Title
Characterizing Vegetation-Hydrology Relationships for Tidal Marsh Restoration

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Technical Report

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Characterizing Vegetation-Hydrology Relationships for Tidal Marsh Restoration
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Sea Grant sponsorship to this program was used to establish the role of some of the many factors affecting vegetation distribution and zonation in San Francisco Bay-Delta marshes. Although much of the more recent research has emphasized species interactions, we emphasized physical factors in the belief that these were the principal factors that could be manipulated in early restoration. In particular, we found in our comparative studies of tidal marshes that seasonal changes in soil salinity were likely controlling distribution and biomass production in the vegetation. However, soil salinity itself is partly a function of tidal hydrology, since tidal input is capable of both increasing and decreasing salinity. As one of the principal accomplishments of this past year, we were able to develop a conceptual model of vegetation response to physical gradients in the marsh environment, for the major dominant vegetation species. The conceptual model is presented in Fig.1 (this figure modified from an earlier version in Foin *et al.* 2000).

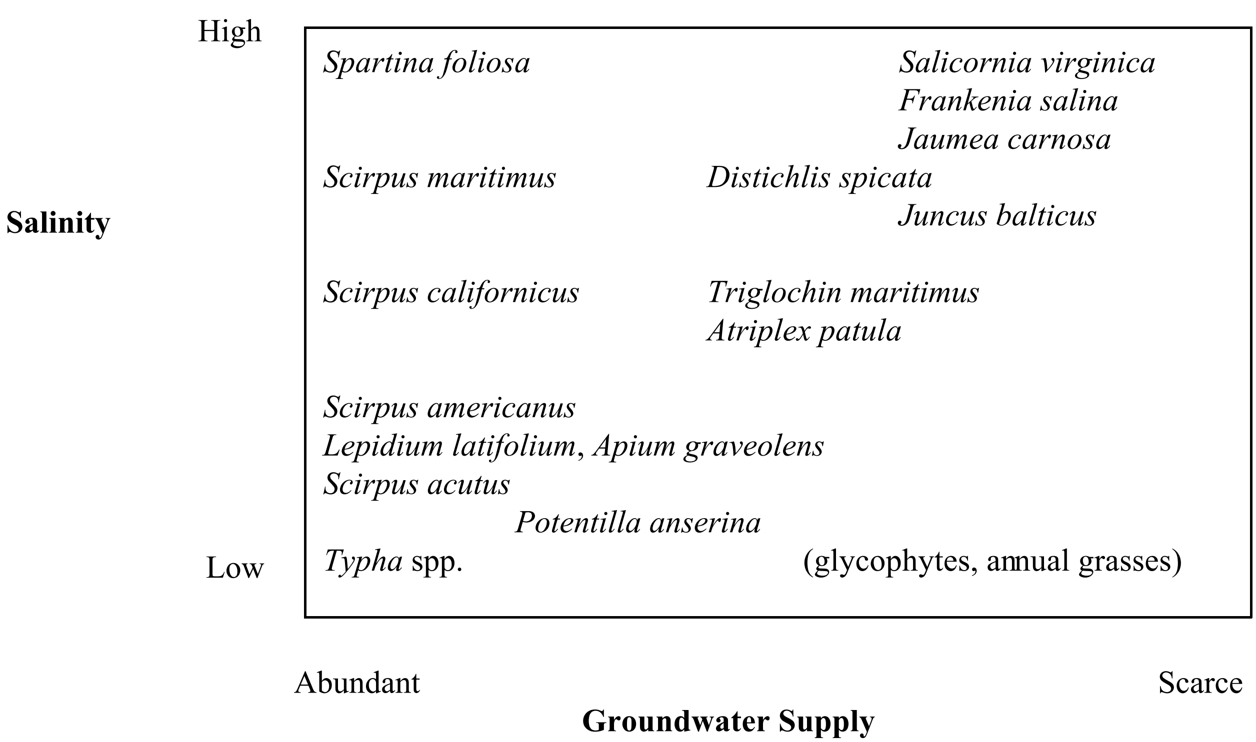

Fig. 1. Conceptual model of the distribution of marsh vegetation dominant along gradients of salinity and hydrology in tidal marshes of the San Francisco Bay- Delta drainage system.

The two axes are salinity and hydrology. State space in the graph is occupied by different species; where a species name is place represents the conditions hypothesized to be the area where dominance is maintained. The streamside zone occurs on the left-hand side of the graph, and is mostly dominated by several *Scirpus* sp. The marsh plain occupies the right side of the graph, with *Distichlis spicata*, *Juncus balticus*, and *Salicornia virginica* as the most important dominants. a narrow zone in the middle represents the transitional zone. There are no species unique to this zone that do not also occur elsewhere in the marsh. The interaction of salinity and hydrology may be summarized as a progressive narrowing of the streamside and transition zones as salinity increases, accompanied by changes in dominants.

The model identifies two principal gradients that must be accounted for to explain the trends seen in this graphical model: 1) water s edge to inland, and 2) from the edge of the ocean upstream to tidal influence under mostly freshwater regimes. These gradients were critical in choosing sites that permitted study of the influence of environmental factors varying with the gradient.

The model was developed from the research of Sanderson *et al.* (2000, 2001), who first detected that the structure of the vegetation was strongly linked to its position in the tidal drainage network. The authors attributed the pattern of zonation to the relative access to tidal inundation; the closer to the stream, the taller and more productive the dominant species found there. Cluster analysis supported this model, and did a later numerical model using weighted distance from channel edge in Petaluma Marsh (Sanderson *et al.* 2001). Through all this research, Sanderson *et al.* thought the cause was access to tidal flow at each site.

Our previous research has proven consistent with the Sanderson model in that we have detected the same distribution and productivity patterns in other marshes, but differs in that we now ascribe a much larger role to salinity rather than hydrology. Early versions of the mathematical model, based on growth responses to hydrology and salinity have been consistent with the current conceptual model. The initial mathematical model (HSIM-1) is based on simulating tidal hydrology and trends in salinity, and matching these up to growth responses by each species to prevailing hydrology and salinity conditions (Figure 2).

Figure 2. STELLA II model flowchart for the hydrology-salinity marsh model (HSIM-1), as implemented for the streamside edge with four potential dominant species.

Competition is not explicit in these simulations, even though it probably exerts a major influence on vegetation pattern. Despite this, the response of the model reproduces the distribution seen in the field at Fagan Slough under moderate streamside salinities and abundant tidal inundation (Figure 3). Insofar as biomass is proportional to dominance, the order of the four species used is accurate.

Figure 3. Response of *Scirpus acutus* (SCAC), *S. americanus* (SCAM), *Typha angustifolia* (TYAN) and *Lepidium latifolium* (LELA) to marsh hydrology and salinity over the course of a simulated season. Time scale is in months.

The model was the direct result of experimental research carried out over the past year. The major lines of research carried out in 2000-2001 were:

* completion of measurements of sediment deposition rates in Fagan Slough and Rush Ranch;
* a reciprocal transplant experiment utilizing dominant vegetation species in Fagan Slough and Rush Ranch, following a pilot experiment in 1999-2000;
* measurement of salinity and depth to water table in Fagan Slough and Rush Ranch; and
* experimental manipulation of salinity and hydrology in laboratory mesocosms.

Most of the data analysis from each of these studies remain to be completed. Preliminary results indicate for support for several conclusions:

* inorganic sedimentation does not appear to play a key role in vegetation zonation and is not an important influence in this respect;
* organic fractions in the sediment are produced and deposited locally; allochthonous inputs are distributed mostly in the streamside areas;
* further inland, organic materials are mostly produced below ground level and definitely deposited locally;
* the vegetation in the field has a pattern of distribution consistent with the model;
* early analysis of the reciprocal transplant experiment is also consistent with the salinity model.

The progress made toward explaining the vegetation pattern in the tidal marsh is the major discovery made in the previous grant. We have confirmed that the pattern is real, and extending our understanding about how the pattern changes as one moves up and down the estuary and from streamside to the inland edge. Even more importantly, we have developed convincing evidence that salinity is more limiting to growth and distribution of the vascular vegetation in tidal marshes of the San Francisco Estuary than hydrology.

Literature Cited

Foin, T. C., S. D. Culberson, and M. R. Pakenham-Walsh. 2000. A productivity-based conceptual model of tidal marsh vegetation development. Abstracts of the CALFED Science Conference, Sacramento, October 2000.

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Sanderson, E. W., T. C. Foin, and S. L. Ustin. 2001. A simple geographical model of salt marsh plant distributions with respect to a tidal channel network. Ecol. Modelling 139: 293-307.

Update on Publications and Presentations- 2000-2001 R/CZ-154

Publications

Sanderson, E. W., T. C. Foin, and S. L. Ustin. 2001. A simple geographical model of salt marsh plant distributions with respect to a tidal channel network. Ecological Modelling 139: 293-307.

Presentations

Culberson, S. D., T. C. Foin, and E. W. Sanderson. 2000. Vegetation and tidal marsh hydrology of three marshes within the San Francisco Bay/Delta estuary, CA, USA. *Proceedings of the 16th Annual Conference, Society of Wetlands Scientists, Quebec City*.

Foin, T. C., S. D. Culberson, and M. R. Pakenham-Walsh. 2000. A productivity-based conceptual model of tidal marsh vegetation development. Abstracts of the CALFED Science Conference, Sacramento, October 2000.