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The effect of environmental factors on floating fresh marsh end-of-season biomass

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ABSTRACT

We used both stepwise and quantile regression to determine the sources of environmental variation that explained the observed inter-annual variation in end-of-season freshwater floating marsh aboveground biomass over an 18-year period. The vegetation at our study site had high species diversity with an average of 20 species recorded from 10 0.25 m^{-2} plots. However, *Panicum hemitomon* was clearly the dominant contributing 74% of the total biomass. Only three other species (*Solidago sempervirens*, *Vigna luteola*, and *Thelypteris palustris*) were so common that they were sampled in all years. We expected that the most important factors controlling interannual variation in aboveground biomass are temperature and nitrogen availability. We also expected that nitrogen availability to the plants is affected by water movement through and under the mat driven by precipitation (lower N), evaporation (transportation of higher N waters to roots), and local runoff (higher N). Stepwise regression analysis indicated that *P. hemitomon* average biomass was negatively related to average water level and positively related to maximum water level and had a curvilinear response with TKN. Using quantile regression the best fit for *P. hemitomon* maximum-biomass with two parameters was obtained using hot days (positive relationship) and maximum water level (negative relationship). Both analytical methods showed maximum water level (negative relationship) and cold front passage (positive relationship) to be the environmental parameters that best explained interannual variation in *S. sempervirens* biomass. *V. luteola* biomass was positively related to temperature. Stepwise regression added chloride concentration as an additional positive parameter explaining *V. luteola* biomass, while quantile regression identified nitrogen as an important positive parameter. Both analytical methods identified pH, TKN, and water level as environmental parameters that were negatively correlated with *T. palustris* biomass. The overall negative effect of water level on all species was unexpected in this floating mat system. We initially assumed that higher water levels were due to higher runoff which should have a positive effect on biomass. However, higher water levels may also be related to a higher retention time in this fresh-water tidal system, which decreases water exchange and nutrient replenishment.

1. Introduction

In southeastern Louisiana approximately 75% of the 106,154 ha of freshwater marshes mapped in 1990 for Barataria and Terrebonne basins exhibited floating characteristics (Evers et al., 1996). Approximately half of these floating marshes were dominated by *Panicum hemitomon*. In the mid-20th century O'Neill (1949) mapped approximately 100,000 ha of freshwater floating marshes dominated by *P. hemitomon* in coastal Louisiana. In the last four decades some of these *P. hemitomon* dominated floating marshes have converted to seasonally floating marshes dominated by *Eleocharis baldwinnii* and open water (Sasser et al., 1996; Visser et al., 1999). In the context of Louisiana's loss of coastal wetlands (Evers et al., 1992; Britsch and Dunbar, 1993; Barras et al., 2008), documenting the factors that affect biomass production in each coastal vegetation type is an important step in developing new restoration approaches. At our study site, Sasser et al. (1995) showed that although fluctuation in aboveground biomass occurred, species composition and species diversity are remarkably stable as was the area of marsh in Lake Boeuf, making this an ideal system to study the causes of interannual variation in aboveground biomass.

In freshwater wetlands aboveground biomass production is assumed to be mostly related to nutrient availability and flooding (Sharitz and Pennings, 2006). In highly organic freshwater wetlands, plant growth is often limited by phosphorus (Brown, 1981; Verhoeven and Schmitz, 1991; Verhoeven et al., 1996; Bedford et al., 1999; Chiang et al., 2000). However, field

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fertilization experiments (DeLaune et al., 1986) and greenhouse experiments with *P. hemitomon* (Mayence and Hester, in press) identified nitrogen as limiting aboveground production. Because *P. hemitomon* dominated marsh floats at the water surface, adjusting vertically to changes in water level (Sasser et al., 1996), processes in floating marshes are different from those of attached marshes. First the *P. hemitomon* dominated floating marsh at Lake Boeuf has a constant hydroperiod; it is generally saturated with water and never flooded. Water flooding over the surface of an attached marsh is a source of nutrients and sediments (Childers and Day, 1988; Childers et al., 1993). In *P. hemitomon* dominated floating marshes, hydrologic and nutrient continuity with adjacent water bodies occurs underneath the floating mat (Sasser et al., 1991). Nutrient concentrations in the water below the mat are higher than nutrient concentrations in the mat. However, it is not clear if the marsh mat is a source or a sink of nutrients below the mat (Sasser et al., 1991). The mat averages approximately 0.5 m thick and most if not all the roots are located within the mat (Sasser et al., 1996). Interannual variation in aboveground biomass for these floating marshes has been previously related to temperature, precipitation, evaporation and water level (Sasser et al., 1995). Based on the information above, we hypothesized that the most important factors controlling interannual variation in *P. hemitomon* aboveground biomass are temperature and nitrogen availability We also expected that nitrogen availability to the roots is affected by water movement through and under the mat driven by precipitation, evaporation, and local runoff. Rainfall may dilute nutrient availability in the floating mat because rain water has a lower nutrient concentration than the surface water (Turner et al., 2002). However, at the same time runoff from adjacent agricultural areas may increase nutrient concentrations in the water below the mat. Since our site is a tidal fresh marsh salinity possibly could affect biomass production. Because our site is located in the upper end of the estuarine basin, salinity was expected to stay well below the tolerance level of *P. hemitomon*. Therefore, we expected that salinity would not be a factor affecting interannual variation in biomass.

This study used a rare long-term reference data set that was collected as part of a pipeline monitoring program. In an earlier paper (Sasser et al., 1995), we reported on the analysis of the first 11 years of data (1980 through 1990) using stepwise regression analysis to evaluate the effect of regional climate and water level factors on end-of season biomass. Teal and Howes (1996) showed that analysis of longer datasets can give different results than analysis of shorter segments from the same dataset. Here we analyzed the complete data collected from 1978 through 1995. In addition, different analytical approaches may provide different insights. In this analysis of our data we used both the stepwise and quantile regression (Sharf et al., 1998; Cade et al., 1999; Cade and Guo, 2000; Visser et al., 2006) to elucidate the effects of multiple factors that affect aboveground biomass.

2. Methods

This analysis utilized an 18-year end-of-season biomass data set collected as a reference dataset for a study on the environmental impacts of a pipeline at Lake Boeuf, Louisiana. We used available environmental data from other sources that were not collected in exactly the same area, but within the same watershed, to examine the effect of environmental factors on end-of-season biomass. Where data was available, we showed the spatial coherence of these environmental factors over distances similar to the distance between environmental monitoring sites and our biomass sites. Although spatial coherence for many environmental factors is low on a daily time scale, when integrated over a growing season, spatial variation is much smaller than interannual variation. The integration of environmental variables over the growing seasons followed Sasser et al. (1995) and Visser et al. (2006).

2.1. Data Sources

Environmental data for the period of our vegetation data were obtained from several sources. Climate data were obtained from the National Climate Data Center. Data from weather stations nearest to the study site consisted of daily measurements of pan evaporation (Houma, LA; 29°35′N, 90°44′W), precipitation (Thibodaux, LA; 29°46′N, 90°47′W; and New Orleans, LA; 29°59′N, 90°15′W), minimum and maximum temperature (Thibodaux and New Orleans, LA), and cloud cover (New Orleans, LA). Water stage data were obtained from the US Army Corps of Engineers (http://www.mvn.usace.army.mil/eng/edhd/Wcontrol/wcmain.htm) for the Bayou Chevreuil at Chegby, LA (29°54′42″N, 90°43′48″W) and the Intracoastal canal at Harvey, LA (29°54′31″N, 90°05′02″W). Water quality data were obtained from the Louisiana Department of Environmental Quality station in Bayou Chevreuil (29°55′N, 90°44′W).

2.2. Biomass

Plant growth at Lake Boeuf starts after the last frost and senescence starts in October. We harvested plots within a 2-week period around October 1, when peak biomass generally occurs (Sasser and Gosselink, 1984). Ten 0.25 m^2 plots were sampled along a transect perpendicular to Theriot Canal near Lake Boeuf (29°47′N, 90°37′W). The first plot was selected through a throw of a quadrat frame each year. Subsequent plots were determined by sampling at 20 m intervals on a transect line perpendicular to the adjacent canal. This sampling arrangement minimized the probability of the same plot being harvested in subsequent years. Although this sample size may be relatively small for determining effects on species composition in this species rich study site, the sample size was sufficient to capture the spatial variation in biomass for the most common species at the site.

All standing plant materials within each plot were clipped at mat level and placed in plastic bags. The harvested plant material was returned to the laboratory, where live plants and any attached dead leaves were separated from dead material not attached to live plants. Live plants with any attached dead material were sorted by species and oven dried at 65 °C to constant weight. Total aboveground biomass was determined by summing the weight of all species for each harvested plot. This end-of-season aboveground biomass was referred to as biomass throughout this manuscript.

Last frost varied from December 25 the previous year (1991 growing season) to March 23 (1986 growing season). However, major biomass production generally starts when temperatures rise in April (Sasser and Gosselink, 1984). *P. hemitomon* produces 1.21 crops per year as determined from tagged stems (Sasser and Gosselink, 1984), with the early spring recruits lasting throughout the growing season, and a second late summer cohort, that is substantially smaller in stature than the spring cohort. Since growing season varies in length from last frost to harvest, we used an average growing season length of March 15 through September 15 to determine the interannual variation in environmental variables.

2.3. Temperature

P. hemitomon uses the C_4 biochemical pathway of photosynthesis with a temperature optimum between 30 and 40 °C (Larcher, 1995). We defined the number of days on which the