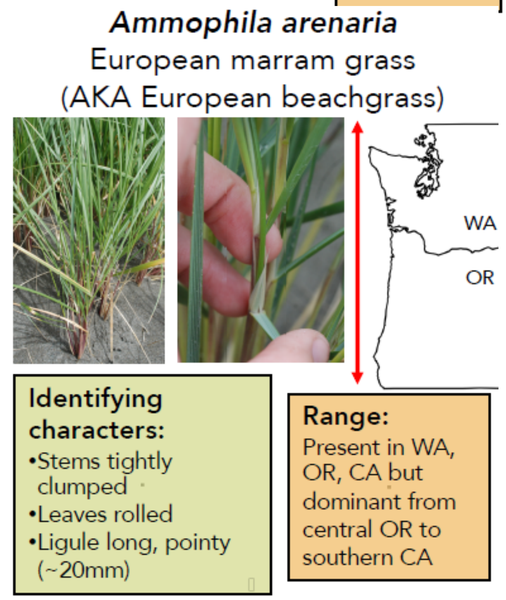
SIMILAR SPECIES:

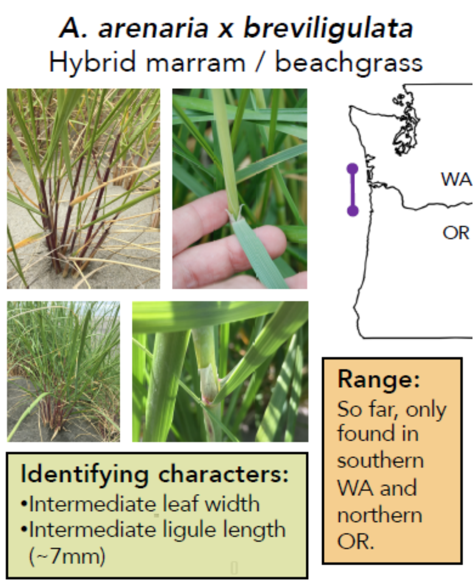
Leymus mollis (*Elymus mollis* syn.), American dune grass, is a native grass that can be abundant at sites with *A. arenaria* along the Washington Coast and co-occurs with *A. breviligulata* and the hybrid beach grass (Hacker, 2023). The range of *L. mollis* used to range from Southern California to Alaska, has now been largely replaced by *Ammophila* species (Pickart, 2021).

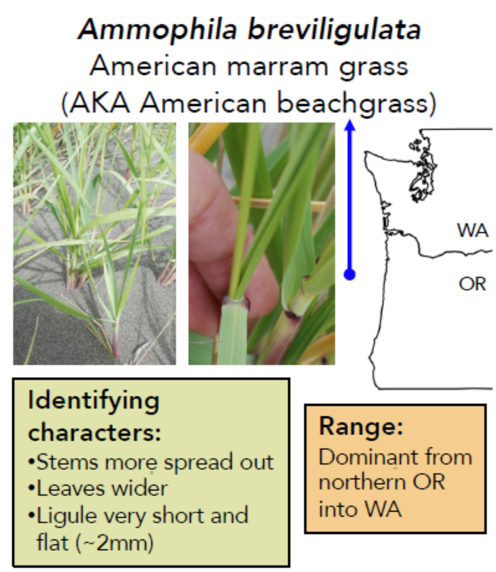
L. mollis has wider leaves than *Ammophila* species. *L. mollis* leaves also have a waxy coating and a very prominent midvein. Their ligules, where the leaves attach to the stem, are very short, around 1mm long, while *Ammophila* species have very apparent ligules (Mostow, 2020). *A. breviligulata* has thinner stems, blades, and grows more densely than *L. mollis* (Emery *et al*., 2019). Dunes vegetated by *L. mollis* are broader, shorter, and more sparsely covered than dunes vegetated by *Ammophila* species (Pickart, 2021).

Assistance and resources for IDing *Ammophila* and *L. mollis* can be found on the Hybrid Beachgrass Hunt project on iNaturalist here: https://www.inaturalist.org/projects/hybrid-beachgrass-mapping-in-the-pacific-northwest?tab=observations&subtab=map









Identifying characters, images, and range for *Ammophila* species and *L. mollis* from Mostow's 2020 brochure: *A guide to beach grasses of the Pacific Northwest.*

HABITAT:

A. breviligulata is a pioneer species, which quickly colonizes dunes. They can survive sand accumulation at a rate of 1 meter a year (Maun and Lapierre, 1984). Sand accumulation causes the grass to grow more vigorously (Seliskar, 1995). This all adds up to it being very adapted to unstable habitats, including surviving fire. Fire even may be beneficial to their growth. The energy stored in its extensive root systems help it recover after fire, being covered by sand, and when fragments are dispersed during storms (Burkman, 2008).

A. arenaria in it's native habitat by Neal Kramer (2009)

In its native range, *A. arenaria* can grow at temperatures as low as 0°C, though does better with nighttime winter lows at 10°C and daytime summer highs up to 40°C. They can tolerate over 1m of sand burial a year. It can grow where the water table is 26m below the ground, so they get much of their water from precipitation, and are very drought tolerant. They grow the most vigorously in higher pH, they can grow in pH as low as 4.5. The sand they tend to grow in has low nutrients. They can survive in soil with up to 1.5% sea salt concentration. (Huiskes, 1979).

In Washington, *A. breviligulata* is dominant on the foredunes and the area leading up to the dune, from the ocean. In this area before the dune, it forms 2-meter-long hummocks (Seabloom and Wiedemann, 1994). *A. arenaria* are sparse and patchy at sites dominated by *A. breviligulata*, which matches with a shift to *A. breviligulata* throughout the last 2 decades (Hacker, 2023). Hybrid *Ammophila* makes up 75% of plants at some invaded sites along the Washington-Oregon coastline. Infestations have been observed increasing 3% to 42% per year. The ability to survive sand accumulation and the nearby species richness was about the same as both parent species (Askerooth, 2023; Hacker, 2023). *Ammophila* invaded sites are less prone to invasion by other species than sites where native *L. mollis* are dominant, despite all species accreting sand at about the same rate (Hacker, 2023). *Ammophila* have higher biomass on beaches and parts of dunes that have higher seaweed washing up, likely due to the increase in nitrogen and phosphorus from this wrack (Constant, 2019).

BIOLOGY

GROWTH AND DEVELOPMENT:

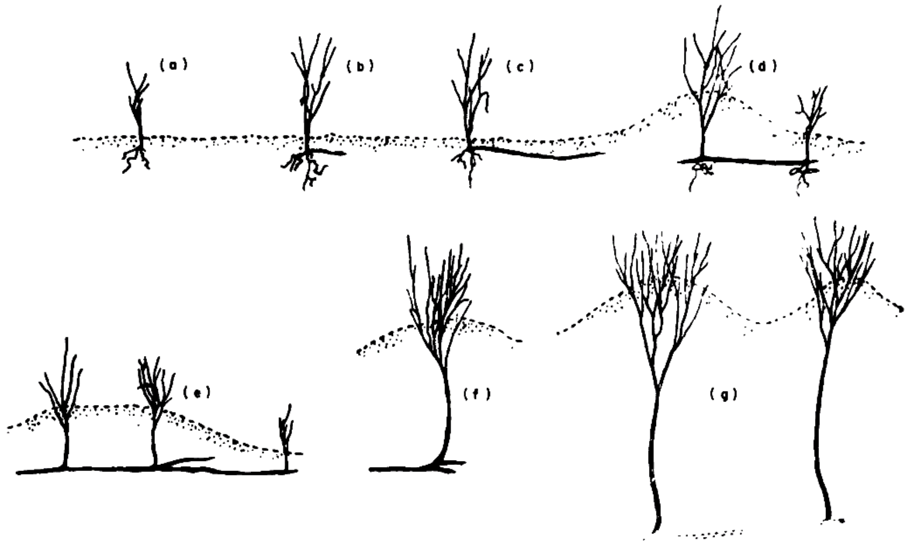


FIG. 3. Diagram of successive stages (a–g) in the growth of *Ammophila arenaria* during continuous burial by sand (after Gemmell, Greig-Smith & Gimingham. (1953)).

A. arenaria growth in sand dune (Huiskes, 1979).

The more *A. breviligulata* is buried by sand, the slower shoots emerge, up to 1 meter of sand burial. There are three stages of growth after burial, first the stem internodes grow longer, then the number of nodes per stem increase, then the leaves grow upwards until they reach the sand surface. Burial often increases plant biomass, especially if buried earlier in the growing season (Maun, 1984). Leaf area, number of tillers, number of buds on each tiller, amount and length of vertical rhizomes, new plants from vertical and horizontal rhizomes, overall plant height, and chlorophyll concentration all increase with sand burial, which also increase plant vigor (Disrali, 1984). *A. breviligulata* is highly rhizomatous and can expand by six to ten feet a year (Burkman, 2008).

When first colonizing a site in its native range, *A. arenaria* will be present in small numbers, but will spread in future years and can become a monoculture on the now stabilized sand dune, unless erosion destroys the dune. They do not stop growing in the winter, as they have buds at both the surface and in buried layers, though their spread is slower than in summer (Huiskes, 1979). *A. arenaria* generally have young plants, usually without rhizomes, at the foreshore side of a dune. They don't form tussocks on mobile dunes but makes very thick tussocks on stabilized dunes (Greig-Smith *et al.*, 1947). *A. arenaria* is also highly rhizomatous and vigor declines without sand accumulation (Pickart, 1997). In California, it showed exponential growth, with infestations spreading along shores, and dispersing to start new populations (Pickart, 2021).

Both *Ammophila* species and their hybrid are very phenotypically plastic, in that they change their growth rates and other traits and behaviors based on the local environment (Mostow *et al.*, 2021). For instance, in the northern end of their native range (Michigan,) growth is restricted by high temperatures, seedlings have more moisture in their shoots, and have a higher chlorophyl concentration, while at the southern end of their native range (North Carolina,) the plants are more salt tolerant, not as sensitive to warm temperatures, and have a larger biomass (Seneca and Cooper, 1971).

Hybrid infestations grow significantly each year. Individuals grow 31% on average each year and tend to form higher dunes than either parent *Ammophila* species. In monoculture infestations, hybrids grew faster and had higher shoot densities than their parent taxa, after 18 months of growth (Askerooth, 2023).

In Washington and Oregon, the dunes dominated by *A. arenaria* are generally taller and steeper than *A. breviligulata* dunes*. A. arenaria* has less lateral growth than *A. breviligulata*, and thus can accrete sand in a taller dune structure (Biel *et al*., 2019; Hacker, 2023).

REPRODUCTION:

A. breviligulata seem to put more resources into reproduction by rhizomes, and only make inflorescences under certain situations (Maun, 1984). Their main mode of reproduction and dispersal is though rhizome fragments spreading on water (Seabloom and Wiedemann, 1994). Even in its native range, *A. breviligulata* rarely allocates any biomass to sexual reproduction. They seem highly adapted to asexual reproduction, and wave action seems to activate dormant growth buds (Maun, 1984). Storms disperse fragments, which can survive over 140 hours floating in ocean water and still resprout (Burkman, 2008). When sexual reproduction does occur, seeds don't need cold treatment in the southern end of their native range, around North Carolina, but do need it near their northern range, in Michigan (Seneca and Cooper, 1971). Seedlings do not have as much success establishing as vegetation fragments (Laing, 1958). *A. breviligulata* has a low genetic diversity in Washington and Oregon, so clonal spread is likely how they have established along the coast (Mostow *et al*., 2021).

Illustrated plate of A. arenaria, from Plants for A Future.

A. arenaria reproduce much more by rhizome than by seed, as inflorescences are not frequently made (usually only in the first few years after establishment,) and seedlings usually dry out or are buried before establishment can occur. Across Europe, germination can happen after the seeds fall in autumn, but mostly occurs in July and August. In their native range, it takes at least two years for a seedling to become an established plant. When the flowers occur, they are wind pollinated, and similarly, seeds are wind dispersed (Huiskes, 1979). Fertilization and moisture helps establishment from seed greatly (Van Der Putten, 1990). In New Zealand, seeds have been seen to survive and remain viable for up to 21 years (Konlechner and Hilton, 2009). *A. arenaria* has larger genetic diversity in

Oregon and Washington than *A. breviligulata*, likely due to a history of plantings, rather than by vegetative spread (Mostow *et al*., 2021).

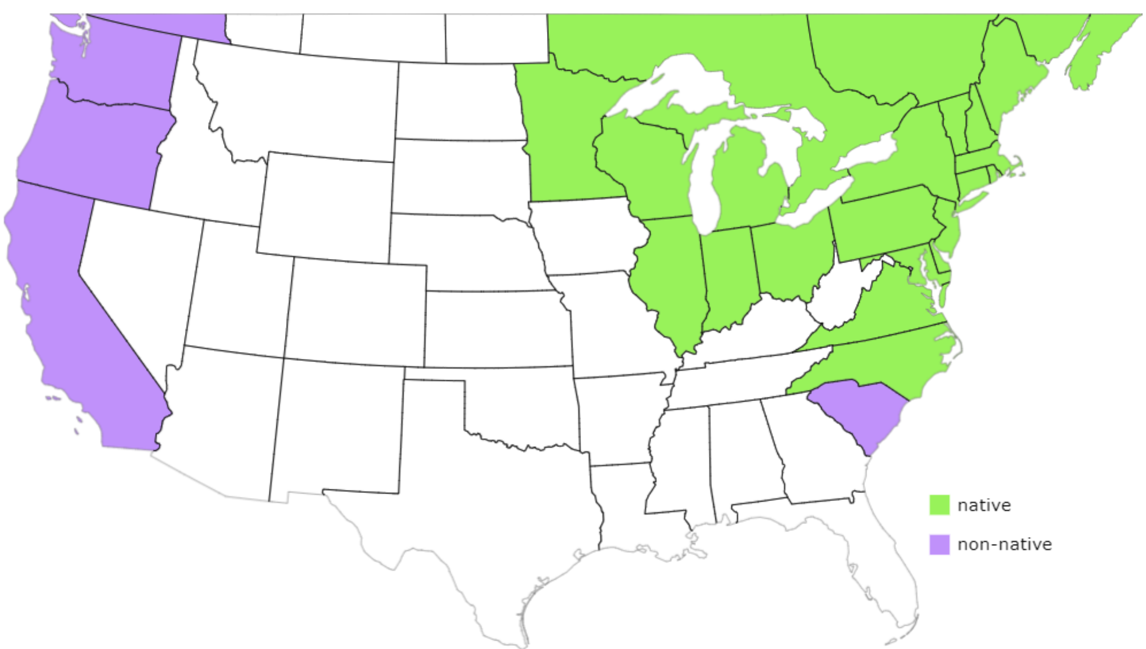
Hybrid *Ammophila* individuals can have maternal parentage from either parent species. Additionally, there is little to no reproductive barriers preventing hybridization. In Washington, hybrids are found in locations where *A. breviligulata* is dominant, and *A. arenaria* may be limiting hybridization (Askerooth, 2023). Hybridization has probably happened multiple times (Mostow *et al*., 2021). The hybrid may be sterile (Hacker, 2023), but due to the focus of asexual reproduction and dispersal, this is unlikely to slow infestations.

GEOGRAPHIC DISTRIBUTION:

NATIVE DISTRIBUTION

A. breviligulata occurs from Newfoundland to North Carolina, along the Atlantic coast, and inland to the Great Lakes (Maun, 1984). It is the most dominant and ecologically important pioneer species on coastal dunes in its native range (Cheplick, 2005). In this range it is also important to protect the nearby habitats and human facilities from storms, droughts, and erosion (Emery and Rudgers, 2014). Since the 1980s, there has been a significant die out of *A. breviligulata* across its native range, especially near Chesapeake Bay (Seliskar and Huettel, 1993).

A. arenaria grows along sea and ocean coasts across Europe (and Northern Africa) from 30°N (around the Canary Islands and Southern Morocco) to 63°N (Southern Sweeden and Norway), and East to throughout the Black Sea and around Turkey. In the UK, they have been found to hybridize naturally with *Calamagrostis epigejos x Ammocalamagrostis baltica* (Huiskes, 1979).

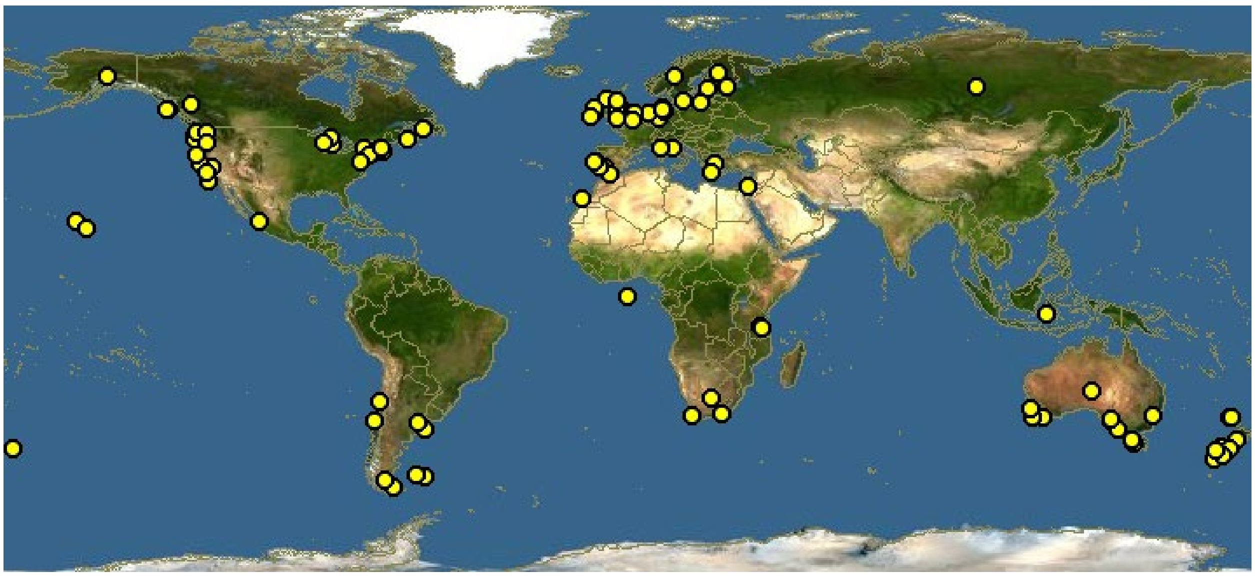


A. breviligulata native and non-native range from Native Plant Trust.

NON-NATIVE DISTRIBUTION

There are *A. breviligulata* populations from along the West Coast of North America from Southern California to Southern Alaska (Pickart, 1997), as well as at least one population known in the United Kingdom (Discover Life).

A. arenaria is has been found invading on coasts from latitude 32° to 60° on both sides of the equator (Pickart, 2021). Some locations of these infestations include Tasmania, mainland Australia (Hertling and Lubke, 1999), New Zealand (Hilton *et al*., 2005), South Africa (Hertling and Lubke, 2000), Chile, Argentina, Hawaii, along the West Coast of North America from Mexico to Alaska, and within the entire native range of *A. breviligulata* on the East Coast of North America (Discover Life).



A. arenaria records from DiscoverLife.org.

HISTORY:

A. arenaria was introduced to the West Coast in the 1800's (Zarnetske *et al*., 2010), but wasn't planted widely along the West Coast until the early 1900's, for dune stabilization, and has since been considered naturalized in many places (Seabloom and Wiedemann, 1994). By the 1950's it had spread from Mexico to Canada (Mostow *et al*., 2021).

A. breviligulata may have first been planted on the West Coast in 1935, along the Clatsop Peninsula, near the mouth of the Columbia River and Southwest Washington State. In the following years, there were further plantings of *A. breviligulata* along Washington's coast, like near Ilwaco in Southwestern Washington (Seabloom and Wiedemann, 1994).

From 1941 to 1974 *A. breviligulata* spread, outcompeted, and replaced *A. arenaria* in many places along the West Coast (Seabloom and Wiedemann, 1994).

Before these introductions, the coastal dunes of the Pacific Northwest were low-lying and often shifting (Askerooth, 2023). Many of these dunes are now densely vegetated, tall, linear ridges (Emery *et al.*, 2019). *Ammophila* species have been being removed from the West Coast for ecological restoration since the 1990s (Zarnetske *et al*., 2010).

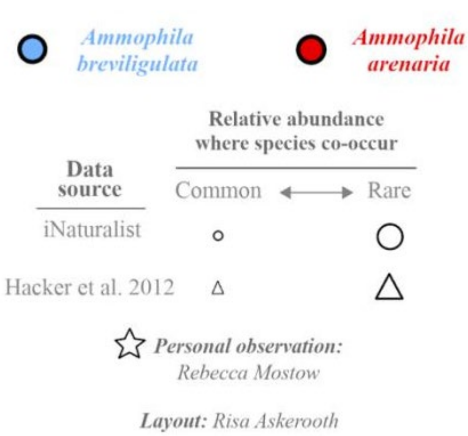
It wasn't until 2012 that *Ammophila* hybrids were first suspected to be present, and possibly found at sites in Oregon and Washington (Hacker, 2023).

WASHINGTON:

These dune systems make up 42% of Washington's and Oregon's coasts, which are the habitats of several threatened and endangered plant and animal species. The dunes also provide protection against wind and water for coastal human communities (Hacker 2023).

A. breviligulata occurs along the length of Washington's coast from the mouth of the Columbia River to the Strait of Juan de Fuca (Seabloom and Wiedemann, 1994), including in the Salish Sea, to the San Juan Islands and Puget Sound (Burke Herbarium).

A. arenaria also occurs along the length of Washington's coast from the mouth of the Columbia River to the Strait of Juan de Fuca, and into the Salish Sea to the San Juan Islands, though in lower densities than *A. breviligulata* (Seabloom and Wiedemann, 1994).



Ammophila records map (Askerooth, 2023).

The hybrid has been found at a dozen sites in Washington and Oregon. The furthest north the hybrid has been found in Washington is Ocean Grove, Washington (Mostow *et al*., 2021).

NEARBY TO WASHINGTON:

OREGON:

A. breviligulata occurs from the northern quarter of Oregon's coast and north into Washington (Pickart, 2021).

The first plantings of *A. arenaria* were made in Oregon in 1910 (Pickart, 2021). This plant is now found along the entire coast of Oregon, 42% of which is made up of coastal dune habitats (Seabloom and Wiedemann, 1994).

The hybrid has been found from Southeastern Washington to Pacific City Oregon (Mostow *et al*., 2021).

IDAHO:

Not present.

BRITISH COLUMBIA:

A. breviligulata is found in Southeastern British Columbia, in the Salish Sea region around Vancouver Island and Vancouver, BC (Consortium of Pacific Northwest Herbaria).

There are records of *A. arenaria* from Graham Island and down the coast around Vancouver Island (Consortium of Pacific Northwest Herbaria).

Both *Ammophila* species and their hybrid have been found on Vancouver Island (Askerooth, 2023).

CALIFORNIA

A. arenaria was first planted in Golden Gate Park, in San Francisco, California in 1869 (Pickart, 2021). By the 1950's and 1960s, *A. arenaria* was present on 25% of the California coastline (Mostow *et al*., 2021). Both *Ammophila* species have been found near San Francisco and Eureka California (Askerooth, 2021)

LISTINGS:

Though both *Ammophila* species are known to be non-native and invasive in many places around the world, only California has only *Ammophila arenaria* listed as invasive on an official list (Invasive Plant Atlas).

ECONOMIC AND ECOLOGICAL IMPORTANCE:

DETRIMENTAL:

Both *Ammophila* species have become dominant in many coastal ecosystems, where they can completely replace native plant communities. As of 1994, *A. arenaria* stands may have slightly more biodiversity, and their dunes may also be less likely to be overtopped by waves. However, *A. breviligulata* have been overtaking *A. arenaria* in most coastal sites along Washington's coast for decades (Seabloom and Wiedemann, 1994). *A. breviligulata* may have more of a negative impact on native plants, due to its higher tiller density. With climate change, this tiller density is projected to increase, as infestations in warmer areas have more tillers on their rhizomes (Emery and Rudgers, 2014). *A breviligulata* is also predicted to increase its range south. Added to sea level rise with climate change, the increase in American beach grass is of great concern (Hacker, 2023).

Dune systems make up 40% of Washington's and Oregon's coasts, which are the habitats of several threatened and endangered plant and animal species (Hacker, 2023). *Ammophila* dunes had lower nematode (Emery and Rudgers, 2014), bee, other arthropods, other invertebrates, and vertebrate diversity (Pickart, 2021). The federally threatened, Western Snowy Plover (*Charadrius alexandrinus nivosus*) habitat is greatly reduced by *Ammophila* species in Washington and Oregon (Zarnetske *et al.*, 2010. Federally endangered Pink Sand Verbena (*Abronia umbellate* ssp. *breviflora*), federally threatened Streaked-Horned Lark (*Eremophila alpestris strigata*), and species of concern Footsteps of

A. arenaria roots, by Steve Matson (2016)

Spring (*Sanicula arctopoides*) populations are also greatly decreased where *Ammophila* species are present (Askerooth, 2023; Hacker, 2023; Pickart, 2021). Control of invasive beach grasses help increase plover and native plant populations (Hacker, 2023; Zarnetske *et al.*, 2010).

In addition to reducing biodiversity, habitat complexity, and habitat resilience, *Ammophila* infestations also can cause dunes to block sea views, form wetlands behind dunes, and allow forest and shrub habitats to push into the beach ecosystem (Seabloom and Wiedemann, 1994). The native dune grass, *Leymus mollis*, which is being outcompeted by *Ammophila* species, holds more below ground carbon biomass than *Ammophila* species (Hacker, 2023). The negative impacts on soil caused by *Ammophila* can persist for decades (Parsons and Becker, 2021)

In a presentation to the Noxious Weed Committee of the Washington State Noxious Weed Control Board, on July 12th, 2023, Andrea Thorpe (Washington State Parks, Natural Resource Program Manager) stated that *Ammophila* infestations readily burn, and that these wild grass fires are difficult to access and control by wildland firefighters. She reported that just over the 2023 4th of July weekend her staff had to put out several *Ammophila* fires in Washington State Parks. A couple weeks before the writing of these findings, huge fires, fueled by different invasive grasses on Maui, Hawaii, caused massive amounts of devastation to the island and its inhabitants (Frosch *et al.*, 2023). Across the Western US, wildfires on

A. breviligulata stand at Lake Michigan.

invasive grasslands are greatly increasing the risks and damage to humans, our infrastructure, and ecosystems (Cornwall, 2022).

The increasing *Ammophila* hybrid has traits that are likely to make it a better invader of Washington's native dune ecosystems, while causing further decreased biodiversity and other ecosystem services in those infested areas (Askerooth, 2023; Mostow *et al.*, 2021)

BENEFICIAL:

Coastal dunes, formed by *Ammophila* provide protection against wind and water for coastal human communities, especially during storm surges (Seabloom and Wiedemann, 1994; Seliskar and Huettel, 1993). This protection also lowers concern about sea level rise for these communities behind the dunes, (Seliskar, 1995). Increasing storms with climate change will only increase the desire for protective dunes along the coast (Pickart, 2021; Seabloom *et al.*, 2012).

The wetlands that form behind *Ammophila* dunes do provide habitat for some coastal and wetland species, and that the dune stabilization can provide substrate for some non-coastal species (Emery and Rudgers, 2014).

The biomass maintained by *Ammophila* dunes can add nutrients and organic matter to the otherwise bare sand (Maun and Lapierre, 1984).

CONTROL:

MECHANICAL:

Mechanical (using heavy machinery like bulldozers) and manual (hand pulling and digging) techniques are the most common methods of mechanical removal (Zarnetske *et al.*, 2010), though a combination of mechanical, cultural and chemical actions have the best results in controlling *Ammophila* species. (Pickart, 2021).

Pickart (2021) reports that manual hand pulling and digging is the most effective, but also the most expensive in terms of staff and volunteer time. While it may be prohibitively expensive, these manual removal methods also are able to keep many native species in-tact. This is especially important, since individual native plants tend to "hide" amongst *Ammophila* stands (Pickart, 1997)

A. breviligulata from IllinoisWildflowers.info

Mechanical removal using heavy machinery is effective for a long time, as it creates a completely clean canvas of dune, though this also buries beneficial microbes and native species that were intermingling with the *Ammophila* (Parsons and Becker, 2021; Pickart, 2021). After burial below 3 feet of sand, *Ammophila* stands showed moderate resprouting, which required manual control. Burial must be done deeper than 1 meter, as *Ammophila* can survive 1 meter of sand accumulation a year, which also increases their growth rate generally. Mechanical removal is not possible at some sites, due to access and dune angle (Pickart, 1997).

For manual removal, The Western Weed Control Handbook recommends beginning removal of *A. arenaria* in March by digging. Do 8 removals throughout the rest of the season, repeating again the following year (DiTomaso *et al.*, 2013).

CULTURAL:

Ammophila are fire-tolerant plants. While the above-ground biomass readily burns, the deep rhizomes are unharmed in most fires, and quickly reestablish (Burkman, 2008).

Ammophila can't grow when sand accumulates faster than 1 meter per year (Maun and Lapierre, 1984; Seabloom and Wiedemann, 1994). When there is less nitrogen potassium, and phosphorus, *Ammophila* species will grow less vigorously (Constant, 2019; Hacker, 2023), especially when combined with drought (Seliskar, 1995). They do better at beaches with more algae washing up, as this wrack brings in a lot of nutrients to baren beaches (Constant, 2019). Very dry and hot summers can cause mass die out, especially when combined with nematode infestation (Seliskar and Huettel, 1993). They seem very susceptible to die back when recreation increases, as more people walk across tussocks (Nickerson and Thibodeau, 1983)

The Army Corps of Engineers have sprayed saltwater, using sprinklers and a pump from the ocean, to raise soil salinity to at least 2% at 3 feet of sand depth to kill *Ammophila*, as they can survive up to 1.5% salinity. Some native plants may have a higher salt tolerance than *Ammophila*, so this method could be used while protecting native species, though will likely kill soil microbes and many other native species (Pickart, 1997).

BIOLOGICAL:

Several nematode species have been found to potentially cause die out of *A. brevifolia* along the Atlantic Coast of North America. These species are*: Hoplolaimus sp.*, *Longidorus breviannulatus*, *Trilineellus sp.*, *Helicotylenchus multicinus*, *Meloidogyne sp.*, and *Xiphinema sp*. (Seliskar, 1995; Seliskar, 1993).

A. breviligulata in its native range, with wild horses (Seliskar, 2003).

A small grass fly, *Meromyza pratorum*, will feed only on *A. arenaria* in Western Europe, where their larvae feed on the vegetative parts of tillers. In their native range, these flies lay eggs in July on leaf axils, then overwinter on the axillary buds, and complete their life cycle the next spring while feeding on young leaves. They can kill 30-40% of tillers, though this can be survived by the beachgrass stand. There are several other insects that will feed on European beach grass in its native range, though none of them will only feed on *A. arenaria*. Additionally, there are quite a few species of fungi which can parasitize from European beach grasses, though none seem to harm the plant greatly or they do not only grow on *A. arenaria* (Huiskes, 1979).

In its native range, *A. arenaria* seedlings are eaten by rabbits, while other small mammals eat their seeds (Huiskes, 1979). A buildup of pathogens has also been seen to kill *A. arenaria* in Europe (Emery and Rudgers, 2014). A cutworm, *Euxoa spp.* (Maun, 1984), and horses (Seliskar, 2003) will eat *A. brevifolia* in its native range.

CHEMICAL:

Backpack spraying, by hand, is frequently used, as the topography of many dunes make using an ATV with a boom very difficult. Spraying is frequently done after a prescribed burn, as the burn gets rid of the thick thatch, so that the herbicide can actually reach living plant material (Zarnetske *et al.*, 2010). Spraying of herbicides may be the most cost-effective control method for *Ammophila* species (Pickart, 1997).

AROMATIC AMINO ACID INHIBITORS	
Glyphosate *Roundup*, *Accord XRT II*, *Rodeo*, and others	**Rate:** 8% to 10% v/v solution (*Roundup ProMax*) as a spot treatment, 33% to 50% v/v solution as a wiper solution **Timing:** Postemergence to non-dormant plants during active growth. **Remarks:** Glyphosate is a nonselective herbicide. It has no soil activity. With *Rodeo*, use a non-ionic surfactant (0.5% to 1.5% in spot treatments, 1% to 2.5% in wiper treatments). Effectiveness may be increased by addition of ammonium sulfate. Standing dead biomass may still have to be removed to allow revegetation. This treatment is only marginally effective and most land managers find better control when glyphosate is tank mixed with imazapyr.
BRANCHED-CHAIN AMINO ACID INHIBITORS	
Imazapyr *Habitat*, *Arsenal*, *Stalker*, *Chopper*, *Polaris*	**Rate:** 2 to 3 pt product/acre (0.5 to 0.75 lb a.e./acre) **Timing:** Best when applied pre- or postemergence in fall or spring to non-dormant plants. Applications in fall may be most effective. Some areas allow application only from September to February due to the presence of snowy plovers, an endangered species. **Remarks:** Imazapyr is a nonselective herbicide. It also has a relatively long soil residual activity and may have longer-term effects on the plant community.
Imazapyr + glyphosate + *Habitat*, *Arsenal*, or *Polaris* + *Roundup* and others	**Rate:** 2% *Roundup ProMax* or other trade name with similar amount of active ingredient + 1% *Habitat* v/v solution for spot treatment. **Timing:** Postemergence in fall or spring to non-dormant plants. Applications in fall may be most effective. **Remarks:** This combination appears to have improved efficacy and fewer negative effects compared to imazapyr alone. This tank mix is often used because the quicker response to glyphosate indicates that the application was successful. Success of treatment is enhanced with multiple applications per year.

Table of *A. arenaria* chemical control options from the Western Weed Control Handbook (DiTomaso *et al.*, 2013).

A. arenaria have been controlled with glyphosate but have mixed results. The rate used in California was 7% glyphosate, with a follow up treatment being needed. Imazapyr is preferred over glyphosate. (Zarnetske *et al.*, 2010). 8% glyphosate with 0.5% to 1.5% non-ionic surfactant is used along the entire West Coast by many agencies, for a spray to wet application. For wiper applications, they report agencies using 33% glyphosate with 1% to 2.5% non-ionic surfactant (Pickart, 1997).

Due to the close related-ness between both *Ammophila* parent species as well as the hybrid, any chemical methods to control *A. arenaria* will also likely work on the hybrid and *A. breviligulata*.

RATIONALE FOR LISTING:

These dune systems make up 42% of Washington's and Oregon's coasts, which are the habitats of several threatened and endangered plant and animal species. The dunes also provide protection against wind and water for coastal human communities and are largely stabilized by invasive *Ammophila* species (Hacker 2023). *Ammophila* beach grasses negatively impact many native species that use Washinton's coastal system, including several at-risk species. Land and property managers have limited budgets and resources to protect native species and control invasive species, while also protecting and maintaining facilities and human communities (Pickart, 2021).

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