15

# Using Digital Point-Intercept and Sub-meter Navigation to Assess Vegetation Recovery in Fire Island's Wilderness

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## Introduction

After disturbance, ecological assessments are essential to quantify ecosystem impacts and resilience, which usually dictate implementation of treatments and allocation of resources to maximize recovery potential (Miller, Chambers, and Pellant 2015). Rapid assessment methods typically compliment or extend long-term studies, or refine landscape-scale assessments from aerial imagery, and they provide reliable information about the status of the disturbed area (Fennessy, Jacobs, and Kentula 2004). Rapid assessment methods should be simple and reproducible, and should reduce the cost and time spent assessing resource status (Medeiros and Torenzn 2013). We used and validated a rapid assessment method for coastal vegetation recovery after a dune overwash event.

Traditional point intercept methods (TPI) consist of locating plots and manually quantifying vegetation present. Windy conditions make identifying the natural orientation of vegetation in a plot difficult, herein referred to as wind bias (Cagney, Cox, and Booth 2011). In coastal environments, wind bias may be considerable owing to presence of onshore and offshore breezes. Digital point intercept methods (DPI) use a mounted camera to take nadir photographs of plots, which are analyzed using image software (Booth, Cox, and Johnson 2005). DPI is less susceptible to wind bias

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due to camera shutter control (Booth, Cox, and Johnson 2005), and allows for vegetation cover and species frequency quantification using GIS-based tools (Gobbett and Zerger 2014). Other advantages to DPI include increased sample size due to less time invested per plot, and the ability to reanalyze original plot images from digital archives (Chen et al. 2010). We combined DPI with sub-meter GPS navigation to eliminate the need for permanent plot markers and to facilitate rapid movement between plot locations. Because plot locations are georeferenced, both temporal and spatial analyses of vegetation recovery are possible (Legendre and Legendre 1998).

The purpose of this study was to adapt a rangeland vegetation assessment method for recovering coastal vegetation. Our objectives were to explore DPI for rapid assessment of vegetation cover, test sub-meter GPS navigation as an alternative to conventional plot layout procedures, and compare TPI and DPI estimates of vegetation cover among permanent vegetation plots.

## Study area

Fire Island is a barrier island located off the south shore of Long Island, New York, USA (40.6476° N, 73.1459° W). Fire Island National Seashore consists of a mosaic of natural areas, managed by the United States National Park Service (NPS), and 17 private residential communities. Within the National Seashore exists the only federally-designated wilderness area in New York State, the Otis Pike Fire Island High Dune Wilderness (OPWA).

Barrier island physiognomy is characterized by strong ocean to bay stratification of vegetation (Ehrenfeld 1990), and the beach is highly vulnerable to inundation from coastal storm surge and sea-level rise. Before Superstorm Sandy made landfall in October 2012, the primary dune system in the OPWA was 4–15 m high and relatively intact (Hapke et al. 2010). Superstorm Sandy produced an unprecedented storm surge that obliterated sections of the primary dune at more than 10 locations on Fire Island, which carried sand inland and buried existing vegetation (Hapke et al. 2013). Plant species such as American beachgrass (*Ammophila breviligulata*) and beach pea (*Lathyrus japonicus*) will initiate succession in overwashes over time (Ehrenfeld 1990).

## Materials and methods

Using ArcGIS and aerial imagery, we delineated boundaries of nine post-Sandy overwashes. Paired fenced and unfenced permanent plots were randomly placed within each overwash using Carsonite posts. Fenced plots were enclosed using welded wire fence material (2 x 4 in), twelve inches of which were buried to increase stability. All permanent plots were surveyed using TPI and DPI.

We used the *Create Fishnet* tool in ArcGIS (Version 10.1, http://arcscripts.esri.com/, accessed 10 October 2014) to overlay a 10 x 10 m grid within each overwash to identify additional plots for DPI sampling. Optimal grid size was determined using inter-patch distances measured from aerial imagery (Legendre and Legendre 1998).

Permanent plots were surveyed September 22 through 24, 2015 using TPI. A map was used to locate the permanent plots, at which a 1 m$^2$ quadrat was oriented with the post in the southeast corner. The 1 m$^2$ quadrat contained 50 points with a 10 cm north-south interval and 20 cm east-west interval. At each point, a pin flag was lowered vertically to the ground and species presence was recorded if vegetation contacted the pin. The sampling protocol was executed with two people: a vegetation identifier and a recorder. Species presence was entered into a digital database, verified, and used to estimate percent species cover for each plot.

DPI surveys were conducted from September 11–14, 2015. A Canon T3i digital single-lens reflex camera with 18–55 mm zoom lens was mounted 2 m above the ground on an adjustable, aluminum frame with a 1 $m^2$ base (Booth et al. 2004). The camera was placed in the nadir position. Survey date and plot number were written on a dry-erase board, which was placed within the camera extent but outside the quadrat. The camera zoom was adjusted to capture the frame base and dry-erase board (Figure 1). Camera shutter speed was set to 1/2000th of a second to minimize blurring of windblown vegetation, and the shutter was released using a Bluetooth remote. Photographs of each plot were stored for later processing. The protocol was executed with two people: a navigator and a camera frame carrier.

Plot locations were downloaded into a sub-meter, handheld Trimble GeoXT 2008 Series GPS unit with TerraSync. Navigation to plot locations was accomplished by using the realtime, satellite-based augmentation system available through the TerraSync application. Accuracies to less than 60 cm were verified in the field by repeatedly navigating to a known fixed location from approximately 50 m away using the Trimble GPS. A pin flag was inserted into the ground at the plot location, and with the aid of a mounted compass, the camera frame was oriented due north with the pin flag in the southeast corner (Figure 1). A twin-sized bed sheet attached to two 122 cm wooden dowels was used to shade the plot from direct sunlight, which reduced glare and shadows (Cox and Booth 2009).

Post-processing photographs required three main steps: label with survey date and plot number, crop to within the quadrat, and analyze for vegetation cover. A grid of 100 points, twice the number surveyed with TPI, was created using Geospatial Modelling Environment software (Version 0.7.3.0). The grid was placed inside a 5 cm buffer of each image to minimize edge effects. The 100-grid-point file was used as input to PointSampler, an ArcGIS extension that sequentially prompts the user to identify cover at each point using user-defined categories. PointSampler created a tabulated file containing the identified cover category for each point, which was used to compute percent species cover.

We assessed vegetation cover for 30 sets of 100 random points and one set of 100 systematic points on the same photograph to validate the use of systematic points for future analyses. The mean percent cover and 95% confidence interval were computed by species for the 30 sets of 100 random point placements and compared to percent cover derived from the single set of 100 systematic points. For TPI and DPI methods, percent cover was calculated by dividing the total number of contacts of each species by the total number of points and multiplying by 100.

Logistics of DPI and TPI were compared using measured field and data processing times. For TPI, field time included locating permanent plots, aligning the quadrat, removing vegetation from beneath the frame, collecting species contacts, and securing fenced plots before departure. Processing time included transferring species contacts from data sheets to a digital database and verifying each entry. For DPI, field time included navigating to plots, aligning the quadrat, removing vegetation from beneath the frame, and taking a photograph. Processing included renaming photographs, clipping images, identifying species contacts using PointSampler, and extracting the resultant table to a digital database.

Accuracy of TPI and DPI estimates were assessed using a third, independent cover estimation. We selected 30 images containing various amount of beach grass cover, classified images using maximum likelihood classification in ArcGIS into three classes of cover (bare sand, senescent/

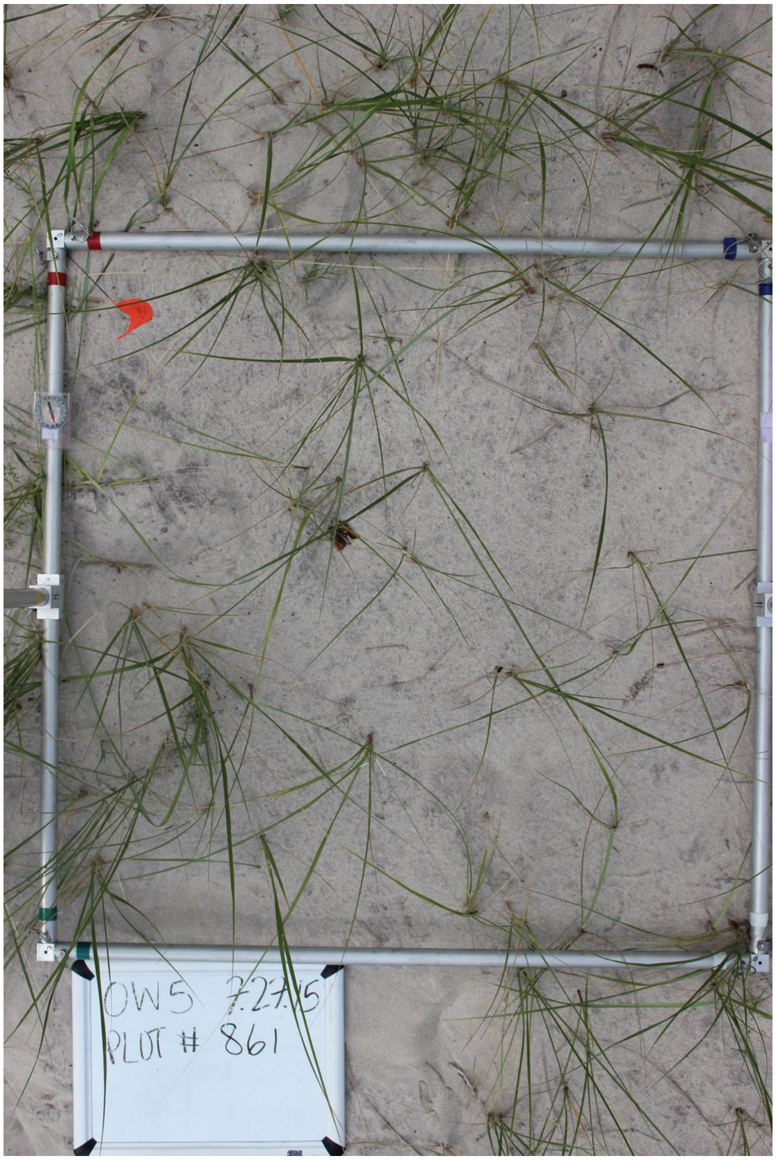


**Figure 1**. An overwash vegetation plot photographed on July 27, 2015. The orange pin flag located in the top-left (southeast) corner was located using sub-meter navigation and the frame was oriented north using a mounted compass.

brown beach grass, and young/green beach grass), and assessed stratified accuracy of classified images (Stehman and Czaplewski 1998). To calculate accuracy, we isolated pixels of each class, created 50 random points in each class (n = 150), identified true and classified cover at each point, calculated confusion matrices for each image (Congalton 2007), removed plots with class-level accuracies less than 60%, and calculated overall accuracy for remaining plots (Stehman and Czaplewski 1998). We used classified images with overall accuracies more than 80% as our basis for truth. Classified images were clipped by 5 cm inside the quadrat perimeter, congruent with the DPI point grid, to test for edge effects. All comparisons were made using standard linear regression.

## Results

Fifty-two permanent plots (19 fenced, 33 unfenced) were surveyed using TPI and DPI. An additional 624 plots were surveyed using DPI. Systematic sampling resulted in cover estimates within the 95% confidence intervals obtained from random sampling (Table 1), therefore systematic points were used to assess vegetation cover for remaining images.

TPI required 2,160 person-minutes in the field and 360 person-minutes for processing, which amounts to 48.4 minutes per plot. DPI required 2,220 person-minutes in the field and 216 person-minutes for processing, which amounts to 3.6 (SE 0.16) minutes per plot. Plot images with class accuracies less than 60% were removed from further analyses. Classified images (n = 25) were, on average, 88% accurate for bare sand and 91% accurate for green *A. breviligulata*. Senescent *A. breviligulata* was occasionally misclassified as bare sand, but 82% of pixels containing senescent *A. breviligulata* were accurately classified.

TPI resulted in higher percent beach grass cover estimation at most cover values compared to DPI (Figure 2a). Percent beach grass cover from classified images showed a strong, positive linear relationship with DPI estimates (Intercept 3.32 (SE 1.97), Grass 0.85 (SE 0.04), Figure 2b). Regression of percent *A. breviligulata* cover from clipped, classified images on DPI estimates (Figure 2c) revealed an intercept not different from zero and slope not different from unity (Intercept 1.30 (SE 1.59), Grass 0.94 (SE 0.03)), indicating removal of a significant edge effect.

## Discussion

We documented an order of magnitude difference in time required to collect and process vegetation cover between DPI and TPI methods. Consequently, we were able to incorporate substantially more spatial replicates and achieve greater coverage of each overwash using DPI. Like Booth et al. (2005) and Cagney, Cox and Booth (2011), digital methods required significantly less processing time than traditional methods. We demonstrated wind bias in TPI estimates of cover relative to DPI, which was ameliorated in DPI estimates by use of camera shutter priority (Booth et al. 2004).

Although DPI surveys preceded TPI surveys by ten days (less than 200 GDD), we discount the elapsed time as a significant source of bias in cover estimates. Experience in the OPWA shows that peak vegetation biomass occurs in July and senescence is only substantial after mid-October (Dilustro and Day 1997). Other potential sources of bias for DPI include inaccurate vegetation identification due to fuzzy edges or shadows, lack of ability to assess multi-layer vegetation, edge effects, and observer bias (Chen et al. 2010).

We minimized inaccurate identification from fuzzy vegetation edges by using high-resolution images (18 mega-pixel quality). Shadow attenuation using multiple high-dynamic-range (HDR) images was problematic; high winds make perfect alignment of multiple images difficult (Cox and Booth 2009), increasing the presence of fuzzy edges. We chose instead to shade the plot in the field (Booth et al. 2004), which eliminated glares from direct sunlight and lessened extreme contrasts.

**Table 1.** Average percent cover of bare sand, *A. breviligulata* (AMBR), and litter, including 95% confidence limits, for the same vegetation plot derived from 30 replicates of 100 random points compared to a single replicate of 100 systematic points.

| Cover | Random Sample | | | Systematic Sample |
|---|---|---|---|---|
| | Average Estimate | LCL | UCL | Estimate |
| Sand | 73.9 | 71.9 | 76.0 | 76 |
| AMBR (young/green) | 19.7 | 17.8 | 21.5 | 18 |
| AMBR (senescent/brown) | 5.9 | 4.9 | 6.9 | 6 |
| Litter | 0.1 | 0 | 0.2 | 0 |

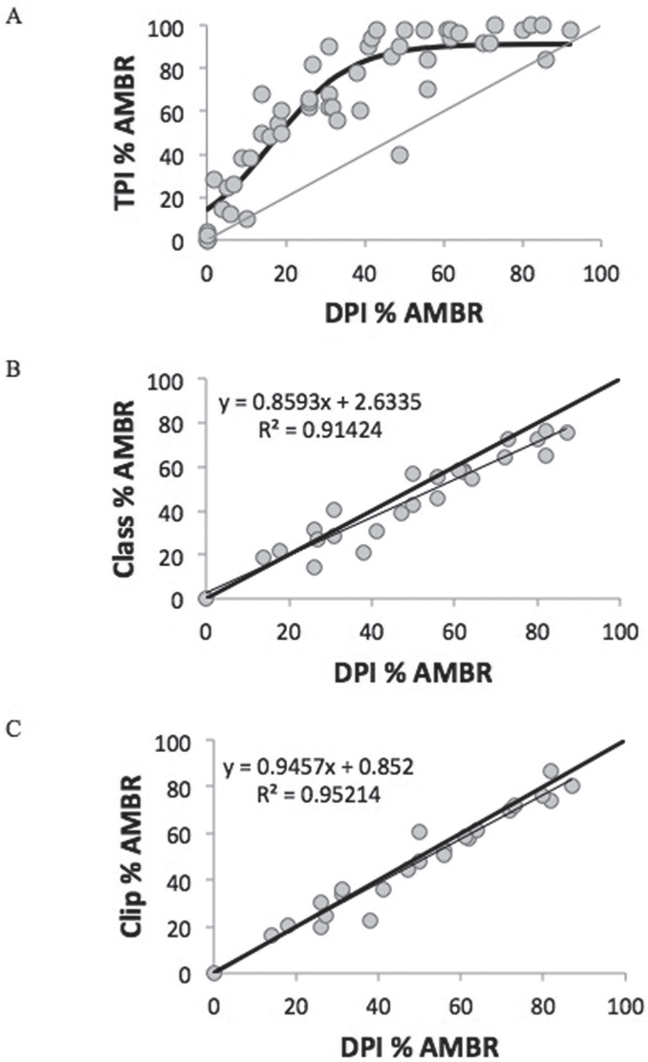


**Figure 2**. Regression of *A. breviligulata* cover estimated from traditional point intercept methods on cover estimated from digital point intercept methods (A), classified *A. breviligulata* cover on digital point intercept cover (B), and cover of *A. breviligulata* estimated from clipped, classified images on digital point intercept cover (C). The thin, grey line indicates a 1:1 relationship. The ordinary, non-linear least-squares curve-fit is shown in A and simple linear regression equations are shown in B and C.

DPI methods are only accurate for single-layer vegetation as some plants near the ground could be obscured from view in the nadir image. The vegetation we assessed was predominantly present in one layer due to prostrate growth forms of many coastal plants (Stuckey and Gould 2000) and the sparsely populated nature of recovering overwashes. In a few instances, particularly along the edges of overwashes, grasses, forbs and shrubs overlapped, creating multi-layered vegetation. In these cases, obscured vegetation was identified in the field and recorded as present in the plot. As we do not expect rapid shrub encroachment into overwashes, we believe DPI is suitable for future monitoring.

Edge effects were revealed in the classification of the plot photographs. Dislodging beach grass from under the camera frame reduced estimated cover inside the 5 cm buffer along the quadrat perimeter, especially in plots with substantial cover. The effect measured was not a removal of grass within the frame, but rather a redistribution of leaves in such a way that created a greater chance for missed contacts (i.e., clumping). Edge effects were potentially present in TPI estimates, but were not quantifiable due to a lack of archival data. Observer bias was minimized by using a well-trained team with clearly defined roles (e.g., navigator and facilitator). Species identification was verified by at least two additional qualified specialists to ensure accuracy, and image classification was conducted by one observer.

In conclusion, TPI is useful for temporal analyses of relative vegetation cover, particularly where multiple layers of vegetation are present. TPI estimates may be easily corrected for wind bias using an equation derived from another method, such as DPI. DPI requires less post-processing for accuracy, saves time in the field, allows for larger sample sizes, reduces wind bias, minimizes edge effects, and allows for future and comparative analyses of archived plot images. We recommend the use of DPI methods in coastal and windy environments where single-layer vegetation predominates. Sub-meter navigation was sufficient, but finer-scale research questions may require permanent plot markers to ensure precision and accuracy of cover estimation at a particular location. An extension of DPI using unmanned aerial vehicles for locations with accessibility concerns is ripe for investigation.

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