



Dune Vegetation Monitoring

Analysis of 2011 Survey Data and Changes in Plant Communities since 2005

Natural Resource Data Series NPS/NER/NRDS—2013/434



ON THE COVER

Dune grassland area near the Atlantic coastal bluff of Cape Cod National Seashore; photo by Stephen Smith.

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Contents

	Page
Figures.....	v
Tables.....	vii
Appendixes	ix
Executive Summary	xi
Introduction.....	1
Background.....	1
Rationale for Monitoring Dune Vegetation.....	2
Methods.....	3
Study Sites	3
Vegetation Surveys.....	4
Environmental Conditions	4
Analysis of Aerial Photography.....	4
Data Analysis.....	4
Results.....	5
Vegetation.....	5
All Sites (2005 vs. 2011)	11
Individual Transect Sites.....	14
Analysis of Aerial Photography.....	21
Bluff Erosion.....	21
Succession.....	23
Broad-scale Environmental Factors.....	24
Precipitation	24
Wind.....	25

Contents (continued)

	Page
Nitrogen and Sulfate Deposition (Wet)	26
Salt Spray	27
Temperature	27
Discussion	29
Future Monitoring.....	30
Literature Cited	33

Figures

	Page
Figure 1. Map depicting 2000 aerial cover of dune vegetation habitat (green) within CACO and examples of dune landscapes from selected areas.	1
Figure 2. Map of dune grassland (DG) transect locations and site layout (see Appendix A for higher resolution images of site locations within each transect).	3
Figure 3. Number of species by plot in 2011 (arrows show bluff edge plots; the rest of the plots are located progressively inland from left to right; circles indicate plots with maximum species richness by transect).	5
Figure 4. NMDS of 2011 species composition (all 60 plots).	6
Figure 5. NMDS of all DG transects (sumCC of all plots along each transect) for 2005 and 2011 (polygons contain transect points that showed the largest dissimilarity between years).	12
Figure 6. NMDS of each individual plot (note: all plots outside of central cluster are bluff-edge locations that converted to beach).	13
Figure 7. NMDS of DG1 plots.	14
Figure 8. NMDS of DG3 plots.	15
Figure 9. NMDS of DG4 plots.	16
Figure 10. NMDS of DG5 plots.	17
Figure 11. NMDS of DG6 plots.	18
Figure 12. NMDS of DG7 plots.	19
Figure 13. NMDS of DG9 plots.	20
Figure 14. Inland migration of the coastal bluff at DG5 by ~25 m during 1995 (left) – 2010 (right).	22
Figure 15. Inland migration of the coastal bluff at DG9 by ~29 m and concurrent loss of beachgrass cover during 1995 (left) – 2010 (right).	22
Figure 16. Accretion at DG1 between 1995 (left) and 2010 (right).	22
Figure 17. Succession in the Province Lands dunes during 1995-2010.	23
Figure 18. Succession in the Province Lands dunes during 1995-2010.	23

Figures (continued)

	Page
Figure 19. Annual precipitation recorded at MA01 (NADP site within CACO, Truro) from 1981 to 2010.....	24
Figure 20. Wind rose showing strength and direction of winds by season for Cape Cod.....	25
Figure 21. Nitrate deposition (kg/ha/yr.) at MA01 between 1982 and 2010.	26
Figure 22. Sulfate deposition (kg/ha/yr) at MA01 between 1982 and 2010.....	26
Figure 23. Mean annual temperature at Provincetown, MA from 1895–2005 (data from NEISA).....	27
Figure 24. Species accumulation plot based on 2011 vegetation data.....	30

Tables

	Page
Table 1. The appearance or disappearance of various species in vegetation surveys conducted in 2005 and 2011 (P=present, A=absent).	7
Table 2. Average frequency of occurrence of species recorded in vegetation surveys (all 60 plots) in 2005 and 2011.	8
Table 3. Summed cover class scores of all species recorded in vegetation surveys (all 60 plots) in 2005 and 2011.....	10
Table 4. SIMPER data for cover scores summed by transect, including average abundances (i.e., cover) (Av. Ab) for 2005 (05) and 2011 (11), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant assemblages between years.....	12
Table 5. ANOSIM data for change in vegetation communities between 2005 and 2011 by transect.	12
Table 6. SIMPER data for cover scores by plot, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	13
Table 7. SIMPER data for DG1, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	14
Table 8. SIMPER data for DG3, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	15
Table 9. SIMPER data for DG4, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	16
Table 10. SIMPER data for DG5, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	17
Table 11. SIMPER data for DG6, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	18
Table 12. SIMPER data for DG7, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	19

Tables (continued)

	Page
Table 13. SIMPER data for DG9, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.	20
Table 14. Bluff erosion/accretion by transect between 1995 and 2010.	21
Table 15. Precipitation trends at MA01 by month from 1982–2010.	24

Appendixes

	Page
Appendix A. Maps of sampling locations by transect (each symbol represents the two replicate 10 m ² plots) (aerial photos from 2001).	35
Appendix B. Complete list of vascular plant species recorded in the 2011 dune vegetation survey.	39

Executive Summary

In 2011, monitoring was conducted to follow up on a 2005 survey of dune vegetation habitat and for continued development of a long-term vegetation monitoring protocol for this ecosystem. In 2005, thirty vegetation sampling sites were established in what was then dune grassland habitat throughout Cape Cod National Seashore (CACO), arranged along seven transects running perpendicular to the coastline from Chatham to Provincetown. Each site consisted of two 10×10-m plots. In addition to distance from coastline, sites were characterized by integrating GIS technology to assess landscape changes and succession.

In 2011, forty-seven vascular plant species were recorded, three of which were exotics. This is the same number of species recorded in 2005, although some changes were observed. Specifically, twelve species not recorded in 2005 appeared in the 2011 survey and nine species present in 2005 were not documented in 2011. Exotic taxa found in 2011 were *Artemisia stelleriana* (dusty miller), *Bromus tectorum* (cheatgrass), and *Rosa rugosa* (salt spray rose); all of which were present in 2005. One formerly state-listed species, *Corema conradii* (broom crowberry [Special Concern]), was found at a single site (also noted in 2005 at the same site). By 2011, seven bluff edge plots had converted to bare beach due to bluff erosion. In the other 53 plots, species richness was highly variable among plots, ranging between zero and 13, with a mean value of 4.6 (± 0.4 SE). As in 2005, species richness generally increased with increasing distance from the coast.

Notwithstanding the seven bluff edge plots that converted to bare beach due to bluff erosion, there were very few statistically significant changes in dune vegetation between 2005 and 2011 within the permanent monitoring sites. In addition, two sites appear to be converting from grassland to salt marsh as a result of changes in the tidal prism of adjacent estuaries, although they are still mostly dune habitat. Aerial photography showed that succession is occurring at a rapid rate in many areas of the dune grassland habitat, although this process has slowed or reversed in areas closest to the bluff edge. In fact, considerable erosion of the bluff edge on both the Cape Cod Bay and Atlantic sides of CACO was evident from aerial imagery. This process results in a substantial narrowing of dune grassland habitat. Analysis of climatological data revealed winter season rainfall is increasing while summers are becoming dryer. In addition, while nitrogen and sulfur deposition are decreasing, they are still at levels that can substantially alter successional processes by disrupting competitive processes, which results in species replacements.

It is clear from comparisons with 2005 data that these plant communities are largely influenced by physical factors, such as erosion and changes in coastal geomorphology; however, other factors, such as constituents in atmospheric wet deposition (e.g., precipitation and nitrogen in precipitation) and temperature are likely to be having an effect over longer time scales. Future plant community surveys, as well as additions of sites to the monitoring network for even better spatial coverage (based on species-area analysis), should be effective in tracking these kinds of changes over time.

Introduction

Background

Coastal dunes make up roughly one third of the Cape Cod National Seashore (CACO), covering approximately 8,500 acres from Chatham to Provincetown. Dunes predominate on barrier beaches and spits, along the coastal margins of the Atlantic Ocean and Cape Cod Bay, and across the northern tip of the peninsula—an area known as the Province Lands (Figure 1). The Province Lands began forming after glacial retreat (~6,000 years ago) as eroded sediments from the outwash plain were transported north and deposited by long-shore currents. Sand from the beaches of this elongating hook was then blown inland to form the dunes. Although mature forest eventually became established here, most of the vegetation was removed by European settlers for use in building and to clear land for agriculture and for livestock grazing. This resulted in a rapid destabilization of the ground surface, and by the mid-1800s the area had been converted to a sparsely vegetated system of shifting dunes.



Figure 1. Map depicting 2000 aerial cover of dune vegetation habitat (green) within CACO and examples of dune landscapes from selected areas.

Smaller areas of dunes are located along the edges of the glacial outwash plain between Truro and Eastham (both Atlantic- and Cape Cod Bay-side bluffs). This part of the landscape is much older; present-day dunes are created and sustained through wind erosion of the bluffs with subsequent inland sand deposition. On newer landforms, such as barrier beaches and spits, sand accretion and overwash events continue to create dune habitat. Collectively, these processes have resulted in major changes in the geomorphology of Cape Cod over time.

As a whole, the dunes are variably covered with vegetation. Some areas are primarily grassland, while others have succeeded to the point where shrubs and sub-shrubs predominate. Characteristics of these plant communities and changes through time are regulated by internal (e.g., succession) as well as external (e.g., erosion) processes.

Rationale for Monitoring Dune Vegetation

In addition to their aesthetic appeal, the dunes support a variety of flora and fauna that are largely confined to this environment. For example, plants such as *Polygonella articulata* (sand jointweed) and *Cyperus grayi* (dune flatsedge) occur almost exclusively within dune habitat. Vast expanses of lichens, bryophytes (mosses and liverworts), and mushrooms (comprising biological soil crusts or BSCs) occur as well. The dunes are home to many species of wildlife such as the hognose snake (*Heterodon platyrhinos*) and Fowler's toad (*Bufo fowleri*) (Tupper and Cook 2008, Cook et al. 2009). Moreover, the Province Lands are a population center for the endangered Eastern spadefoot toad (*Scaphiopus holbrookii*) (R. P. Cook, CACO wildlife biologist, pers. Comm.). A number of rare bird species, including the Vesper sparrow (*Pooecetes gramineus*), are also dependent upon this habitat (Kearney and Cook 2001). From a landscape perspective, the dunes constitute early successional, open landscape that is rapidly disappearing on Cape Cod through natural successional processes.

Numerous natural and anthropogenic factors may influence this ecosystem, including chronic and episodic climatological events, invasive exotic species, precipitation quality and quantity, air quality, and climate change. Plant communities responding to these influences will, in turn, affect dune migration, which can be alternatively suppressed and re-activated depending on vegetation changes on the land surface (Forman et al. 2008). Thus, understanding spatial and temporal patterns in dune vegetation communities is important from a management standpoint and in predicting landscape-level change. Understanding dune vegetation change cannot be done without looking closely at climatological as well as other factors.

While numerous studies on CACO dune vegetation have been conducted in the past, they have been rather limited in scope and largely focused on the Province Lands region. In addition, these older studies were not designed for long-term monitoring. Most importantly, the vast majority of studies were done before the advent of GPS technology. As such, it would be extremely difficult, if not impossible, to resample any of the original sites. To reliably monitor how the system evolves through time and responds to various influences, a standard, repeatable protocol is necessary. This report summarizes the methodology and results of a repeat survey in 2011 of the 60 dune vegetation plots surveyed in 2005, compares these data to the previous survey data (Smith 2005), and makes recommendations for future monitoring of this ecosystem.

Methods

Study Sites

The vegetation monitoring methods for this habitat are based upon methods developed in Smith (2005). Sites consisting of two 100-m² (10×10-m) plots (Figure 2) were established along a transect at distances 0, 50, 100, 200, 300 m (etc.) away from the coastal bluff in a direction perpendicular to the shoreline (Smith 2005). In the text and figures of this report, the sites are labeled DG (transect number)-1 (bluff site), DG (transect number)-2 (50-m site), DG (transect number)-3 (100-m site), etc. Transects include DG1, DG3, DG4, DG5, DG6, DG7, and DG9 (Figure 2). Note: there is no DG2 nor DG8; they were originally established but could not be monitored when it was discovered that they were located on private land. The transects have a variable number of sites due to differences in the width of the dune grassland habitat from coastal bluff to woodland, forest, or back-barrier salt marsh communities that existed in 2005. Seven plots (=3.5 sites) converted from dune edge grassland to bare beach between 2005 and 2011. While the plot markers were long gone, vegetation (or lack thereof) was still recorded at the original GPS locations.

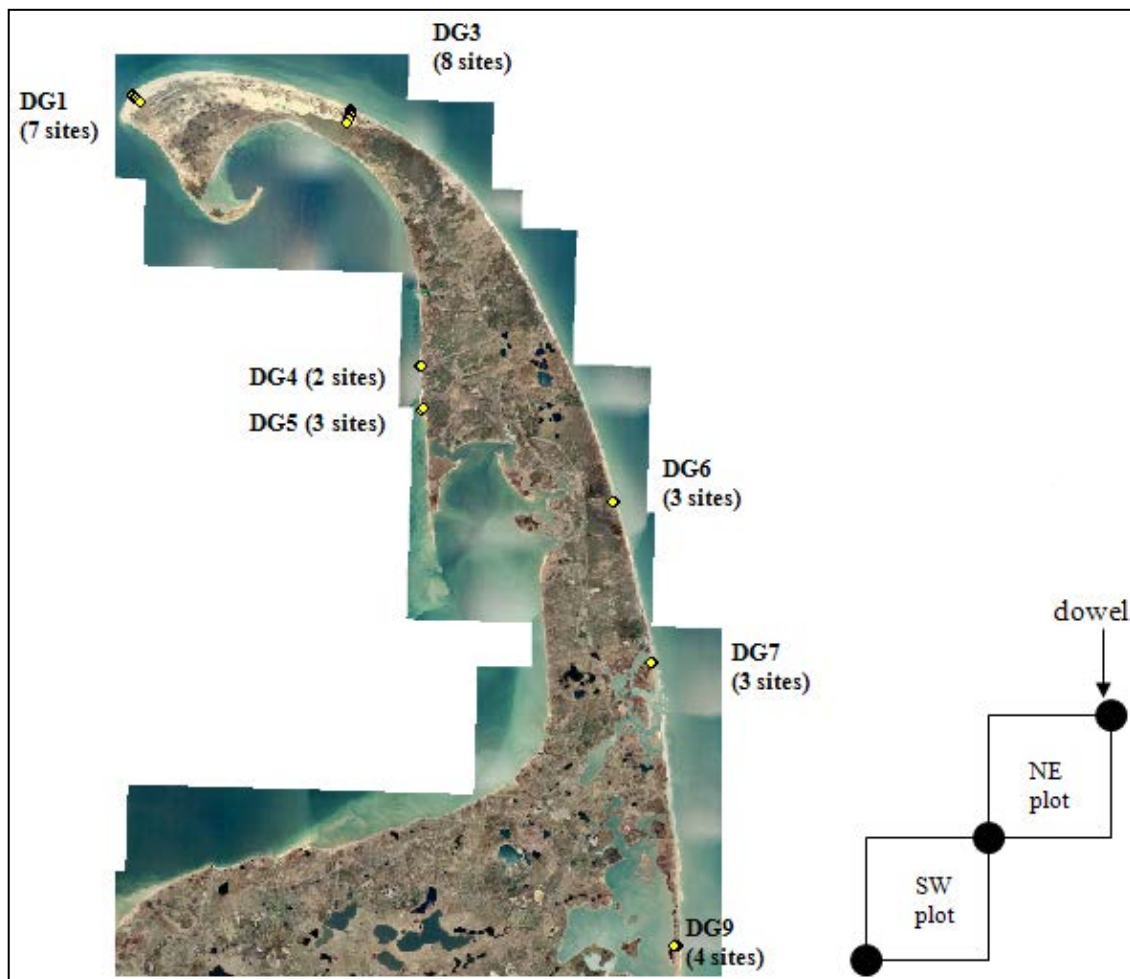


Figure 2. Map of dune grassland (DG) transect locations and site layout (see Appendix A for higher resolution images of site locations within each transect).

Vegetation Surveys

A pair of plots (10×10-m) oriented diagonal to each other (Figure 2) were established at each site in 2005, with three metal dowels marking their corners for relocation in subsequent surveys (Smith 2005). Each pair constitutes an individual site along multi-site transects. In 2005 and 2011, the cover of all species occurring within each plot was assessed visually according to the Braun-Blanquet (1932) scale (0=0%, 1=>0–1%, 2=>1–5%, 3=>5–25%, 4=>25–50%, 5=>50–75%, 6=>75–100% [see Smith {2005} for a more detailed explanation]). Total plant cover per site (i.e., the total cover encompassed in both the NE and SW plots) was then calculated as the summed cover values (as ordinal cover scores cannot be averaged) for each species.

Determination of whole site cover was done in this manner (i.e., sum of two plots) because a 100-m² plot nears the area limit of what can reasonably be assessed using visual estimates of cover. The cover of soil algae, lichens, and mosses were also recorded, although these were not identified to species, as distinguishing between closely related taxa is extremely difficult and sometimes involves highly technical laboratory methods. In addition, percent area of bare ground was recorded.

Environmental Conditions

Precipitation and nitrogen and sulfate deposition data were obtained through the National Atmospheric Deposition in which CACO participates by generating data from a permanent climatological station in Truro (NADP; <http://nadp.sws.uiuc.edu>).

Temporal trends in precipitation and constituents of wet deposition from 1982–2010 (available dataset) were analyzed by regression analysis. Wind data were obtained through <http://www.weatherunderground.com> (Provincetown) and summarized (daily from 2004–2005) by Forman et al. (2008).

Analysis of Aerial Photography

Aerial photography, available as part of CACO's aerial images library, as well as those provided in Google Earth™, was used to examine changes in landforms (e.g., erosion or accretion) and vegetation (succession) through time. The temporal analyses of images in this report generally includes comparisons of 1995 to 2010 (the latter date is most recent imagery available). The 1995 photo set is of particularly good quality and the 15-year interval is a time period over which one can see large changes in the landscape.

Data Analysis

Regression analysis was used to assess correlation between specific pairs of variables (e.g., rainfall vs. year). A number of non-parametric techniques offered ways in which to interpret plant cover score data with respect to temporal trends (Primer ver. 6). Non-metric Multidimensional Scaling (NMDS) was used to explore variability in community composition based on Bray-Curtis similarity matrices on raw cover scores. Summed cover class (sumCC) scores were used to pool data by transect (Law and Britten 1995, Newell and Leathwick 2005). Analysis of Similarities (ANOSIM) provides a test of significance for differences in species composition and distribution over time and between sites and transects. Similarities Percentages (SIMPER) indicated which taxa contribute most to dissimilarities among communities, and Principal Component Analysis (PCA) occasionally was used to illustrate the magnitude of influence that individual species had on disparity among sites in ordinal space. The Wilcoxon signed rank procedure tested for significant changes in the cover scores individual species between 2005 and 2011.

Results

Vegetation

Three complete sites (DG5-1, DG6-1, and DG9-1) and one plot at another site (DG3-1NE) converted to beach between 2005 and 2011 and contained no vegetative cover in 2011. Forty-seven vascular plant species and one non-vascular bryophyte, *Polytrichum virginiana* (juniper haircap moss), occurring within the other 53 plots were recorded in 2011. The five most abundant species by cover were *Ammophila breviligulata* (American beachgrass), *Solidago sempervirens* (seaside goldenrod), *Deschampsia flexuosa* (hairgrass), *Toxicodendron radicans* (poison ivy), and *Morella pensylvanica* (northern bayberry). Four salt marsh species, *Suaeda maritima* (sea blite), *Distichlis spicata* (spikegrass), *Elymus virginicus* (Virginia wild rye), and *Baccharis halimifolia* (saltbush), were found at two sites that encompassed a salt marsh–dune ecotone (DG1-6, DG9-4) in 2011 (all except *Suaeda* were also found in 2005). Three freshwater wetland species, *Vaccinium macrocarpon* (cranberry), *Juncus canadensis* (Canadian rush), and *Juncus greenii* (Green’s rush), were found at two sites where dune slack wetland–dune ecotones occurred (DG3-4, DG3-5). Three species were exotics, *Artemisia stelleriana* (dusty miller), *Bromus tectorum* (cheatgrass), and *Rosa rugosa* (salt spray rose). No state-listed rare species were found, although a formerly listed species, *Corema conradii* (broom crowberry), was found at DG6-3 as it was in 2005.

Species richness was quite variable among the remaining 53 dune plots along each transect in 2011, ranging between two and 14 and averaging 5.2 species per plot (Figure 3). However, a perceptible trend can be distinguished in that maximum species richness for each transect always occurs within plots that are landward of the bluff edge plots.

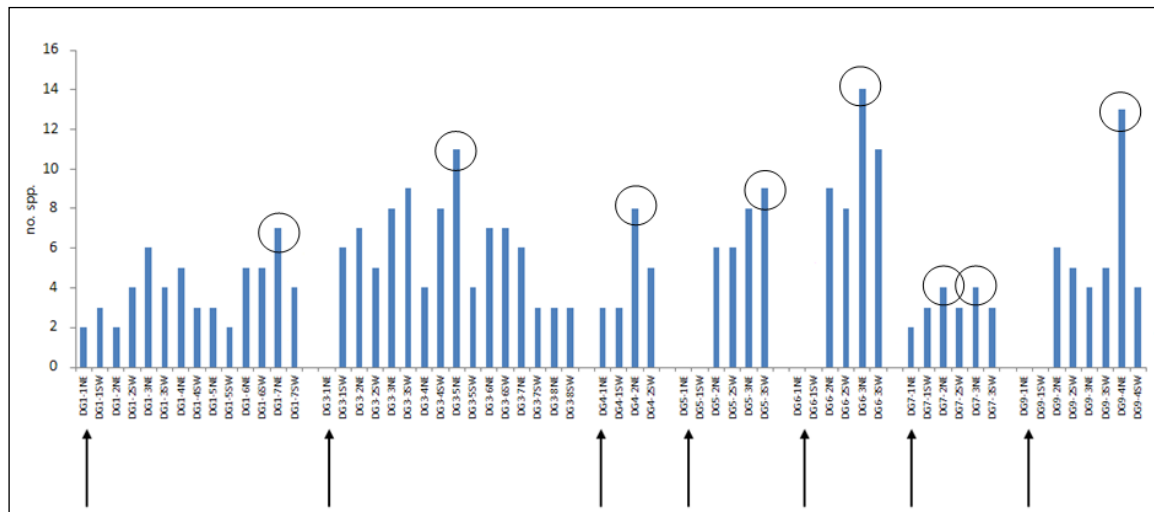


Figure 3. Number of species by plot in 2011 (arrows show bluff edge plots; the rest of the plots are located progressively inland from left to right; circles indicate plots with maximum species richness by transect). The seven plots with no species were converted to beach by erosion since 2005.

When the vegetation communities for 2011 are plotted using NMDS, there is a central cluster of the majority of plots. However, the seven bluff edge plots that were converted to beach due to erosion stand out from the rest (Figure 4).

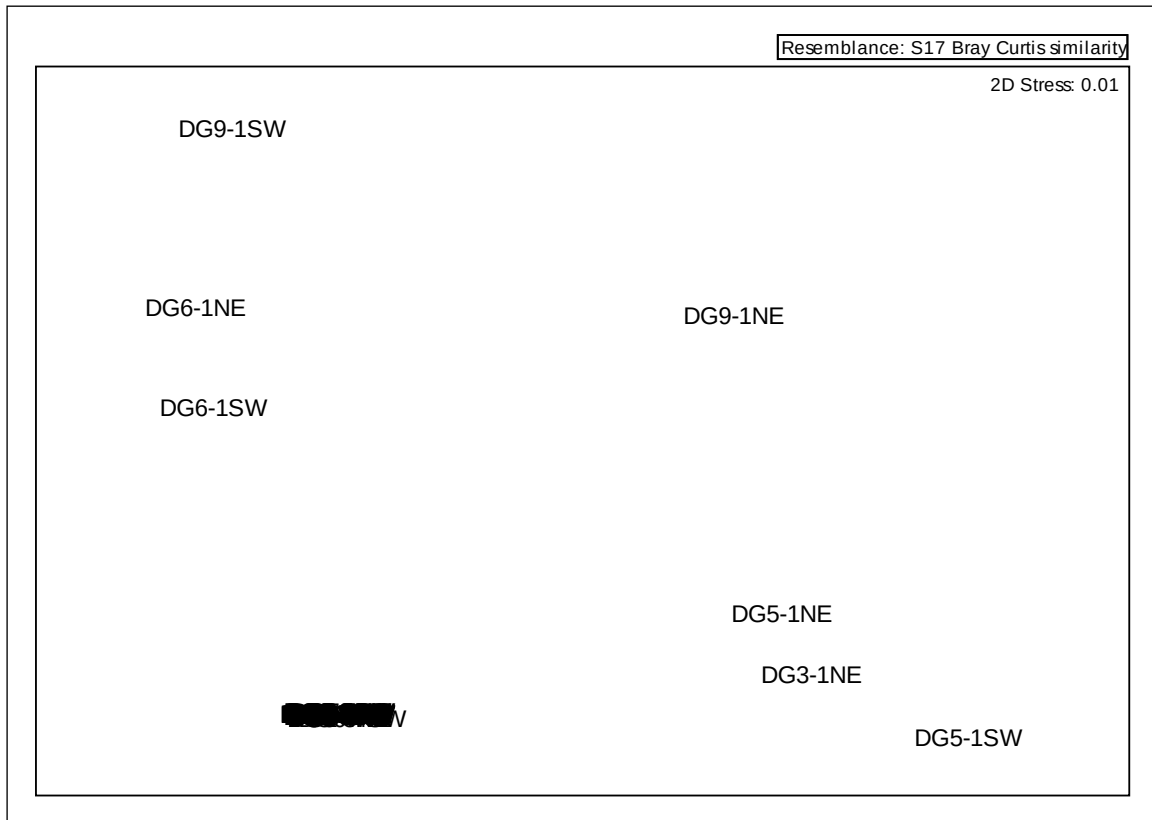


Figure 4. NMDS of 2011 species composition (all 60 plots).

Nine species that were recorded in 2005 were not present in the 2011 survey (Table 1). Conversely, twelve species not recorded in 2005 were present in 2011, four of which were salt marsh taxa occurring in sites DG1-6 and DG9-4.

Table 1. The appearance or disappearance of various species in vegetation surveys conducted in 2005 and 2011 (P=present, A=absent).

Species Scientific Name	2005	2011
<i>Achillea millefolium</i>	P	A
<i>Aster ericoides</i>	A	P
<i>Baccharis halimifolia</i>	P	A
<i>Bromus tectorum</i>	P	A
<i>Honckenya peploides</i>	A	P
<i>Distichlis spicata</i>	P	A
<i>Erigeron annuus</i>	A	P
<i>Lactuca canadensis</i>	P	A
<i>Limonium carolinianum</i>	A	P
<i>Linaria vulgaris</i>	P	A
<i>Onothera biennis</i>	P	A
<i>Polygama polygala</i>	A	P
<i>Quercus ilicifolia</i>	P	A
<i>Rumex acetosella</i>	P	A
<i>Salicornia bigelovii</i>	A	P
<i>Salicornia maritima</i>	A	P
<i>Salicornia virginica</i>	A	P
<i>Spartina alterniflora</i>	A	P
<i>Spartina patens</i>	A	P
<i>Xanthonium strumarium</i>	A	P
<i>Yucca filamentosa</i>	A	P

In terms of frequency of occurrence among all plots in both years, *Achillea millefolium* (common yarrow), *Ammophila breviligulata*, *Juncus greenii*, *Arctostaphylos uva-ursi* (bearberry), and *Cakile edentula* had the highest values (Table 2). From the standpoint of the largest changes in frequency between 2005 and 2011, it was *Achillea millefolium* (decreased), *Ammophila breviligulata* (decreased), *Andropogon virginicus* (broomsedge bluestem; decreased), *Arctostaphylos uva-ursi* (decreased), *Artemisia campestris* (wormwood; decreased), and *Yucca filamentosa* (golden sword; increased).

Table 2. Average frequency of occurrence of species recorded in vegetation surveys (all 60 plots) in 2005 and 2011.

Species Scientific Name	Freq 2005	Freq 2011	Change
<i>Achillea millefolium</i> (common yarrow)	0.97	0.85	-0.12
<i>Ammophila breviligulata</i> (beachgrass)	0.77	0.65	-0.12
<i>Andropogon virginicus</i> (broomsedge bluestem)	0.27	0.17	-0.10
<i>Arctostaphylos uva-ursi</i> (bearberry)	0.33	0.25	-0.08
<i>Artemisia campestris</i> (wormwood)	0.07	0.00	-0.07
<i>Artemisia stellariana</i>	0.20	0.15	-0.05
<i>Aster ericoides</i>	0.05	0.00	-0.05
<i>Baccharis hamifolia</i>	0.07	0.02	-0.05
<i>Bromus tectorum</i>	0.07	0.02	-0.05
<i>Cakile edetula</i>	0.37	0.32	-0.05
<i>Chamaesyce polygonifolia</i>	0.03	0.00	-0.03
<i>Honckenya peploides</i>	0.03	0.00	-0.03
<i>Corema conradii</i>	0.03	0.00	-0.03
<i>Cyperus grayii</i>	0.03	0.00	-0.03
<i>Deschampsia flexuosa</i>	0.18	0.15	-0.03
<i>Dicanthelium acuminatum</i>	0.18	0.15	-0.03
<i>Dicanthelium</i> spp.	0.27	0.23	-0.03
<i>Distichlis spicata</i>	0.05	0.03	-0.02
<i>Elymus virginica</i>	0.02	0.00	-0.02
<i>Erigeron annuus</i>	0.03	0.02	-0.02
<i>Hieracium</i> sp.	0.02	0.00	-0.02
<i>Hudsonia ericoides</i>	0.02	0.00	-0.02
<i>Hudsonia tomentosa</i>	0.03	0.02	-0.02
<i>Juncus canadensis</i>	0.03	0.02	-0.02
<i>Juncus greenei</i>	0.32	0.30	-0.02
<i>Lactuca canadensis</i>	0.07	0.05	-0.02
<i>Lathyrus japonica</i>	0.02	0.02	0.00
<i>Lechia maritima</i>	0.03	0.03	0.00
<i>Lichen</i>	0.02	0.02	0.00
<i>Limonium caroliniana</i>	0.02	0.02	0.00
<i>Linaria vulgaris</i>	0.03	0.03	0.00
<i>Morella pensylvanica</i>	0.03	0.03	0.00
<i>Oenothera biennis</i>	0.07	0.07	0.00
<i>Panicum lanuginosum</i>	0.20	0.20	0.00
<i>Parthenocissus cinquefolia</i>	0.02	0.02	0.00
<i>Pinus rigida</i>	0.02	0.02	0.00
<i>Pityopsis falcata</i>	0.02	0.02	0.00
<i>Polygonella articulata</i>	0.02	0.02	0.00
<i>Polytrichum juniperiana</i> (moss)	0.07	0.08	0.02
<i>Polygala polygama</i>	0.05	0.07	0.02
<i>Prunus maritima</i>	0.23	0.25	0.02
<i>Prunus serotina</i>	0.00	0.02	0.02
<i>Psuedognaphalium obtusifolium</i>	0.02	0.03	0.02
<i>Quercus ilicifolia</i>	0.00	0.02	0.02
<i>Rosa rugosa</i>	0.00	0.02	0.02
<i>Rosa virginiana</i>	0.00	0.02	0.02
<i>Rumex acetosella</i>	0.00	0.02	0.02
<i>Salicornia bigelovii</i>	0.00	0.02	0.02
<i>Salicornia maritima</i>	0.00	0.02	0.02
<i>Salicornia virginica</i>	0.00	0.02	0.02
<i>Schizachyrium scoparium</i>	0.00	0.02	0.02
<i>Solidago sempervirens</i>	0.00	0.02	0.02
<i>Spartina alterniflora</i>	0.00	0.03	0.03
<i>Spartina patens</i>	0.03	0.07	0.03
<i>Suaeda maritima</i>	0.00	0.03	0.03
<i>Toxicodendron radicans</i>	0.03	0.07	0.03
<i>Vaccinium macrocarpon</i>	0.00	0.03	0.03
<i>Xanthonium strumarium</i>	0.02	0.07	0.05
<i>Yucca filamentosa</i>	0.03	0.10	0.07

Shaded rows distinguish most abundant taxa and/or those exhibiting the largest changes in frequency over time.

For summed cover class values, *Toxicodendron radicans*, *Deschampsia flexuosa*, *Ammophila breviligulata*, *Solidago sempervirens*, *Lathyrus japonica* (beachpea), and *Hudsonia tomentosa* were the most abundant taxa in both years (Table 3). The largest changes in sumCC values between 2005 and 2011 occurred in *Morella pensylvanica* (decreased), *Toxicodendron radicans* (decreased), *Elymus virginicus* (increased), *Deschampsia flexuosa* (increased), and *Ammophila breviligulata* (increased), *Prunus maritima* (beach plum; decreased), *Rumex acetosella* (sheep sorrel; decreased), and *Suaeda maritima* (increased). That said, *Morella pensylvanica* was the only taxon to undergo significant change (decreased), as assessed by the Wilcoxon signed ranks test between 2005 and 2011. A portion of the reduction in *M. pensylvanica* and *T. radicans* is due to a small number of plots converting to beach. However, the trend is still apparent when these plots are removed from the analysis. All other changes, while perhaps biologically noteworthy, were not statistically significant.

Table 3. Summed cover class scores of all species recorded in vegetation surveys (all 60 plots) in 2005 and 2011.

Species Scientific Name	sumCC 2005	sumCC 2011	Change
<i>Morella pensylvanica</i>	38	23	-15
<i>Toxicodendron radicans</i>	52	40	-12
<i>Deschampsia flexuosa</i>	55	45	-10
<i>Ammophila breviligulata</i>	228	219	-9
<i>Prunus maritime</i>	33	24	-9
<i>Rumex acetosella</i>	9	0	-9
<i>Distichlis spicata</i>	8	0	-8
<i>Solidago sempervirens</i>	63	55	-8
<i>Bromus tectorum</i>	5	0	-5
<i>Cyperus grayii</i>	5	1	-4
<i>Dicanthelium acuminatum</i>	5	1	-4
<i>Lechia maritime</i>	17	13	-4
<i>Artemesia campestris</i>	32	29	-3
<i>Rosa rugosa</i>	4	1	-3
<i>Achillea millifolium</i>	2	0	-2
<i>Dicanthelium Depauperatum</i>	6	4	-2
<i>Lactuca canadensis</i>	2	0	-2
<i>Oenothera biennis</i>	2	0	-2
<i>Pinus rigida</i>	8	6	-2
<i>Andropogon virginicus</i>	2	1	-1
<i>Artemesia stellariana</i>	6	5	-1
<i>Baccharis halimifolia</i>	1	0	-1
<i>Corema conradii</i>	2	1	-1
<i>Hieracium sp.</i>	1	0	-1
<i>Linaria vulgaris</i>	1	0	-1
<i>Parthenocissus cinquefolia</i>	2	1	-1
<i>Pityopsis falcate</i>	21	20	-1
<i>Rosa virginiana</i>	5	4	-1
<i>Hudsonia ericoides</i>	1	1	0
<i>Prunus serotina</i>	2	2	0
<i>Schizachyrium scoparium</i>	1	1	0
<i>Vaccinium macrocarpon</i>	1	1	0
<i>Arctostaphylos uva-ursi</i>	6	7	1
<i>Aster ericoides</i>	0	1	1
<i>Honckenya peploides</i>	0	1	1
<i>Juncus Greenei</i>	4	5	1
<i>Polygala polygama</i>	0	1	1
<i>Psuedognaphalium obtusifolium</i>	3	4	1
<i>Quercus ilicifolia</i>	0	1	1
<i>Salicornia biglovii</i>	0	1	1
<i>Salicornia maritima</i>	0	1	1
<i>Salicornia virginica</i>	0	1	1
<i>Yucca filamentosa</i>	0	1	1
<i>Cakile edetula</i>	1	3	2
<i>Erigeron annuus</i>	0	2	2
<i>Juncus canadensis</i>	1	3	2
<i>Limonium caroliniana</i>	0	2	2
<i>Spartina alterniflora</i>	0	2	2
<i>Xanthonium strumarium</i>	0	2	2
<i>Panicum lanuginosum</i>	4	7	3
<i>Spartina patens</i>	0	3	3
<i>Polygonella articulata</i>	2	6	4
<i>Chamaesyce Polygonifolia</i>	2	7	5
<i>Lathyrus japonica</i>	29	35	6
<i>Hudsonia tomentosa</i>	27	35	8
<i>Suaeda maritime</i>	2	11	9
<i>Elymus virginicus</i>	2	16	14

Shaded rows distinguish most abundant taxa and/or those exhibiting the largest changes in cover over time.

All Sites (2005 vs. 2011)

Plant communities of the dune vegetation monitoring network, as a whole (all cover scores summed by transect), did not change statistically between 2005 and 2011 (ANOSIM $R=-0.156$, $p=0.98$) (Figure 5). SIMPER analysis indicated that *Ammophila breviligulata*, *Deschampsia flexuosa*, *Toxicodendron radicans*, *Artemisia campestris*, and *Lathyrus japonica* accounted for the large proportion of dissimilarity between survey years (Table 4).

The conversion of seven dune grassland plots to beach, however, did not significantly alter the vegetation landscape along whole transects, as only DG7 showed significant difference between years (Table 5).

Species composition changes between the two survey years were significant when every plot from each transect was run through ANOSIM (ANOSIM $R=0.022$; $P=0.021$) (Figure 6). This was primarily due to shifts in bluff-edge plots which converted to beach due to coastal erosion.

SIMPER analysis revealed that *Ammophila breviligulata*, *Deschampsia flexuosa*, *Toxicodendron radicans*, *Solidago sempervirens*, and *Lathyrus japonica* accounted for the largest proportion of dissimilarity between survey years (Table 6). In this regard, the top four out of five species were the same when data were analyzed on a per plot basis as compared to a transect basis. Some notable changes occurred in individual plots. For example, bluff edge plots at DG5, DG6, and DG9 converted to beach due to erosion since 2005 and, for those plots, vegetation was non-existent in 2011.

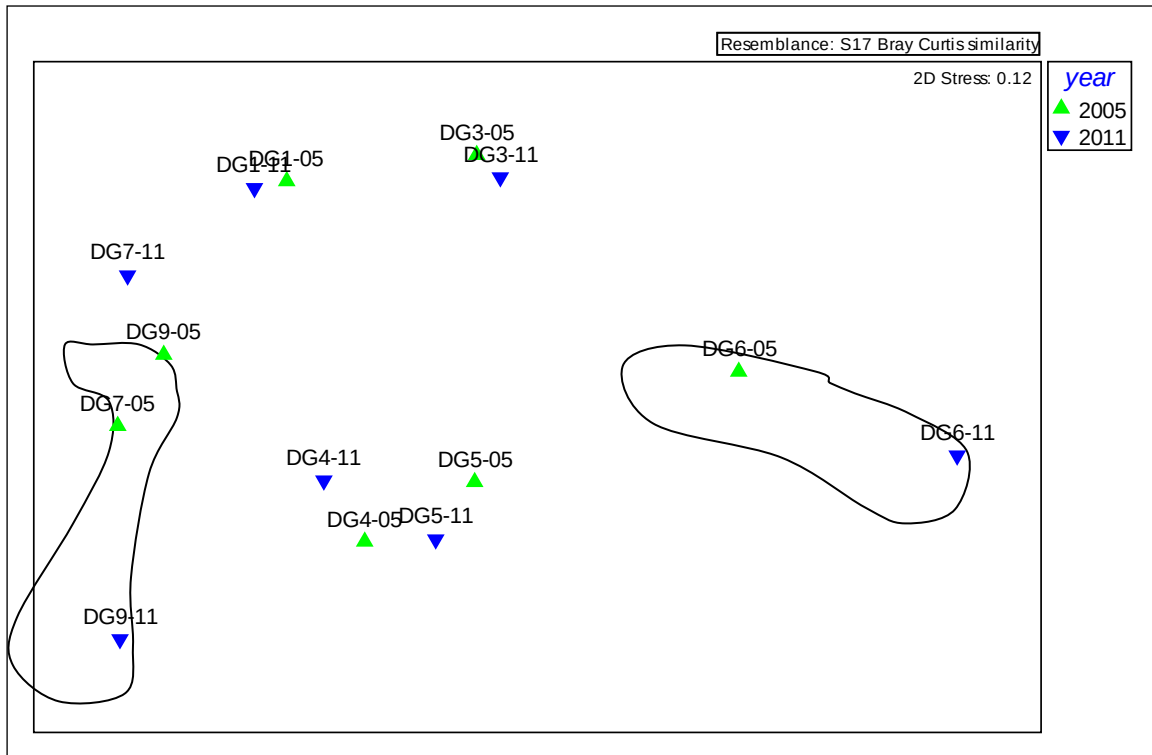


Figure 5. NMDS of all DG transects (sumCC of all plots along each transect) for 2005 and 2011 (polygons contain transect points that showed the largest dissimilarity between years).

Table 4. SIMPER data for cover scores summed by transect, including average abundances (i.e., cover) (Av. Ab) for 2005 (05) and 2011 (11), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant assemblages between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Ammophila breviligulata</i>	32.57	31.29	8.94	16.23
<i>Deschampsia flexuosa</i>	7.86	6.43	3.96	7.19
<i>Toxicodendron radicans</i>	7.43	5.71	3.84	6.97
<i>Artemisia campestris</i>	4.57	4.14	3.59	6.53
<i>Lathyrus japonica</i>	4.14	5.00	3.42	6.21

Table 5. ANOSIM data for change in vegetation communities between 2005 and 2011 by transect.

Transect		
All	R=0.022	p=0.25
DG1	R=0.016	p=0.30
DG3	R=-0.031	p=0.77
DG4	R=-0.135	p=0.63
DG5	R=0.061	p=0.23
DG6	R=0.125	p=0.113
DG7	R=0.377	p=0.004
DG9	R=0.047	p=0.19

Shaded row indicates the only significant result

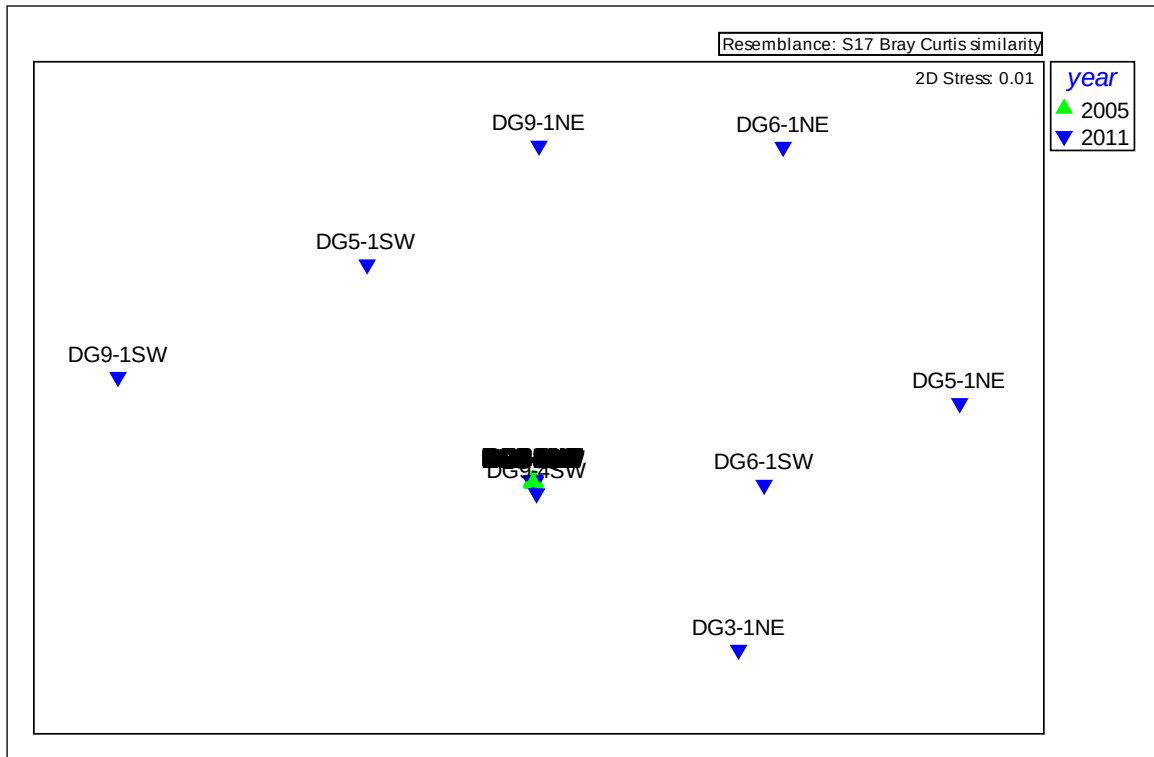


Figure 6. NMDS of each individual plot (note: all plots outside of central cluster are bluff-edge locations that converted to beach).

Table 6. SIMPER data for cover scores by plot, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Ammophila breviligulata</i>	3.8	3.7	12.6	19.0
<i>Deschampsia flexuosa</i>	0.9	0.8	5.4	8.2
<i>Toxicodendron radicans</i>	0.9	0.7	5.2	7.9
<i>Solidago sempervirens</i>	1.1	0.9	4.3	6.5
<i>Lathyrus japonica</i>	0.5	0.6	4.2	6.3

Individual Transect Sites

Transect DG1 (2005 vs. 2011)

This transect runs NW-SW through a wide area of dunes at the tip of the Provincetown peninsula. There was no significant difference in plant community composition between 2005 and 2011 (ANOSIM $R = 0.016$, $p = 0.30$) (Figure 7) for DG1. SIMPER analysis of DG1 indicated that *Ammophila breviligulata*, *Deschampsia flexuosa*, *Toxicodendron radicans*, *Solidago sempervirens*, and *Lathyrus japonica* accounted for the largest proportion of dissimilarity between survey years (Table 7).

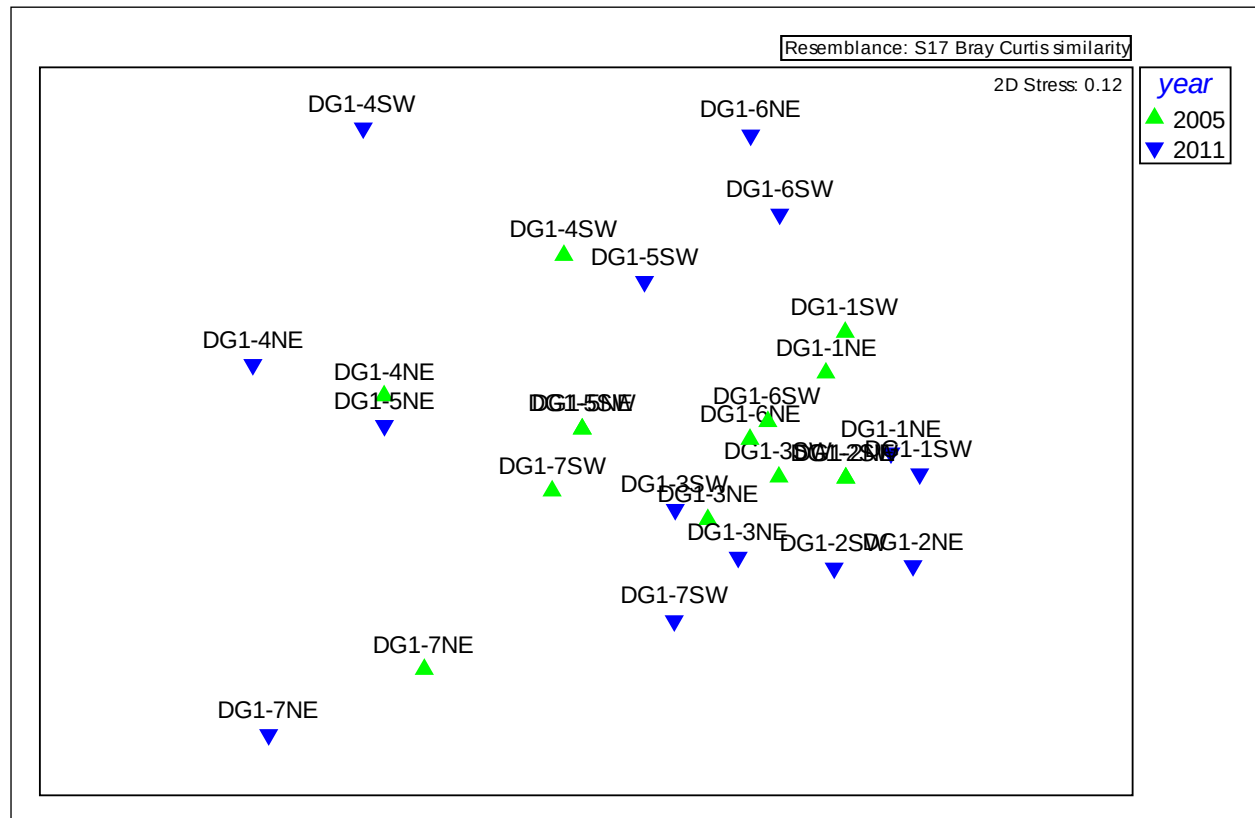


Figure 7. NMDS of DG1 plots.

Table 7. SIMPER data for DG1, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Ammophila breviligulata</i>	4.2	4.1	13.1	25.5
<i>Deschampsia flexuosa</i>	1.1	0.9	8.3	16.2
<i>Lathyrus japonica</i>	0.3	0.7	4.8	9.3
<i>Solidago sempervirens</i>	0.7	1.0	4.0	7.7
<i>Toxicodendron radicans</i>	0.4	0.6	3.8	7.4

Transect DG3 (2005 vs. 2011)

Oriented in a NE-SW direction, this transects through two sets of parabolic dunes, between which is a large plain with a number of dune slack wetlands. For DG3, no significant shift in plant community composition or distribution occurred between 2005 and 2011 (ANOSIM $R=-0.031$, $p=0.77$) (Figure 8). The separation in ordinal space of plot DG3-1NE was due to the conversion of the NE plot to beach by erosion, resulting in no plant cover for that location in 2011. SIMPER analysis of DG3 indicated that *Ammophila breviligulata*, *Deschampsia flexuosa*, *Toxicodendron radicans*, *Prunus maritima*, and *Morella pensylvanica* accounted for the largest proportion of dissimilarity between survey years (Table 8).

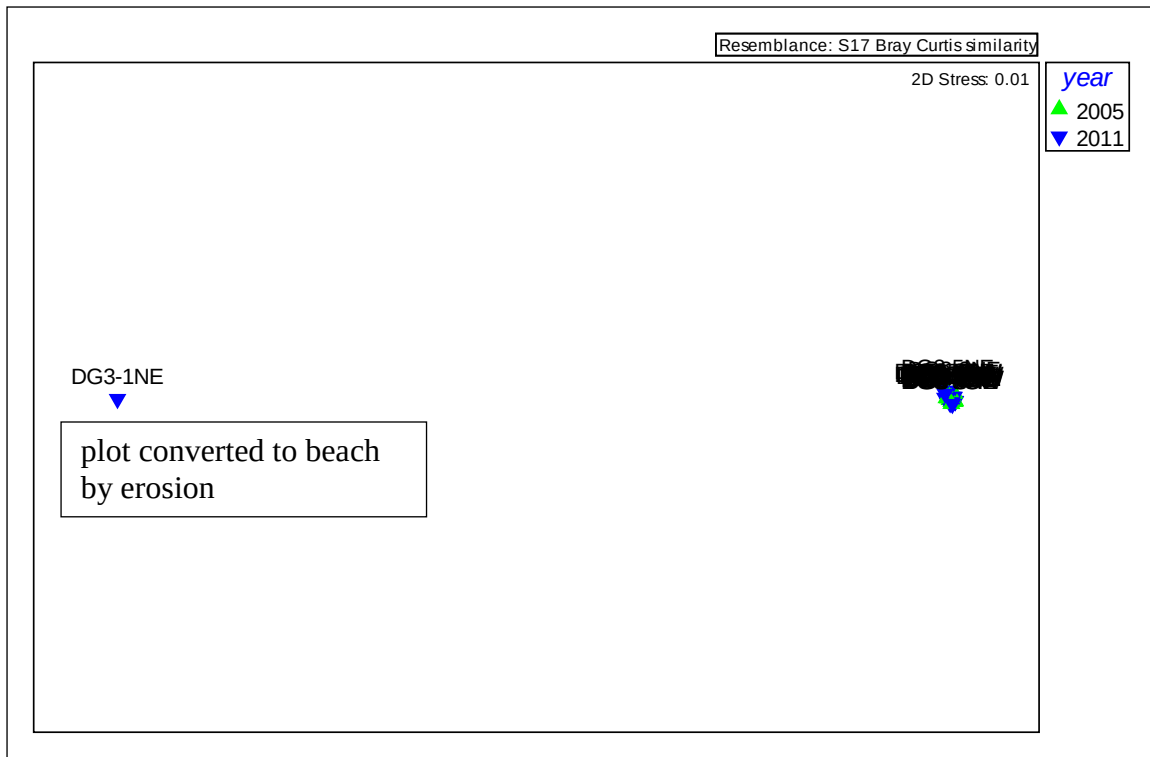


Figure 8. NMDS of DG3 plots.

Table 8. SIMPER data for DG3, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Ammophila breviligulata</i>	3.2	3.2	8.7	14.3
<i>Deschampsia flexuosa</i>	1.8	1.5	7.2	11.8
<i>Toxicodendron radicans</i>	1.3	1.0	6.3	10.3
<i>Prunus maritima</i>	1.3	0.9	5.7	9.3
<i>Morella pensylvanica</i>	1.1	0.9	4.9	8.0

Transect DG4 (2005 vs. 2011)

Transect DG4 is located on the west side of the Seashore, adjacent to Cape Cod Bay. It covers a relatively narrow band of coastal dune area that transitions quickly into a forested landscape. There was no significant difference in plant community composition or distribution between 2005 and 2011 for DG4 (ANOSIM $R=-0.135$, $p=0.63$) (Figure 9). Plot DH4-2SW changed due to appearance of *Chamaesyce polygonifolia* (seaside sandmat) in 2011. SIMPER analysis of DG4 showed that *Toxicodendron radicans*, Lichen spp., *Ammophila breviligulata*, *Chamaesyce polygonifolia*, *Rosa virginica*, and *Deschampsia flexuosa* accounted for the largest proportion of dissimilarity between survey years (Table 9).

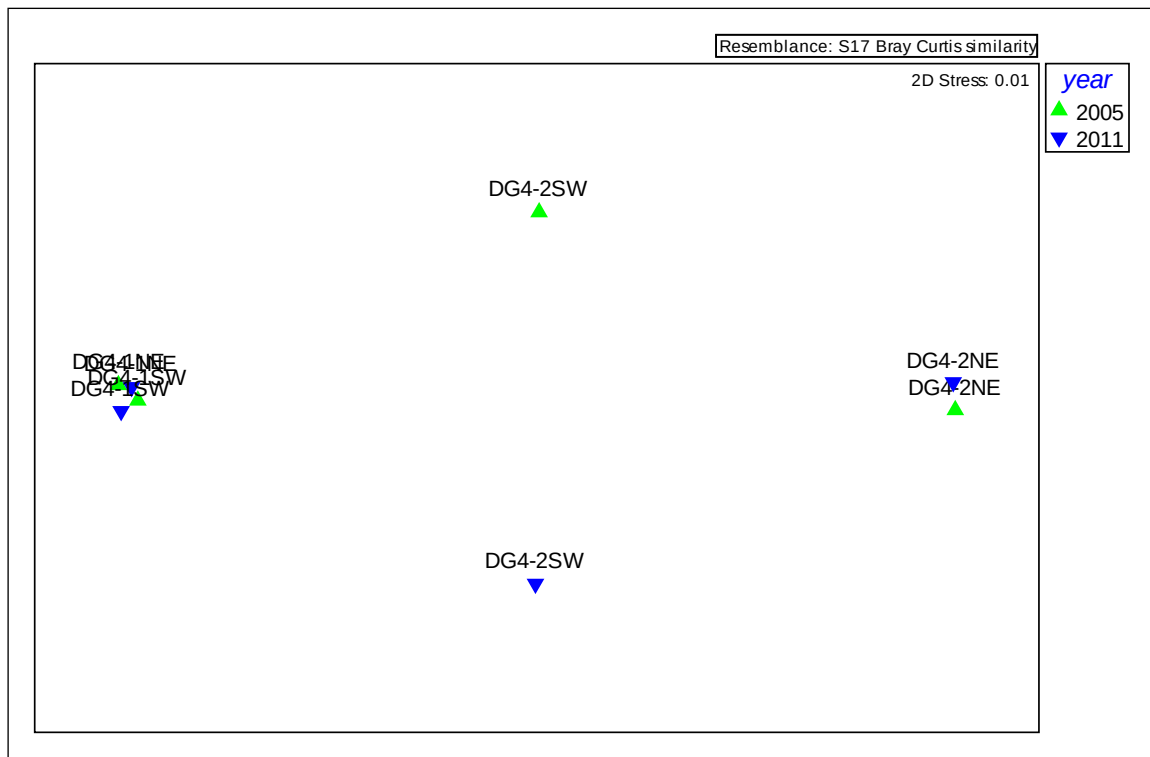


Figure 9. NMDS of DG4 plots.

Table 9. SIMPER data for DG4, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Toxicodendron radicans</i>	3.5	3.5	6.0	21.5
Lichen	1.0	1.3	5.5	19.7
<i>Ammophila breviligulata</i>	5.3	6.3	5.1	18.5
<i>Chamaecycae polygonifolia</i>	0.0	0.5	2.2	8.0
<i>Rosa virginiana</i>	0.3	0.5	2.2	7.8
<i>Deschampsia flexuosa</i>	0.5	0.3	2.2	7.8

Transect DG5 (2005 vs. 2011)

Transect DG5 is also located along Cape Cod Bay several km south of DG4. At this location, no significant change in plant community composition was evident between 2005 and 2011 (ANOSIM $R=0.061$, $p=0.23$) (Figure 10). With respect to individual plots, DG5-1SW and DG5-1NE were impacted by coastal erosion and had converted to beach by 2011. SIMPER analysis of DG5 revealed that *Ammophila breviligulata*, Lichen spp., *Artemisia campestris*, *Toxicodendron radicans*, *Deschampsia flexuosa*, and *Hudsonia tomentosa* (beach heather) accounted for the largest proportion of dissimilarity between survey years (Table 10).

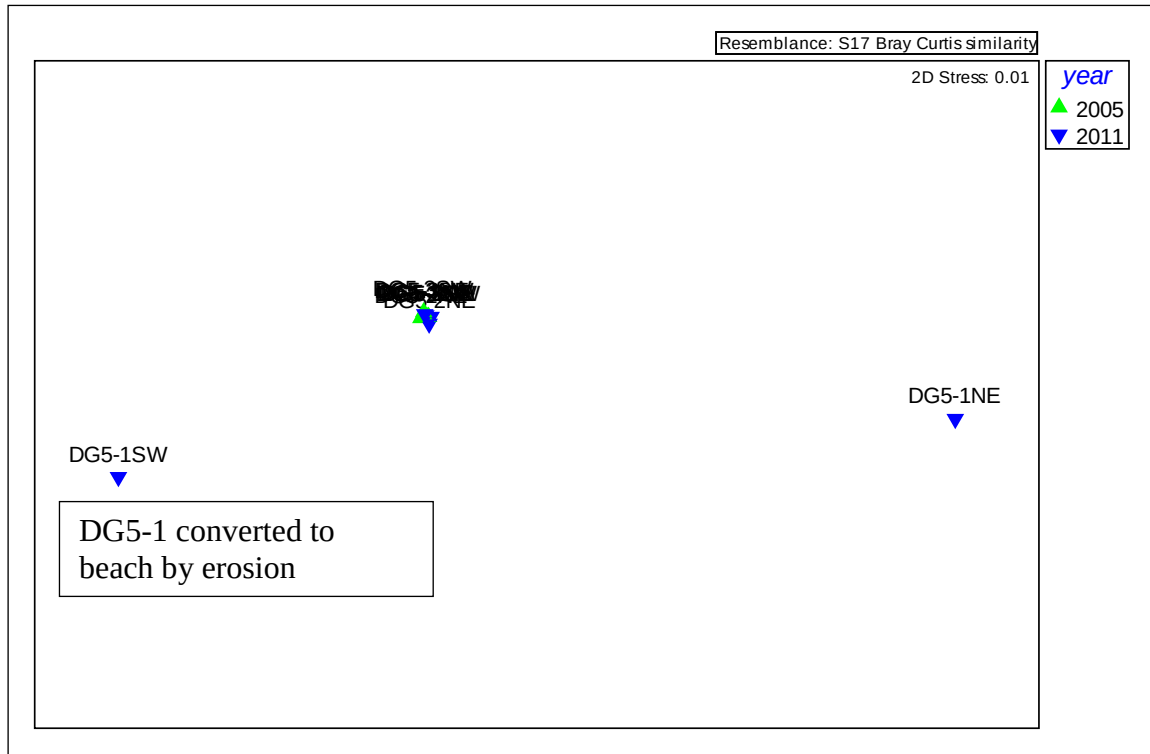


Figure 10. NMDS of DG5 plots.

Table 10. SIMPER data for DG5, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Ammophila breviligulata</i>	3.5	3.5	11.1	17.2
Lichen spp.	3.2	1.8	10.7	16.5
<i>Artemisia campestris</i>	2.5	1.5	7.0	10.9
<i>Toxicodendron radicans</i>	1.7	0.3	6.1	9.5
<i>Deschampsia flexuosa</i>	1.2	0.7	4.2	6.5
<i>Hudsonia tomentosa</i>	0.7	0.7	3.3	5.1

Transect DG6 (2005 vs. 2011)

This transect is situated along the coastal bluff in the Marconi area of CACO. There is no significant difference in plant community composition or distribution between 2005 and 2011 (ANOSIM $R=0.125$, $p=0.11$) (Figure 11). Plots DG6-1SW and DG6-1NE converted to beach by 2011 due to bluff retreat. *Hudsonia tomentosa*, *Ammophila breviligulata*, *Morella pensylvanica*, *Solidago sempervirens*, and *Acrostaphylos uva-ursi* accounted for the largest proportion of dissimilarity between survey years according to SIMPER analysis (Table 11).

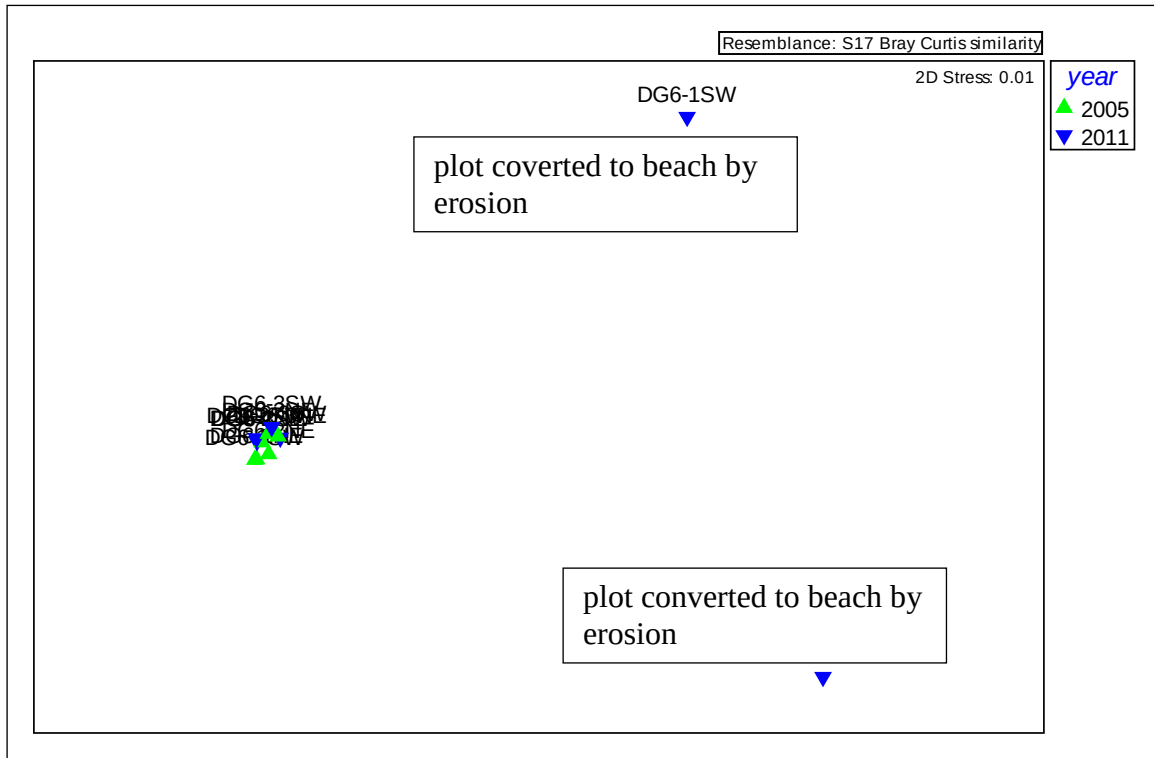


Figure 11. NMDS of DG6 plots.

Table 11. SIMPER data for DG6, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Hudsonia tomentosa</i>	3.0	3.8	9.7	14.9
<i>Ammophila breviligulata</i>	3.2	1.2	9.2	14.1
<i>Morella pensylvanica</i>	2.7	1.2	7.0	10.7
<i>Solidago sempervirens</i>	2.0	0.7	6.6	10.1
<i>Acrostaphylos uva-ursi</i>	1.0	1.2	4.1	6.2

Transect DG7 (2005 vs. 2011)

A significant shift in the plant community occurred between 2005 and 2011 (ANOSIM $R=0.377$, $p=0.004$) (Figure 12). Based on SIMPER analysis, *Ammophila breviligulata*, *Lathyrus japonica*, *Solidago sempervirens*, *Erigeron annuus* (eastern daisy fleabane), and *Artemisia stellariana* accounted for the largest proportion of dissimilarity between survey years along DG7 (Table 12).

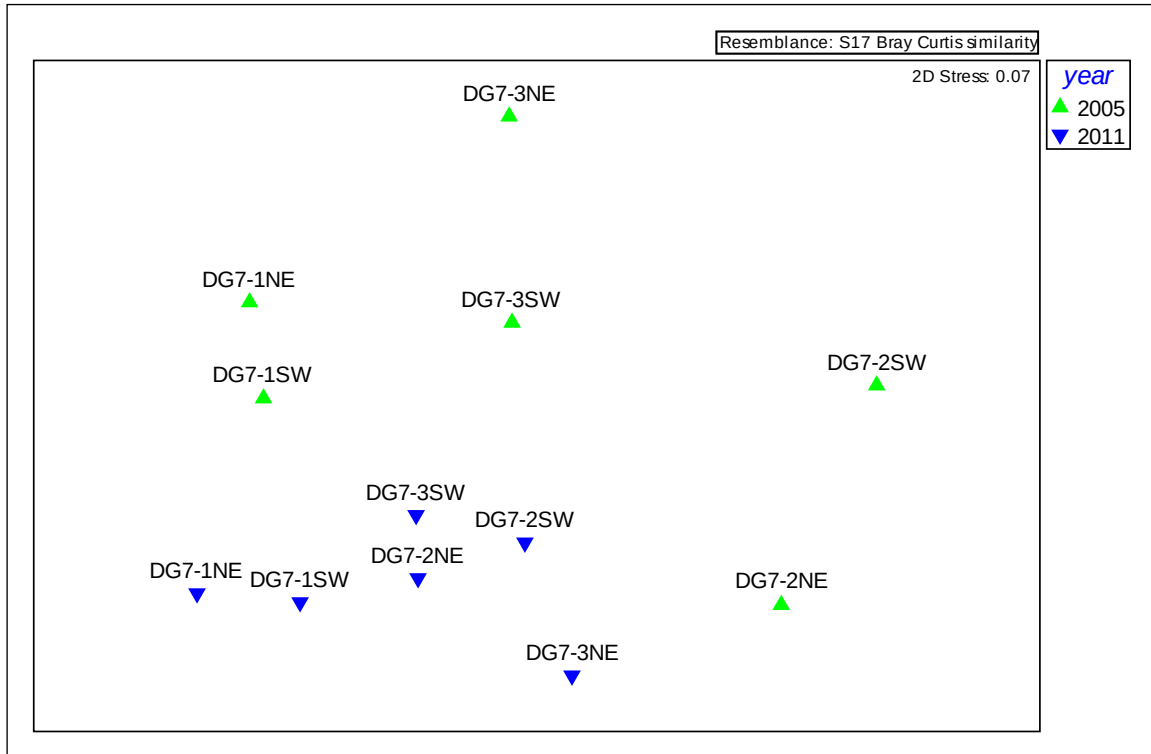


Figure 12. NMDS of DG7 plots.

Table 12. SIMPER data for DG7, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Ammophila breviligulata</i>	4.2	6.7	12.3	41.8
<i>Lathyrus japonica</i>	2.2	3.0	6.5	22.2
<i>Solidago sempervirens</i>	1.5	1.5	5.0	17.1
<i>Erigeron annuus</i>	0.0	0.3	1.6	5.6
<i>Artemisia stellariana</i>	0.3	0.0	1.6	5.5

Transect DG9 (2005 vs. 2011)

There is no significant difference in plant community composition or distribution between 2005 and 2011 (ANOSIM $R=0.047$, $p=0.19$) (Figure 13). Plots DG9-1SW and DG9-1NE converted to beach by 2011 due to erosion, while a portion of DG9-4SW converted to salt marsh since 2005 due to the increase in tidal amplitude of Pleasant Bay from the 2007 break. SIMPER analysis of DG9 showed that *Ammophila breviligulata*, *Artemesia campestris*, *Lathyrus japonica*, *Elymus virginicus*, and *Solidago sempervirens* accounted for the largest proportion of dissimilarity between survey years (Table 13).

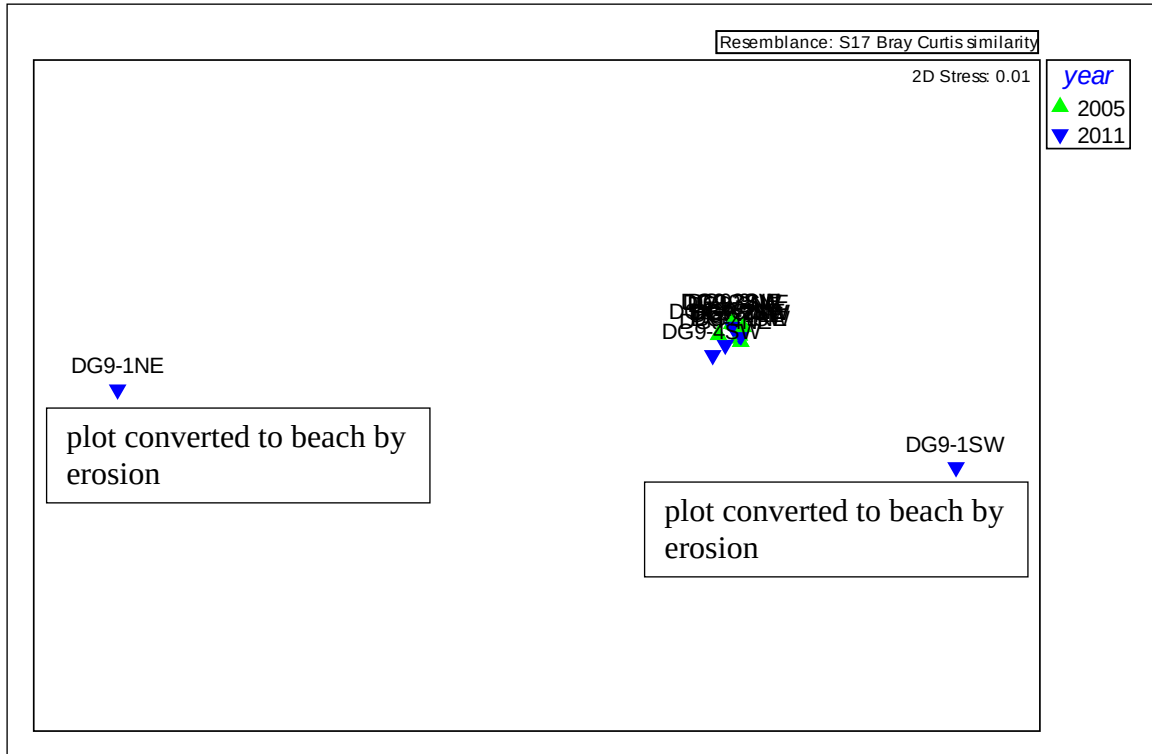


Figure 13. NMDS of DG9 plots.

Table 13. SIMPER data for DG9, including average abundances (Av. Ab), average dissimilarity values (Av. Diss), and percent contribution (Contrib%) to overall dissimilarity in plant communities between years.

Species	Av.Ab05	Av.Ab11	Av.Diss	Contrib%
<i>Ammophila breviligulata</i>	4.0	2.1	14.8	22.2
<i>Artemisia campestris</i>	2.0	2.5	12.2	18.2
<i>Lathyrus japonica</i>	1.4	0.6	6.9	10.3
<i>Elymus virginicus</i>	0.3	1.5	6.0	8.9
<i>Solidago sempervirens</i>	1.5	0.8	5.3	7.9

Analysis of Aerial Photography

Bluff Erosion

A substantial amount of coastal bluff erosion occurred between 2005 and 2011 as evidenced by the vegetation plots that converted from dune grassland to bare beach (due to coastal erosion) during this period (Table 14; Figures 14 and 15). A comparison of aerial photography in 1995 and 2010 showed this process in a more dramatic fashion. For example, in Figure 14, which highlights a section of the Cape Cod bay coastline, approximately 25 m of bluff retreat is evident. In contrast, the DG1 transect is in an area of accretion (Table 14; Figure 16).

Table 14. Bluff erosion/accretion by transect between 1995 and 2010.

Transect	Trend	Change in Bluff Position
DG1	Accretion	+77 m
DG3	Erosion	-23 m
DG4	Erosion	-4 m
DG5	Erosion	-25 m
DG6	Erosion	-34 m
DG7	Erosion	-25 m
DG9	Erosion	-28 m



Figure 14. Inland migration of the coastal bluff at DG5 by ~25 m during 1995 (left) – 2010 (right).



Figure 15. Inland migration of the coastal bluff at DG9 by ~29 m and concurrent loss of beachgrass cover during 1995 (left) – 2010 (right).



Figure 16. Accretion at DG1 between 1995 (left) and 2010 (right).

Succession

Succession in dune grassland areas is clearly evident in comparisons of aerial photographs, particularly in areas undergoing early succession. In this regard, the Province Lands region exhibits remarkable change. Figures 17 and 18 show the appearance of numerous shrubs and trees between 1995 and 2010 in select areas of this landscape that were dominated by grasses or were unvegetated.

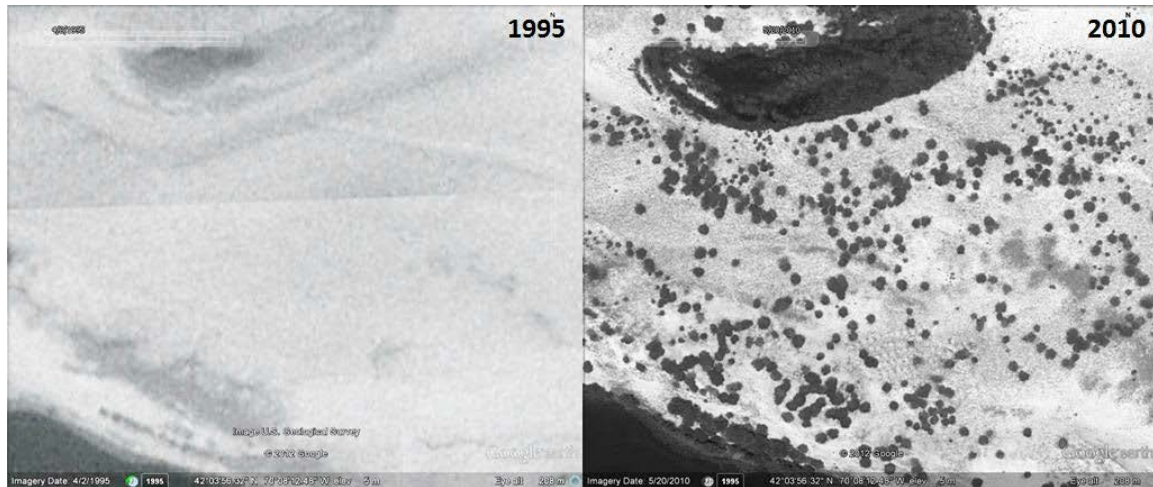


Figure 17. Succession in the Province Lands dunes during 1995-2010.

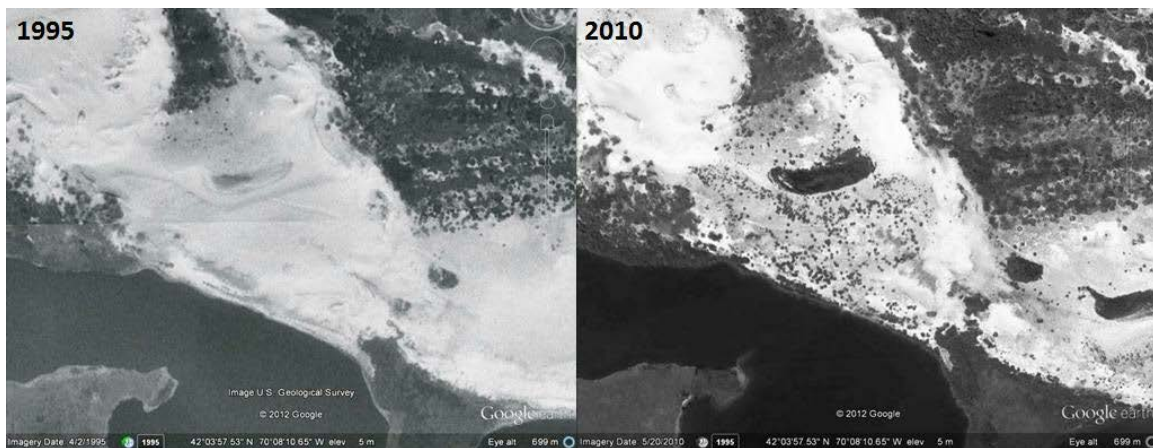


Figure 18. Succession in the Province Lands dunes during 1995-2010.

Broad-scale Environmental Factors

Precipitation

There has been a distinct rise in annual precipitation over the last 10+ years on Cape Cod. Data collected within CACO (site MA01) as part of the National Atmospheric Deposition program (NADP) show this trend clearly (Figure 19). In particular, 2009 and 2010 were very wet compared to previous years within this 30-year time period.

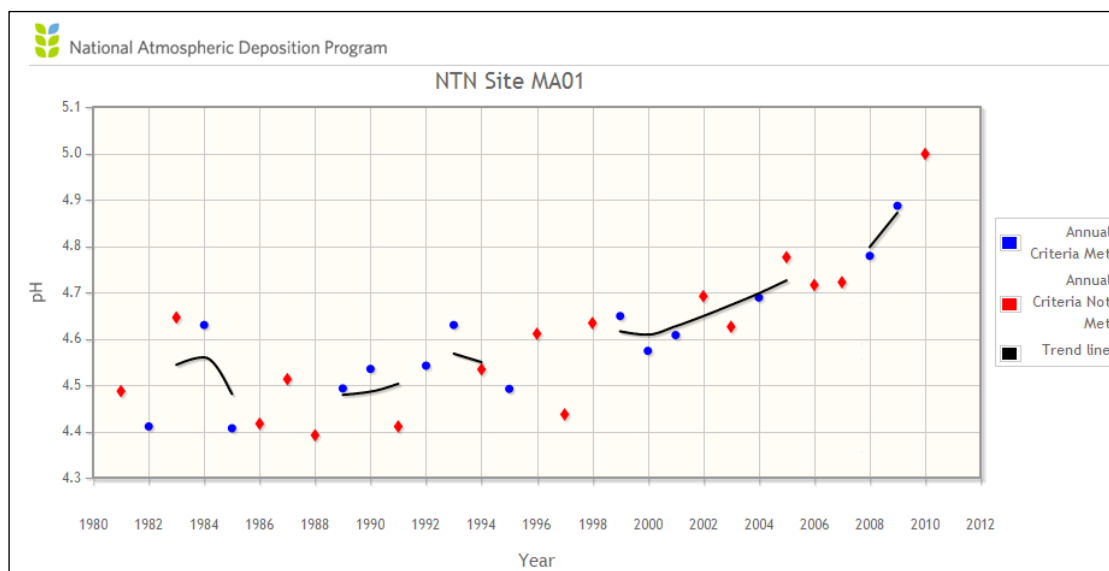


Figure 19. Annual precipitation recorded at MA01 (NADP site within CACO, Truro) from 1981 to 2010.

Interestingly, when broken down by month, precipitation during the growing season (i.e., May–September) has actually decreased, while certain months of the dormant season (October–April) have shown clear increases (Table 15). Specifically, April, October, and December have been getting wetter since 1982. Although regression analysis of these trends does not indicate statistical significance, they may be ecologically important nonetheless and perhaps the beginning of a significant trend.

Table 15. Precipitation trends at MA01 by month from 1982–2010.

Month	Trend	F	p
Jan	-	0.20	0.65
Feb	-	2.71	0.11
Mar	none	0.02	0.88
Apr	+	1.11	0.30
May	none	0.003	0.96
Jun	-	0.65	0.43
Jul	-	3.17	0.08
Aug	-	1.08	0.31
Sep	+	0.34	0.57
Oct	+	0.24	0.63
Nov	-	0.58	0.45
Dec	+	3.81	0.06

Data source: NADP; "-" indicates decreasing trend; "+" indicates increasing trend; highlighted rows show months that are nearest to statistical significance in terms of rainfall regressed against year

Wind

Wind strength and predominant direction is highly seasonal on Cape Cod. In the summer and fall months, winds come mainly from the south. In the spring, winds tend to blow from the north and south, and occasionally from the west. In the winter, strong winds originate from the west and north (Figure 20), which corresponds with the direction of migration of parabolic dunes to the southeast (Forman et al. 2008).

Wind abrasion and wind-blown sand abrasion were characterized in Smith (2005). Unsurprisingly, these factors are most prominent closer to the bluff edge.

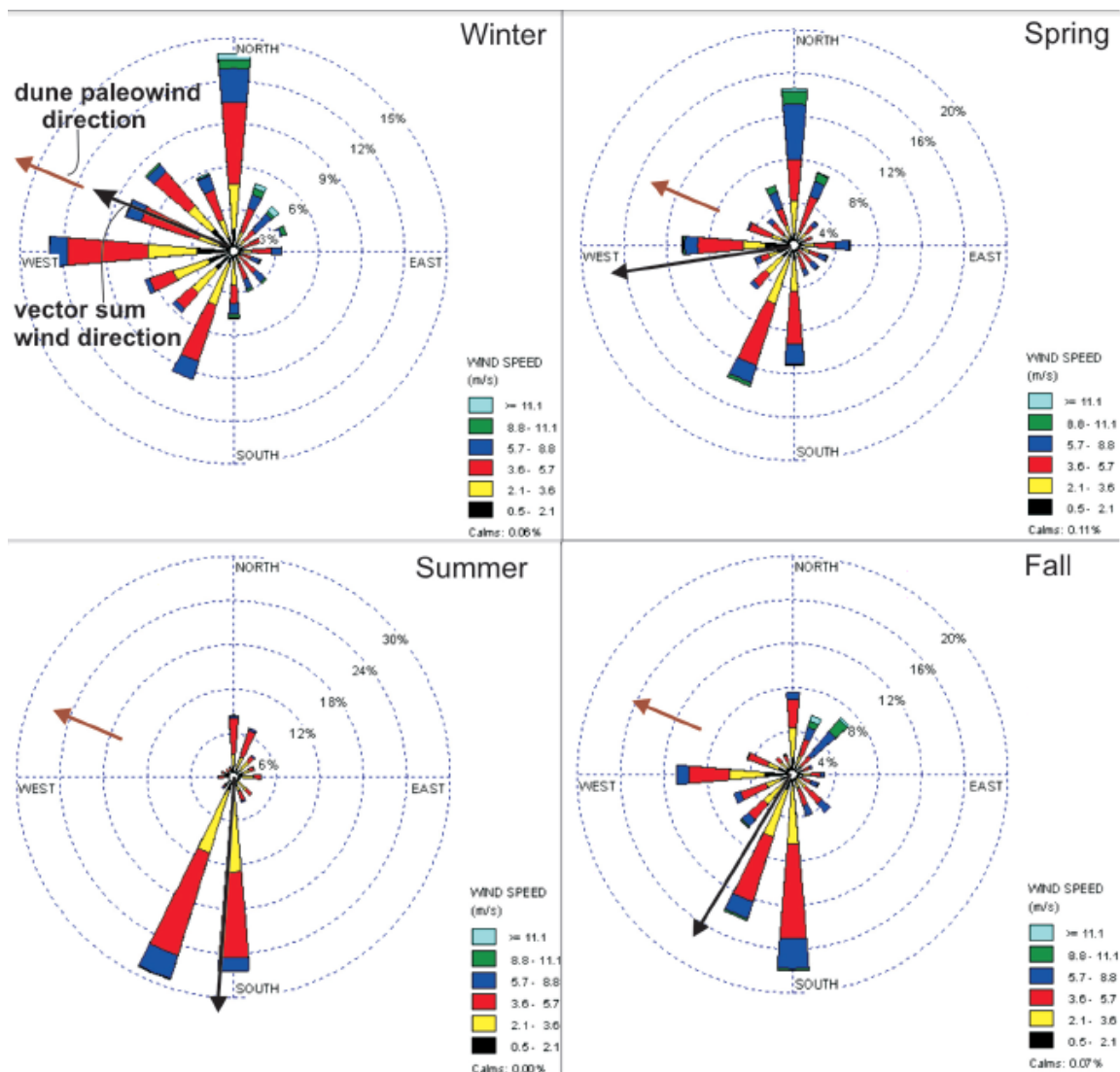


Figure 20. Wind rose showing strength and direction of winds by season for Cape Cod, Provincetown; figure reproduced from Forman et al. 2008; data are from 2004–2005.

Nitrogen and Sulfate Deposition (Wet)

Nitrogen (N) deposition from precipitation in dune environments can profoundly influence plant communities (Plassmann 2009), especially through the acceleration of succession. In fact, even relatively minor amounts of N deposition can significantly impact dune communities in this way (Veer 1997, Remke et al. 2009). Critical loads of N for coastal dunes might be lower than previously thought, in the range of 4–6 kg/ha/yr wet deposition (Remke et al. 2009). Current $\text{NO}_3 + \text{NH}_4$ deposition at CACO is around 9 kg/ha/yr, suggesting that dune vegetation processes have been, and still are being, influenced by this nutrient, even though NO_3 deposition shows a decline over the past few decades (Figure 21).

Sulfate (SO_4) contributes to the acidity of rainwater and the deleterious effects of acid rain on plant growth are well-documented. In addition to the direct effect of acidic precipitation on plant physiology, it also tends to decrease the availability of nutrients. In this way it can counteract the growth-promoting effects of N deposition (Kooijman et al. 1998). The trend of decreasing SO_4 (Figure 22) may, therefore, result in an elevated effect of N deposition.

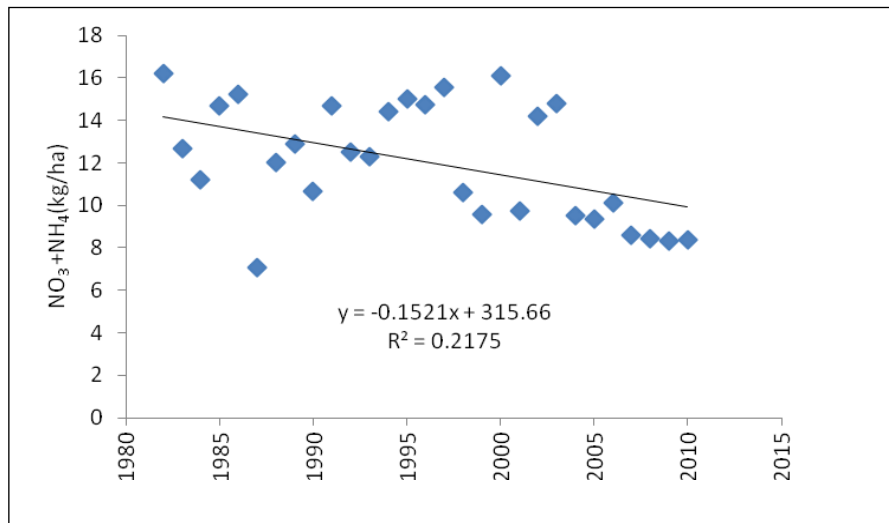


Figure 21. Nitrate deposition (kg/ha/yr.) at MA01 between 1982 and 2010.

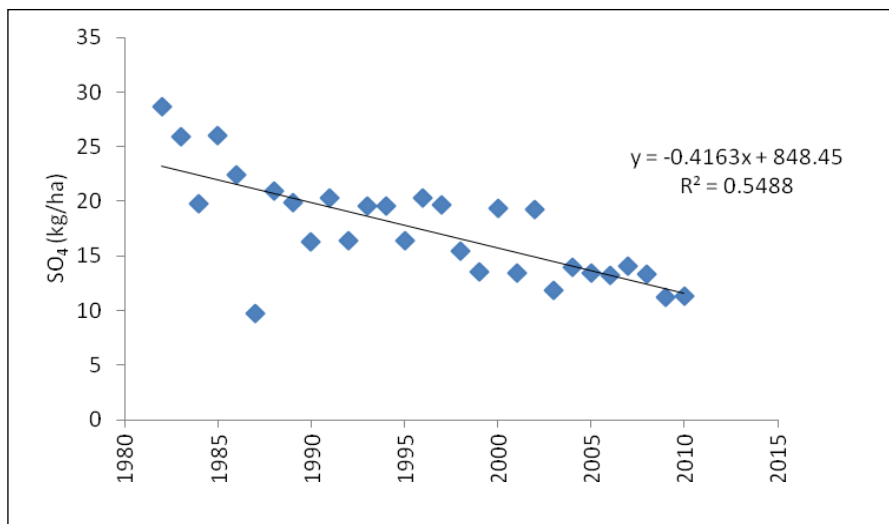


Figure 22. Sulfate deposition (kg/ha/yr) at MA01 between 1982 and 2010.

Salt Spray

Salt spray has a significant effect on coastal dune vegetation (Griffiths et al. 2003a, 2003b, 2004) and was previously assessed in Smith (2005). Salt spray is highest nearest the bluff and decreases dramatically inland. Although some taxa are much more tolerant than others, this variable generally tends to stress plants and can even cause mortality (Levy 1990, Griffiths et al. 2003b). Salt spray was not re-measured in the 2011 survey, but the spatial trends in this variable are relatively predictable with respect to plot distance from the bluff edge. It is simply another factor to consider when assessing vegetation patterns with respect to their proximity to the coast and for predicting future community change.

Temperature

Elevated temperatures and an increase in the length of the growing season will surely have an impact on dune plant communities, primarily as a result of its effects on succession (Vestergaard 1991). Data retrieved from New England Integrated Sciences and Assessment (NEISA; neisa.unh.edu) show the increasing mean annual temperature trend at Provincetown for the last 100+ years (Figure 23). Moreover, this trend is expected to continue into the future as a result of global warming (IPCC 2007).

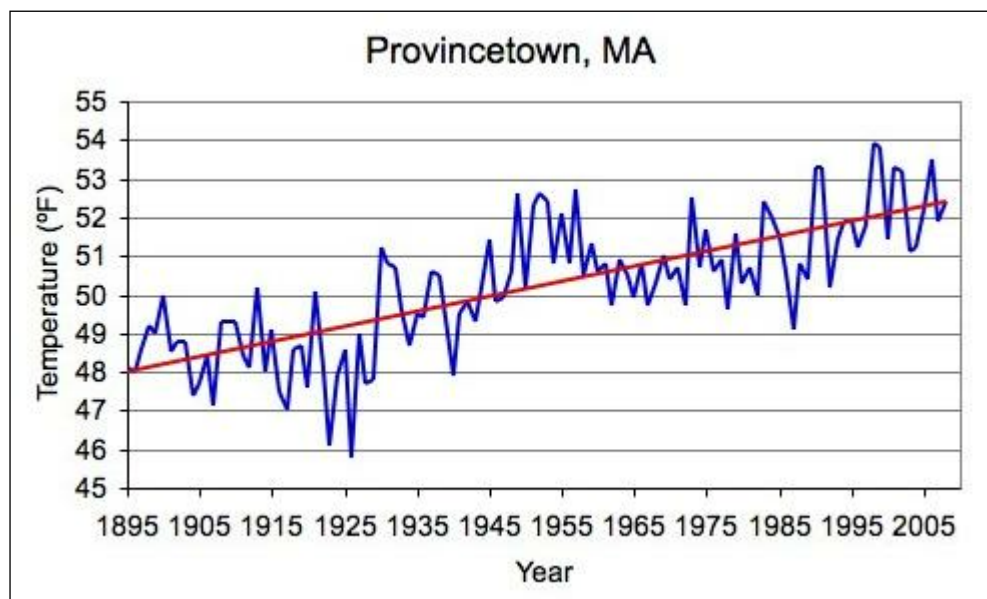


Figure 23. Mean annual temperature at Provincetown, MA from 1895–2005 (data from NEISA).

Discussion

It has become quite apparent through ground-level monitoring conducted in 2005 and 2011 along with aerial image analysis that dune grassland vegetation is largely controlled by physical factors. Erosion is of particular importance, as has previously been reported by Roman and Nordstrom (1988) and Shao et al. (1998). Precipitation is also most likely an influential factor. In this regard, Forman et al (2008) reported that increased dune movement correlated with dry periods. Since dune movement is itself dependent upon the abundance of stabilizing vegetation, the assumption that plant cover is lower during dry periods (and vice versa) is supported.

It should be noted that vegetation monitoring may reveal opposite trends depending on the position of the sites. Inland sites that are many tens of meters away from the coastal bluff will be subject to much less erosion, salt spray, sand burial, or wind stress (Smith 2005). These areas are likely to exhibit noticeable succession over time. However, sites that are closer to the bluff edge may start to show “reverse succession” in that the abovementioned environmental factors, which cause physiological and physical stress, are likely to cause disturbances that result in plot and/or plant loss, and/or favor pioneer plant species (Turner et al. 1998, Ripley and Pammenter 2004). The complexity of dune vegetation patterns in relation to environmental factors has been summarized by Miller et al. (2010), who wrote that “... plant communities through time are caused by climatic events: changes in foredune vegetation are correlated with temperature and summer precipitation, interdune vegetation with storm surge, and backdune vegetation with precipitation and storm surge ...”.

Lower amounts of precipitation during the growing season likely suppress the growth of dune grassland taxa, possibly favoring more drought-tolerant species, and thereby retarding successional processes. It is unclear what the increasing trend in precipitation during the dormant season may mean ecologically, but its effect on plant communities may be inconsequential since there is little to no active growth during this time. Notwithstanding, succession across this landscape is clearly evident as grasslands and areas of low-statured shrubs are increasingly overtaken by taller shrubs and trees. While this is a natural process, this change in landscape character has implications for a number of plant and animal taxa that rely upon this open habitat for survival.

Sea-level rise is expected to increase rates of erosion, which may result in increasingly narrower strips of dune grassland habitat and a breakdown of the successional process (Feagin et al. 2005). Sea-level rise will also facilitate the expansion of salt marsh habitat into dune grasslands where these habitats abut, such as barrier beaches with adjacent back barrier marshes. In this way, dune grasslands will undergo significant “squeeze” where erosion cuts it away from the seaward side and salt marsh encroachment occurs from the back barrier (landward) side.

Future Monitoring

Seaward-most sites along six of the seven transects have been or eventually will be converted to beach through erosion, while along one transect (DG1) new land is being created through accretion. Therefore, it is advisable that more vegetation sites be established to insure adequate spatial coverage and so that the power to detect change is not diminished. In terms of species composition, the number of plots appears to be adequate according to two models, but insufficient according to others (Figure 24). As such, the establishment of more sites is warranted, as may be separate analyses where converted plots are both deleted and included for a more complete interpretation of change.

As is frequently the case in ground-level monitoring, large changes can occur outside the network of sampling sites. Aerial photography can help in this regard; however, ground-level monitoring is crucial for ground-truthing signatures from aerial photography and to provide higher resolution data.

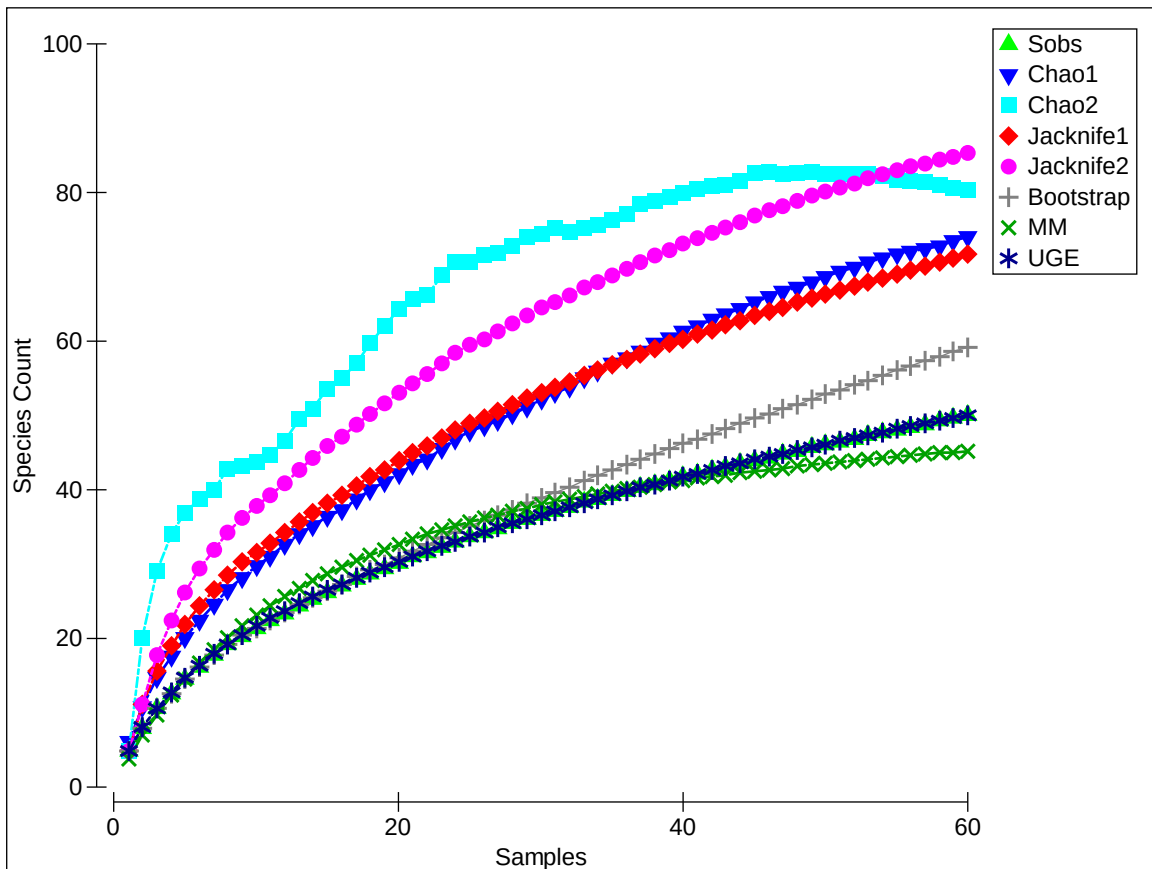


Figure 24. Species accumulation plot based on 2011 vegetation data. Note that asymptotes were only reached at 60 samples (plots) in two out of seven models (Chao2 and Sobs) indicating the need for more sites.

The dune vegetation monitoring conducted in 2005 and 2011 can serve as the basis for developing a long-term monitoring protocol. Along with an analysis of landform changes and various environmental factors, the protocol should provide CACO managers with valuable information that can be used for resource management as well as infra-structure planning. For the foreseeable future, the frequency of monitoring can be maintained at a 5-year interval. This seems appropriate considering that substantial coastal change occurred over this time period, as did the encroachment of salt marsh vegetation into dune communities. In addition, dune vegetation monitoring does not require a lot of time and effort, so it is feasible to survey once every ~5 years from the standpoint of labor and personnel requirements. Other parameters that were measured in 2005, including salt spray and sand deposition, should be re-sampled during the next survey.

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Appendix A. Maps of sampling locations by transect (each symbol represents the two replicate 10 m² plots) (aerial photos from 2001).



Vegetation sampling site locations along DG1.



Vegetation sampling site locations along DG3.



Vegetation sampling site locations along DG4.



Vegetation sampling site locations along DG5.



Vegetation sampling site locations along DG6.



Vegetation sampling site locations along DG7.



Vegetation sampling site locations along DG9

Appendix B. Complete list of vascular plant species recorded in the 2011 dune vegetation survey.

Scientific Name	Common Name
<i>Achillea millifolium</i>	common yarrow
<i>Ammophila breviligulata</i>	beachgrass
<i>Andropogon virginicus</i>	bluestem broomsedge
<i>Arctostaphylos uva-ursi</i>	bearberry
<i>Artemesia campestris</i>	field sagewort
<i>Artemesia stellariana</i>	dusty miller
<i>Aster ericoides</i>	heath aster
<i>Baccharis halimifolia</i>	saltbush
<i>Bromus tectorum</i>	cheatgrass
<i>Cakile edetula</i>	sea rocket
<i>Chamaesyce polygonifolia</i>	seaside sandmat
<i>Honckenia peploides</i>	seaside sandplant
<i>Corema conradii</i>	broom crowberry
<i>Cyperus grayii</i>	Gray's sedge
<i>Deschampsia flexuosa</i>	hairgrass
<i>Dicanthelium acuminatum</i>	tapered rosette grass
<i>Dicanthelium depauperatum</i>	starved panicgrass
<i>Distichlis spicata</i>	spike grass
<i>Elymus virginica</i>	wild rye
<i>Erigeron annuus</i>	annual fleabane
<i>Hieracium</i> sp.	hawkweed
<i>Hudsonia ericoides</i>	pine barren goldenheather
<i>Hudsonia tomentosa</i>	beach heather
<i>Juncus canadensis</i>	Canada rush
<i>Juncus greenei</i>	Greene's rush
<i>Lactuca canadensis</i>	Canada lettuce
<i>Lathyrus japonica</i>	beach pea
<i>Lechia maritima</i>	pinweed
<i>Limonium caroliniana</i>	sea lavender
<i>Linaria vulgaris</i>	butter and eggs
<i>Morella pensylvanica</i>	northern bayberry
<i>Oenothera biennis</i>	evening primrose
<i>Panicum lanuginosum</i>	panic grass
<i>Parthenocissus cinquefolia</i>	Virginia creeper
<i>Pinus rigida</i>	pitch pine
<i>Pityopsis falcata</i>	sickle-leaved goldenrod
<i>Polygonella articulata</i>	sand jointweed
<i>Polygala polygama</i>	racemed milkwort
<i>Prunus maritima</i>	beach plum
<i>Prunus serotina</i>	black cherry
<i>Psuedognaphalium obtusifolium</i>	rabbit-tobacco
<i>Quercus ilicifolia</i>	scrub oak
<i>Rosa rugosa</i>	salt spray rose
<i>Rosa virginiana</i>	Virginia rose
<i>Rumex acetosella</i>	sheep sorrel
<i>Salicornia biglovii</i>	dwarf saltwort
<i>Salicornia maritima</i>	slender grasswort
<i>Salicornia virginica</i>	Virginia glasswort

Scientific Name	Common Name
<i>Schizachyrium scoparium</i>	little bluestem
<i>Solidago sempervirens</i>	seaside goldenrod
<i>Spartina alterniflora</i>	smooth cordgrass
<i>Spartina patens</i>	salt marsh hay
<i>Suaeda maritima</i>	sea blite
<i>Toxicodendron radicans</i>	poison ivy
<i>Vaccinium macrocarpon</i>	cranberry
<i>Xanthoxylum strumarium</i>	cocklebur
<i>Yucca filamentosa</i>	Adam's needle

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