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# EFFECT OF TRAMPLING ON *AMBROSIA CHAMISSONIS* AND *CAKILE MARITIMA* COVER ON CALIFORNIA BEACHES

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ABSTRACT

California beach plants are capable of dealing with harsh conditions, but little is known about how this community responds to human-induced impacts. The objective of this paper is to determine if beaches experiencing higher degrees of impacts from trampling have more cover of two common plant species thought to grow particularly well under difficult conditions, *Ambrosia chamissonis* (Less.) Greene and *Cakile maritima* Scop. Seventeen sites were sampled between 2007 and 2009 with one meter wide belt transects and the sites were divided into three groups; high (people walk anywhere on the beach), medium (foot traffic is restricted to trails), and low impact levels (little to no access). Cover of all species present were recorded. Cover of *A. chamissonis* is statistically higher on beaches with a high level of impact than low and medium levels. *Cakile maritima* cover is statistically higher on beaches with medium levels than those with low or high levels of impact. However, the total cover of all species is not significantly different between any level of impact.

Key Words: *Ambrosia chamissonis*, *cakile maritima*, cover, fencing, foot-traffic, management, trails, vegetation.

*Ambrosia chamissonis* (Less.) Greene (Asteraceae; beach-bur) is a California native perennial plant found throughout the state in coastal areas (Hickman 1996) from the high waterline through the dunes, but populations most often peak in the middle section of the beach between the high water line and foredunes (Barbour et al. 1976). *Ambrosia chamissonis* is a maritime-endemic species, endemic to the west coast of North America and restricted to maritime habitats (Breckon and Barbour 1974). It produces 5–10 mm cylindrical burs with ten to twenty or more sharp spines (Hickman 1996; Fig. 1).

*Cakile maritima* Scop. (Brassicaceae) (Fig. 2) is a European native naturalized in California, introduced in 1935 near San Francisco (Barbour and Rodman 1970). It is an annual found on beaches and dunes along the Pacific coast of North America (Hickman 1996) but has been observed by Boyd and Barbour (1993) to survive two or three reproductive seasons. *Cakile maritima* is found frequently on the leading edge of the vegetation on the beach, but is found throughout the beach with the highest cover of this species in the middle section (Barbour et al. 1976).

Both species are able to tolerate the challenging conditions typical of a beach environment. *Ambrosia chamissonis* is one of the most successful coastal plants at dealing with environmental challenges (Couch 1914). It thrives in the harshest locations on the coast–those with the highest rates of evaporation, unstable soil, high wind velocity, extreme soil temperatures, and intense light (Purer 1936). Capable of rapid growth, it stabilizes flat surfaces and can withstand partial burial (Purer 1936). A long central taproot and adaptations to fluctuations in xylem-sap tension help it survive water stress (DeJong 1979). Barbour and DeJong (1977) found that *A. chamissonis* was less tolerant than expected of high intensity salt spray and salt water inundation, but Fink and Zedler (1990) found *A. chamissonis* to be tolerant of sea spray, sea water over-wash, and sand burial. The distribution of *A. chamissonis* is not influenced by the presence of the invasive European beach grass, *Ammophila arenaria* Link (Poaceae; Boyd 1992).

*Cakile maritima* has a high tolerance for salt spray and inundation with salt water (Barbour and DeJong 1977). It is able to survive dry periods because of a tolerance for higher xylem-sap tensions and has shallow roots (DeJong 1979). Its cover decreases in areas less than one meter from stands of *A. arenaria* (Boyd 1992).

While many species of plants found on California beaches are adapted to deal with the unique conditions of the natural environment, many seem unable to cope with human-created impacts such as trampling. Schlacher et al. (2007), Schlacher et al. (2008), and Defeo et al. (2009) reviewed the literature related to threats to sandy beaches world-wide. All three indicate that recreation and trampling are a threat to coastal plant communities, but there seems to be very little literature that addresses how recreational activities, such as walking on the beach, affects the plant communities present. No literature on the subject is currently available for California's beaches.

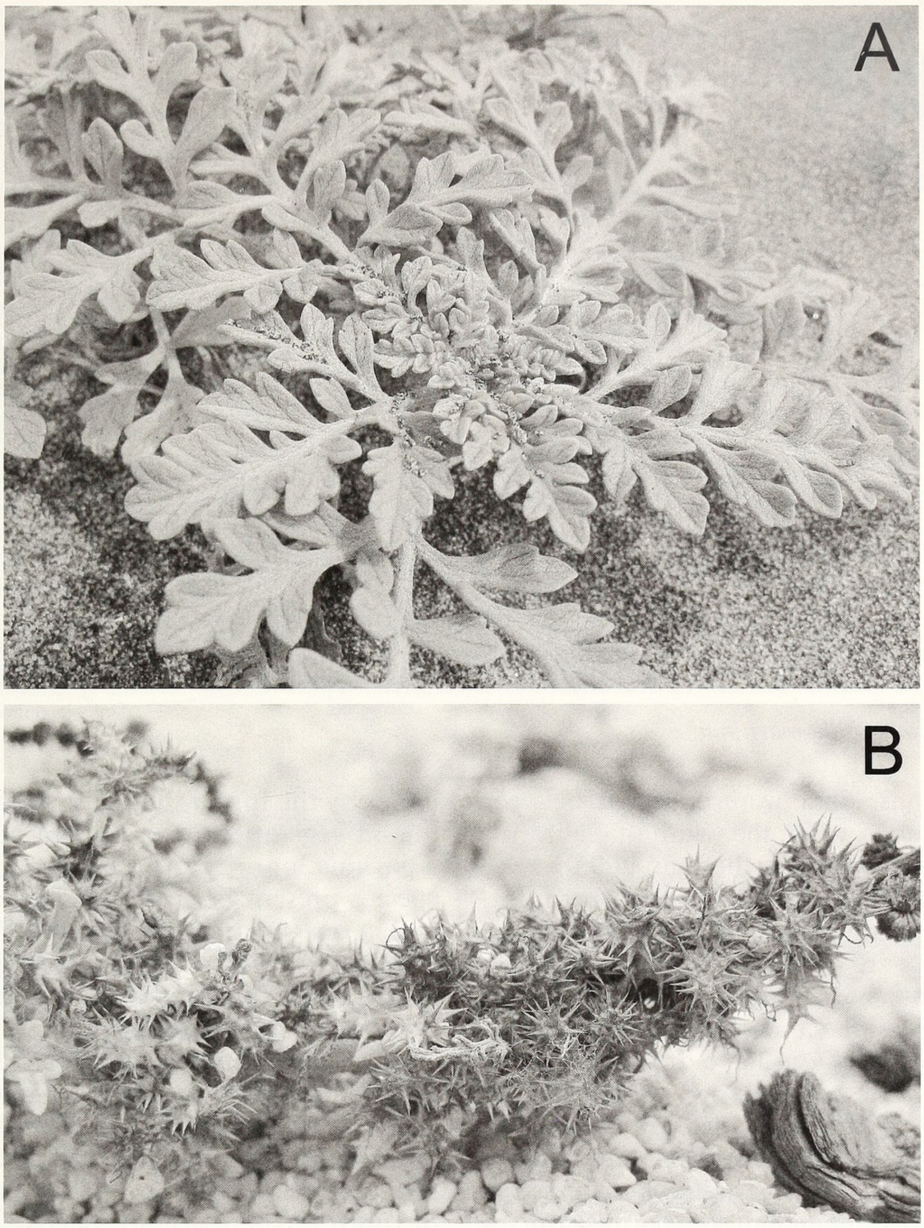


FIG. 1. (A) Foliage of *Ambrosia chamissonis* (B) burs attached to a flower stock in late summer.

*Ambrosia chamissonis* and *C. maritima* are the only two species of beach plants whose range extends the length of the California coast. Both are known to be capable of dealing with many stresses typical of the beach environment, but how they respond to human foot-traffic is not well understood. Different management strategies, such as fencing or marked trails, applied to beaches available for human recreation may affect the amount and type of plant cover present at a particular location, but no research exists on the topic.

Over the course of three years of data collection, my observations suggest that beaches with less protection from human foot-traffic have more cover of *A. chamissonis* and *C. maritima*, less cover of other species, and have overall less plant cover of all species than those with more protection. The objective of this study is to determine whether beaches with a higher degree of human impact have more *A. chamissonis* and *C. maritima* cover and less cover of other species.

## METHODS

### Study Area

Data were collected in the summer of 2007 at Leo Carrillo State Park, Point Mugu State Park, Point Mugu Naval Air Weapons Station, McGrath State Beach, San Buenaventura State Beach, and Ormond Beach. The following summer, 2008, data were collected at Pacifica State Beach, Pescadero State Beach, MacKerricher State Park, and Redwoods National Park. In 2009, data were collected at Carmel River State Beach, Zmudowski State Beach, Salinas River State Beach, Coal Oil Point Reserve, Pismo State Beach, Montaña de Oro State Park, and Morro Strand State Beach, for a total of 17 sites (Fig. 3). For all

FIG. 2. Foliage of *Cakile maritima*.

three field seasons, data were collected between June and September, when the width of California beaches are most stable (Leatherman 2003).

Sites were carefully selected along the California coastline to maintain physical environmental conditions that are as consistent as possible among different sites. Selected beaches were mainly comprised of sand, not rock or gravel above high water line, and have dry sand at high tide. Beaches were not narrow or backed by houses. Beaches with high cover of *Ammophila arenaria* were avoided because they were narrow, with high dunes close to the high water line. Site selection was also dependent on permission for access from the managing agency.

## Data Collection

Measurements were made at each of 17 beaches along four to 20 belt transects (divided into 1-meter square quadrats) parallel to each other and perpendicular to a straight line roughly corresponding to the high water line (Barbour and Robichaux 1976). The number of transects at each beach depended on the length of the vegetated section of the beach. In the 2007 data collection, transects were spaced ten meters apart following the methods of Barbour and Robichaux (1976). In 2008 and 2009, the transects were spaced five meters apart to increase the density of data for better results interpolating cover between points for a related study. The transects began at the high water line (indicated by a change in the sand color and often presence of wrack; Leatherman 2003) and stopped inland at the end of the beach vegetation (indicated either by the top of the foredune, the beginning of inland vegetation, or a human-built area such as a parking lot or road). The percent cover for each species present in every square meter (delineated with a one square meter quadrat frame) along the length of the transect was visually estimated to the nearest 5% for the area that fell within the quadrat frame (Barbour et al. 1976).

Each beach was assigned to one of three treatments (high, medium, or low impact) based on the level of disturbance of the site and the way visitors are managed (Fig. 4). The distribution of foot traffic is visible on a sandy beach in the form of footprints left behind. Beaches assigned to the low impact group were mainly undisturbed, having little or no evidence of human disturbance (footprints, trash, etc.). These sites were either very well protected, with measures like fencing or complete closure, or were sampled at a location on the beach where few visitors are able to access, such as an area far from visitor access points. Beaches assigned to the medium impact group had evidence of at least moderate amounts of foot traffic, but the disturbance was limited mainly to specific areas like trails. Within this group, some beaches had more concentrated traffic than others, but all beaches within this group had some form of trail. Unprotected beaches were assigned to the high impact group and were those with evidence of high amounts of unrestricted foot traffic; visitors walk on most areas of the beach.

## Data Analysis

Carmel River State Beach, South Beach at Leo Carrillo State Park, and Mugu Beach at Point

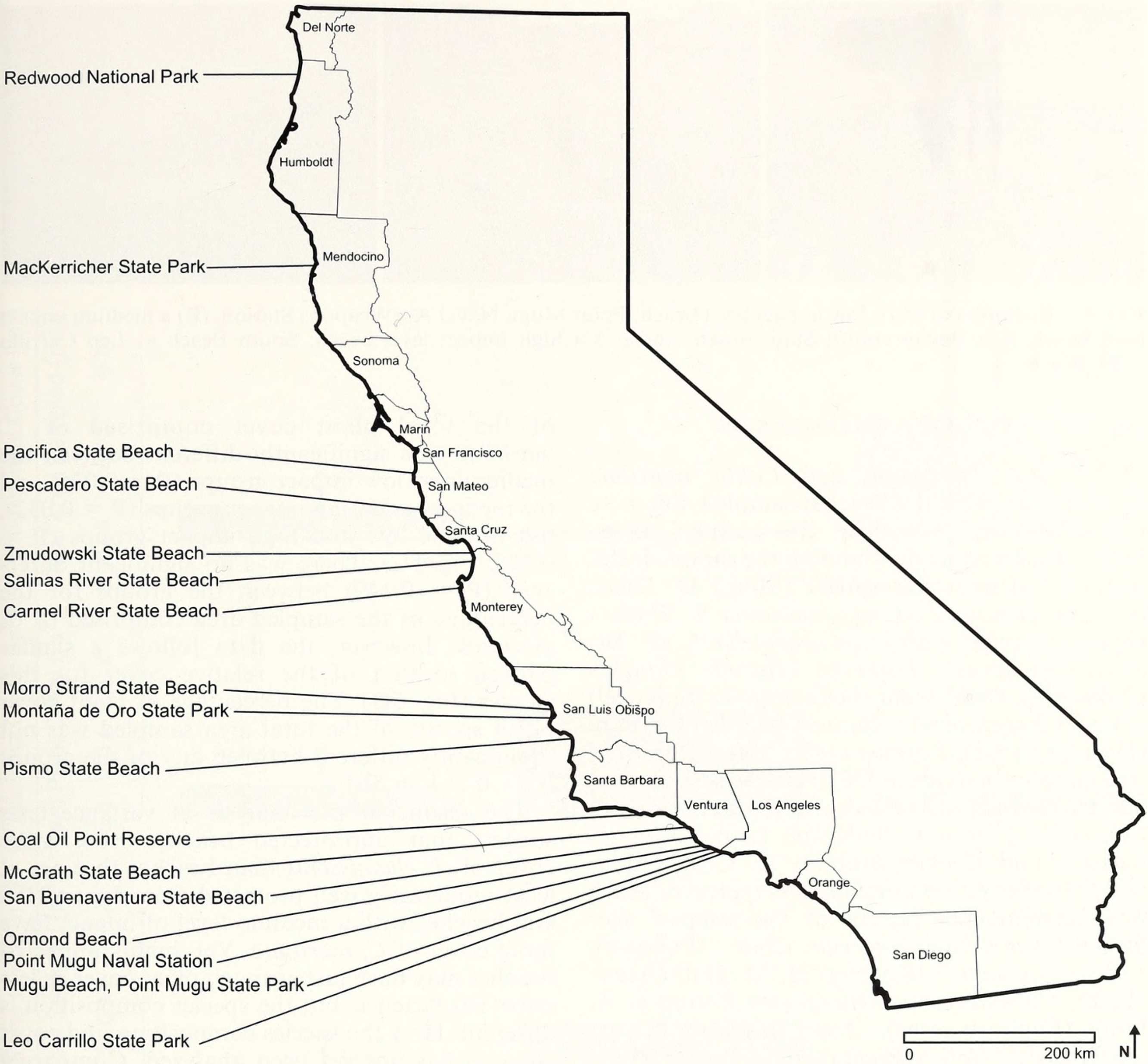


FIG. 3. Locations of sites sampled between 2007 and 2009.

Mugu State Park were assigned to the high impact level group. Ten Mile Dunes at MacKerricher State Park, Morro Strand State Beach, Pacifica State Beach, Pismo State Beach, the beach at Kuchel Visitor Center at Redwood National Park, Salinas River State Beach, Sandspit Beach at Montaña de Oro State Park, San Buenaventura State Beach, and Zmudowski State Park were assigned to the medium impact level group. Sands Beach at Coal Oil Point Reserve, McGrath State Beach, Point Mugu Naval Air Weapons Station, Ormond Beach, and Pescadero State Beach were assigned to the low impact level group.

To test the null hypothesis that higher levels of impact do not lead to dominance of *Ambrosia chamissonis* or *Cakile maritima*, five tests were performed. For each beach, the area was calculated as the area of each species' (either *A. chamissonis* or *C. maritima*) cover ($m^2$) normalized by the total area sampled ($m^2$) (i.e., absolute cover percentage expressed as a decimal number). The mean for each group of beaches (e.g., high versus medium versus low impact) was compared using a single factor analysis of variance test. Relative cover for each species was tested as the area of each species' cover ($m^2$) normalized by the area of all plant cover ($m^2$) using analysis of variance. Because lower cover of one species might be attributed to lower over-all cover, normalized total plant cover, calculated as the area of all species cover ($m^2$) divided by the total area sampled ($m^2$), was analyzed using analysis of variance. Where a significant difference was detected with the analysis of variance tests, a Tukey test was used to determine which groups were significantly different.

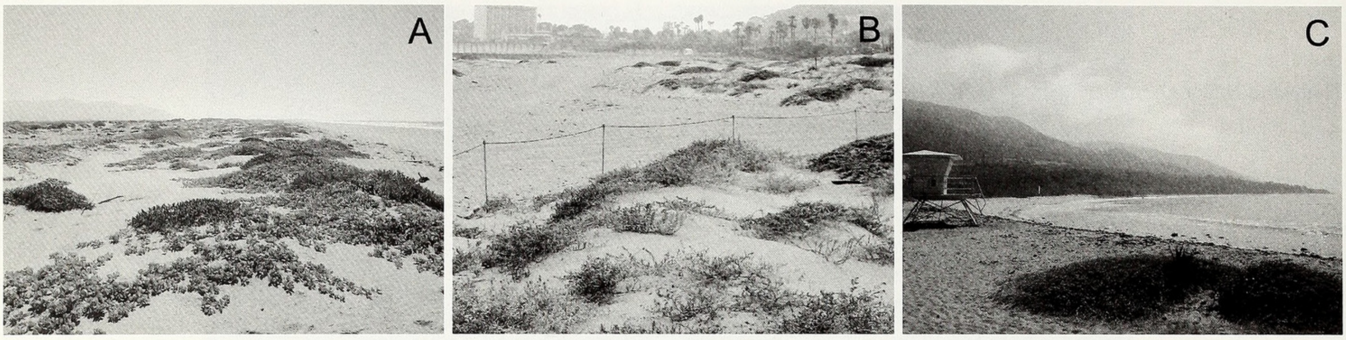


FIG. 4. Examples of (A) a low impact level beach, Point Mugu Naval Air Weapons Station, (B) a medium impact level beach, San Buenaventura State Beach, and (C) a high impact level beach, South Beach at Leo Carrillo State Beach.

## RESULTS AND DISCUSSION

*Ambrosia chamissonis* and *Cakile maritima* were present at all the beaches sampled, but were not necessarily present in the sampled areas. Other species typically found on the sampled sites included *Atriplex leucophylla* (Moq.) D. Dietr. (Chenopodiaceae), *Abronia maritima* S. Watson (Nyctaginaceae), *Calystegia soldanella* (L.) R. Br. (Convolvulaceae), *Lathyrus littoralis* Douglas (Fabaceae), *Camissonia cheiranthifolia* (Sprengel) Raim. (Onagraceae), *Abronia latifolia* Eschsch. (Nyctaginaceae), *Leymus mollis* Trin. (Poaceae), *Artemisia pycnocephala* DC (Asteraceae), *Ammophila arenaria* Link (Poaceae), *Carpobrotus* spp. (Aizoaceae), *Abronia umbellata* Lam. (Nyctaginaceae), and *Glehnia littoralis* A. Gray (Apiaceae). Species present that are less typical of beach plant communities present at the sampled sites included *Pennisetum setaceum* Chiov. (Poaceae), *Coreopsis gigantea* (Kellogg) H. M. Hall (Asteraceae), *Chamaesyce albomarginata* Torrey & A. Gray (Euphorbiaceae), *Aster subulatus* Michx. (Asteraceae), *Heliotropium curassavicum* L. (Boraginaceae), *Ehrharta calycina* Sm. (Poaceae), *Cuscuta californica* Hook. & Arn (Cuscutaceae), *Croton californicus* Mull. Arg. (Euphorbiaceae), *Eriogonum parvifolium* Sm. (Polygonaceae), *Yucca whipplei* Torr. (Liliaceae), *Lotus scoparius* (Nutt.) Ottley (Fabaceae), *Distichlis spicata* (L.) Greene (Poaceae), *Tetragonia tetragonioides* (Pall.) Kuntze (Aizoaceae), *Malacothrix saxatilis* (Nutt.) Torr. & A. Gray (Asteraceae), and *Opuntia littoralis* (Engelm.) Cockerell (Cactaceae).

The relative percentage of the total plant cover comprised of *A. chamissonis* was significantly different between the low and ligh impact groups ($P = 0.0016$) and the medium and high impact groups ($P < 0.001$), but not the medium and low impact groups ($P = 0.33$; Fig. 5A). Similarly, the percentage of the total sampled area comprised of *A. chamissonis* was also significantly different between the low and high impact groups ($P < 0.001$) and the medium and high impact groups ($P < 0.001$), but not the medium and low lmpact groups ($P = 0.26$; Fig. 5B). The relative percentage of the total plant cover comprised of *C. maritima* was significantly different between the medium and low impact groups ($P = 0.025$) and the medium and high impact groups ($P = 0.032$), but not the low and high impact groups ($P = 0.945$; Fig. 5C). There was no significant difference ($P = 0.149$) between the groups for the percentage of the sampled area comprised of *C. maritima*, however, the data follows a similar pattern to that of the relative cover for this species (Fig. 5D). The percentage of plant cover of all species of the total area sampled was not significantly different between any of the groups ($P = 0.5$; Fig. 5E).

The results of the analysis of variance tests suggest that unprotected beaches have more cover of *A. chamissonis* than beaches that are at least moderately well protected from foot traffic and beaches with a medium level of impact have more cover of *C. maritima*. Yet, highly impacted beaches may have just as much plant cover as less impacted beaches, but the species composition is different. How the species composition and cover changes has not yet been analyzed. Comparing how species (other than the two discussed here) change at this broad scale is difficult because other species have a more limited distribution and do not occur on many beaches. *Ambrosia chamissonis* and *C. maritima* are the only species with a geographic range allowing them to grow on all the beaches in the study area. To compare how other species change with varying levels of impacts, species would need to be grouped for comparison at a broader geographic scale, for example, into successional roles (which have yet to be determined) or growth forms.

The differences in survival between these two plants might be due to differences in their physical characteristics – for example, *A. chamissonis* is woody with a deep tap root while *C. maritima* is succulent with spreading shallow roots. *Ambrosia chamissonis* is likely not outcompeting other species in the areas of high foot traffic, but rather is one of the only species to do well in an environment characterized by flat and constantly shifting substrate. Couch (1914)

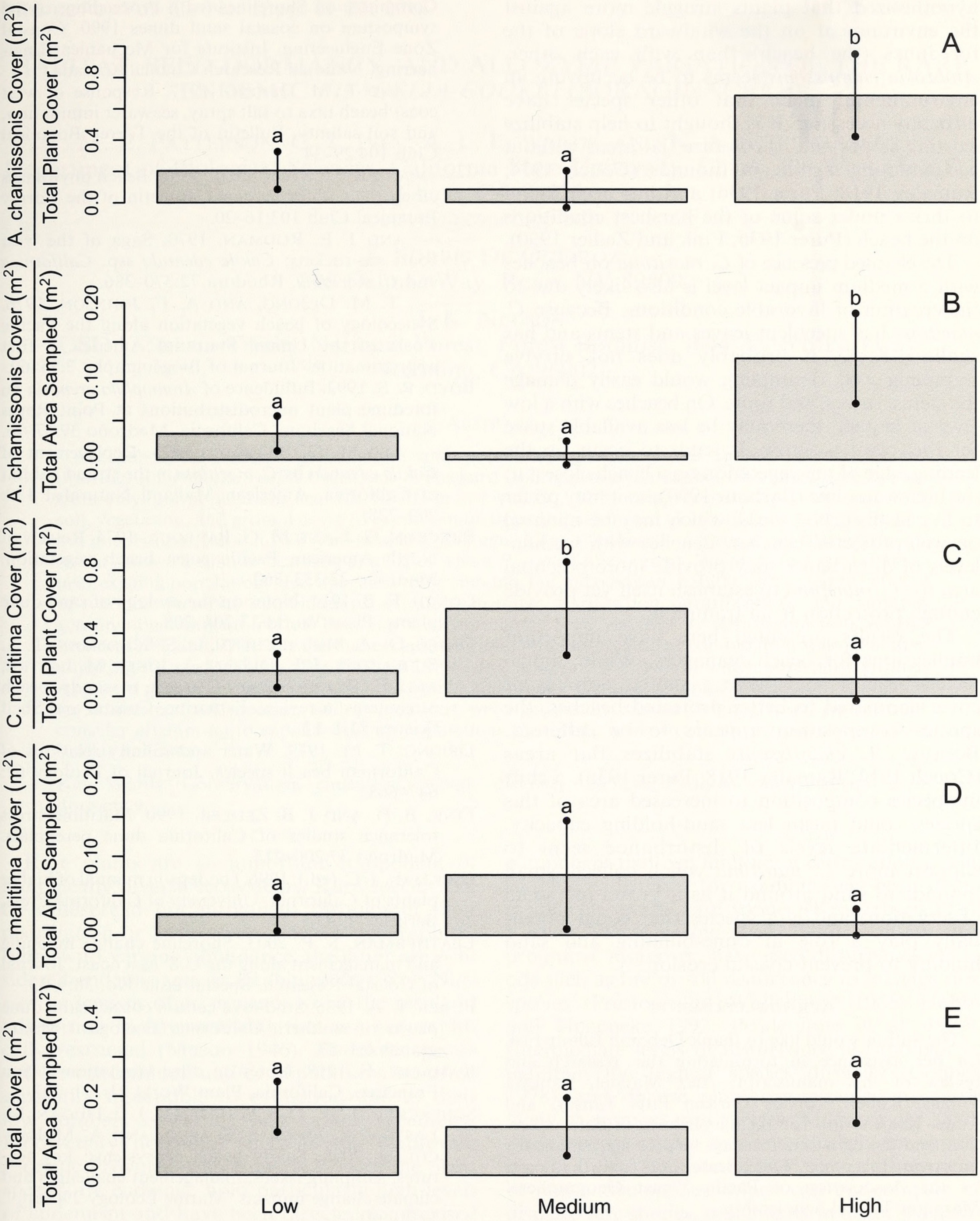


FIG. 5. Measures of species cover for low, medium, and highly impacted beaches: (A) Mean percent cover of the total plant cover comprised of *A. chamissonis;* (B) mean percentage of the total sampled area comprised of *A. chamissonis*; (C) mean percent cover of the total plant cover comprised of *C. maritima;* (D) mean percentage of the total sampled area comprised of *C. maritima*; (E) mean cover of all species as a percent of the total area sampled. Within each graph, different lowercase letters indicate values that are statistically different.

hypothesized that plants struggle more against the environment on the windward slope of the foredunes (the beach) than with each other. *Ambrosia chamissonis* seems to be occupying an environmental niche that other species have difficulty accessing. It is thought to help stabilize existing slopes and to colonize flat areas without accumulating significant mounds (Couch 1914; Ramaley 1918; Purer 1936) and has been found to thrive under some of the harshest conditions on the beach (Purer 1936; Fink and Zedler 1990).

The elevated presence of *C. maritima* on beaches with a medium impact level is also likely due to the creation of favorable conditions. Because *C. maritima* has succulent leaves and stems and has shallow roots, it probably does not survive trampling well. Trampling would easily damage the stems, leaves, and roots. On beaches with a low level of impact, there may be less available space for this plant to grow. It tends to occur on the leading edge of the vegetation on a beach closest to the high water line (Barbour 1990), so it may prefer to live in disturbed areas, which may be minimal on well-protected beaches. Beaches with medium levels of disturbance may provide more potential area for *C. maritima* to establish itself yet provide enough protection from trampling.

The results presented here have important implications for beach managers. While unprotected beaches may have a similar amount of cover compared to better protected beaches, the species composition appears to be different. Because *A. chamissonis* stabilizes flat areas (Couch 1914; Ramaley 1918; Purer 1936), a shift in species composition to increased area of this species could mean less sand-holding capacity. Intermediate levels of disturbance seem to support more *C. maritima* which collects small mounds of sand around it as it grows (personal observation) and is a species that could potentially play a role in dune-building and sand holding to prevent coastal erosion.

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