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Are Landscape Patterns Related to Marsh Loss Processes?

J.A. Nyman[1], M. Carloss[2], R.D. DeLaune[3] and W.H. Patrick, Jr.[4]

Abstract

Marsh loss that occurs in Louisiana is seldom associated with shoreline erosion of lakes and bayous; instead, marshes break up internally. Marsh loss is attributed to processes that stress vegetation, such as salt-water intrusion or excessive flooding, and occurs in two landscape patterns. Previous workers classified marsh loss as either concentrated in "hotspots" or scattered in the marsh interior. Those workers found that although hotspots accounted for only 12% of all marsh in their study areas, they accounted for 43% of all marsh loss. We recently studied marsh loss processes where it occurred in a hotspot pattern and in a scattered pattern. Marsh loss at the hotspot proceeded by the previously recognized process of inadequate vertical accretion, which led to excessive flooding of the marsh surface, and subsequent plant stress followed by collapse of the marsh surface and ponding. Marsh loss at the scattered site proceeded by erosion of soil below the living root zone, which is a process that has not previously been recognized as important in Louisiana. Additional study is

[1]Research Associate, Wetland Biogeochemistry Institute, LSU, Baton Rouge LA 70803-7511. phone: 504 388-6422
[2]Biologist, New Iberia Field Office, Louisiana Department of Wildlife and Fisheries, Rt. 4, Box 78 Darnell Rd., New Iberia, LA 70560. phone: 318 369-3807
[3]Professor, Wetland Biogeochemistry Institute, LSU, Baton Rouge LA 70803-7511. phone: 504 388-6421
[4]Director and Boyd Professor, ibid., phone: 504 388-8806

needed to determine if such internal erosion is important elsewhere in Louisiana, and if landscape patterns can be associated with marsh loss mechanisms.

Introduction

The conversion of coastal marsh to open water causes the loss of valuable wildlife and fisheries habitat throughout the world (Coleman and Roberts 1989). Most documented cases are from the Atlantic and Gulf coasts of the United States (Gagliano et al., 1981, Hackney and Cleary 1987, Kearney and Stevenson 1991, Phillips 1986, Morton and Paine 1990). Marsh loss is particularly severe in Louisiana where on average, 2,278 ha of marsh convert to open water each year (Gagliano et al. 1981).

Lateral erosion of water bodies is the most often cited mechanism of marsh loss outside Louisiana (Kearney and Stevenson 1991, Morton and Paine 1990, Phillips 1986). In Louisiana however, vegetation stress followed by plant dieback and pond formation is believed to be the primary mechanism of marsh loss (Gagliano et al. 1981, Turner 1990). Plant stress is commonly assumed to originate from one of two sources in Louisiana. The earliest recognized plant stress was saltwater intrusion into non-saline marshes caused an absence of overbank flooding by the Mississippi River, and the presence of a network of canals throughout the marsh zone (Viosca 1928). The resulting conversion from less saline conditions to more saline conditions has been associated with rapid marsh loss (Sasser et al. 1986). Later, it was recognized that rapid subsidence also contributes to marsh loss (Gagliano and van Beek 1973). In some marshes, vertical accretion is slower than submergence. Such marshes are slowly sinking lower and lower relative to mean water levels, which results in flooding stress on vegetation and subsequent marsh loss (DeLaune et al. 1983). Regardless of what causes marsh loss, the resulting water bodies might provide avenues for subsequent salt water intrusion. Thus, the mere documentation of marsh types converting from fresher to more saline conditions following marsh loss is not necessarily indicative of saltwater intrusion causing marsh loss.

Leibowitz and Hill (1987) recently discovered that marsh loss occurs in two landscape patterns in coastal Louisiana. Marsh loss was scattered throughout the marsh interior in the most common landscape pattern. Marsh loss rates in these areas averaged less than 0.5%/yr. Less common were areas where marsh loss was concentrated in large hotspots. Marsh loss rates in these areas averaged just over 2.7%/yr. Hotspots occupied less than 12% of all marsh, but accounted for almost 43% of all the marsh loss in that previous study (Leibowitz and Hill 1987).

We recently completed studies of marsh loss processes in a hotspot landscape and a scattered landscape in coastal Louisiana. The details of those studies are contained elsewhere (unpublished manuscripts in review). The purpose of this paper is to contrast the findings of those two field studies. Those studies were designed as detailed examinations of marshloss processes, rather than as test of hypotheses regarding landscape patterns. Thus the findings presented in this paper do not constitute a rigorous comparison of the processes occurring in the two landscapes. Rigorous, statistically valid comparisons would require that more than one site be studied in each landscape pattern. However, the findings presented in this paper may suggest avenues for such future research.

Study Areas

The study site that contained the hotspot was near Lake Barre, Louisiana (Figure 1). This site was selected because this area of Louisiana is sediment poor, and is in the delta lobe abandonment phase of the delta lobe cycle (Coleman and Gagliano 1964, Coleman 1988). During this phase of the delta cycle, marshes do not receive river borne sediments, but subsidence continues. This leads to increased flooding and saltwater intrusion. There were also a few oil and gas canals in the area, but their role in increasing wetland loss is unknown. Vegetation type maps indicate that the border between saline and brackish marsh migrated 4-5 km inland between the 1940's and 1988 (O'Neil 1949, Chabreck and Linscombe 1978, Chabreck and Linscombe 1988). Small places where marsh converted to open water were scattered throughout the marsh interior. Additionally, a large hotspot formed after 1974 (Britsch and

Kemp 1990). Much of it coincides with an area that converted from brackish to saline. Broken marsh, solid marsh, and irregular shaped lakes all existed in the hotspot area before 1974. Thus, the landscape pattern at this site consisted of a large hotspot imbedded in the typical pattern of interior broken marsh surrounded by solid marsh. Marsh loss rates for the 15 minute map containing this site increased since 1974, and averaged 515 ha/yr between 1974 and 1983 (Britsch and Kemp 1991).

The other study site was at Marsh Island, Louisiana (Figure 1). Marsh Island was selected because it has slower subsidence than the Lake Barre site, and because it is closer to the sediment rich waters of the Atchafalaya River than the Lake Barre site is. Limited oil and gas exploration also occurred at Marsh Island. Vegetation type maps indicated that vegetation

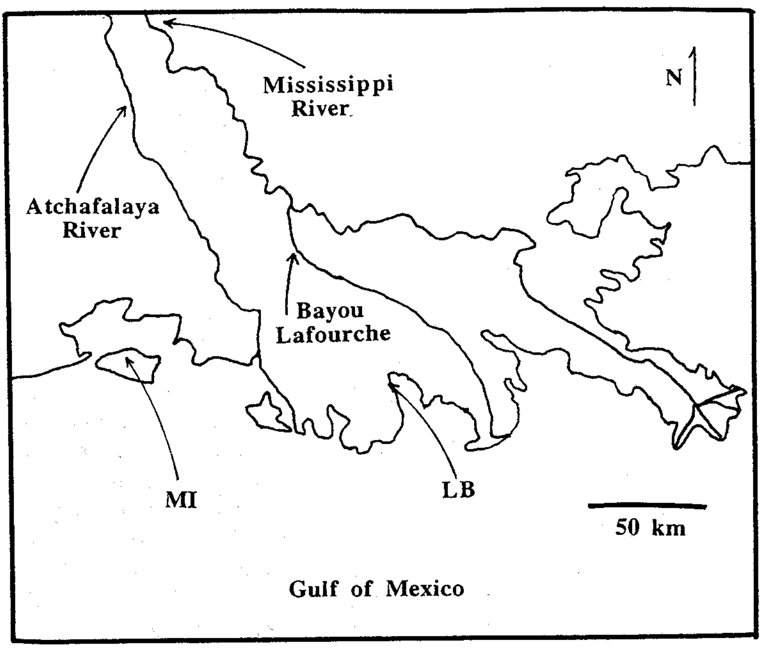

Figure 1. Location of Lake Barre (LB) and Marsh Island (MI) marshes studied in southeast Louisiana, USA.

has been brackish since at least the 1940's (O'Neil 1949, Chabreck and Linscombe 1988). The landscape at this site followed the typical pattern of internal broken marsh where marsh loss occurs, surrounded by solid marsh adjacent to bayous and large lakes. Marsh loss rates for the 15 minute map containing this site decreased since 1974, and averaged 62 ha/yr (Britsch and Kemp 1991).

Results and Discussion

Hotspot Marsh Loss. Vertical accretion in the Lake Barre study area was extremely rapid relative to other marshes, which we did not expect. Vertical accretion averaged almost 1 cm/yr, which was substantially greater than the average for southeast Louisiana, which is 0.72 cm/yr (Nyman et al. 1990).

Although vertical accretion was extremely rapid, it was inadequate to counter submergence in the area. Submergence was estimated to be greater than 1.3 cm/yr. Thus inadequate vertical accretion leading to excessive flooding stress on marsh vegetation, and subsequent plant die-back and pond formation was indicated as the marsh loss mechanism at this site.

Plant production was lower in this study site than in other Louisiana marshes. There was therefore less organic matter available for soil formation and for export to the surrounding estuary at this site than at other marshes. Aboveground, belowground biomass ratios and soil Eh indicated that flooding stress on vegetation was high. Thus the poor production was attributed to flooding stress, as would be expected if there was a vertical accretion deficit.

Conversion of marsh to open water was monitored at the hotspot. There was no distinct border between marsh and open water (Figure 2). Instead, hummocked vegetation gradually gave way to open water. As hummocks died, which was attributed to flooding stress, elevation of the marsh surface decreased over 10 cm within the following 2 years (unpublished data). This caused the conversion of marsh to open water, and was attributed to a collapse of the living root network in the upper layers of the soil. Plant stubble was still rooted in place beneath the water, and no evidence of surface erosion was noted until long after marsh converted to open water.

It was concluded that marsh loss could be countered in this study area with extremely large mineral sediment additions, which do not seem feasible. At least 11 cm of mineral sediments would have to be pumped onto the marsh surface just to restore marsh elevation to normal. Assuming that such a mineral deposit would have a bulk density of 0.80 g/cm^3, then

Figure 2. View from bayou edge, looking inland, to area where marsh loss occurs near Lake Barre, Louisiana; early May 1992.

88 kg/m^2 of sediment would be required. Furthermore, additional sediments would be needed each year to counter on-going submergence. We used the sediment requirements for brackish and saline marsh estimated by Nyman et al. (1990) and the amount of mineral sediments actually deposited in the study area to estimate the amount of mineral sediments required each year in addition to those naturally deposited. We estimated that mineral sedimentation in saline marsh would have to increase by 0.5 kg m^{-2} yr^{-1} so that it was 2.5 g m^{-2} yr^{-1}. Mineral sedimentation in brackish marsh would have to increase even more, by 0.7 kg m^{-2} yr^{-1} so that it was 1.4 kg m^{-2} yr^{-1}.

Interior Breakup. Conditions were very different at the study area where marshloss was scattered throughout the marsh interior. Vertical accretion averaged 0.55 cm/yr, which was much slower than at the Lake Barre site. However, vertical accretion was adequate to counter the moderate submergence rate in this area, which was estimated at only 0.31 cm/yr. Vertical accretion was actually greater in broken marsh (0.60 cm/yr) where marsh loss occurred, than in solid marsh (0.50 cm/yr) where marsh loss did not occur. Contrary to our initial expectations, there was no difference in soil Eh between solid marsh and broken marsh, and broken marsh soil was well drained. End-of-season, standing-crop plant biomass at this study site was typical of healthy brackish marshes, and did not differ between broken marsh and solid marsh. These data indicated that marsh loss at this site was unrelated to either salinity stress or flooding stress.

The mechanism of marsh loss appeared to be soil erosion below the living root zone, as indicated by the vertical and often undercut marsh water interface, and by the separation of sod clasts (Figure 3). We were unaware that the marsh water interface was undercut until we were caught in the middle of a field trip by a winter weather front that produced extremely low water levels. This also appears similar to the erosion of floating, fresh marsh in Louisiana described by Gagliano and Wicker (1989), except that erosion at Marsh Island does not seem to be related to tidal action (unpublished manuscript in review). Thus, some marsh loss in Louisiana is not associated with plant stress as is currently believed, but is similar to the internal erosion reported in a Chesapeake Bay brackish marsh (Stevenson et al. 1985).

It was concluded that marsh loss in this study area could be countered only by increasing the elevation of the pond bottoms so that the loosely consolidated soil below the living root zone at the marsh/water interface would not be exposed to open water (Figure 4). This may be possible without pumping sediments. If the broken marsh areas could be drained for a short time each year for several years, perhaps emergent vegetation could grow in the pond areas and build up the elevation of the pond bottoms by the production of a thick root mat. It might be possible to achieve this goal with modification

Figure 3. View of the broken marsh interior where marsh loss occurs at Marsh Island, Louisiana; early October, 1990.

of current Louisiana marsh management techniques, which are usually directed at improving wildlife habitat by producing favorable plant communities.

Conclusions

Some marsh loss was caused by the previously recognized process of inadequate vertical accretion, followed by plant stress, plant die-back, which was followed by collapse of the surface peats that caused ponding. This mechanism was important in a area experiencing rapid marsh loss in a hotspot pattern. Other marsh loss was caused by erosion of soil below

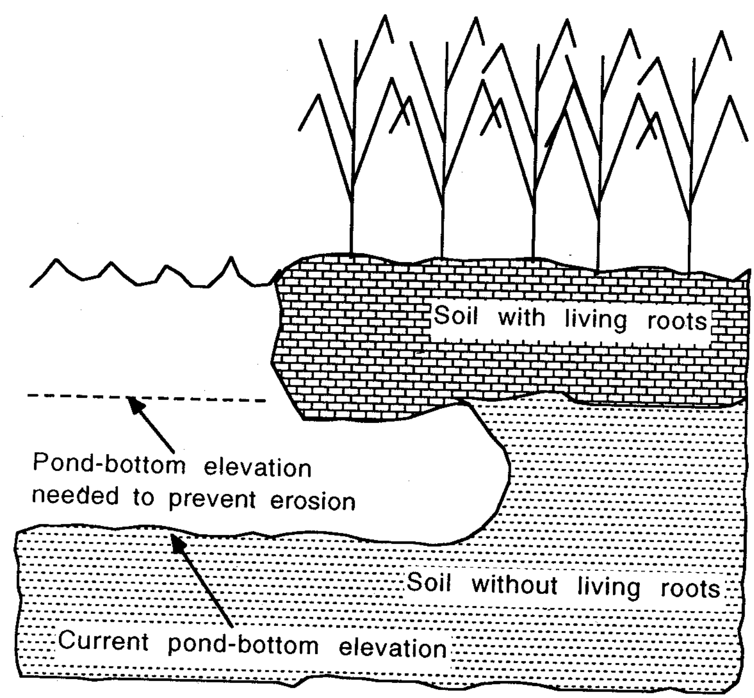

Figure 4. Cross sectional diagram of eroding marsh/water interface in interior marsh showing pond bottom elevation needed to prevent erosion.

the living root zone at the edges of irregularly shaped, interior marsh ponds. This was found to occur in an area where marsh loss occurred only in the internal breakup pattern, which is much more widespread in Louisiana than hotspots, but slower than in hotspots. Internal erosion has been documented in a Chesapeake Bay brackish marsh and appears to have occurred in a Louisiana floating, fresh marsh (Gagliano and Wicker 1989), but has not generally been considered important in Louisiana. It is not yet known if internal erosion is as widespread in Louisiana as the broken marsh interior landscape pattern is, or if hotspots result from plant stress. These are important points because marsh restoration in Louisiana generally seeks to prevent marsh loss by preventing plant stress, but hotspots are relatively rare.

Acknowledgments

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