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REFERENCE WETLANDS FOR ASSESSING WETLAND MITIGATION PROJECTS: WHEN IS ONE NOT ENOUGH?

Background

Reference wetlands, defined as natural wetlands usually of high ecological integrity, are critical for assessing the “success” of mitigation wetlands in replacing wetlands lost by impacts permitted under section 404 of the Clean Water Act (Figure 1). Brinson and Rheinhardt (1996) define reference wetlands as *sites within a specified geographic region that are chosen for the purposes of functional assessment, to encompass the known variation of a group or class of wetlands, including both natural and disturbance mediated variations.*”

For a given mitigation project, reference wetlands may consist of a single wetland, a *reference pair*. Or it may be a subset of the population of reference wetlands, also known as *reference standards*, defined as “*the subset of reference wetlands that correspond to the highest level of functioning of the ecosystem across a suite of functions*” (Brinson and Rheinhardt 1996). Functions related to hydrology, biogeochemistry, plant habitat and animal habitat (Brinson et al. 1995) are compared in mitigation and reference wetlands to determine the degree to which mitigation wetlands replace wetland functions lost when



Figure 1. A natural *Spartina alterniflora* salt marsh along the coast of Georgia.

Section 404 permits are issued. The Functional Capacity Index (FCI), the ratio of the functional capacity of a mitigation wetland with the functional capacity of a reference standard, **per unit area**, is used to determine if and to what extent the mitigation wetland provides the same level of function (e.g. frequency of overbank flooding) as the reference standard (Smith et al. 1995). The Functional Capacity Index ranges from zero (no function) to one (100% function).

When evaluating wetland mitigation projects, how does one decide whether to use a single reference wetland or multiple reference wetlands, that is, a population of relatively unaltered wetlands of the same class, for comparison? The advantage of using a single proximal reference wetland is that it presumably is exposed to the same suite of environmental conditions (hydrology, water quality, land use) as the mitigation site. The advantage of using multiple reference wetlands, on the other hand, is that it captures the natural variation inherent in the population of relatively unaltered wetlands that is not accounted for by using a single reference wetland. In essence, the paired approach controls for local environmental conditions because the matched pairs are in close proximity to each other. Alternatively the reference population approach compares a single mitigation site against the variation among a range of spatially distributed sites.

Study Goal

We compared vegetation- and soils-based performance standards that were used to gauge the success of tidal salt marshes created for mitigation (Figure 2) using both a single reference salt marsh, a *refer-*



Figure 2. A created *Spartina alterniflora* salt marsh (top) and a natural *Spartina alterniflora* reference marsh (bottom) along the North Carolina coast.

ence pair, and a population of relatively unaltered salt marshes, a *reference population*. Success is here defined as the attainment of structural and functional characteristics similar to the reference marsh(es) but individual mitigation projects may have additional requirements including binding permitting requirements and other standards that are part of a comprehensive monitoring program. The marshes were created for a variety of reasons, including compensatory mitigation but also for dredge spoil stabilization, shoreline erosion control and research. Our goal was to assess whether a single, proximal reference marsh, is adequate for gauging success of the created marshes or whether a population of relatively unaltered reference marshes from the region is superior.

“SALT MARSHES PROVIDE CRITICAL ECOSYSTEM SERVICES, INCLUDING FOOD WEB SUPPORT, WATER QUALITY IMPROVEMENT AND DISTURBANCE REGULATION TO THE WORLD’S GROWING COASTAL POPULATIONS.”

Study Area

Our study sites, both created and natural tidal salt marshes (Figure 2), are located on North Carolina (NC) along the southeastern U.S. coast (Figure 3). Salt marshes are widely distributed in temperate regions of the world and are found on every continent except Antarctica. They provide critical ecosystem services, including food web support, water quality improvement and disturbance regulation to the world’s growing coastal populations. The primary productivity of salt marshes supports food webs of estuarine finfish, shellfish, and waterfowl. They maintain and improve water quality by trapping sediment, nutrients and pollutants. Salt marsh soils also sequester carbon and emit little in the way of greenhouse gases, especially methane.

We collected our data from eight created marshes and eight natural marshes, each natural reference marsh pair either adjacent or in close proximity to its created marsh. All marshes are inundated twice daily by the tides with a salinity of 20 to 30 parts per thousand (psu) (Seawater salinity is 35 psu). They all are dominated by the native species smooth cordgrass, *Spartina alterniflora* (Loisel). The natural marshes are much older than the created marshes, from several hundred to several thousand years old based on dating of soil cores using ^{210}Pb and ^{14}C . For a more detailed description of the sites, see Craft et al. 2003.

Methods

We used several performance standards for comparison: aboveground biomass, stem height & density, macro-organic matter (MOM) – the living and dead root and rhizome mat, and soil organic carbon (C) and nitrogen (N). These are reflective of biological production, habitat, food web support and water quality improvement, respectively. One-time measurements were made in eight created marshes of varying age and their respective natural marsh reference pair.

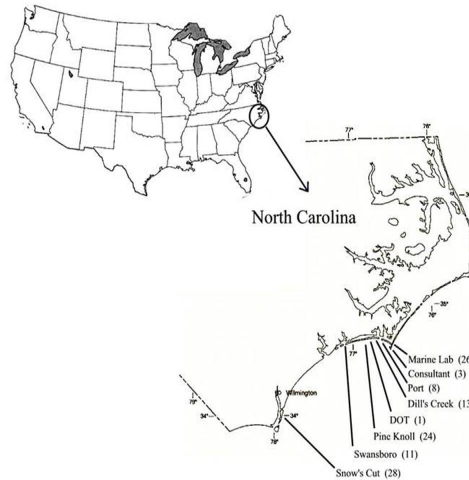


Figure 3. Map of the North Carolina coast showing the location of our eight created and eight paired natural reference marshes (from Craft et al. 2003).

Aboveground biomass was sampled by harvesting material from 0.25 m² plots (n=10 per site), drying the biomass and weighing it. Stem height was determined from measurements of the five tallest stems in each quadrat. Macro-organic matter was collected using a soil corer, 8.5 cm diameter by 30 cm deep. Cores were sieved through a 2 mm mesh screen and the root/rhizome material was collected, dried at 70°C and weighed. Soil organic C and N were sampled by collecting 30 cm deep soil cores and measuring percent organic C and total N using a CHN analyzer. Soil bulk density (g/cm³) was measured by drying a subsample at 105°C, weighing it and dividing the weight by the volume of the core. These data were used to calculate soil organic C and N pools (g/m²) in the top 30 cm, biologically speaking, the most important part of the soil profile.

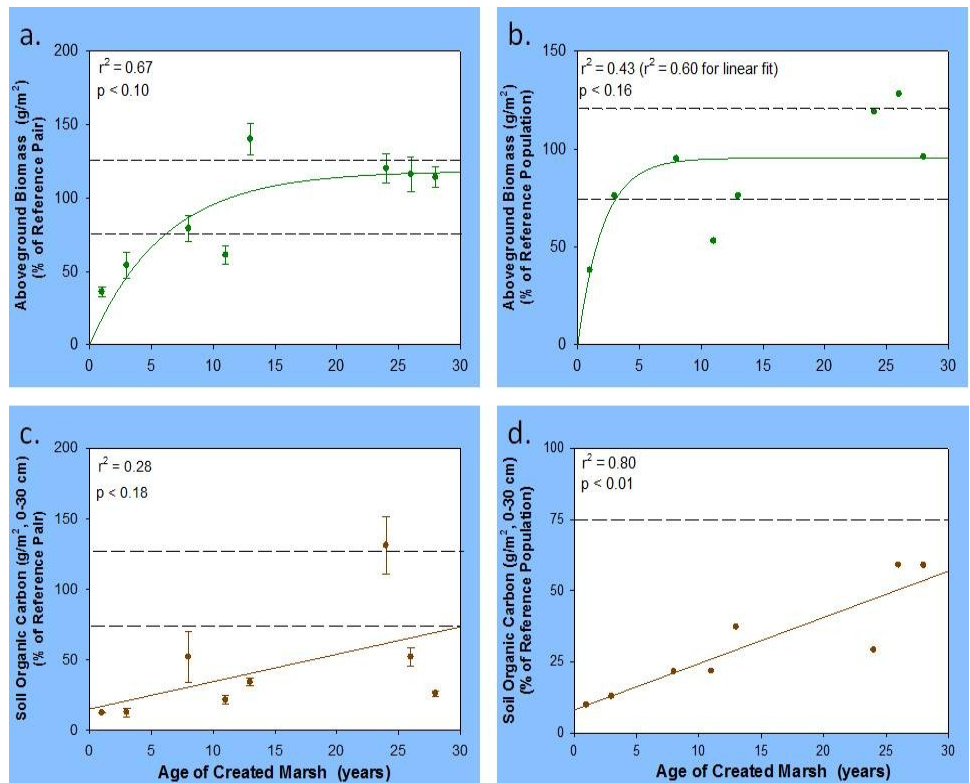


Figure 4. Regressions of *Spartina* aboveground biomass and soil organic carbon against created marsh age when comparing against a reference pair (a,c) and a reference population of eight marshes (b,d). Error bars on a,c represent standard errors of the mean. Dashed lines represent the 75th and 125th percentiles.

“THE REFERENCE PAIR APPROACH IS BEST SUITED TO TRACK DEVELOPMENT OF ABOVEGROUND PERFORMANCE STANDARDS WHILE THE REFERENCE STANDARD APPROACH IS BETTER FOR TRACKING THE DEVELOPMENT OF BELOWGROUND STANDARDS.”



Findings

Predicting the level of performance over time to determine if created tidal salt marshes are performing as well as natural tidal salt marshes varied depending on whether the *reference pair* or *reference population* approach was used. For example, the *goodness of fit* (r^2) of regressions of aboveground biomass (Figure 4) and stem height versus created marsh age were greater when comparing against the *reference pair* (Table 1). In contrast, the r^2 of regressions of belowground performance standards, MOM and soil organic C (Figure 4) and N pools, versus age were greater when comparing against the *reference population* (Table 1). Thus, for aboveground performance standards, the *reference pair* may be a better predictor because of site specific differences in elevation, wave climate, soil properties (e.g. nutrients) and other factors that affect *Spartina* growth. For belowground performance standards such as MOM and soils that take longer to develop than aboveground vegetation, reference marsh age may be a more important factor for determining the relative equivalence than the environmental factors mentioned above.

Performance standards, except for aboveground biomass (Table 1), exhibited a linear response with created marsh age. Some performance standards were better predictors of equivalence than others. For example, aboveground biomass and stem height were good predictors when compared against the *reference pair*. Stem density was not a good predictor, regardless of the approach used. Belowground perform-

ance standards, MOM and soil organic C and N pools, were even better predictors but only when comparing to the *reference population*. This finding is important because both MOM and soil organic C have been successfully used as indicators for more difficult to measure functions such as microbial activity (i.e. decomposition), biogeochemistry (CO₂, CH₄ fluxes), water quality improvement (denitrification) and food webs (benthic infauna) (Craft and Sacco 2003, Craft et al. 2003).

Significance

1. The performance standards described above are relatively easy to measure and they provide more information on development of wetland structure and function than performance standards required by most U.S. Army Corps of Engineers (COE) mitigation permits.
2. Our performance standards, with the

exception of stem density, exhibit predictable trajectories, increasing over time and, thus, are useful metrics for gauging the success (or failure) of salt marsh mitigation projects.

3. The *paired reference* method is best suited to track development of aboveground performance standards. The *reference standard* approach is better for tracking the development of belowground standards, MOM and soil organic C and N pools.

4. Regardless of the choice of reference methods, the five year monitoring plan advocated by the COE and EPA is not long enough to determine whether salt marsh mitigation and other wetland mitigation creation projects are successful in replacing wetland functions and values that are lost when natural wetlands are lost to development activities.

Table 1. Regressions of created marsh *Spartina alterniflora* stem height, stem density, macro-organic matter, and soil N versus age when comparing against a reference pair and a reference population of eight marshes.

	Percent of Reference Pair			Percent of Reference Population		
	Trajectory	r ²	Years to Equivalence	Trajectory	r ²	Years to Equivalence
Stem Height (cm)	Linear	0.70 (p = 0.01)	10	Linear	0.50 (p = 0.05)	1
Stem Density (Number/m ²)	None	0.01 (p = 0.92)	1	None	0.01 (p = 0.94)	1
Macro-Organic Matter (g/m ²)	Linear	0.48 (p = 0.05)	15-20	Linear	0.88 (p = 0.001)	15-20
Nitrogen (g/m ²)	Linear	0.33 (p = 0.14)	>30	Linear	0.69 (p = 0.01)	>30

Additional Information

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About the Author(s):

Christopher Craft is the Duey-Murphy Professor of Rural Land Policy at the School of Public and Environmental Affairs at Indiana University, Bloomington. In addition to restoration and ecosystem development, his research interests include wetlands and (1) soil-vegetation processes including carbon sequestration, (2) water quality and (3) climate change.

Anya Hopple is a Bachelor of Science (Environmental Science) student in the School of Public and Environmental Affairs at Indiana University, Bloomington.

Contact Information:

Christopher Craft
Indiana University
702 N. Walnut Grove
MSB II Room 408

Phone: (812) 856-1837
E-mail: ccraft@indiana.edu

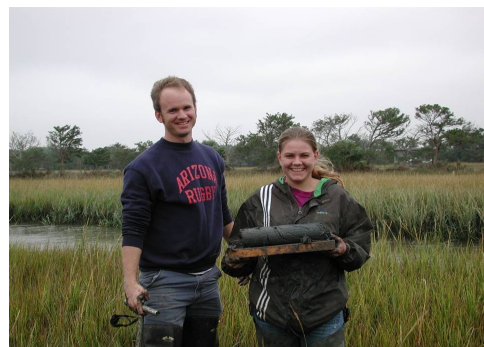


Figure 5. Students, Josh Hall and Jillian Bertram, collecting soil cores for organic C and N analysis...Nice catch!

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Karen L. McKee
mckee@usgs.gov