Point Density Requirements for Assessing Salt Marsh Elevation

Using Real-Time Kinetic Surveying and Empirical Bayesian Kreiging GIS Analysis

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Introduction

Assessing the vulnerability of salt marshes to drowning due to sea level rise and increased inundation is a complex process. One important component is elevation, which requires high resolution topographic survey data of the marsh platform and the complex sloping features of the edge and inter-marsh creek systems. Available LiDAR as been used to assess marsh elevation, but due to limitations of the technology and complex features of the salt marsh habitat, questions have arose concerning its accuracy in this habitat. RTK-GPS survey data has been shown to be highly accurate, but collecting these data can be time consuming, and it is important to understand the collection resolution needed to capture these data while avoiding redundant information. In 2014, The Partnership for the Delaware Estuary, The Nature Conservancy, and Natural Lands Trust assessed the vulnerability of three representative salt marshes in the Delaware Bayshore region of New Jersey. A pilot study was conducted to assess the point density, and therefore survey time, needed to characterize the elevation profiles of these marshes.

The goal of this effort was to find the sampling density which maximizes data and spatial coverage while minimizing resource, or time, investment. Outcomes are considered in the context of vegetation vulnerability assessments and restoration planning needs.

Methods

Site Selection

To assess the point density needed to characterize a salt marsh platform, it was important to select a study site that would not under represent the complexity (hummock/hollow formations, intra-marsh creeks, slopped edges and levee), thus biasing the point density needed to a lower value. The site selected was an 5000m^2 area of salt marsh at Money Island, NJ (Fig. 1) which included all complex formations listed above.

Data Collection

An RTK GPS was used to take 789 elevation measurements along transects across a 5000m^2 area of complex salt marsh platform (Fig. 1). This density of points was the highest number possible to be taken in one tidal cycle, limited by the speed of the instruments combined with the difficulty of moving across a salt marsh. A higher density of points was taken in "transition areas" (clustered collection technique) including: creeks, marsh edges, and other steep changes in elevation.

Three point density datasets are compared in this analysis:

- **All Points**: 798
  - -Original dataset, full resolution
- **Half Points**: 399
  - -every other point removed from all points, 1/2 resolution
- **Quarter Points**: 200
  - -every other point removed from half point, 1/4 resolution

Elevation Interpolation

We used Empirical Bayesian Kriging, a geostatistical tool in ArcGIS 10.2.1, to interpolate an elevation surface (Figs. 3-5) and associated predicted error (Figs. 6-8) for each dataset (default parameters). Each interpolated surface with EBK gives outputs of predictive performance (Figs. 12 & 13) of the model created from each point density dataset.

Analysis

Elevation Comparison: RTK vs. LiDAR

LiDAR is known to be problematic for assessing fine scale (cm) salt marsh elevation due to its inability to penetrate dense salt marsh plants. In order to compare RTK resolution, LiDAR was obtained for the study area to calculate elevation error. The RTK points were laid over the LiDAR and ArcGIS map algebra was used to calculate the difference in elevation difference between the two datasets (Fig. 2).

Model Cross Validation

Predictive capability of interpolated models were compared using EBK tool outputs. EBK statistics for each model are generated by process of removing a point of known value one at a time and comparing to the interpolation at that point. This generates estimates of model error (Figs .12 & 13).

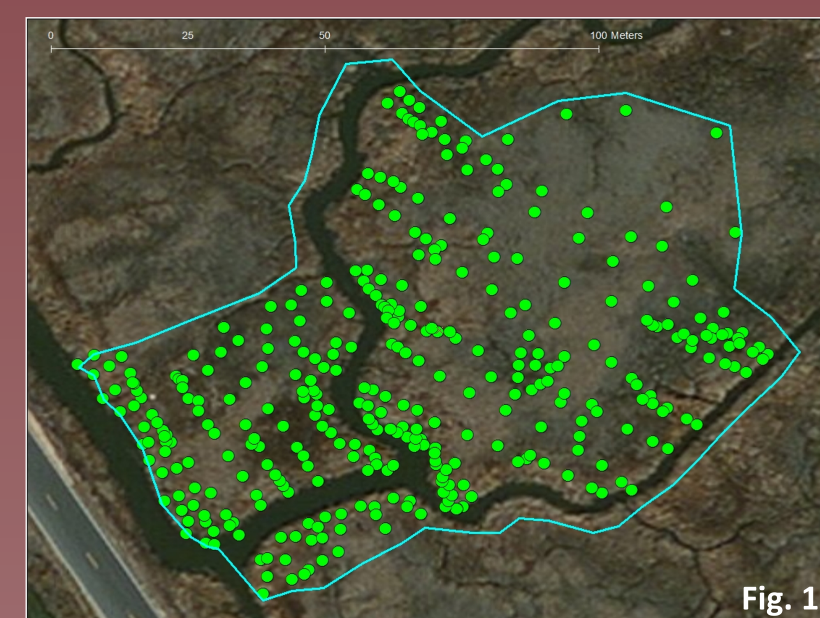

Fig. 1

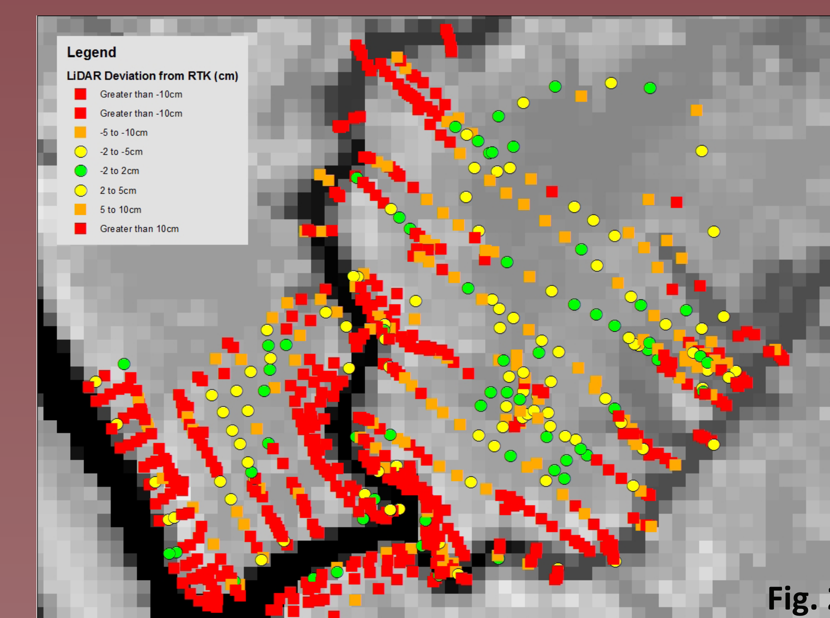

Fig. 2

789 Points | 399 Points | 200 Points

Elevation Interpolation / Predicted Error / Dispersion

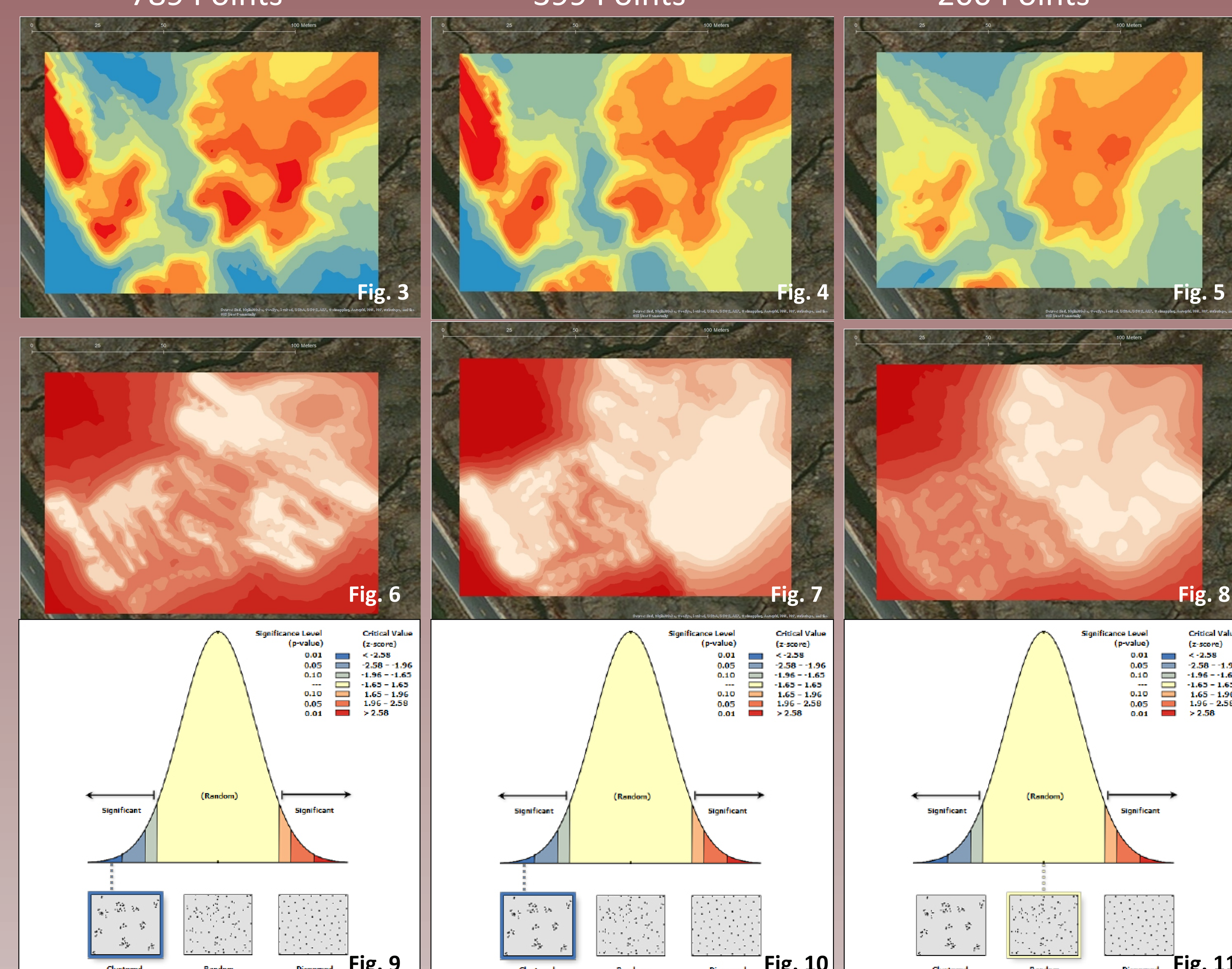

Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9, Fig. 10, Fig. 11

Elevation Interpolation Maps
Interpolated elevations compared between the three simulations.
Reds = High Elevation
Blues = Low Elevations

Estimated Error Maps
Predicted standard error associated with model interpolation.
Red = High Error
White = Low Error

Nearest Neighborhood Analysis
Describes the dispersion of the points used for model selection. Our goal was to have a clustered grouping to be more able to describe areas of the marsh with high topographic variability; potential areas of transition.

Model Comparisons

Fig. 12

Fig. 13

Results: Elevation Comparison RTK vs. LiDAR

Results showed that 82% of the LiDAR elevations deviated by more than 5cm from the RTK elevation measurements (Fig. 2). Elevations that were within 5cm accuracy tended to be located on the topographically less complex high marsh platform, while measurements along the sloping edges of the low marsh and inter-marsh creeks almost uniformly deviated by more than 10cm.

Conclusion: An error range of 5-10 cm for LIDAR was considered unacceptable for local site project planning due to the sensitivity of marshes to small changes in elevation, and hence on-the ground RTK elevation surveys are recommended for high resolution data until more advanced aerial survey technologies are available.

Results: Model Comparison

Figure 3 visualizes the predicted surface elevations from the All Points model across the marsh platform. These results represent the highest resolution topography available with the data collected. The Half Point Interpolated surface map (Fig. 4) shows a similar pattern of higher elevations on the marsh platform and decreasing elevations moving creek-ward. Creeks appear well defined. Comparison between high and half point densities revealed minimal elevation prediction error differences between the models. The QQ plots had no outstanding tail and appeared normally distributed. Prediction errors were also similar and within satisfactory ranges (Fig. 12).

As the point density was further reduced to 200 (Fig. 5), areas of highest elevations on the marsh platform have been eliminated and transition areas moving creek-ward have also lost resolution. Similarly, predicted standard error in the All Point s and Half Points models appear lower (Fig. 12) than in the Quarter Points model (Fig. 13). Half and quarter point density model comparison exhibited greater discrepancies (Fig X). The QQ plot for the Quarter Point model exhibits a skewed tail, indicating that it is falling out of normality and there is an increase in the root mean square error.

Interestingly, the Half Point predicted error map depicts lower predicted error across the high marsh areas than in the All Points map (Figs. 7 & 8). This may be an artifact of removing the micro hummock/hollow topography on the high marsh platform.

Nearest Neighbor Analysis revealed high and half point density models retained clustered point densities ($p < 0.5$) necessary to predict complex topographic changes, while the quarter point model exhibited a random distribution ($p > 0.5$) Typically, the majority of salt marsh area is comprised of vast expanses of high marsh, with a lower percentage of sloping transition areas along the marsh edge and intra-marsh creeks. It is important to map these edge in a clustered manner so that they are not under represented in model and may represent significant areas of risk and focused projects. The point resolution in the Quarter Point model was reduced to the extent that it no longer appeared clustered, but was random (Fig. 11).

Conclusions: When compared to the All points elevation interpolation map (Fig. 3), the Half Point this map appears to show a similar pattern of higher elevations on the marsh platform in similar areas, and decreasing elevations moving creek-ward. Since Prediction Errors are similar, nearest neighbor analysis indicates clustered spreading of points in both, and maps appear visually similar, it was determined that no increase in elevation spatial resolution was gained by collecting more than 400 points/5000m^2 (half point density). As this marsh was a topographically complex salt marsh it was determined that an RTK sample density at around 400 points per 5000m^2 was adequate to produce high quality interpolations across the marsh surface. This was one representative marsh and similar studies should be preformed in marshes of different character to gauge whether this recommended point density is broadly relevant.

Acknowledgements: Our partners at **The Nature Conservancy**, **Natural Lands Trust** and the **New Jersey Recovery Fund**. Special thanks for field support from Moses Katkowski and Jacqueline Jahn, and GIS support from Megan Boatright and Diane Rosencrance. Funding for this project was provided by **Bayshore Sustainable Infrastructure Planning Project** (BaySIPP) and funded by the grant, "Creating a Sustainable Infrastructure Plan for the South Jersey Bayshore"