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# MANAGEMENT, MONITORING, AND PROTECTION PROTOCOLS FOR SEABEACH AMARANTH AT CAPE HATTERAS NATIONAL SEASHORE, NORTH CAROLINA

# MANAGEMENT, MONITORING, AND PROTECTION PROTOCOLS FOR SEABEACH AMARANTH AT CAPE HATTERAS NATIONAL SEASHORE, NORTH CAROLINA

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## I. Species Description

The seabeach amaranth (*Amaranthus pumilus*) is an annual plant, with no vegetative reproduction, in the Family Amaranthaceae native to the beaches of the Atlantic Coast (Figure 1). Historically the plant occurred in 31 counties of nine states from Massachusetts to South Carolina (USFWS 1996). Currently seabeach amaranth is known from NY, NJ, DE, MD, VA, NC and SC. The species was federally listed as Threatened by the U.S. Fish and Wildlife Service on April 7, 1993 (USFWS 1993). Seabeach amaranth has a global rank of G2, The Nature Conservancy). Within North Carolina numbers of plants increased from 2002 to 2003 from 5700 to 9366 plants along 112 miles of beach (Dale Suiter, USFWS). However, these numbers represent a fraction of the reports of approximately 40,000 individuals reported in the late 1980's and in 1995. For example, there were three to fifteen thousand individuals per year within Cape Hatteras National Seashore (CAHA) in the period 1987 to 1990 but only 50 to 133 individuals have been found in the period 2001 to 2003 (Table 1).

The plants must recruit annually from seed banks either *in situ* or from other source populations dispersed by water, wind, or from on or offshore sediments distributed by anthropogenic factors (Jolls et al. 2004). Seeds must be scarified (the seed coat broken by nicking or abrasion, Hancock and Hosier 2003) or cold stratified (chilling for weeks) before germination of any magnitude can occur (Baskin and Baskin 1998, Blazich 2005, Jolls et al. 2001).

**Table 1.** Numbers of naturally occurring plants of *A. pumilus* at Cape Hatteras (CAHA) and Cape Lookout (CALO) National Seashores since 1985. Empty cells represent no data. Censuses were completed by a variety of personnel and agencies, typically in July and August. (From Jolls et al. 2004).

| SITE | 2003 | 2002 | 2001 | 2000 | 1998 | 1997 | 1996 | 1995 | 1990 | 1988 | 1987 | 1986 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hatteras Point | 16 | 45 | 37 | 1 | 9 | 59 | 2 | | 2830 | 800 | 5200 | 200 | |
| Hatteras Inlet | 2 | 75 | 16 | 1 | 47 | 16 | 62 | 0 | 252 | 1718 | 274 | 300 | 450 |
| N. Ocra-coke | 36 | 13 | | | 0 | 6 | 14 | 1 | 250 | 13,310 | 1409 | 100 | 100 |
| Totals | 54 | 133 | 53 | 2 | 56 | 81 | 78 | 1 | 3332 | 15,828 | 6883 | 600 | 550 |

Germination takes place over a relatively long period of time, generally beginning in April and continuing at least through July (USFWS 1996). Upon germinating, this plant initially forms a small unbranched shoot but soon begins to branch profusely into a clump, often reaching 30 cm in diameter and consisting of 5 to 20 branches (Figure 1). Occasionally a clump may get as large as a meter or more across, with a hundred or more branches. The stems are fleshy and pink-red or reddish, with small rounded leaves that are 1.3 to 2.5 cm in diameter. The leaves are clustered toward the tip of the stem, are normally a somewhat shiny, spinach-green color, and have a small notch at the rounded tip. Flowers and fruits are relatively inconspicuous and are borne in clusters along the stems. Flowering begins as soon as plants have reached sufficient size, sometimes as early as June in the Carolinas but more typically commencing in July and continuing until their death in late fall or early winter. The plants are reported to be monoecious (having male and

**Figure 1.** Seabeach Amaranth. New York Natural Heritage Program, Photographer: Stephen M. Young

female flowers on the same plant) (USFWS 1996). Seed production begins in July or August, reaches a peak in most years in September, and continues until the plant dies. The species is a prolific seed producer of waxy seeds which are relatively large (2-2.5 mm) and are believed to be viable for long periods (New Jersey DEP 2003). Seed dispersal may occur by wind, water and possibly birds, and whole plants and seeds are temporarily buoyant.

## II. Habitat Description

The plant grows only on Atlantic Coast beaches, mainly on coastal overwash flats at the accreting ends of the islands and lower foredunes and on ocean beaches above mean high tide (occasionally on sound-side beaches) (NatureServe 2005). It often grows in the same areas selected for nesting by shorebirds such as plovers, terns, and skimmers. It is intolerant of competition with other plants and does not occur on well-vegetated sites. According to Weakley and Bucher (1991), this species appears to need extensive, dynamic, natural areas of barrier island beaches and inlets. Within this dynamic landscape, *A. pumilus* functions as a fugitive species, occupying suitable habitat as it becomes available (NatureServe 2005). Seeds may survive many years buried in the sand; they germinate when brought near the surface by overwash events or more severe storms.

The U.S. Fish and Wildlife Service Recovery Plan (1996) includes the following relevant information regarding this species' habitat requirements:

> "One of the more striking features of the distribution of seabeach amaranth in the Carolinas is its near absence from the northern third of the North Carolina coast. From Cape Hatteras north, only two plants were found in each of the years 1987 and 1988. It is not currently known whether the virtual lack of amaranth in this area is related to natural or historic factors. A hypothesis emphasizing the importance of natural forces would note that the present North Carolina strongholds of seabeach amaranth appear, in general, to be the south-facing coast of Brunswick County, the south- and southeast-facing coasts of Carteret and Onslow Counties, and the south- and southeast-facing coasts of Dare and Hyde Counties. The east- or even northeast-facing coasts of Currituck, northern Dare, northern Carteret, and New Hanover Counties generally support smaller, more scattered populations of seabeach amaranth.
>
> Dolan and Lins (1987) indicate that "the rate of shoreline erosion along the barrier islands of Virginia varies with the configuration of the shoreline. Erosion rates are highest where the shoreline faces northeast and lowest where it faces southeast." Greater erosion on east-facing beaches in the Carolinas may reduce seabeach amaranth habitat, compared to the south-facing beaches immediately west of each of the great capes (Hatteras, Lookout, and Fear). Long Island's (New York) Atlantic shore is also south-facing. Moreover, seabeach amaranth is (at least during periods of sea level rise) a species primarily of inlets, and Oregon Inlet is the only inlet from Cape Hatteras north to the North Carolina/Virginia line. An alternate hypothesis notes that the stretch of North Carolina from which seabeach

amaranth is absent corresponds almost exactly with the construction of a continuous barrier dune by the National Park Service, Civilian Conservation Corps, and Work Projects Administration from the 1930s to 1950s. Dolan and Lins (1987) state:

Thirty years of artificial dune stabilization have altered the ecology and geology of the Outer Banks. A comparison of a cross section of Hatteras Island and Core Banks, representing the altered and natural states of barrier islands, shows how stabilization has changed the morphology and ecology of the beaches, dunes, and marshes. Viewed from the air, the most striking contrast between the natural and altered barrier islands, other than the artificial barrier dune, is a marked difference in beach width. Unaltered islands have beaches from 100 to 180 m wide, whereas on Hatteras Island the beach has been reduced to 30 m or less. The paradox suggests that manmade structures do not merely fail to protect beaches but actually work to destroy them.

We do not know whether seabeach amaranth was present here prior to artificial dune stabilization and was eliminated by its results. A species with a similar habitat, seabeach knotweed (*Polygonum glaucum*), was known from Chicamacomico, North Carolina, prior to the commencement of dune stabilization and has not been seen in recent years. No vascular plants regularly occur at a lower topographic position on beaches than seabeach amaranth, though several others--most notably, saltwort (*Salsola australis*) and sea rocket (*Cakile edentula*)--often occur with seabeach amaranth at the lowest elevations that support vascular plants. Seabeach amaranth occupies elevations from 0.2 to 1.5 m above mean high tide.

Christensen (1988) states that "strand vegetation consists of an assemblage of short-lived plants whose spatial distribution shifts from season to season and year to year. Many of these species are salt-tolerant and have life-history characteristics that allow them to invade suitable habitat when it becomes available." This natural community or vegetation type is classified by Schafale and Weakley (1990) as Upper Beach, although seabeach amaranth is sometimes found on sand spits 50 m or more from the base of the nearest foredune (Mangels, personal communication, 1996).

Seabeach amaranth appears to need extensive areas of barrier island beaches and inlets, functioning in a relatively natural and dynamic manner. This allows it to move around in the landscape, as a fugitive species, to occupy suitable habitat as it becomes available.

Populations of seabeach amaranth, like the habitat upon which it grows, are highly dynamic, with numbers of plants often fluctuating dramatically from one year to the next. The plants generally occur in a sparse to very sparse distribution pattern. The plants are often widely scattered, especially on upper beaches where the average density can be as low as one plant per kilometer. Because amaranth usually occurs in a zone about 10 m wide this translates to a density of one plant per hectare. A more typical beach density would be 10 plants per 100 m of linear beach (100 plants per ha), and occasionally, on accreting beaches, dense populations of 100 plants per 100 m of linear beach (1,000 plants per ha) can be found. Island-end flats generally have higher densities than beaches. The overall range of densities is about the same as on upper beaches (1 to 1,000 plants per hectare), but higher densities are encountered more often. Density is presumed to be determined by a complex set of factors, including previous year's seed set, seed bank, pattern of deposition of seeds by wind and water, weather conditions (especially rainfall) determining germination and survival of seedlings, predation by webworms, disturbance by human use, storms, and hurricanes.

This plant shares its beach habitat with a number of other rare species, both plant and animal. Seabeach knotweed, the purslanes (*Sesuvium portulacastrum* and *S. maritumum*), and seabeach morning-glory (*Ipomoea imperati*) are all considered rare within the Carolinas. A number of gulls, terns, skimmers, sandpipers, oystercatchers, and plovers also use this habitat for resting, roosting, or nesting. Included in this group are the State and/or federally listed piping plover (Charadrius melodus), least tern (*Sterna antillarum*), Wilson's plover (*Charadrius wilsonia*), black skimmer (*Rhynchops niger*), and Caspian tern (*Sterna caspia*). The endangered roseate tern (*Sterna dougallii dougallii*) also occurs in some of the same places. Some of the largest seabeach amaranth populations are associated with nesting sites of the least tern, Caspian tern, piping plover, or Wilson's plover. In the Carolinas, sea turtles also nest in this habitat; loggerheads (*Caretta caretta*) are the most common, but on rare occasions, green sea turtles (*Chelonia mydas*) also nest here. Both turtles are federally and State-listed as threatened."

Some notable studies have recently assessed habitat requirements and experimented with *A. pumilis* recovery methods (Sellars 2001, Sellars and Jolls 2001, Jolls et al. 2004). A model developed by Sellars based on topographical factors, including highly accurate elevation measures obtained from LIDAR data, was used to predict *A. pumilis* occurrence and habitat with evaluations based on the occurrence of 164 plants in Carteret and Brunwick Counties, NC. This work found that elevation was the most limiting topographic variable controlling the occurrence of *A. pumilis.* Subsequent work used natural plant occurrences on Cape Lookout with a stepwise discriminant function analysis with grayscale (passive) LIDAR data to assess the role of vegetation cover. This work found that passive LIDAR (an index of bare sand) and elevation has been able to predict 72% of the plant occurrences and excluding 98% of the landscape as unsuitable habitat (Sellars et al. 2003).

These studies were extended in 2002-04 to Assateague Island and Cape Hatteras National Seashores. This study sought to develop a greater understanding of the species' ecology and to develop guidelines for *A. pumilis* re-introduction to historic or extirpated sites selected using remotely sensed data, GIS and a program of reintroduction from greenhouse/laboratory-reared plants (Jolls et al. 2004). Further modeling work using LIDAR data and known locations of plants for several years yielded estimates of total suitable habitat of 254 ha at CAHA. Inlet areas tended to have wider beaches and potentially greater *A. pumilis* habitat.

Habitats delineated by the GIS modeling work were used to select sites for transplanting greenhouse-raised plants both within and outside preferred habitats. Planting in "good" habitats was considered to be in the range of 0.77 and 2.00 m above mean high water and in areas not experiencing strong erosional trends. Survival to 10 weeks for transplants ranged from 33-100% at CAHA. Plants placed below the specified elevation range grew larger than plants placed above the range, likely due to greater availability of water and nutrients. However, their probability of survival can be low due to the higher risk of overwash. Plants placed above the specified elevation range were found to be limited in size due to water/nutrient availability and biotic factors such as increased competition and herbivory.

Johnson (2004) and Johnson, Jolls and Holbert (in review) report on a growth chamber experiment that evaluated the competitive effects of perennial plant neighbors (*Cakile edentula*, *Iva imbricata* and *Uniola paniculata*). *A. pumilis* plants experienced reduced survival and growth with these other plants and reduced growth when grown with other *A. pumilis* plants. Association with other *A. pumilis* plants is less detrimental than with the other species in term of survival, plant diameter, total competitive response and relative growth rate, although the limiting resources and mechanisms remain unknown. According to the authors: "Reduced performance of *Amaranthus* planted with neighbors in this experiment suggests that this species is a relatively poor competitor and may suffer lower reproductive fitness from competitive interactions with associates on the beach." The specific mechanisms of competition were not investigated but are cited as a future research need, particularly the abiotic resource partitioning (Hutchinson 1961) and the relative effects of biotic and abiotic factors among the associate species in the dune community.

## III. Threats to Reproduction and Survival

The predominant threat to *A. pumilis* is loss of suitable habitat, primarily due to beach stabilization efforts and storm-related erosion (USFWS 1993). This species occupies a narrow and precarious elevation niche, bounded by its relative intolerance of flooding in lower beach settings and competition with other plants in upper beach and dune settings. Its placement within upper beach and overwash area habitats is severely limiting because these areas are often absent on barrier islands that are experiencing beach erosion. If sea levels continue to rise then beach erosion and habitat loss will accelerate, especially where beach stabilization efforts limit the ability of barrier islands to respond naturally to such changes (USFWS 1993).

Previous surveys have found very few *A. pumilis* plants on east- and north-east facing coastlines, which experience the greatest erosion rates. South-facing beaches, such as those immediately south of Cape Hatteras, have lower erosion rates and likely provide better habitat for *A. pumilis*. Construction and maintenance of a continuous barrier dune by the North Carolina Department of Transportation to protect Route 12 is likely also a significant factor.

Intensive recreational use, both vehicular and pedestrian, also threatens the plant's survival. Its stems are easily broken or crushed by foot traffic and tires, thus, even minor traffic can be detrimental during the growing season (USFWS 1993). Although some may argue that recreational uses in the dormant season may even be helpful by decreasing and/or limiting the cover of perennial vegetation, there are no data to support this premise and heavy traffic can erode substrates and pulverize or bury seeds below depths from which seeds can germinate. Particularly in the Carolinas, webworms (caterpillars) can defoliate the plants to the point of killing them or at least preventing reproductive functions.

The U.S. Fish and Wildlife Service (1996) Recovery Plan includes the following additional relevant information regarding threats to this species' reproduction and survival:

> "Habitat loss and degradation due to shoreline development and beach stabilization and intensive use by off-road vehicles during reproductive seasons has contributed to the decline of each of these listed species… Although management of the ecosystem as a whole is always the preferable approach and is the ultimate recommendation of this plan, as well as of the recovery plans for the other federally listed species, in some cases single-species management actions are necessary and appropriate. The proposed reintroduction of seabeach amaranth to habitat from which it has disappeared all along the Atlantic Coast is another such species-specific action that is being recommended.
>
> At island ends, inlet migration generally means that land is accreting on one side of the inlet and eroding on the other. On the eroding side of the inlet, habitat for seabeach amaranth is usually small or absent. Accreting sides of inlets are, along with accreting capes, the most favorable habitat for the plant. Since most of the beaches in the Carolinas are eroding, upper beach habitat for seabeach amaranth is generally poor. The near absence of seabeach amaranth from North Carolina north of Cape Hatteras is related to this fact. North of Cape Hatteras there are 165 km of beach (nearly all of it strongly eroding) with only a single inlet (Oregon Inlet). In both 1987 and 1988, only two individuals were found in this stretch, and one of those was found in a casual or adventive site on a sound-side beach back of Avon.
>
> Local exceptions to beach erosion can be found in the Carolinas, such as in Brunswick County, North Carolina, on the west end of Holden Beach, where beach accretion has led to a thriving population on the upper beach. Brunswick County has been a stronghold for seabeach amaranth throughout the 1980s, with populations (some of them large) on nearly every barrier island. Reasons for the health of these populations are the localized accretion of beaches, frequency of inlets, and absence of erosion-control structures.
>
> Human recreational use of the beach habitats favored by seabeach amaranth is, of course, extensive, and sometimes intensive, especially on Long Island, New York. From the point of view of seabeach amaranth, this use can be divided simply into two categories--vehicular and pedestrian. Many beaches in the Carolinas and New

York allow off-road-vehicle (ORV) traffic, at least during some seasons. On some beaches, traffic is relatively light, whereas on others it can approach traffic jam proportions. In general, ORV traffic occurring during seabeach amaranth's dormant season could potentially have some negative impacts, including the pulverization of seeds. At levels of ORV use generally found on Carolina beaches, there is little evidence of highly detrimental effects, unless it results in massive physical erosion or degradation of the site, such as can be seen at the northern end of Carolina Beach. In some cases, off-season ORV traffic may even provide some benefits for seabeach amaranth. This appears to be true at Cape Hatteras, where a large sand flat would probably proceed through succession into dominance by perennial grasses and shrubs except for heavy winter truck traffic by fishermen. In spring and summer much of the area is fenced off from traffic by the National Park Service in order to protect nesting habitat for least terns, piping plovers, and other shorebirds. Following nesting, in early fall, fencing is removed to allow truck traffic. Physical disturbance by trucks helps prevent the widespread establishment of perennials, which would render the area unsuitable as a nesting ground for birds and as unsuitable habitat for seabeach amaranth.

While seabeach amaranth populations are somewhat tolerant of ORV use from December until May, the brittle, fleshy stems are easily broken, and growing plants (May to December) do not generally survive a single pass by a truck tire. Thus, even minor beach traffic directly across the plants during the growing season is detrimental, causing mortality and reduced seed production. In the Carolinas, traffic has been successfully routed around these sensitive areas, and most ORV drivers have been respectful of the public land that has been roped off for nesting birds or seabeach amaranth. The seabeach amaranth and nesting shorebirds often occur together in the Carolinas, even outside roped-off areas. On New York's heavily used beaches, however, the interiors of shorebird exclosures are often the only places where seabeach amaranth is found, strongly suggesting that heavy ORV traffic and beach grooming are rendering most of the beaches unsuitable there (DuBois, personal communication, 1995).

Pedestrian traffic during the dormant season (December to May) is unlikely to have any significant effects in the Carolinas. Even during the growing season pedestrian traffic there generally has little effect on populations of seabeach amaranth. Many beaches with daily use by thousands of sunbathers, joggers, and other recreation enthusiasts have substantial and apparently healthy populations of seabeach amaranth. The main exceptions appear to be in the vicinity of high-rise hotels or condominiums, where beach usage is concentrated and portions of seabeach amaranth populations are sometimes eliminated or reduced by repeated trampling. The general compatibility of human pedestrian recreation enthusiasts and seabeach amaranth lies in their preferences for different parts of the beach. Joggers inevitably prefer packed sand and stay seaward of seabeach amaranth. The great majority of sunbathers prefer to be close to the water and away from beach vegetation, so they generally choose sites seaward of those favored by seabeach amaranth. Island-end flats, the sites most favored by seabeach amaranth, are generally not found desirable by beach-goers, except as a destination to be reached in a long stroll. On the rare beaches where proximity to hotels or condominiums brings heavier use to island-end flats, Bucher and Weakley (1990) saw further evidence of humans avoiding seabeach amaranth habitat. Frequently a low ridge of loose sand, often much favored by seabeach amaranth, parallels the shoreline as it hooks back toward the inlet; joggers, strollers, and birdwatchers stay on the packed sand in front of this ridge, while sunbathers occupy locations in front of or behind it.

Beach replenishment - On the other hand, beach replenishment rebuilds habitat for seabeach amaranth and can have long-term benefits. For instance, Wrightsville Beach was probably the first location in North Carolina where seabeach amaranth was collected, in 1888. It was collected several times later, such as in 1931. A beach replenishment project was begun on Wrightsville Beach in 1965 by the U.S. Army Corps of Engineers (Corps). A jetty was constructed on the south end of Wrightsville Beach in 1966, and the beach was "rebuilt" with sand (all placement of sand was on the north and central portions of the island) (Tom Jarrett, Corps, Wilmington District, personal communication, 1989). Additional renourishment was undertaken in 1970, but then a lapse of 10 years occurred and severe erosion took place. The full length of the beach was surveyed on a regular basis during 1978 to 1980; no seabeach amaranth was found. In 1980 and 1981, a total of 1.7 million cubic yards of sand was placed on the beach. Eighty-five seabeach amaranth plants were found on the north end in 1985 and twelve plants were found on the south end. A further renourishment of 900,000 cubic yards was placed in 1986. That same year, 611 plants were found on the north end (the south end was not surveyed). In 1987, the censuses recorded 431 individuals on the north end and 69 on the south, and in 1988, the north end had 2,521, and the south had 414. Overall, Wrightsville Beach is now one of the largest and least variable populations of seabeach amaranth known. It has apparently reestablished itself (whether from a seedbank or from colonization is not known) on this renourished beach. It is interesting that on the south end, which accreted because of the jetty, a population has also become reestablished, though consistently smaller than on the renourished north end.

At Atlantic Beach, dredge spoil placement has also apparently aided in the reestablishment of a population of seabeach amaranth. A very large renourishment project at Carolina Beach, North Carolina, however, has failed to help seabeach amaranth. A few plants are present, but it is one of the poorest populations in the State, despite repeated renourishment since the 1960s. Reasons include the use of a 2,000-foot-long rock wall and heavy ORV use during the growing season.

Habitat loss and degradation are, by far, the greatest threats to the continued existence of seabeach amaranth. However, on a more local scale, predation (herbivory) by webworms (the caterpillars of small moths) is a major source of mortality and lowered fecundity in the Carolinas… Potential webworm herbivory

> would seem to be greater in the South, so it seems unlikely that herbivory is the cause of the extirpation of seabeach amaranth in the North. Not only are there more potential species of webworm in the South, but also they are likely to produce more broods over the course of a longer warm season… Webworms appear to have strong effects on seabeach amaranth. Most populations experienced moderate to severe herbivory by webworms in both 1987 and 1988."

It is noted that if control measures against webworms are needed, BT (*Bacillus thuringensis*), which affect lepidopterans, could be detrimental to important and beneficial moths and butterflies, including a rare skipper butterfly that occurs on Bogue Banks, NC (Atlantic Beach to Emerald Isle) and parts of Cape Lookout National Seashore (Shackleford Banks). This skipper (*Atrytonopsis* sp.) has not been named yet, but is considered to be very rare and limited to the sand dunes in this central part of the North Carolina coast.

## IV. Adaptive Resource Management

Adaptive Resource Management (ARM) is an approach of prepared responsiveness, whereby policy and management actions are integrated with feedback systems based on monitoring and evaluation (Holling 1978; Lessard 1998; Bellamy et al. 2001). ARM is an iterative process that integrates planning and management decisions with research and monitoring to improve management in achieving management goals and objectives. Implicit is the notion that management policies are implemented as experiments evaluated to yield new knowledge and progress in achieving management objectives. Land managers implement policies and adjust prescriptions based on knowledge gained from periodic monitoring efforts.

### *1. Framework for ARM*

**A. Questions to be addressed**

1. What is the location and abundance of *A. pumilis* plants within CAHA?
2. How consistently does *A. pumilis* occur in areas of suitable habitat within CAHA? How consistent are *A. pumilis* population levels?
3. What factors limit germination and survival to reproductive maturity, including the production and success of seed banks.

**B. Proposed ARM Experiment**

**Effects of human disturbance (Item 1.C above):** – The principal human disturbance affecting *A. pumilis* is ORV and pedestrian traffic. Both can easily crush and/or kill *A. pumilis* plants and have the potential to disturb substrates and deeply bury seeds during the off-season (which prevents subsequent germination). A null hypothesis for investigating this issue is that human disturbance frequency and intensity has no effect on *A. pumilis* germination and survival to reproductive maturity. A research design involving the experimental application of differing levels of wheeled or foot traffic to randomly assigned vegetative plots is the best method for evaluating the crushing resistance and tolerance of common plant species and communities (Marion and Cole 1996). For obvious reasons such a design would be inappropriate for naturally-occurring individuals of any rare species. However, it should be possible to identify areas of equivalent *A. pumilis* habitat that are: 1) closed to human use, 2) open to use but receiving low use, and 3) open to use but receiving high use. It may even be possible to identify areas that receive differing levels of exclusive use by either pedestrian or ORV traffic. A before-and-after design is also possible if areas of the beach are closed to ORV traffic for a period (e.g., the completion of nesting by rare bird species) and then opened to traffic. If study areas have insufficient numbers of native plants it may be possible to place greenhouse-cultivated plants as was done in earlier CAHA studies (Sellars 2001, Sellars and Jolls 2001).

Ideally, such a study should be conducted in July-September when *A. pumilis* plants are sufficiently large to locate and evaluate for damage. Documentation of the type, numbers, duration, and locations of ORV and pedestrian visitation within the study sites can be conducted with either direct observation or cameras set up with timers on a sample of weekday and weekend days. Weekly surveys to assess the number, location, and condition (plant diameter, mm) of all *A. pumilis* plants would be conducted to evaluate human disturbance effects.

**C. Research Needs:** *A. pumilis* is inherently difficult to investigate and manage because it is both temporally and spatially dynamic. Management is also challenging due to the paucity of research documenting the relative importance of various factors affecting *A. pumilis* germination and survival. Some primary factors noted in the existing literature include presence of an adequate seed bank, seed depth in substrate, availability of suitable habitat, competition with other plants, effects of overwash events, webworm herbivory, and human disturbance. It is likely that the relative importance of these factors vary from one location to another so research within CAHA is vital to resource protection decisions. A number of studies have examined issues related to habitat suitability (Sellars 2001, Sellars and Jolls 2001, Sellars et al. 2003, Jolls et al. 2004), plant germination (Blazich et al. 2005, Jolls et al. 2001), and the effect of competition with other plants (Johnson et al., in review). However, a comprehensive program of basic research on *A. pumilis* that seeks to integrate existing knowledge, explore gaps in knowledge, and examine the relative importance of influential factors is needed.

**Factors Limiting Seed and Seedling Success (Item 1.A.3. above) -** Such research might begin with survivorship studies on seedlings found or planted on CAHA beaches. Such work could identify the most critical phase of the species life-history and limiting factors. This could be complemented with studies that examine natural seed storage, viability and long distance transport. The effects of off-season pedestrian and ORV traffic on *A. pumilis* seeds, including potential damage and depth of burial, is another important research topic. It is unclear what effects off-season human uses have on the integrity of *A. pumilis* seeds and depth of burial. Finally, there is evidence that freshwater may play an important role in this species germination and growth. Investigation of this linkage can help determine whether the species is a true halophyte or whether it simply seeks out non-competitive environments characterized by higher salt concentrations. Additional research needs include the impact of beach stabilization and/or “nourishment”, including descriptive work documenting populations sizes relative to sites which have or have not been impacted.

## *2. Habitat Management Recommendations*

### A. Current management

No active management for amaranth occurred in 2005. Monitoring surveys are incomplete (as of 8/30/05) but one plant was located in the Bodie Island flats. Resource closures for birds were established when nesting occurred or was expected at Hatteras Island, Bodie Island, Green Island, Cape Point and South Ocracoke; thus, where *A. pumilis* might have occurred, the plant benefited from the bird protection enacted. Likely areas where *A. pumilis* may have germinated include the inlet-pond area at Bodie Spit, Cape Point, and South Ocracoke. In the past when *A. pumilis* is found outside of areas closed for bird protection, or in the Fall, park staff have either fenced off an area of approximately 10 m in diameter or placed one of the bird nest protection cages over the plant with appropriate signs asking visitors to stay clear of the location. These protection measures are continued until the plants have died, occasionally as late as December.

### B. Management Options

**<u>Option A: Highest Degree of Protection</u>**

1. Completely close all potential *A. pumilis* habitat (as defined by historic and extant populations within the last 10 years) at CAHA to all recreational activities year round. It is acknowledged that this species has substantial overlap with the habitats of rare bird species (e.g., Piping Plover & American Oystercatcher) and that habitat protection for these species will also benefit *A. pumilis* populations. During August, efforts should be directed to carefully monitor *A. pumilis* plants at all sites where it has been noted in the past decade or in any new suitable habitats.
2. Essential vehicles (law enforcement, NPS personnel, approved researchers) should only enter restricted areas subject to the guidelines in the Essential Vehicles section of Appendix G of the Revised Recovery Plan for the piping plover (USFWS 1996). Vehicles should not exceed 10 mph.
3. Locate and eliminate all individuals of beach vitex (*Vitex rotundifolia)*, a recent invasive beach plant from South and North Carolina. This species grows in similar habitats and outcompetes *A. pumilis*, thus is a threat to coastal dune habitats.

**Predicted effects:**

There should be no direct recreational impacts on any *A. pumilis* plants within the boundaries of CAHA, and no impact on their habitats under this management regime. There remains a small probability of Essential Vehicle impact on plants and seeds due to crushing and burial, respectively.

**<u>Option B:  Moderate Protection</u>**

1. Completely close all potential *A. pumilis* habitat (as defined by historic and extant populations within the last 10 years) at CAHA to ORV traffic and boat landings from April 15 until November 30. This could include areas on Bodie Island Spit, Green Island, Hatteras Island, including Cape Point, South Beach, and Hatteras Spit, and Ocracoke Island, including North Ocracoke (inlet area), and South Ocracoke.
2. At the seven sites mentioned above, pedestrians should be allowed within a 50 m corridor (ca. 150 ft) from the high tide line landward, from sunrise to sunset. At areas of CAHA outside of the seven focal areas, monitoring for *A. pumilis* should be conducted during August (see Monitoring section below). Where plants are found, resource closures (10 m diameter) with signs should be erected to protect each plant.
3. Interpretive signs about the trampling susceptibility of *A. pumilis* should be placed at all ORV entry points to CAHA, at all boat ramps and marinas, and at Park kiosks.
4. Same as Option A, # 2 and 3 above.

**Predicted effects:**

There may be limited mortality to plants and burial of seeds caused by ORVs within the 50 m zone. The risks of mortality to plants and seeds in areas outside of the focal sites, however, is higher. Potential negative effects of Essential Vehicle use (ORV use by NPS staff, monitoring personnel, trappers) are the same as in Option A. Chances of spreading beach vitex is higher than under Option A.

**<u>Option C: Minimum Protection</u>**

1. Restrict all ORV and pedestrian recreation to a corridor within 50 m (ca. 150 ft) of the oceanside mean high tide line from sunrise to sunset, at all potential *A. pumilis* habitat (as defined by historic and extant populations within the last 10 years) from April 15 to November 30. This includes the seven sites referred to in Option B # 1 above. In August, monitor the areas for *A. pumilis* plants as prescribed below. Vehicle speed should not exceed 10 mph.
2. Enact recommendations for Option A # 2-4 above.

**Predicted effects:**

Plants and seeds are placed at risk by pedestrians and recreational ORVs and boats at the focal sites and all other areas. Adult plants may be crushed and seeds buried. Enforcement requirements are higher under this option than under options A or B, thus increasing the probability of harm to plants. Effects outside of the seven focal areas and potential effects of Essential Vehicle use, and ORV monitoring are the same as under Options A and B. Chances of having beach vitex spread is enhanced with more vehicle access.

### *3. Monitoring Protocols*

**A. Monitoring:** Thorough surveys to locate and count all *A. pumilis* plants should be conducted annually in early August in all areas of potential habitat to track plant numbers and distribution and to identify areas for closure. The location of all individual plants or plant clusters should be recorded with a GPS device with sub-meter accuracy. The diameter (mm) of each plant should be recorded and whether it is located in an area open or closed to pedestrian and/or ORV traffic. Any evidence of these uses (e.g., footprints or tire tracks) within 20 feet should also be recorded. A follow-up monitoring survey in late September is also recommended to examine survivorship and seed production. This survey should focus on finding new plants and relocating previously surveyed plants to evaluate survivorship and plant diameter growth. It is also recommended that some experimental surveys be conducted in May to see if seedling or juvenile plants can be identified and to ensure their protection.

### *4. Reporting Procedures*

**A. Reporting:** Field data should be recorded on field forms developed in conjunction with other partner agencies, scientists and managers. GPS data should be downloaded to CAHA computers, error checked, post processed and made available to partners and scientists. Field forms should be quality checked by an independent examiner and data electronically entered, analyzed where needed, summarized in reports in text, tabular and graphic form, and submitted to both CAHA management personnel and other cooperating agency personnel and other scientists and managers as requested. Reports should be available both in electronic form (pdf preferred) and in limited numbers of hard copy.

### *5. Data Management*

**A. Raw data collection:** Field data sheets should include, at a minimum, the date, the reference location (GPS and usually a code number), a point or specific area, and observer name or initials. Because of the large amount of data included in these different data collection efforts, we strongly urge that all individuals engaged in data collection be trained in advance of the actual data collection period. Regardless of how clear a field form appears to be, questions always arise about how to record certain types of data. Such training should include the identification of seedling, juvenile, flowering and fruiting plants and the use of GPS devices.

**B. Data entry:** Because the National Park Service (as well as other agencies) has determined that Microsoft Access will be the official database management software in the monitoring programs, we recommend it as the primary management tool. In some cases, Excel spreadsheets may be used since this is what the cooperators/contractors often provide. However, conversion of Excel to Access is not difficult and the structure of the tables is quite similar.

Quality assurance and quality control are best maintained by having the field data reviewed and entered into the database on the same day it is collected. Two individuals should first review the data to reduce error propagation. Generally it is best to have the person collecting the data also doing the data entry, followed by having a second person compare the computer printout with the original field sheets. This second step can be done at a later date to reduce fatigue on field days.

**C. Data storage:** Field data sheets should be stored in a safe, low-fire-risk location in or near the NPS Headquarters in Manteo. Upon entry into a PC's electronic Access database, an extra copy of the database should be generated on a separate portable hard drive, or on CDs which then should be maintained in a separate building. If a computer network is available at the site, the files can be more easily transferred electronically to other PC sites, rather than having to physically transfer media between locations. Security demands by the NPS may require extra steps in the data management outlined here.

**D. Data analysis techniques:** The methods for analyzing the data will vary greatly depending upon the question and the level of analysis of interest. Excellent statistical support and advice is available both at the USGS Patuxent Wildlife Research Center (Drs. Jim Nichols, James Hines, John Sauer, William Kendall, Michael Runge, and Jeff Hatfield) or from universities. Biologists at CAHA should consult with one or more statisticians whenever statistical analyses are to be conducted.

## V. Acknowledgements

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The USGS Patuxent Wildlife Research Center developed these protocols, based on the best available scientific information, to guide management, monitoring and research activity at CAHA that would result in the protection and recovery of each species. These protocols do not attempt to balance the need for protection of these species with other activities that occur at CAHA, nor was NPS management policy considered in detail. A draft of the protocols was sent to species experts for scientific review; the final draft of protocols were reviewed by NPS personnel to ensure that description of recent management at CAHA was accurately represented and that the approach was consistent with our work agreement.

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