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SIMULATED SALT MARSHES: METHODS FOR REDUCING EXPERIMENTAL ERROR[1]

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Abstract.--The dynamic nature of southern California salt marshes complicates prolonged field experiments. To create a more predictable system for manipulative experiments, we constructed artificial saltmarsh mesocosms at an outdoor laboratory. Construction, maintenance, and applications are reviewed.

INTRODUCTION

Southern California salt marshes are highly variable due to both natural and man-caused disturbances. Tijuana Estuary has experienced several environmental extremes in recent years (Zedler and Nordby 1986). There were major floods in 1978 and 1980, and in 1983, prolonged reservoir discharge lowered soil salinities. In addition, storm waves washed dune sands into the tidal channels and slowed drainage. The marsh became inundated for longer than normal periods. Then, in 1984, the mouth closed to tidal flushing and was not reopened until 8 months later. The April-December nontidal period coincided with a drought. The marsh soils dried and interstitial salinities exceeded 100ppt.

All of these environmental extremes were useful in suggesting how various environmental factors affect marsh plant growth (Zedler et. al. 1986); however, they interfered with attempts to carry out controlled field experiments. For example, a 1984 field experiment was designed to determine how the timing of reduced soil salinities affect lower-intertidal (*Spartina foliosa* dominant) and mid-intertidal (*Salicornia virginica* dominant) marsh communities. Replicate cylinders (3 per treatment per community) were imbedded in the soil and irrigated in winter, summer, year-round, and with one set of cylinders unwatered as a control. The experiment, which was established before tidal closure, worked well until drought and shrinking soils dislodged some cylinders. Not only did the experiment fail to provide a control for normal tidal conditions, but also, the variability among replicates greatly exceeded that between replicates (Zedler 1986). Other experiments have encountered unusually low salinities (Nordby et.al. 1980), prolonged inundation, and sewage spills (Covin and Zedler in press).

Our inability to control environmental conditions during year-long experiments prompted us to simulate salt marshes in an outdoor setting at the Pacific Estuarine Research Laboratory (PERL is located within the Tijuana River National Estuarine Research Reserve and is operated by San Diego State University). A pilot experiment, set up in 1986, indicated that native plants could be grown successfully with artificially-controlled water and salinity levels. Replicates performed similarly, and between-treatment differences were identifiable. A full-scale experiment involving 27 mesocosms is now in progress. We describe here the mesocosm design and methods of controlling inundation and soil salinity levels, following an introduction to the research project.

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RESEARCH OBJECTIVES

The research project is part of a three-year study to examine the effects of altered hydrology on estuarine ecosystems. The work has focused on the salt marsh, which is the dominant habitat type in most southern California estuaries. One goal is to understand how inundation controls the abundance and distribution of dominant plants. Results of the work are being used to design major restoration projects that seek to provide habitat for endangered wetland species such as the Belding's Savannah sparrow (*Passerculus sandwichensis beldingi*) and the light-footed clapper rail (*Rallus longirostris levipes*).

The following hypotheses are addressed in the mesocosm experiment:

1. *Spartina foliosa*, the lower elevation dominant, grows best under nearly continuous inundation and relatively stable soil salinities. It does not tolerate dry, hypersaline soils characteristic of the upper salt marsh.
2. *Salicornia virginica*, the mid-intertidal dominant, grows best at elevations higher than those preferred by *Spartina* and cannot tolerate continuous inundation.
3. The two species cooccur and interact, with *Spartina* outcompeting *Salicornia* under nearly continuous inundation and *Salicornia* outcompeting *Spartina* at higher elevations.

SALT MARSH MESOCOSMS

Physical Structure

Replicate salt marsh mesocosms were constructed in trenches at PERL. Each trench contained nine 2m X 2m slopes (approximately 20 degrees) lined with 10-mil plastic. Perforated drainage hose was laid along the bottom and across the slope prior to filling with soil to facilitate drainage of rainwater and filling with seawater without disturbing the soil surface. On-site soil (river bed/flood plain) was used to create a 30 cm substrate over the plastic and hose (fig. 1). All mesocosms were fenced to prevent grazing (by rabbits) or other physical disturbance.

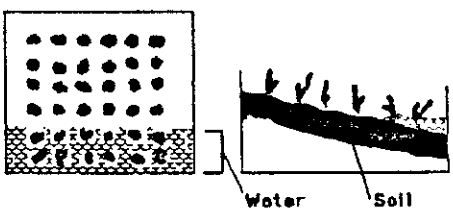

Figure 1: Salt marsh mesocosm design with representative planting density (top and side view).

Planting Scheme

Pilot experiments suggested a high density of initial stems was necessary if complete cover was desired in one growing season. Single stems were planted in a 6 X 6 grid (25 cm apart) in either mixed (checkerboard) or monospecific patterns. These three treatments were replicated ninefold. The vegetation of all mesocosms filled in to a density comparable to a natural marsh within nine months (less than one growing season).

Environmental Gradient

Water level was maintained at the second row of plants (fig. 1) to create conditions comparable to the range from low to high marsh. Moisture and salinity gradients formed along the slope through evapotranspiration (fig. 2), with drier hypersaline soils (>70 ppt) at the upper rows.

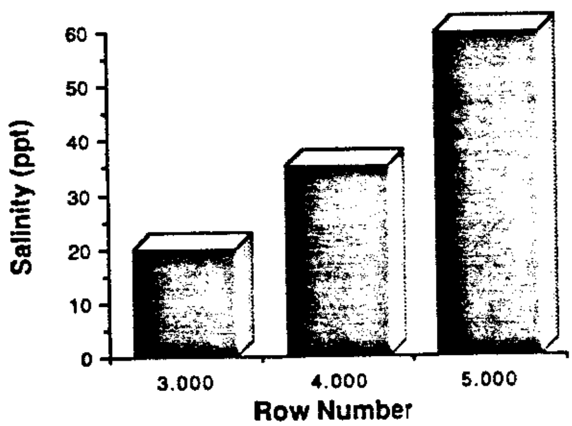

Figure 2: Mean interstitial soil salinity levels in marsh mesocosms at three elevations. Row #1 is submerged and row #6 is at the highest elevation (n = 25).

Soil salinity was moderated by periodically simulating tidal cycles using a small electric pump to fill, leach, and drain the excess salts in the soil. Refilling was done with premixed rock salt and water (25ppt).

Using this sequence along with regular monitoring, temporal and spatial variability in soil salinities was minimized, while maintaining the structural integrity of the slopes. Localized sources of interference (grazing, prior sediment contaminants, physical disturbance, etc.) and the problems of extreme events and sewage spills were eliminated with the mesocosms. This significantly reduced experimental error. The variability that was not eliminated, was measured in the monitoring program and will be analyzed when the experiment is terminated.

Potential Applications

Using this general construction scheme, a variety of experimental manipulations is possible. Hydroperiod frequency and duration are easily manipulated, creating a useful tool for both ecological and physiological experimentation. Experiments may also emphasize varying degrees of salinity, nutrient influx, species diversity, or inorganic materials (e.g. heavy metals). The invasive properties of opportunistic species in the seed bank may also be measured, and extreme events may be simulated with relative ease and efficiency.

Similar technology has been applied to propagation and habitat enhancement projects at PERL. Local marsh vegetation is salvaged from areas impacted by dredging, development, or other disturbances. The transplantation and propagation of these plants provides a local source for restoration projects that include transplantation of native plant species.

ACKNOWLEDGEMENTS

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