Chapter 5 - Sediment, Nutrient, and Vegetation Trends Along the Tidal, Forested Pocomoke River, Maryland*

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5.1. Introduction

The Pocomoke River Swamp was once considered to be an almost impenetrable wilderness, with conditions strongly resembling the Dismal Swamp of North Carolina and Virginia (Beaven and Oosting 1939). The original width of the forested wetland, as evidenced by black organic soils, extended as much as two to three times beyond the active-floodplain edge (pre-channelization) along the upper reaches of the river (Beaven and Oosting 1939). Currently, the Pocomoke River Swamp is extant only by the river and its active (flooded annually) floodplain that ranges from 0.35 km in width along upper reaches to 3.6 km along lower tidal reaches.

Blackwater systems, such as those found on the Coastal Plain, are characterized by very low-stream gradients, wide floodplains, organic stained waters that may appear black, very low total suspended solids, and long hydroperiods (Wharton et al. 1982; Hupp 2000). The historically (pre-channelized) blackwater Pocomoke River, Maryland is a minor tributary to the Chesapeake Bay (Figure 5.1), draining portions of the Delmarva Peninsula with climatic conditions typical of the coastal Mid-Atlantic Region. Under historical, natural conditions, the non-tidal Pocomoke River sequestered organic material for a period of time sufficient to develop 1-2 m of peat deposits at non-tidal upstream sites. Floodplain sediments in the past

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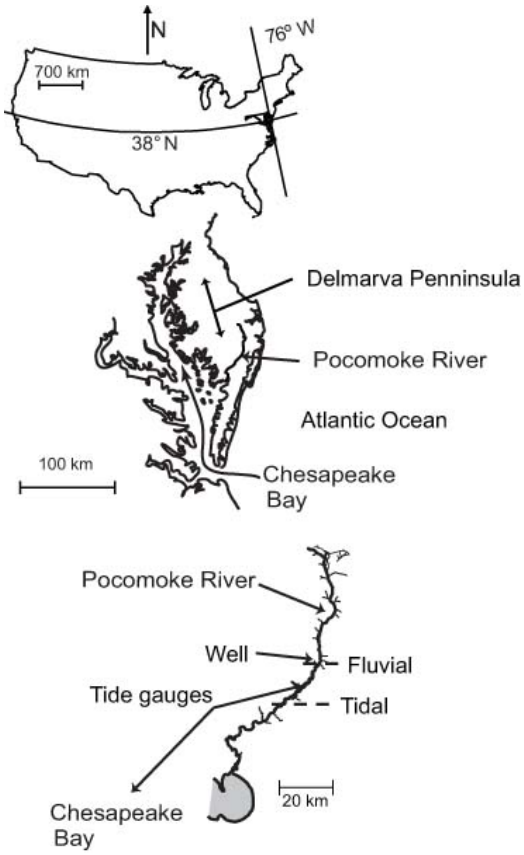

Fig. 5.1. Study sites are located along the Pocomoke River, a minor tributary to the Chesapeake Bay.

ranged from sapric-histosols (organic soils in which the original plant parts are not recognizable) in the headwaters and upper reaches (Beaven and Oosting 1939) to sandy and silty loams in the lower non-tidal reaches (Perkins and Bacon 1928).

The majority of the Pocomoke River drainage basin was ditched (channel created where no channel previously existed) and tributaries were channelized (natural channel modified to facilitate efficient drainage) prior to 1938 (Beaven and Oosting 1939; Ross et al. 2004). The main stem channelization of the Pocomoke began in November 1940 and was dedicated on September 25, 1946 (M. P. Sigrist, USDA, personal communication, 2002). Ditching has increased the drainage density of the basin by nearly 300%. Channelization and incision has made floodplain inundation rare and has drained the groundwater from large portions of the upper ba-

sin floodplain (Kroes and Hupp in review). The Pocomoke River is currently 40% channelized, 50% tidal and embayed, and the remaining 10% has a natural channel with a minor tidal range; only a few small tributaries remain unchannelized.

5.2. Geological history and historical land use

The surface of the southern Delmarva Peninsula is a flat to gently rolling central ridge bordered on the west and east by low plains sloping toward the Chesapeake Bay and the Atlantic Ocean. These surfaces are believed to be remnants of the original depositional surfaces, which formed during emplacement of the marginal-marine and fluvial-estuarine deposits (Mixon 1985; Bricker et al. 2003). The surficial and subsurface deposits (2-60 m) include unconsolidated sand, gravel, silt, clay and peat of Quaternary age (<1.5 million years before present [mybp]). These sediments overlie hundreds of meters of Tertiary (2-65 mybp) greensands and clay-silt. The Tertiary deposits show major paleovalleys running southeastward across the northern, central, and southern parts of the Penninsula (Bricker et al. 2003). The largest paleovalley, crossing the Penninsula near Eastville, Virginia (80 km south of the Pocomoke), was eroded to a depth of 50 m below present sea level and is believed to mark a main drainway of the ancestral Susquehanna-Potomac river system (Mixon 1985).

The Delmarva Peninsula was settled in the early 1600s. Subsistence hoe and shovel-based agriculture was practiced until ploughs were adopted in the late 1700s to early 1800s. The switch from hand tool to plough-based agriculture occurred between the generations of Charles Carroll of Carollton (signer of the Declaration of Independence) and his son Charles Carroll Jr., at that time the major landowners of colonial Maryland. This increase in farm efficiency resulted in an expansion of agriculture. As a result, farm journals of the Carroll estate record intense ditching efforts after 1800. In 1867, the Pocomoke River Improvement Company was founded in order to drain the Cypress Swamp (headwaters of the Pocomoke River) (Scharf 1888). Today, agricultural fields constitute 37% of the drainage basin (Maryland Department of Planning 2002). In some areas, ditches currently constitute 3 of every 4 stream miles on the Delmarva Penninsula (Kroes and Hupp in review).

Forest cover trends in this area are consistent with much of the eastern United States. Forest cover prior to settlement has been estimated at 80 to 90%. The lowest percentage of forest occurred during the Civil War (1861-1865) with as little as 20% cover. Since that time forest cover has

increased; currently forests constitute approximately 45% of land cover within the Pocomoke River watershed (Maryland Department of Planning 2002). Almost all of the forests have been harvested at some time; some are currently managed for timber production.

Poultry rearing has been an important economic contributor to the area since around 1900. The first chicken feed plant was constructed in the area in 1928. Since that time, poultry rearing operations have increased to supply approximately 9% of the chicken production in the United States (USDA, NASS 2002 data).

5.3. Climatic drivers and hydrological characterization

The Delmarva Peninsula receives 1.14 m of total precipitation and 0.29 m of snow in an average year. The average temperature is 12.6° C and the growing season is about 198 days (NOAA, NCDC 2006). The Peninsula is located in an area where hurricanes play a very minor role in its ecology. Since 1854, no hurricane strength storms have made landfall, but in 1999, Hurricane Floyd skirted the coast. While hurricanes are rare, storms can exert a strong influence on the ecology of the Peninsula. On average, a major storm (tropical storm, tropical depression, extratropical storm) crosses the Peninsula every three years (NOAA 2006). Ninety percent of these major storms travel from southwest to northeast. Because of this typical storm trajectory, the associated winds and storm surge may cause the change from forested to marsh environments as saline Chesapeake Bay water is forced up the tidal rivers along the west side of the Peninsula killing salt intolerant trees (Newell et al. 2004). In effect, pushing salt stressed trees over the brink of death. Normal storms generally do not have the wind fetch, duration, and strength necessary to create a large enough surge to push Bay water far up the river.

Low-lying marshes and islands along the Chesapeake Bay and Atlantic Ocean, like Blackwater National Wildlife Refuge, are threatened by sea-level rise of 3 mm/yr, subsidence of variable rates and scales, erosion due to biological factors such as mute swans and nutria (currently eradicated on the Peninsula) and increasing development along shorelines (Larsen et al. 2004). Increases in soil and groundwater salinity due to rising sea level cause many forested wetlands on the Peninsula to retreat inland; these forests are commonly replaced by marsh vegetation. The floodplain along the lower Pocomoke River is one of these areas in transition from non-tidal forests to tidal forests to tidal marshes.

Our study examined sediment, nutrients, and vegetation at two different hydrologic regimes along the unchannelized Pocomoke River: 1) a tidal and wind-driven floodplain (Blades, hereafter Tidal) and 2) a fluvial dominated floodplain with minor tidal influences (Porters, hereafter Fluvial). At the Tidal site, some portions of the floodplain are inundated by overbank water levels almost daily, with complete site inundation during storms (Figure 5.2a). High-water levels at the tidal site are primarily driven by winds blowing from the south or southwest, typical of storms crossing the Chesapeake Bay during the summer. The closest gauge site is located 11 km upstream of the tidal site (NOAA tide station #8571359). At this station, wind and stream flow may have equal influence on water levels. Streamflow has incrementally less influence downstream as the channel increases in cross-sectional area (without significant tributary input) and the floodplain increases in width.

Upstream, at the Fluvial site, the floodplain is primarily inundated during the winter by groundwater derived streamflow (baseflow), with total site inundation occurring during relatively minor (2-3 cm) rainfall events. Inundation during the growing season occurs by storm flows originating from severe thunderstorms or tropical depressions during the summer. This fluvial site shows a minor (0.1-0.3 m) tide and wind signature when stream discharges are primarily contained within the channel (Figure 5.2b).

5.4. Geospatial description

Upstream from the mouth of the river, the floodplain is covered by salt tolerant marsh vegetation such as cordgrass (*Spartina* spp.) and needlegrass rush (*Juncus roemerianus* Scheele) until approximately river kilometer 13 (Figure 5.3). In this region, baldcypress (*Taxodium distichum* [L.] L.C. Rich.) and wax myrtle (*Morella cerifera* L.) establish on higher areas of the floodplain such as the levees. The density of baldcypress increases on the levees further upstream. In the vicinity of river kilometer 17, red maple (*Acer rubrum* L.) and loblolly pine (*Pinus taeda* L.) begin to occupy the levee. Full forest cover of the floodplain occurs around 25 kilometers from the mouth. From this area upstream, the floodplain is dominated by baldcypress, water tupelo (*Nyssa aquatica* L.), red maple, sweetgum (*Liquidambar styraciflua* L.), loblolly pine, American hornbeam (*Carpinus caroliniana* Walt.), and green ash (*Fraxinus pennsylvanica* Marsh.) (Figure 5.4). At approximately river kilometer 55, the embayed portion of the Pocomoke ends; from this point upstream species of oak become common along with the aforementioned species (Figure 5.5).

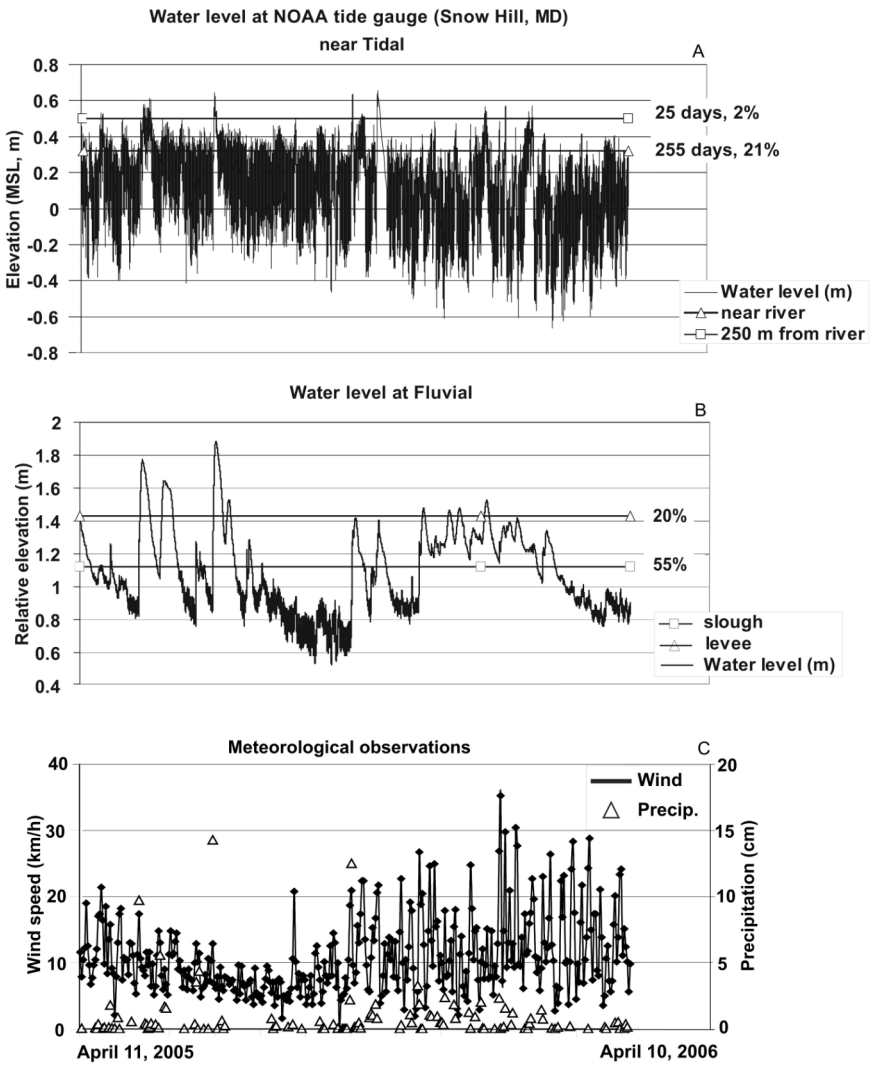

Fig. 5.2. Hydrographs for the Tidal (A) and Fluvial site (B). The hydrograph for the Tidal site is from the closest tide gauge located 11 km upstream of the site. Durations of inundation are indicated for floodplain surfaces. Wind speed and precipitation (C) are compared with these hydrographs.

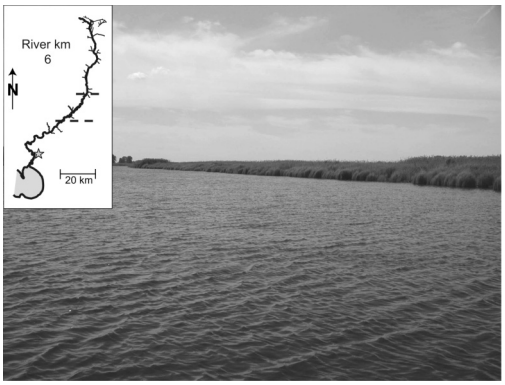

Fig. 5.3. Floodplain vegetation at river kilometer 6. The floodplain is dominated by marsh vegetation at this location.

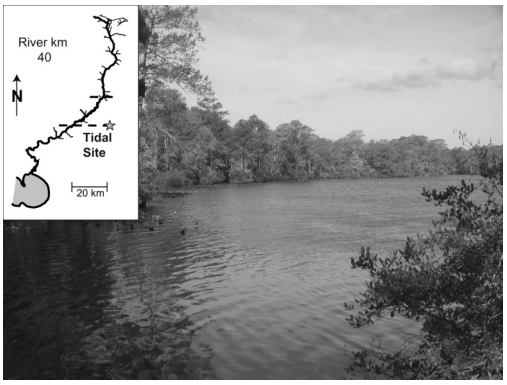

Fig. 5.4. Bank vegetation at river kilometer 40 in the vicinity of the Tidal site. The floodplain banks are dominated by baldcypress.

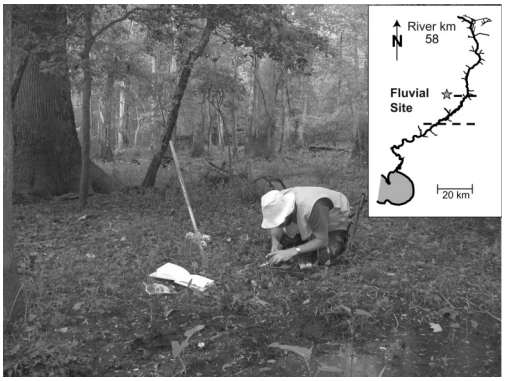

Fig. 5.5. Floodplain vegetation at the Fluvial site (58 km). The floodplain is dominated by American hornbeam, red maple, and ash.

5.5. Ecological characterization

The ecological continuum from marsh to forest described above appears to be driven by salinity and hydroperiod and is typical of embayed rivers entering the Chesapeake Bay. Two sites were compared along the Pocomoke River, separated by hydrologic regime and 19 river km, to exemplify the differences between tidal and fluvial floodplains. One major tributary enters the river between the two sites.

The Tidal site has a large, clearly defined channel with a cross-sectional area of 360 m² (Figure 5.6a). The floodplain topography is dominated by hummocks (raised mounds held together by root masses) and hollows (areas typified by unconsolidated sediment between hummocks). The vertical distance between top of hummock to dense sediment at the bottom of the hollow typically is approximately 0.6 m. The hollows at this site have a nearly constant water level within 0.1-0.2 m of the hummock tops that appears to be maintained by tidal water, rainfall, groundwater discharge, and poor drainage. This tidal site has a diurnal tidal range of 0.6-0.7 m that inundates portions of the floodplain for short durations. During the period of study (1997-2006), water levels never exceeded 0.85 m above mean sea level. The average surface of the floodplain is lowest near the channel and increases about 0.18 m in elevation over a distance of 250 m from the channel (Figure 5.7a). These systems are notoriously difficult to traverse (Wharton et al. 1982; Doumlele et al. 1985) and have received, until recently, little ecological (Rheinhardt 1992) or hydrogeomorphic (Light et al. 2002) study.

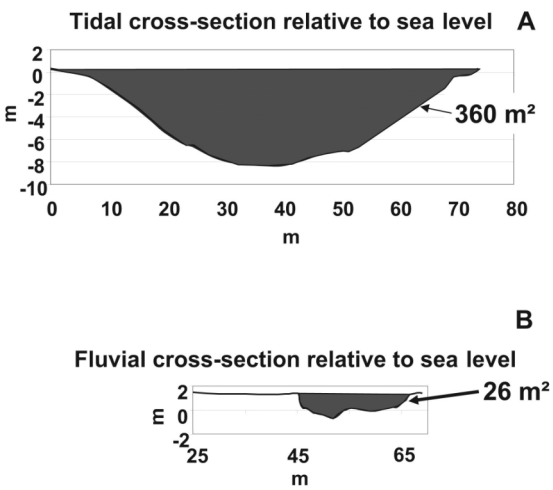

Fig. 5.6. Channel cross-sections at Tidal (A) and Fluvial (B) study sites.

The Fluvial site is typical of a fourth-order southeastern blackwater river (Hupp 2000). This site has a clearly defined channel with a cross-sectional area of 26 m^2 (Figure 5.6b). There are clearly defined flowpaths (sloughs) across the floodplain. These sloughs hold water substantially longer than the surrounding floodplain surface (Ross et al. 2004) at this site for approximately 55% (Figure 5.7a) of a normal year, and generally for extended periods (weeks - months) during the winter months (Kroes and Hupp unpublished well data). Sloughs are important conduits for transmission of water and sediment and increase the riparian connectivity of areas otherwise relatively distant from the channel (Hupp and Noe 2006). This fluvial site has an elevation range of 0.3 m with the highest elevation near the river, on the natural levee, and the lowest point mid-floodplain in the main slough. Pad elevations show the general elevational trend (Figure 5.7b).

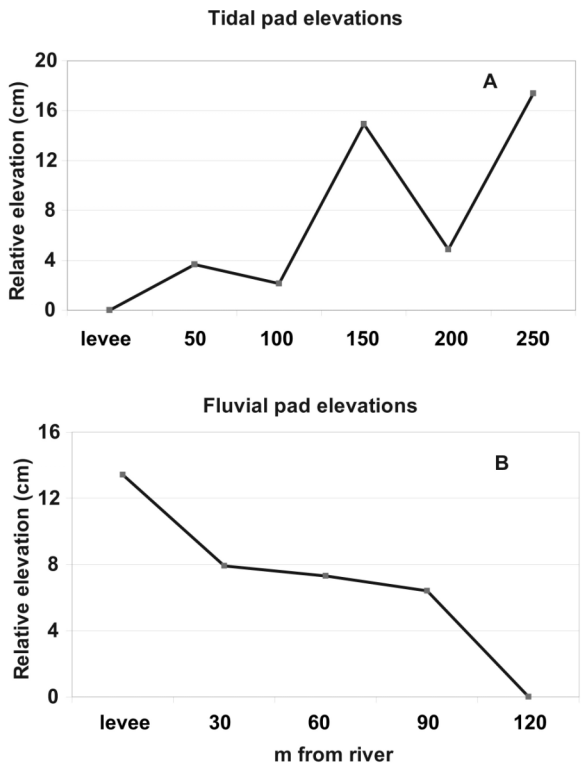

Fig. 5.7. Relative elevations of clay pads at the Tidal site (A) and Fluvial site (B). The Tidal site shows an increase in elevation as distance from the channel increases. At the Fluvial site (B) elevations on the floodplain are highest near the channel and decrease with distance.

5.6. Methods

These sites were investigated for characterization and contrasting of the hydrogeomorphic forms and processes (sedimentation) and vegetation. In 1997, 50 cm x 50 cm white feldspar marker horizons (clay pads, Hupp et al. 1993) were placed along transects at several locations along the Pocomoke River, including the two described here, in order to determine sedimentation rates and analyze recently deposited sediment samples (Kroes and Hupp in review). At Tidal, two transects of six pads each were placed perpendicular to the channel with a spacing of 50 m between pads. At Fluvial, three transects of five pads each were placed with a pad spacing of 30 m. The rates reported here were determined from cumulative deposition during the period 1997-2005. Nutrient and loss-on-ignition (LOI) data reported here were determined from the period 1997-2003.

Hydroperiod data for the sites were determined by two methods: a NOAA tide gauge (Tidal), and a combination surface/groundwater well (Fluvial). The tide gauge was installed in April 2005 and is located 11 km upstream of the Tidal site (6 minute intervals). Another tide gauge (NOAA #8633532) located 35 km south west of the mouth of the Pocomoke River, in the Chesapeake Bay, records similar tidal amplitude with approximately a 4 hour offset (Bay to Snow Hill) between high and low tides. Surveyed river stage at the Tidal site indicated similar tidal amplitude with a timing offset of ±30 minutes from the Snow hill gauge. A ground/surface water well was installed at the Fluvial site in August 2001 (15 minute intervals). The borehole was set to a depth of 1.2 m and measures water to a stage of 2 m above the floodplain surface. Sloughs at the Fluvial site have high connectivity to the river, i.e. river stage is equal to slough stage, and little to no ponding is present at the site. Surveyed standing water elevations in the sloughs and river stage are accurately represented by the well at this location.

Deposition was measured by cutting a plug from the clay pad with the sediments above it and measuring the accumulation. Sediments were collected from three 20-cm^2 cores from each clay pad in 2004. Each core was carefully extracted from the coring tubes and sediment above the marker horizon was collected and composited. These samples were analyzed in 2004 for organic content LOI, total carbon (C), total nitrogen (N), and total phosphorus (P). Samples were dried to a constant mass at 60° C and then weighed. Dried sediment samples were then ground with a mortar and pestle to pass through a 0.5 mm sieve. Coarse organic matter was pre-ground with a Wiley Mill. The organic and mineral content of the sediments was determined by loss-on-ignition at 400° C for 16 hr in a muffle furnace

(Nelson and Sommers 1996). Total C and total N concentrations were determined with a Carlo-Erba CHN elemental analyzer. Preliminary analyses indicated that inorganic C was a negligible proportion of total C (Noe, unpublished data). Total P concentrations were measured in digested sediments by ICP-OES analysis. Sediments were digested at high temperature and pressure by repeated microwave-assisted digestion following sequential addition of HNO_3, HCl and HF, and then HBO_3 acids.

Woody vegetation was analyzed from 400 m^2 plots at both sites near the river (0 m), mid-floodplain (50 m), and backswamp (100 m) (Hupp and Schening 1997). At Tidal, the same plot location protocol was used with the addition of another plot at 250 m from the river. Species composition, importance value basal area, and density were determined from trees with a diameter at breast height (DBH) greater than 2.5 cm (Doumlele et al. 1985; Rheinhardt 1992; Megonigal et al. 1997). Importance value was calculated by combining a species values of relative density, relative basal area, and, relative frequency. Selected trees were cored with an increment borer and aged to calculate growth rates (Tidal n=26, Fluvial n=55).

5.7. Results and discussion

5.7.1. Sediment

The data from the sediment analyses show a distinct contrast between the fluvial and tidal sites. Deposition rates at both sites are typical for forested wetlands on the Atlantic Coastal Plain (Hupp 2000). The range of sediment deposition rates were also comparable between these two sites ranging from 2-6 mm/yr (Figure 5.8), with a mean rate of 3.1 mm/yr at Tidal and 4.0 mm/yr at Fluvial. Soil bulk density at Tidal averaged 0.1 g/cm^3 and 0.33 g/cm^3 at Fluvial. LOI was significantly different between sites (ANOVA df=21 p=0.001); Tidal averaged 70% LOI with a range of 20-90%. LOI increases with distance away from the channel indicating decreased mineral input from river water (Figure 5.8a) The high LOIs indicate that this tidal site traps mineral sediment primarily within 50 m of the river's edge. High deposition rates and LOI indicate that there is either high primary productivity (autochthonous) or that large volumes of organic debris (allochthonous) are being trapped deep within the swamp, in conjunction with a very long hydroperiod.

Fluvial averaged 23% LOI with a range of 15-25%. LOI was lowest at 50 m from the river. Frequent low level flooding during the winter and fall wash leaf litter toward the backswamp or downstream, preventing organic

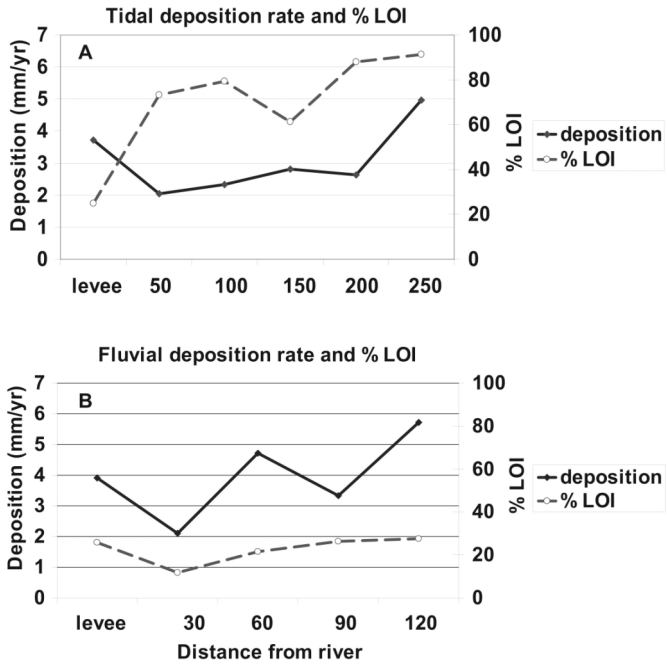

Fig. 5.8. Deposition rates and percent LOI (Loss on ignition) for Tidal (A) and Fluvial (B) sites. At Tidal (A) % LOI is lowest near the river and increases rapidly with distance from the channel. At Fluvial (B) LOI is lowest at intermediate distances.

material accumulation (Figure 5.8b). Low-level flooding, common during late fall, winter, and early spring (Figure 5.2), erodes the levee and high intermediate floodplain and deposits sediment in the backswamp (Kroes and Hupp in review). Deeper flooding during late spring and summer results in coarse sediment deposition on the levee and intermediate floodplain, as well as fine sediment deposition across the floodplain.

These data indicate that the sites store different sediment through differing processes. The Tidal site stores primarily organic material through constant inundation or saturation, similar to backwater flooding, while the Fluvial site stores primarily alluvial mineral sediment as a result of flows across the floodplain.

5.7.2. Nutrients

The degree to which floodplains act as nutrient sinks or sources depends highly on nutrient load in the flooding waters, hydroperiod, geomorphol-

ogy, and other factors (Noe and Hupp in review). The majority of phosphorus in the Pocomoke River is associated with clays and other mineral sediments, whereas nitrogen is associated with organic matter (Noe and Hupp 2005). Nutrient concentrations in recently deposited sediments showed significant (t-test, df=19, %C, p=0.004, %N, p=0.07, P (mg/g), p<0.001) dissimilarity between the Tidal and Fluvial sites. Phosphorus concentrations at Tidal were 50% lower than at Fluvial. The rate of phosphorus accumulation ($g/m^2/yr$) at Fluvial was 6 times greater than at Tidal.

At the Tidal site, there was a decrease in phosphorus concentrations and an increase in C:P ratios at distances greater than 100 m from the channel (Figure 5.9a), indicating a change in sediment source. Phosphorus concentrations decreased more than N, as shown by N:P (Figure 5.10a), suggesting an inverse gradient of mineral and organic matter deposition from the channel to the backswamp. The lowest concentrations of nutrients were found at the highest elevation pads, those 150-250 m away from the channel. Throughout the Tidal site, high C:P ratios (390-1350) in the sediment indicate poor organic matter quality for microbial activity (Brinson 1977); this source becomes extremely poor at 200-250 m from the river (Figure 5.10a). Higher phosphorous concentrations in the sediment near the river at Tidal suggest alluvial sources, or alternatively, sorption of phosphorous to sediments in areas that are regularly inundated by phosphorous-rich river water (near the river). Due to the relatively young age of the tested sediments (5 yr), and the similar rate of deposition throughout the Tidal site, diagenic processes are unlikely to have caused the observed phosphorous gradient, suggesting that sediments are primarily from non-alluvial sources in the backswamp of Tidal. If the deposited sediments in the backswamp of Tidal are autochthonous in origin, then the very high C:P ratios in this sediment suggest a negative feedback loop whereby low rates of organic matter mineralization due to high sediment C:P ratios limit phosphorous availability to plants, which in turn produce phosphorous-poor litter.

The Fluvial site maintains a high level of connectivity with the river. The pads located in the middle of the site (farthest away from the channel and slough) had the lowest concentrations of nutrients (Figure 5.9b). The highest concentrations were found on the lowest pads located along the slough with a hydroperiod of approximately 200 days/yr (Figure 5.2). Relatively constant nutrient ratios with low C:N and C:P ratios across this site suggest that these pads receive a relatively high level of nutrients from the same alluvial source (Figure 5.10b). These data suggest that the tidal Pocomoke stores little alluvial nutrients, with primary nutrient storage oc-

curring along non-tidal reaches (40% of the river, of which 80% is channelized).

5.7.3. Hydroperiod

The differences in nutrient storage and ratios exhibited between the Tidal and Fluvial sites can be explained by hydroperiod and depth of inundation. In order for significant sediments and nutrients from the watershed to be deposited on a floodplain there must be flow across the floodplain during a period of time when sediment concentrations are high (alluvial streams during rising flood stages). There is an order of magnitude difference between channel cross sections and the Tidal floodplain is three times

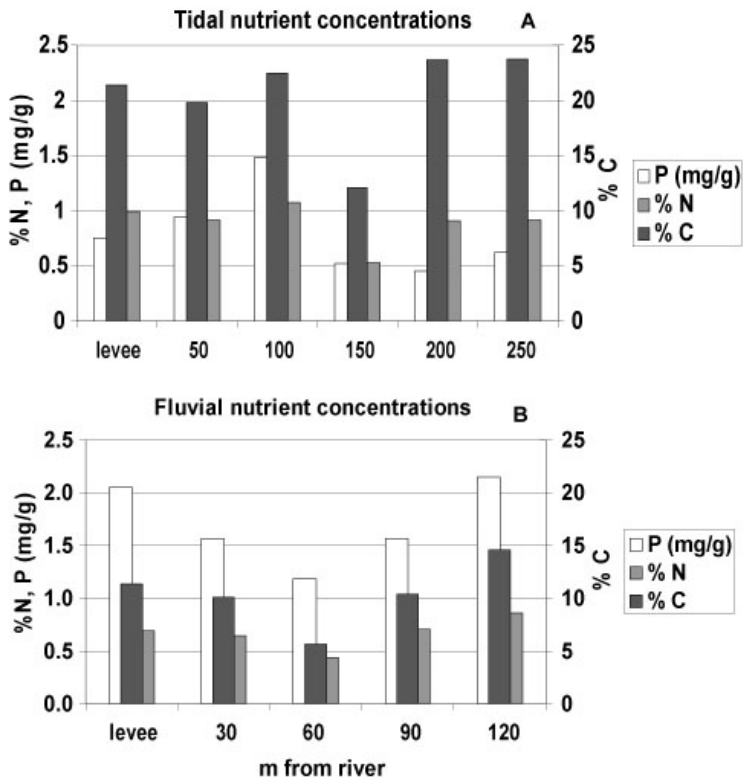

Fig. 5.9. Nutrient concentrations at Tidal (A) and Fluvial (B) sites. Tidal has higher carbon and lower nitrogen and phosphorous concentrations than Fluvial. Phosphorus concentrations at Tidal are lowest far from the channel. At Fluvial P and N concentrations are highest near water flow paths (channel and slough).

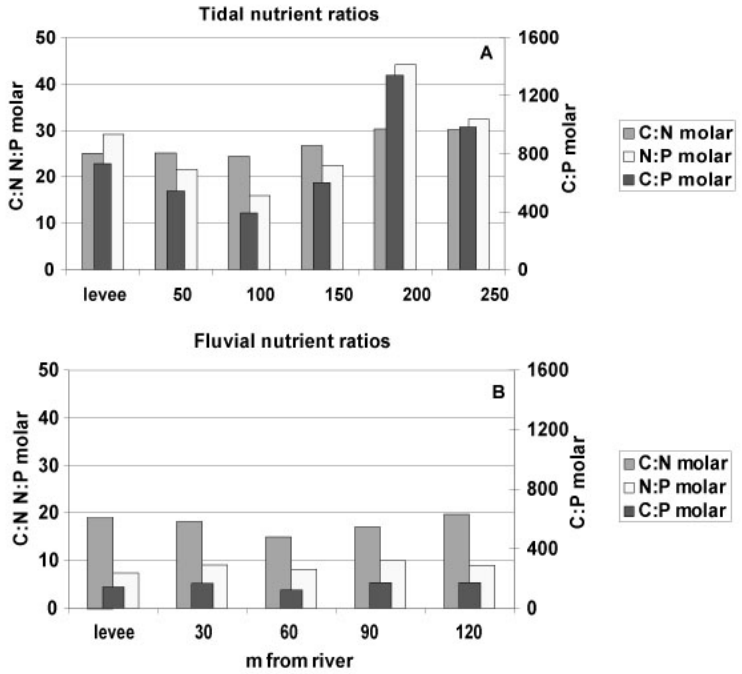

Fig. 5.10. Nutrient ratios at the Tidal (A) and Fluvial (B) sites. Higher nutrient ratios, like those at Tidal, indicate a limiting environment relative to carbon supplies.

the width of the Fluvial floodplain making storm flow inundation of the Tidal floodplain much less probable (Figure 5.11). At Tidal, the lowest pads located near the channel were inundated 255 days/yr but only 21% of the time while the highest pads were inundated by river water 25 days/yr and less than 2% of the time (Figure 5.2). Near the NOAA tide station (11km upstream), wind is equal to or greater than the effect of storm flow on the river stage (Figure 5.12). The channel at the tide gauge has a cross-sectional area of 288 m^2 (Davis 2005) in comparison to 360 m^2 at our Tidal site. At the Tidal site, inundation is controlled more by wind direction and velocity. On the Pocomoke River, there is generally a 1-day lag between storm and peak river discharge at the Tidal Site. Sediment peak discharge most commonly occurs before peak water discharge (Leopold et al. 1964). If wind conditions facilitate inundation of the entire floodplain during a storm, then the peak sediment load (drainage basin originating) comes after the tidal floodplain is already inundated with sediment poor tidal waters. This “preloaded” condition prevents sediment rich waters from diffus-

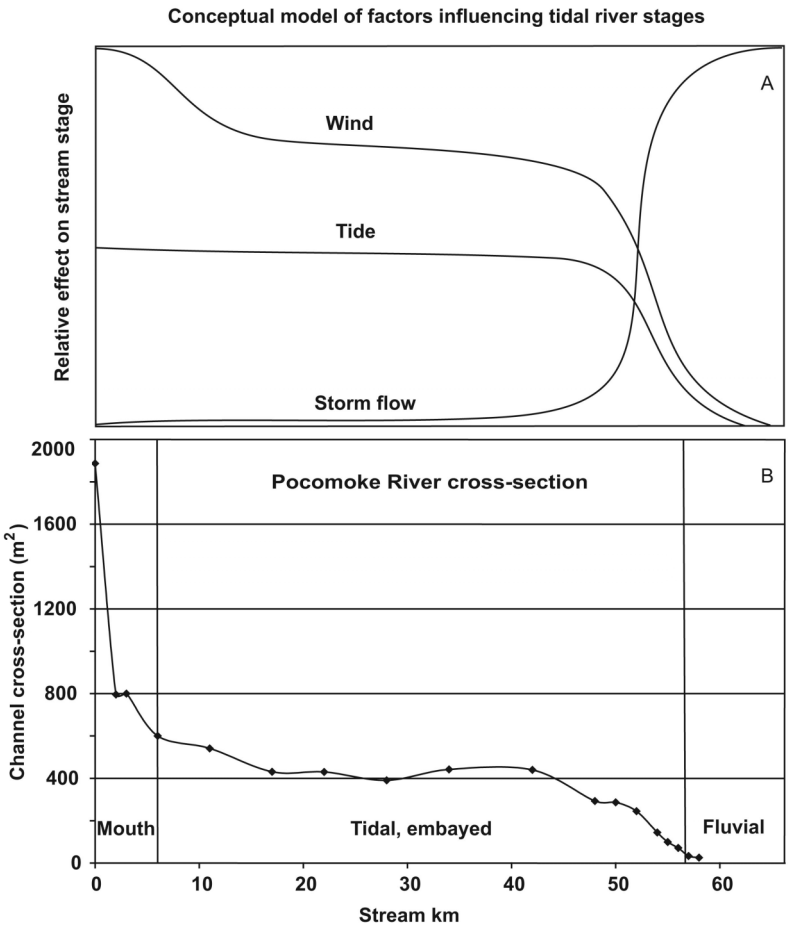

Fig. 5.11. A conceptual model of the factors influencing water levels in the lower Pocomoke River (A), in comparison with measured cross-sectional data measured by Davis (2005) and Kroes and Hupp (in review).

ing across the floodplain (Figure 5.12). For example, steady winds blowing from the west and south have the greatest effect on water levels for the tidal portion of the Pocomoke (Figure 5.12: Period 1 had an average wind direction and speed of 203° at 19 km/h; Period 2: 262° and 16 km/h; Period 3: 203° and 22 km/h). Despite high stream stage at Fluvial (Figure 5.12b) at the beginning of Period 2, water levels were normal at the tide gauge (Figure 5.12a) with low wind speeds (Figure 5.12c). Suspended sediment loads coming from the watershed are further reduced by a rapid water velocity decrease and sediment settling caused by the damming effect of Chesapeake Bay water blown upstream. Lastly, tide dominated sys-

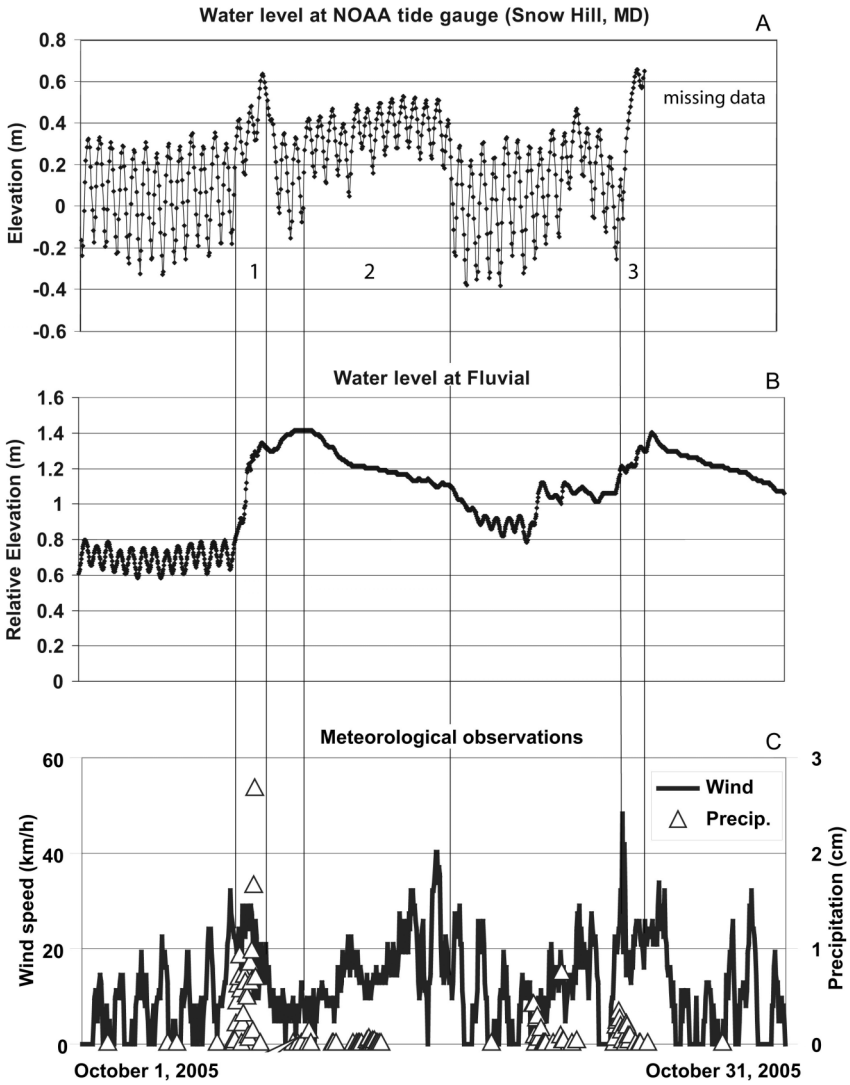

Fig. 5.12. Hydrographs and meterological data with sub-hourly data. Periods of interest are indicated with vertical black lines and are matched by time and date.

tems on the Coastal Plain are inherently less affected by alluvial flooding than non-tidal systems because of their large floodplain capacities (typically underfit; Hupp 2000) and their proximity to sea level.

Tide data near the Tidal site were recorded from September through December 2000 (Davis 2005) and since April 2005 (NOAA tide station #8571359); additionally, single-stage suspended sediment samplers were

established at both sites in 1997. During the tidal record, data indicate that water levels did not exceed 0.3 m of depth on any portion of the Tidal site. Samplers set to collect at 0.65 m above floodplain surface never collected water during their 9 year implementation at the Tidal site. Low depth of flooding combined with high surface roughness (high Mannings coefficient of the hummock and hollow topography), and the presence of low sediment water in place on the floodplain may preclude alluvial sediment import to the Tidal swamp. Water samples collected from this site corroborate this interpretation (Ross et al. 2004). These patterns are similar to the perirheic zone concept developed for non-tidal floodplains (Mertes 1997).

5.7.4. Vegetation

The differences between the Tidal and Fluvial sites were more pronounced in woody vegetation composition. At the Tidal site, the levee was dominated by baldcypress, red maple, and green ash (Figure 5.13a). Green ash maintained a high importance value until around 100 m from the channel where water tupelo increased in importance. At 250 m from the channel, there was a complete species composition shift where water tupelo and sweetgum became the dominant species, with ironwood and loblolly pine present.

The levee at the Fluvial site was dominated by American hornbeam, red maple, sweetgum, and water tupelo. The intermediate zone is dominated by American hornbeam, red maple, swamp chestnut oak (*Quercus michauxii* Nutt.), and willow oak (*Quercus phellos* L.). The backswamp, 100 m from the channel, was dominated by ash, overcup oak (*Quercus lyrata* Walt.), and baldcypress (Figure 5.13b). The reversal of baldcypress presence pattern was clearly evident particularly along the stream banks of the lower tidal reaches (Figure 5.4).

The Tidal site had an average density of 2650 stems/ha. Basal areas at this tidal site ranged from 39-71 m^2/ha. The Fluvial site had an average density of 820 stems/ha with basal areas ranging from 19–35 m^2/ha (Figure 5.14). These values are within normal ranges for the mid-Atlantic tidal (Doumele et al. 1985; Rheinhardt 1992; Megonigal et al. 1997) and fluvial floodplains (Spencer et al. 2001) A reduction in basal area was documented at 250 m from the river at the Tidal site, possibly as a result of decreasing nutrient availability (Figure 5.9a). This pattern of increased basal areas and densities with tidal water flux has been observed at other study rivers in the Chesapeake Bay area. Along the Pamunkey River there was a 15% increase in basal area and a 40% increase in density from fluvial to

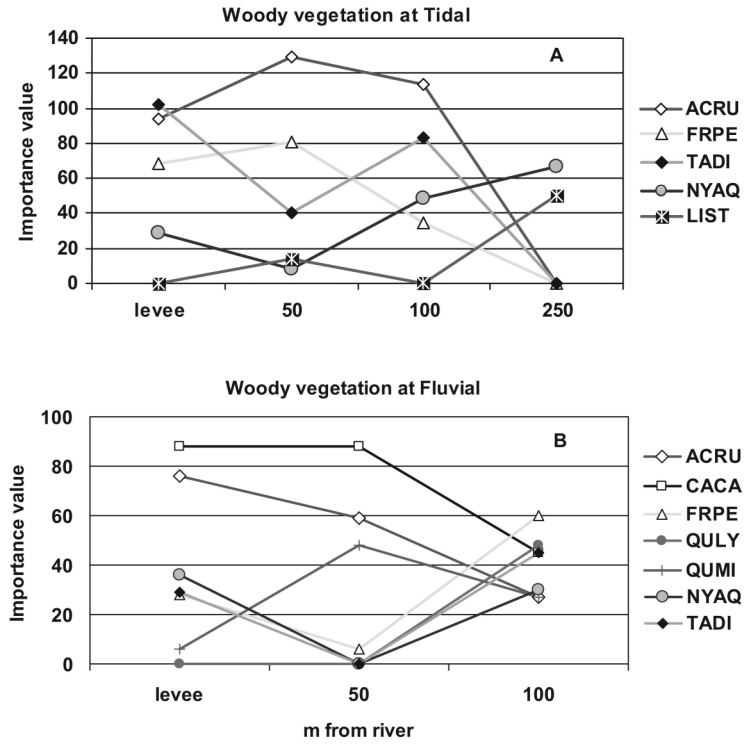

Fig. 5.13. Tree species importance value at Tidal (A) and Fluvial (B) sites. At Tidal, baldcypress (TADI), red maple (ACRU), and green ash (FRPE) were dominant near the river, and water tupelo (NYAQ) and sweetgum (LIST) dominated far away from the channel. Fluvial was dominated by American hornbeam (CACA), and red maple near the channel, with swamp chestnut oak (QUMI) increasing in importance mid-levee. Green ash, laurel oak (QULY), American hornbeam, and baldcypress dominated the backswamp. Species abbreviation is standard notation with first 2 letters indicating genus and the last two indicating species (i.e., bald cypress, *Taxodium distichum,* is TADI).

tidal. The Mattaponi River showed a 28% increase in basal area and a 40% increase in density (Hupp and Schening 1997).

The canopy trees along the Pocomoke River were mature. Individual tree ages were up to 238 years old with a median age of 83 (n=55) at the Fluvial site and 121 at the Tidal site with a median age of 55 (n=26) (Hupp and Schening 1997). At the Tidal site, tree canopies appeared to be thin and generally in poor condition, possibly explaining the overall high density values as greater light availability to the sub-canopy vegetation layers may allow for greater survival of saplings. Despite the appearance of poor canopy condition, trees at the Tidal site exhibited an average dbh growth

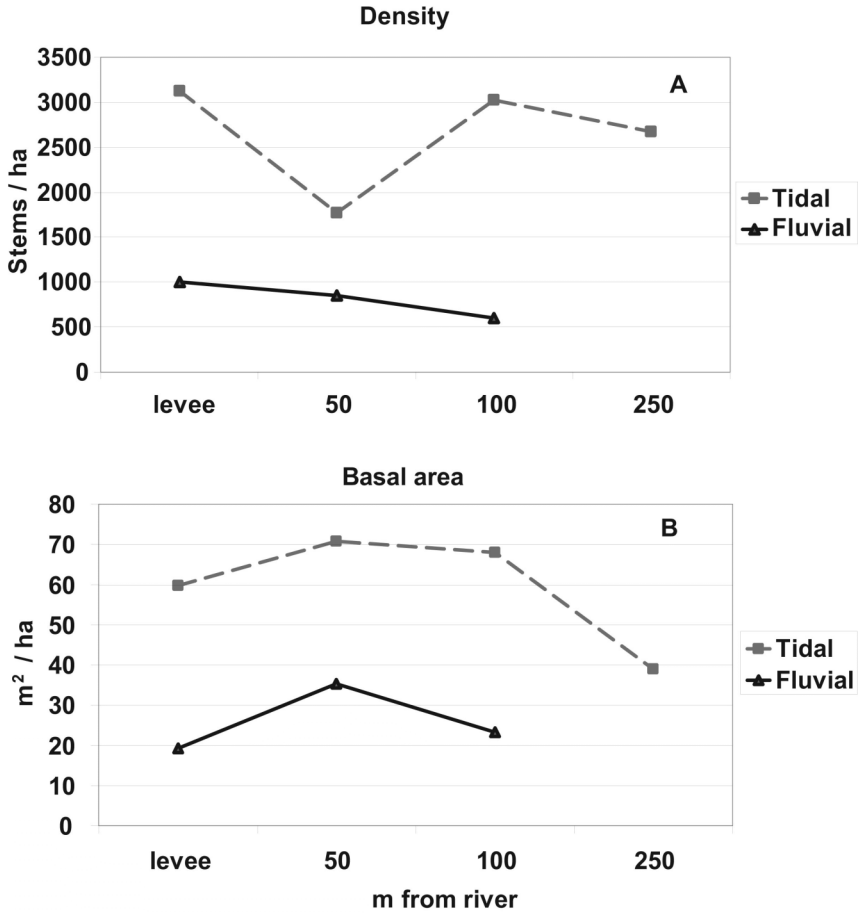

Fig. 5.14. Tree density (A) and basal area (B) at the Tidal and Fluvial sites. Tidal exhibited higher density and basal area than Fluvial.

rate of 0.39 cm/yr whereas at the Fluvial site dbh growth rates were 0.17 cm/yr. Trees of similar age and species exhibit 30-60% faster growth rates at the Tidal site. The extended duration of inundation at the Fluvial site may suppress growth, whereas tidal flushing at the Tidal site may prevent the build up of compounds inhibiting growth (Falcão and Vale 1995). However, the sediments at the Tidal site are perennially saturated and at 250 m from the river are not flushed regularly by tidal action, whereas at the Fluvial site there was a clear tidal signature of 0.1-0.2 m in the groundwater of the floodplain. These vegetation data in combination with nutrient and hydrologic data suggest that between the Tidal and Fluvial sites, hydrologic regime limits productivity more than nutrient availability.

5.8. Conclusion

In comparison to fluvial floodplains, tidal floodplains function differently. Our sites along the Pocomoke are inundated a similar number of days. However, the timing, duration, and depth of inundation vary greatly. Large portions of the Fluvial site were inundated for most of the winter and weeks during the summer. In the absence of steady wind, the tidal site was inundated frequently for short periods of time (hours). During our study, the Fluvial site was inundated frequently by up to 2 meters of water; the Tidal site was not flooded by more than 0.65 m since 1997.

As a result of differing hydrologic regimes, these areas store different sediments from different sources. Fluvial areas are inundated by storm flows originating from rainfall on the watershed and thus store alluvial sediments and nutrients. Depending on the watershed and site location sediments at fluvial sites may range from primarily mineral to organic. These sediments are predominantly from upstream sources with some autochthonous organic material. Tidal sites, being inundated by wind driven waters and to a minor degree stormflow, store a mix of sediments from organic production, downstream marsh and bank erosion, and fine alluvial sediments. At our Tidal site, these sediments were primarily organic. Nutrient data indicate that farthest from the river, the sediments may be primarily of autochthonous origin. In short, the alluvial sediment and nutrient trapping function of riparian areas (Brinson 1993; Hupp et al. 1993) remains substantial and important along alluvial reaches, however, this function may diminish along tidal reaches. Tidal reaches play an important role in the storage of organic carbon.

5.9. Research needs

5.9.1. Current research

Current research on the Pocomoke River consists of ongoing projects of the NAWQA program (USGS National Water-Quality Assessment) and other water quality assessment programs (Maryland Department of Natural Resources). With the exception of the water quality studies along the tidal reaches, to the authors' knowledge, there are no ongoing projects. There are other ongoing projects along the non-tidal river including Sediment Elevation Table (SET) studies to determine subsidence rates along channelized reaches and radioisotopic fingerprinting of suspended sediments to document source areas (both by the USGS). We have maintained a sur-

face/groundwater well at Porter's Crossing (Fluvial) since August 2001 (partial record).

5.9.2. Future research

Future research should be directed toward quantifying the effect of tidal action in the groundwater at sites similar to the Fluvial site described above. The flushing of the groundwater in conjunction with high nutrient concentrations in the sediment may decrease the nutrient storage function of these systems to an unknown degree. Root physiology may differ between tidal and fluvial floodplains. Additionally, research should be devoted to understanding what makes tidal freshwater forests so productive and dense.

5.10. Acknowledgments

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