

STABILITY OF *JUNCUS ROEMERIANUS* PATCHES IN A SALT MARSH

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Abstract: In a Virginia (USA) marsh undergoing transgression due to rising sea level, we examined the stability of the boundary between nearly monotypic patches of *Juncus roemerianus* and adjacent plant communities for 6 years. Patch stability was evaluated by examining interannual changes in 5 cover classes: *J. roemerianus*, *Spartina alterniflora*, *S. patens*, *Distichlis spicata*, and wrack. Patches were chosen at four sites ranging from a low marsh site with mineral soil that receives semidiurnal estuarine flooding to a high marsh site with organic rich soil that receives only storm-induced flooding from the estuary. The semidiurnally flooded site in the low marsh was the only one losing *J. roemerianus* cover and had largest interannual variations in wrack and bare soil. At a high marsh site near a tidal creek, incidence of wrack cover was high and patchy but apparently insufficient to reduce cover of *J. roemerianus*. At the two sites with infrequent estuarine flooding because of distance from tidal creeks, wrack was virtually absent and patches of *J. roemerianus* expanded. Patch expansion at one of these sites occurred even though the marsh subsided, and coverage by the three other species decreased over the course of the study. Overall, *J. roemerianus* patches appeared quite stable, with declines associated with wrack disturbance at the site that had the deepest and most frequent tidal flooding. Patch stability is due in part to the wide tolerance of *J. roemerianus* for hydroperiod and salinity.

Key Words: *Juncus roemerianus*, tidal marsh, salt marsh, wrack, disturbance, Virginia, marsh transgression, rising sea level

INTRODUCTION

Plant community patterns in salt marshes range from distinct, banded zonation to mosaics of species associations. These patterns generally correspond to the elevation and hydrology of the marsh. Marshes with strong tidal signals and steep horizontal gradients of salinity from upland to estuary tend to have distinct zonation (Adams 1963), whereas marshes with lesser tidal signals and gradients are associated with patchiness (Kruczynski et al. 1978). Hydrogeomorphic position, as established by marsh-building processes induced by a slowly changing sea level, develops over long time scales relative to the life history of the plants (Clark 1986). Although plant community patterns are responsive to long-term environmental conditions, the proximal cause for changes in community structure may involve plant species responses to disturbances operating over shorter time scales in association with stressors (Hackney and Cleary 1987) and population interactions (Bertness and Ellison 1987). We previously proposed a conceptual model linking the short- and long-term environmental factors, related to rising sea level, with the transgression of marsh into upland and associated community changes (Brinson et al. 1995).

One aspect of change is the replacement of *Juncus roemerianus* Scheele and other high marsh species by the low marsh dominant, *Spartina alterniflora* Loisel. In this study, the stability of the boundary of *J. roemerianus* patches is used as an indicator of community change.

Juncus roemerianus, the black needlerush, is commonly found in temperate salt marshes along the Atlantic coast from Virginia south to Florida and the Gulf of Mexico (Eleuterius 1976). It has a wide tolerance for environmental conditions (Eleuterius 1984) and may dominate a marsh (Kruczynski et al. 1978, Christian et al. 1990), form a band near upland (Eleuterius and Eleuterius 1979, Frey and Basan 1985), or exist in patches along a broad range of salinity in estuaries. Patterns of *J. roemerianus* cannot be explained entirely by physical habitat differences (Woerner and Hackney 1997). Moreover, little is known regarding stability and persistence of the species.

In this study, we examined the boundary between patches of *J. roemerianus* and other saltmarsh species to gain insight into rates and causes of community change. Our goals were to determine if community changes have occurred over a multi-year period and whether the deposition of wrack (rafts of dead marsh

Table 1. Geographic position of *Juncus roemerianus* patches and occurrence of species at each site.

Site	Relative Elevation (m)	Distance from Creeks (m)	Presence (+) or Absence (-) of Species			
			<i>Juncus roemerianus</i>	<i>Spartina alterniflora</i>	<i>Spartina patens</i>	<i>Distichlis spicata</i>
Organic high	1.40	300	+	0	+	+
Subsiding	1.18	120	+	+	+	+
Near-creek high	1.28	60	+	+	0	+
Near-creek low	1.22	20	+	+	0	+

* In very low abundance.

plant stems and leaves) might be a source of disturbance to initiate boundary changes. These distinct patches of *J. roemerianus* cover a range of tidal flooding regimes and elevations, which are encompassed by our choice of four sampling locations. From our conceptual model linking environmental factors associated with rising sea level to plant community changes reflected by transgression of marsh into upland (Brinson et al. 1995), we made the following prediction: *J. roemerianus* patches are persistent in the face of normal variations in flooding (measured in scale of years) while disturbance from wrack will promote plant community shifts.

METHODS

Study Site and Plots

On the Delmarva Peninsula, Virginia, USA, the Brownsville, Upper Phillips Creek marsh (37° 27'N 75° 50'W) sits between a pine-dominated forest on the mainland to the southwest and a farmed Pleistocene ridge to the northeast (Brinson et al. 1995). Tidal inundation with mean amplitude of 1.45 m comes from Phillips Creek to the south (Hmieleski 1994). The marsh is part of the Virginia Coast Reserve. Here, we established 8 permanent 3 × 8 m plots in July 1990 to determine the stability of the boundary between patches of *J. roemerianus* and adjacent plant communities in different sites in the marsh. Two plots were placed in each of 4 sites (Table 1): high marsh with organic-rich sediments distant from tidal creeks ("organic high"), subsiding marsh distant from creeks ("subsiding"), high marsh near a creek ("near-creek high"), and low marsh near a creek ("near-creek low"). Each plot spanned the interface between a *J. roemerianus* patch (4 × 3 m) and the neighboring assemblage (4 × 3 m).

Measurements

Within each plot, we made yearly observations of ground cover on 2 × 1 m permanent subplots with 1 × 1 m on either side of the interface, as established

in 1990. The subplots were sampled by laying down a 1 × 1 m quadrat divided into 10 × 10 cm grids by white string. We ranked up to three species in order of cover dominance within each grid. Where plants covered less than half of a grid, ground covers were assigned as wrack, litter, and bare soil. In this way, each grid was assigned between 1 and 3 categories of plant and ground cover. We computed the number of grids per 200 possible (in a 2 × 1 m permanent subplot) that contained a category of plant and ground cover. Spearman-rank correlation was used to detect significant trends over time in species and ground cover at the 0.05 level of significance (Sokal and Rolf 1995). Each subplot within a marsh site was taken as an individual sample such that 7 measurements per site provided a sample size of 14. For ease of interpretation in graphs presented here, the number of grids represented by each category of plant or ground cover for the 2 plots within a site were averaged.

We surveyed the relative elevations of the plots and determined elevation using a benchmark within the marsh in 1990. In 1990 and 1995, we measured elevations at 0.5-m intervals along one 8-m side of each plot to determine whether there was a change in microtopography for the period of study.

To further characterize sites, we measured in July 1990 aboveground biomass, macro-organic matter, and soil bulk density on either side of the patch interface (to avoid disturbance in the patches). For aboveground biomass, plants were clipped at their base from 0.0625 m² quadrats, dried at 85°C, and weighed to the nearest 0.1 g. Cores of 3.2-cm or 7.3-cm diameter were taken to 10-cm depth to determine macro-organic matter (live and dead organic matter not passing through a 1-mm sieve, *sensu* Gallagher (1974)) and bulk density after drying at 85°C.

RESULTS

The data are presented in sequence from the site most distant from open water, consistent with a sequence of increasing tidal influence as follows: organic high, subsiding, near-creek high, and near-creek low

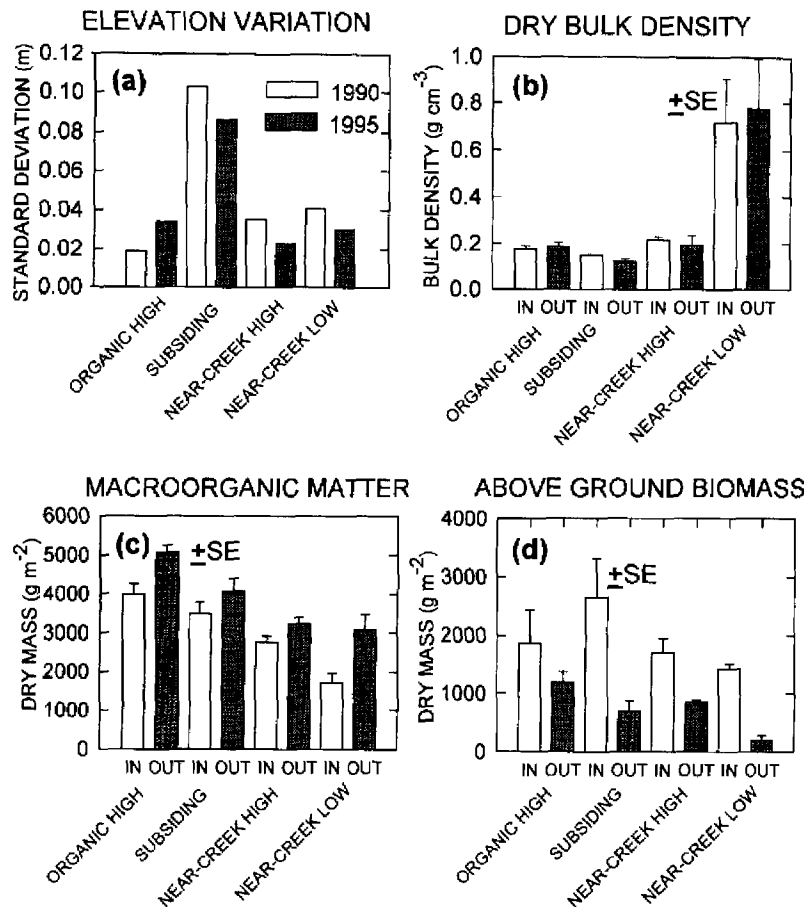


Figure 1. Characteristics of study plots showing (a) variation in elevation, (b) bulk density (0–10 cm depth), (c) percent macro-organic matter (0–10 cm depth), and (d) total aboveground biomass.

(Table 1). Respective distances of sites from creeks are 300 m, 120 m, 60 m, and 20 m. Relative elevations, however, do not decrease correspondingly because the subsiding marsh was the lowest at 1.18 m. The subsiding marsh also had greatest variations in elevation at the horizontal scale of 0.5-m intervals between measures (Figure 1a). Large variation can be interpreted as indication of patchiness resulting from loss of continuous plant cover. Bulk densities of the upper 10 cm were near 0.2 g/cm³ or below for all sites except the near-creek low site at 0.75 g/cm³ (Figure 1b). Macro-organic matter (MOM) progressively decreased from the organic high site to the near-creek low site. MOM within the *J. roemerianus* portion of plots was consistently lower than outside the patches (Figure 1c). In contrast, total aboveground biomass was higher within *J. roemerianus* patches than it was outside at each site (Figure 1d).

Four plant species dominated cover in the plots: *J. roemerianus*, *Spartina alterniflora*, *S. patens* (Aiton) Muhl, and *Distichlis spicata* (L.) Greene. *Spartina alterniflora* was lacking at plots within the organic high site, and *S. patens* was lacking at both near-creek site

plots (Table 1). *Distichlis spicata* was in very low abundance at the near-creek low site (Table 1) and was not found in 1 of this site's plots after 1991.

Changes in vegetation cover over the 6 years are shown in Figure 2 using five cover classes: bare soil, wrack, *J. roemerianus*, *S. alterniflora*, and mixtures of *S. patens* and *D. spicata*. All changes in plant species' cover mentioned are significant at the 0.05 level. On the organic high marsh site, *S. patens*-*D. spicata* decreased and *J. roemerianus* increased; plant cover at the site was complete, with no bare or wrack categories (Figure 2a).

On the subsiding marsh site, *J. roemerianus* again increased (Figure 2b). *Spartina patens*-*D. spicata* decreased, as did *S. alterniflora*, but the latter trend was not significant (Figure 2b). The appearance of bare soil and wrack followed these decreases and was associated with the formation of a depressional area outside the *J. roemerianus* patch. However, the wrack deposition in 1994 was too late to explain increases in bare area and decrease in cover of *S. patens*-*D. spicata*.

In contrast to the other high marsh sites, the near-creek high marsh did not have a significant increase

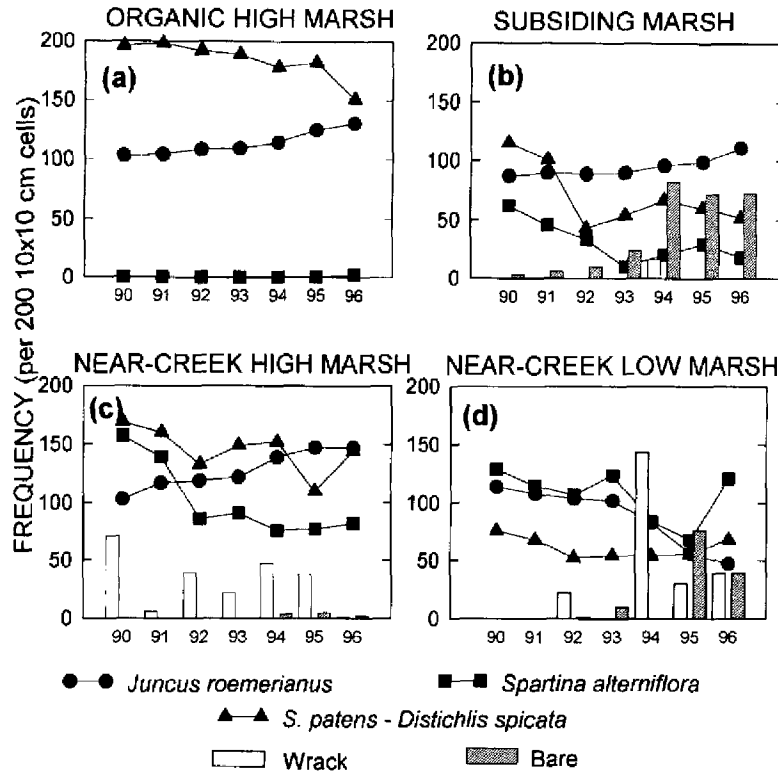


Figure 2. Cover classes over the 6-year period of sampling, 1990–1996.

in *J. roemerianus* cover. This lack of significance resulted from a divergence in cover between subplots. In 1992, wrack was deposited along the interface of one subplot. This reduced its *J. roemerianus* cover, while the cover in the second subplot increased. Subsequent to 1994, *J. roemerianus* cover increased in both subplots. *Spartina alterniflora* plant cover decreased, especially during the first 2 years (Figure 2c). Changes in cover of *S. patens*-*D. spicata* were not significant. Wrack was prevalent in one or both subplots at this site throughout most of the period of study. Minor amounts of bare ground appeared from 1994 to 1996.

The near-creek low marsh showed a decrease in *J. roemerianus*, but trends for other cover classes were not significant (Figure 2d). There was substantial wrack presence during several years. Wrack cover peaked in 1994 and was followed by a year with both the lowest plant cover and the highest bare ground of the 6-year period.

DISCUSSION

The marsh transgression model of Brinson et al. (1995) describes the processes of ecosystem-state change associated with rise in sea level in eroding and transgressing coastal salt marshes. In this model, the neighboring forest ecosystem is replaced by high

marsh with organic-rich soils in which *J. roemerianus* is a common species. The organic high marsh, in turn, is replaced by a subsiding marsh (soil organic matter is lost through oxidation and other processes). The subsiding marsh phase is replaced by near-creek marshes as tidal creeks incise headward and promote more regular tidal inundation. At the Upper Phillips Creek marsh, as in others, *J. roemerianus* patches occur in each of these sites except for the forest ecosystem, but patches are largest and most prevalent in the high marsh position. Given the long-term pattern in which *J. roemerianus* becomes replaced during transgression by *S. alterniflora*, one would expect the near-creek patches to decrease in size most rapidly. Further, the agent of disturbance most likely to initiate species replacement is disturbance by wrack deposition. Wrack disturbance should be most frequent in the near-creek patches.

At the organic high marsh site, *J. roemerianus* patches are actually expanding slowly, and no wrack or bare soil, which develops when wrack cover kills plants, was found in our subplots. Wrack was absent around our plots, also reflecting the great distance of this area from tidal creeks. The virtual absence of *S. alterniflora* at this site may be due to the lack of any bare soil upon which this species could become established (Bertness 1991).

The subsiding marsh shows a pattern of slight in-

crease in *J. roemerianus*. Wrack coverage is minor in spite of the site's lower elevation, in part because the site is distant from tidal creeks (Table 1). The appearance of bare soil as a cover class reflects the die-back and thinning of plant cover classes, particularly *D. spicata*, as the site undergoes a transition to open water lacking emergent plants. The *J. roemerianus* portion of the site appears quite stable, however, and is not being invaded by other species. The relatively large variation in elevation within the plots reflects the development of a hummock and hollow terrain as patches of the organic rich soil subside. Flooding occurs only during extreme high and storm tides, and water fills the hollows for much of the year, except during droughts.

Factors that promote the formation of bare areas and hollows are poorly understood. Contrary to the predictions in the transgression model (Brinson et al. 1995), wrack disturbance does not appear to be a major source of plant removal at the subsiding site. One contributor could be the stress of protracted periods of flooding by brackish water followed by periods of evaporative drawdown and sediment oxidation. New nutrients are not supplied readily by tidal flushing, and toxic end products may accumulate, thus stressing plants (Odum 1980). Anaerobic decomposition of soil organic matter and hence subsidence of the marsh surface may be promoted by the periodic import of sulfate for sulfate reduction. Aerobic decomposition may be promoted by the subsidence process itself in a positive feedback loop. As bare areas open up and subside, the soil surface is exposed directly to the atmosphere during low water-table periods and to shallow water during flooding, both conditions that enhance aerobic decomposition. Further subsidence may lead to an increase in microtopographic relief, thus exposing new vertical surfaces to oxidation. Other factors may have contributed to subsidence in this area. Cattle grazing occurred several decades earlier. Further, the process of hollow formation may be facilitated by muskrat activity through grazing and the building of dens and paths. The importance of each of these factors and the universality of the mechanisms need further study.

The near-creek high marsh site does not show changes in plant cover other than a decrease in *S. alterniflora*. The lack of a significant overall decrease in *J. roemerianus* in the face of wrack disturbance can be explained by subplot differences. Where wrack deposited on the interface, *J. roemerianus* cover decreased. In fact, the interface tends to trap wrack. The short plants (<0.5 m) that surround *J. roemerianus* patches are completely flooded during storm tides, thus allowing wrack to float across the marsh. *Juncus roemerianus* plants commonly approach 1 m in height and thus act as barriers to wrack movement except during

the most extreme and infrequent floods. Consequently, wrack accumulates as windrows, which leads to mortality of plants at the interface and the development of bare soil on the margins of patches. Re-establishment of vegetation may take several years and be species-specific (Tolley 1996).

The near-creek low marsh is the only site that is losing *J. roemerianus* cover. Interannual variations in wrack cover, bare soil, and *S. alterniflora* attest to the dynamic nature of this site. We anticipate that *J. roemerianus* patches at this site are undergoing a relatively rapid transition to wrack and bare area in the face of normal variations in flooding (measured in scale of years) and diminish in size in low marsh areas where disturbance by wrack will promote replacement by other plant species.

Juncus roemerianus patches are found throughout the marsh and may continue to persist even in the mineral low marsh when not affected by wrack. Thus, this species is highly resistant to replacement, a phenomenon noted in other marshes undergoing transition from forested conditions (Hackney et al. 1996, Woerner and Hackney 1997). Changes in the subsiding marsh seem largely independent of wrack deposition at this site, in contrast to our predictions. The effects of wrack disturbance may vary depending on position in a marsh. At the Upper Phillips Creek site in higher marsh areas or distant from creeks, flooding depths seldom allow wrack to be rafted to cover *J. roemerianus* patches completely. When wrack is deposited at higher elevations, it accumulates at patch margins where all species are likely to be affected. In the low marsh or during extreme tides, wrack can cover *J. roemerianus* and rapidly promote patch decline. The effects of wrack disturbance in the low marsh may also interact with the effects of regular tidal flooding (Tolley 1996). Thus, *J. roemerianus* tends to persist over a range of geomorphic settings and tends to show losses where flooding and wrack disturbance interact.

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