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Quantifying Tidal Marsh Channel Density and Distance as a Tool for Describing Vegetation Patterns

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INTRODUCTION AND OBJECTIVES

Fig 1. Vegetation along channels on Coon Island, a brackish tidal marsh

The interaction between hydrology and geomorphology is the critical physical process affecting wetland dynamics. Tidal action influences wetlands at several scales, from seasonal and regional variation in tidal action and salinity to within marsh variation modified by local geomorphology, such as depth and duration. This heterogeneity in system processes is reflected in variations of vegetation diversity and productivity. Brackish tidal wetlands, in particular, reveal a complex expression of this heterogeneity.

We wanted to test the hypothesis that the inundation regime, which is affected by proximity to channels, elevation, tides, drainage characteristics, and salinity, drives plant heterogeneity in brackish tidal wetlands in San Francisco Bay and proposed that it is a major forcing function on plant community diversity. To test this hypothesis, we needed to quantify both plant diversity and some measure of hydrologic heterogeneity. Because heterogeneity in these marshes is defined primarily by the tidal channel network, several indices of channel density and distance to channels were developed and tested against vegetation data at known locations. We assessed these indices to determine which most accurately describes plant diversity patterns.

METHODS

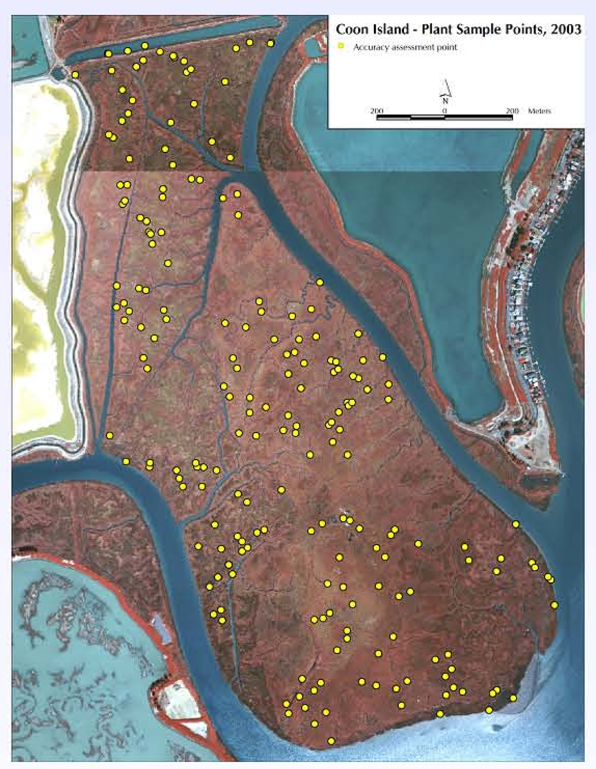

Fig 2. Coon Island map with random point locations

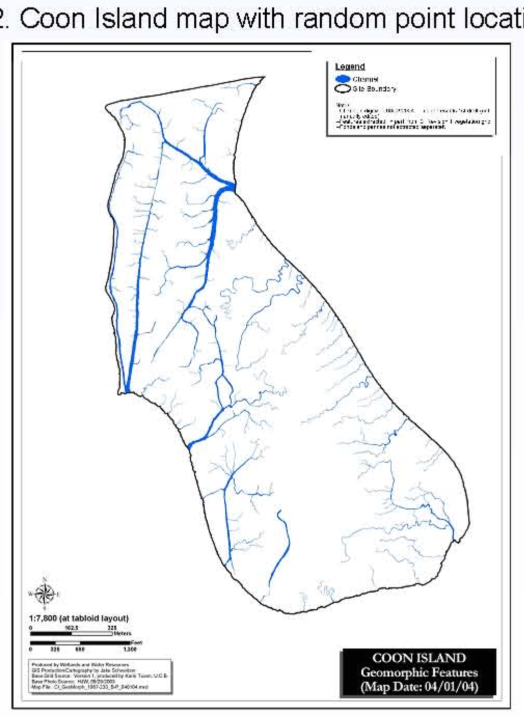

Fig 3. Channel distribution on Coon Island

Our research focused on one of the six IRWM field sites, Coon Island, located along the Napa River. We visited 198 random points throughout the site that were stratified according to preliminary vegetation classes. We recorded the vegetation present and the relative percent cover.

We created a channel network GIS dataset based on Fall 2003 orthorectified CIR aerial imagery. We then developed four GIS-based methods to quantify channel density and distance to channels. Channel density refers to how much of given area is channel, whereas channel distance conveys how far away a channel is to a point. To develop indices of channel density and proximity, we used the ArcInfo GRID module to generate 1-m grid surfaces representing the following metrics:

- Spatial drainage density (m^2/m^2)
- Euclidean normalized distance to nearest channel of any size
- Cumulative inverse-weighted distance to nearest channel of any size

For the fourth metric, we generated the straight-line distance from each point to the nearest channel using ArcView 'Nearest Features' extension.

For each vegetation point, the underlying grid values for each of the metrics were obtained directly or via a spatial overlay function.

We conducted a multivariate analysis using canonical correspondence analysis (CCA) to determine which channel density metric yielded the most ecologically meaningful characterization of geomorphic heterogeneity.

RESULTS

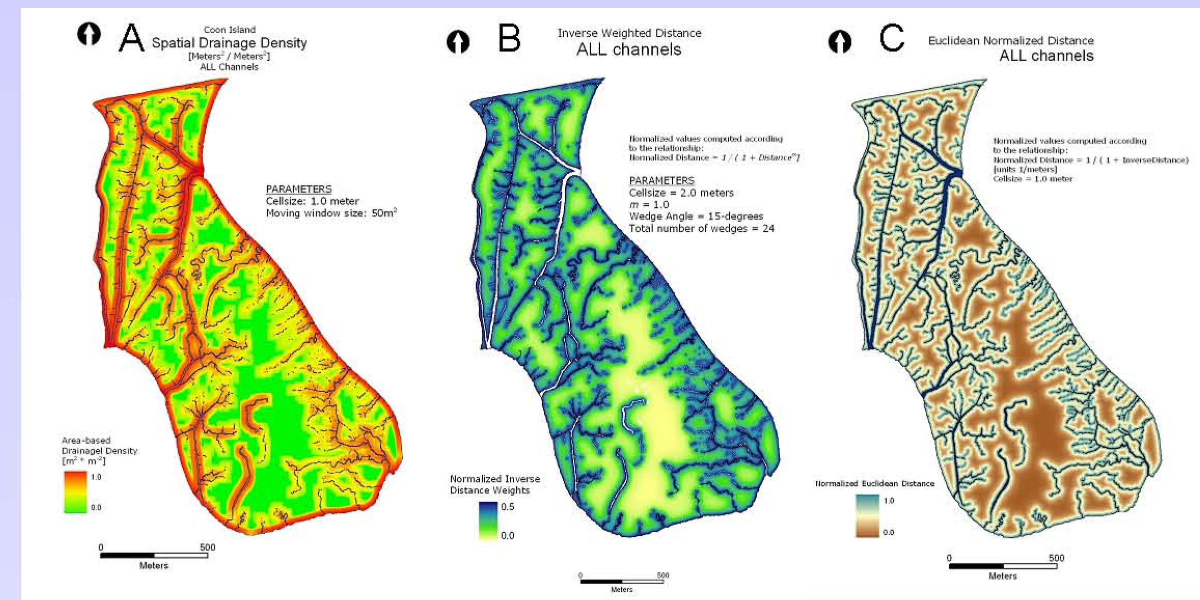

Fig 4. Visual representation of the channel density metrics on Coon Island for (a) spatial density, (b) inverse weighted distance, and (c) Euclidean normalized distance.

Table 1. Correlations and biplot scores for each channel density metric. Larger correlations and biplot scores connote a stronger relationship. Biplot scores represent the direction of the trend on the ordination plot.

	Correlations			Biplot Scores		
Variable	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 1**	**Axis 2**	**Axis 3**
Euclidean Normalized Distance	-0.528	0.24	0.052	-0.18	0.05	0.009
Inverse Distance	-0.849	0.209	0.485	-0.289	0.044	0.083
Spatial Density	-0.743	0.306	-0.593	-0.253	0.064	-0.101
Straight-line Distance	0.83	0.535	0.021	0.283	0.112	0.004

Table 2. Ordination scores for plant species based on the CCA model. Negative Axis 1 scores connote a positive relationship to channel density and/or proximity.

	Rucr	Lajj	Grst	Scca	Poan	Jaca	Lela	Acmi	Scac	Juba	Scam	Savi	Scma	Tyan	Trma	Disp
Axis 1	-3.88	-3.77	-3.18	-2.45	-2.19	-2.08	-1.89	-1.66	-1.61	-1.43	0.26	0.34	0.44	0.75	0.86	1.94
Axis 2	1.38	-1.19	0.86	1.35	-1.71	1.88	-2.22	-1.34	-1.67	-4.22	-0.29	0.94	-0.51	-1.17	0.89	-0.23
Axis 3	-5.04	6.29	0.23	-4.61	-0.31	2.27	4.08	-5.69	-1.26	2.46	0.40	0.19	-0.51	0.28	-3.40	-0.25

Table 3. Overall CCA model summary statistics.

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.134	0.046	0.03
% of variance in species data explained by channel density values	3.5	1.2	0.8
Cumulative % of variance explained	3.5	4.7	5.5
Pearson Correlation	0.612	0.31	0.332
Kendall (Rank) Correlation	0.307	0.18	0.183

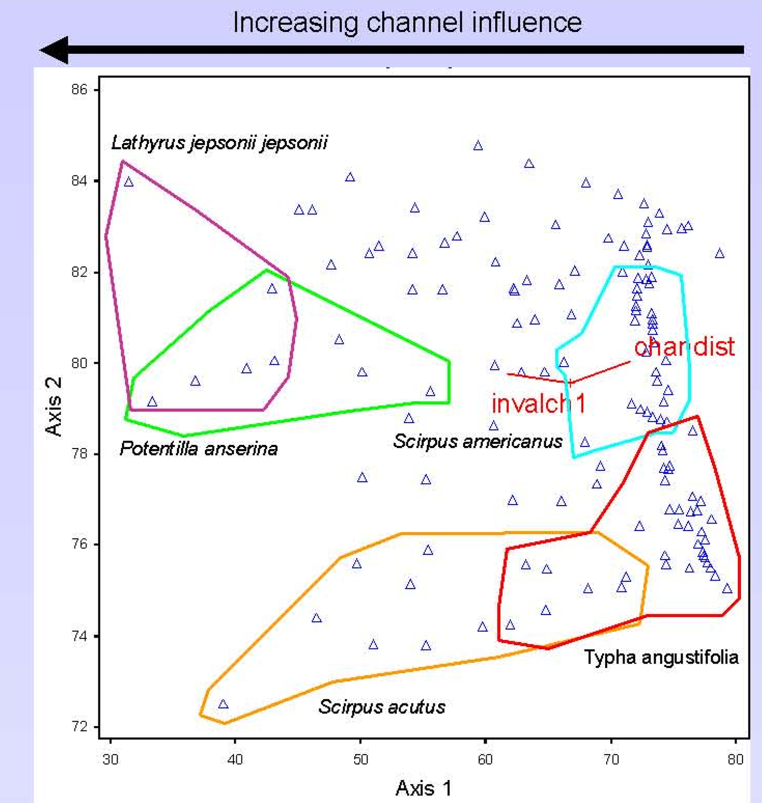

Fig 5. Ordination plot of plant relevé points plotted with the best-fitting channel density and distance vectors. Each point represents one relevé point and each color-coded circle represents the relative distribution of a species across all points. The dominant species, *Scirpus maritimus* and *Salicornia virginica*, were widespread.

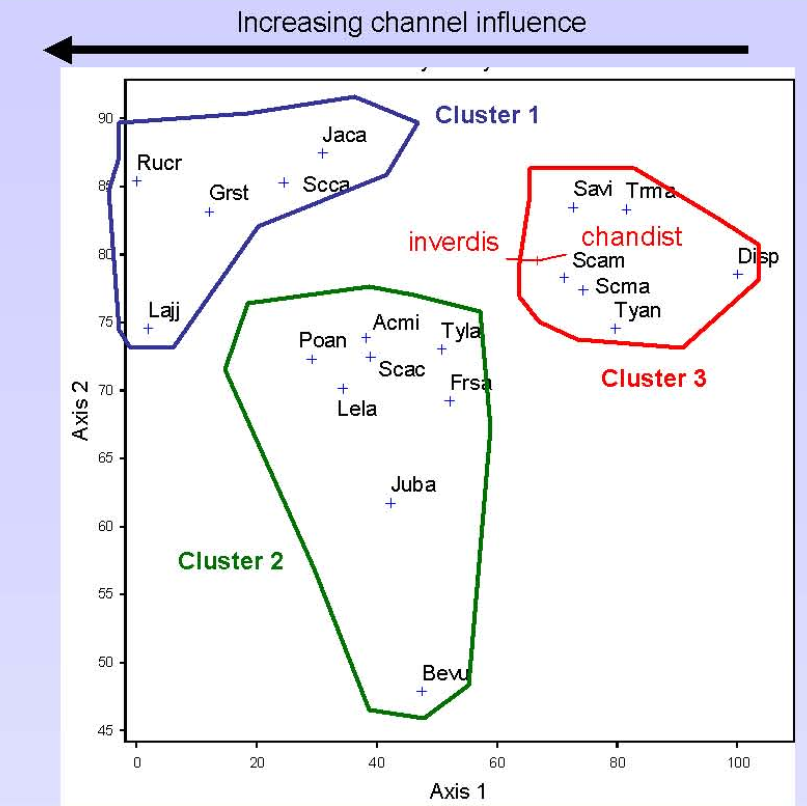

Fig 6. Ordination plot of species based on presence and abundance and their relation to the best fitting channel density vectors. Cluster 1 represents species at channel edges, cluster 2 refers to species close to channels, and cluster 3 represents species that are away from channels.

Computational demands varied greatly among channel density and distance estimation methods. The inverse distance weighted grids were the most computationally and time intensive, requiring 8-10 hours of computer processing. The density grids were the next most intensive, requiring an hour to complete the calculations. The Euclidean distance and straight-line distance computations were comparatively quick to generate, taking less than 10 minutes to calculate.

The inverse distance and straight-line distance metrics fit the vegetation the best (Table 1; Figs. 4 & 5). The vectors were roughly parallel to Axis 1. Some plant species showed a strong relationship with channel density, both positive and negative, whereas others had little to no relationship (Table 1; Figs. 5 & 6). Little of the variance in vegetation distribution, however, was attributed to channel density alone (Table 3).

DISCUSSION AND CONCLUSIONS

A relationship exists between wetland vegetation and channel density and/or proximity; however, the relationship is not strong. Considerable variance remains unexplained, which is probably due to the high species diversity on Coon Island and the relationship to other geomorphic characteristics, especially elevation and salinity, that were not incorporated into this analysis. In contrast to the vegetation as a whole, certain species commonly seen along channels were associated with the channel density/proximity metrics, including *Grindelia stricta*, *Rumex crispus*, *Scirpus californicus*, and the rare species, *Lathyrus jepsonii jepsonii*. The simplest metric, the straight-line distance to channel, performed equally to the more computationally intensive metrics, suggesting that this methodology could be readily and effectively utilized. While measures of channel distance and density alone are not sufficient to be predictive, the results suggest that geomorphic and water quality metrics can be developed to determine the processes best correlated with brackish tidal marsh vegetation.

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