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Commonwealth's Declared Policy:

"to preserve the wetlands and to prevent their despoliation and destruction. . ."

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Introduction

Mary Washington's childhood home still stands on a high buff overlooking the Pamunkey River. Along the section of river below the bluff, the Pamunkey makes a wide meander more than five miles in length, doubling back to within 500 yards of where the meander started. The entire triangular bend of the river and the lush-green swamp occupying the inside of the meander can be easily seen from the bluff. That swamp, known locally as Cohoke swamp, covers over 750 acres.

When George Washington first visited the bluff-top plantation, he may have been surprised at first to discover that the fresh water of the Pamunkey sometimes flowed upriver there, backing up through a myriad of sinuous creeks into the interior of Cohoke. His surprise is understandable because Cohoke swamp, unlike most other freshwater forested wetlands in North America, is tidal.

Although rare, tidal freshwater swamps can be quite extensive where the appropriate physical factors occur: tidal action, fresh water, and low coastal plain relief. Such conditions exist primarily along three tidal freshwater tributaries in lower Chesapeake Bay, along the Chickahominy, the Mattaponi, and the Pamunkey rivers (Fig. 1). Of these three rivers, the largest and best developed stands occur along the Pamunkey; approximately 64% (5,500 acres) of the known acreage of tidal swamps on the lower Chesapeake Bay occurs there.

The same sections of river that support freshwater tidal swamps are also the spawning areas for commercially and recreationally important anadromous fishes (those that migrate from salt water to freshwater to reproduce), including striped bass, American shad, white perch, alewife, and blueback herring. The larval form of these species may spend some of their early developmental period in the adjacent river and associated tidal creeks. Large flocks of waterfowl also overwinter along these same stretches, while others may rest and feed there during their migrations. Therefore, tidal freshwater swamps are an extremely important natural resource.

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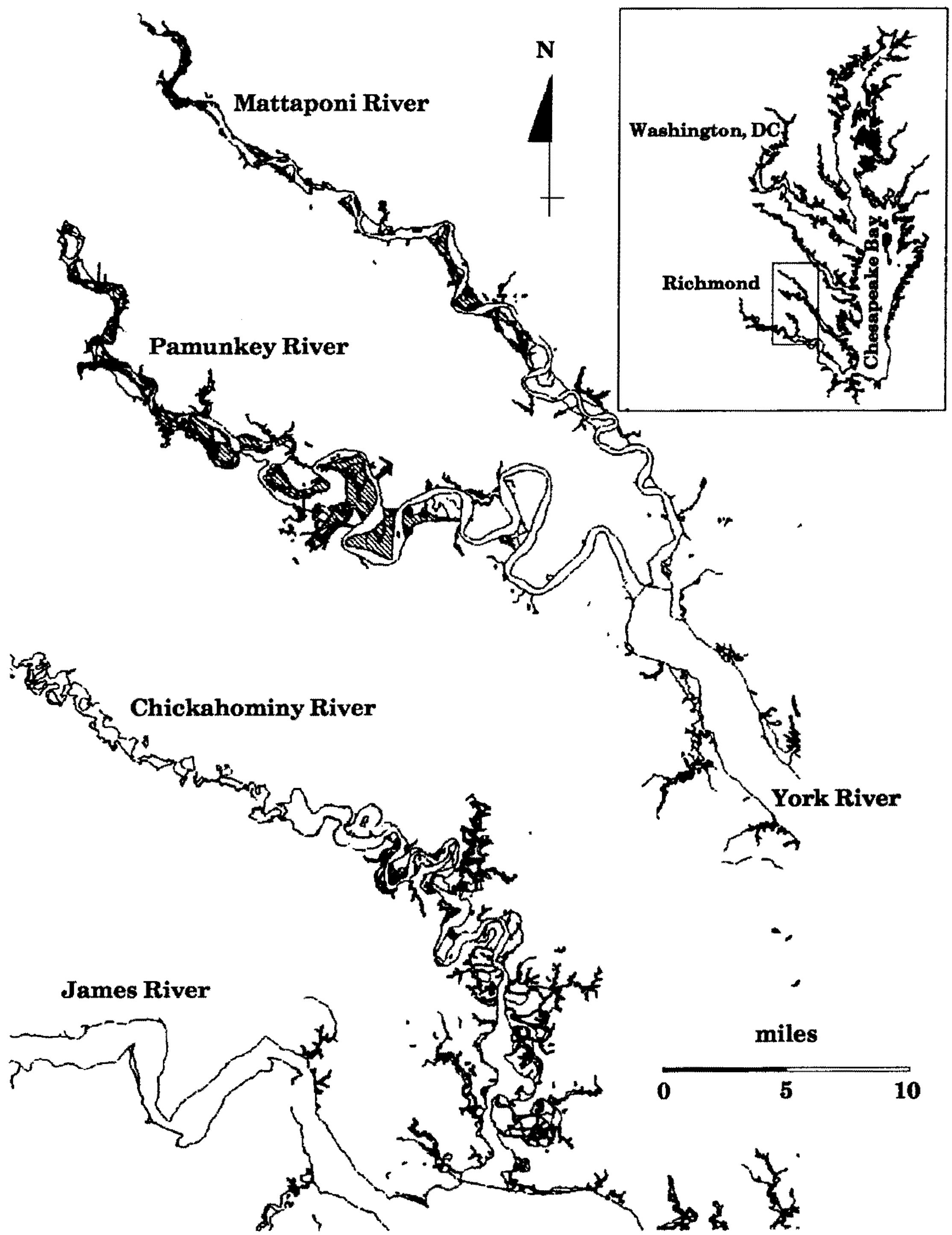

Figure 1. Location of the primary tracts of tidal freshwater swamps in the lower Chesapeake Bay. Most of the 8,750 acres of these swamps occur along the Pamunkey (64%), the Chickahominy (19%), and the Mattaponi (17%) rivers. (Prepared by Berch Smithson, VIMS Coastal Inventory Group.)

Scientists have long appreciated the value of tidal saltwater swamps (mangrove forests) to the biological integrity of tropical estuaries and nearby coastal environments. Less is known about temperate latitude tidal freshwater swamps, particularly about the movement of nutrients and energy through the ecosystem. Further scientific work is needed to determine if tidal freshwater swamps are as important to the Chesapeake Bay estuary and the adjacent coastal zone as mangrove forests are to tropical coastal ecosystems.

Although the nutrient dynamics of tidal freshwater swamps are not yet well understood, a recent study of the vegetation patterns of these swamps provides some insight into their ecology. The results of that study, some of which are presented here, were synthesized from data collected in 23 tidal swamps along more than 65 miles of the Pamunkey River.

Flooding Regime

Tidal swamps along the Pamunkey River are flooded twice daily by tidal action. The mean tidal range is between 2 1/2 and 4 feet, depending upon location. Flooding tides drive water from the river into the tidal creeks of the swamps, and more significantly, forces the water table to rise in synchrony with the rising tide.

As the rising tide approaches its highest point, the hollows (low areas of equal elevation between island-like hummocks, Fig. 2) are flooded. Flooding in the hollows occurs at least once per day and sometimes twice per day (Fig. 3). As the tide ebbs, the water level drops in synchrony with the falling tide, but only until the water level reaches the elevation of the hollows. Below the elevation of the hollows, the rate at which the water table drops becomes much slower than the falling tide, probably because drainage is impeded by the hydraulic con-

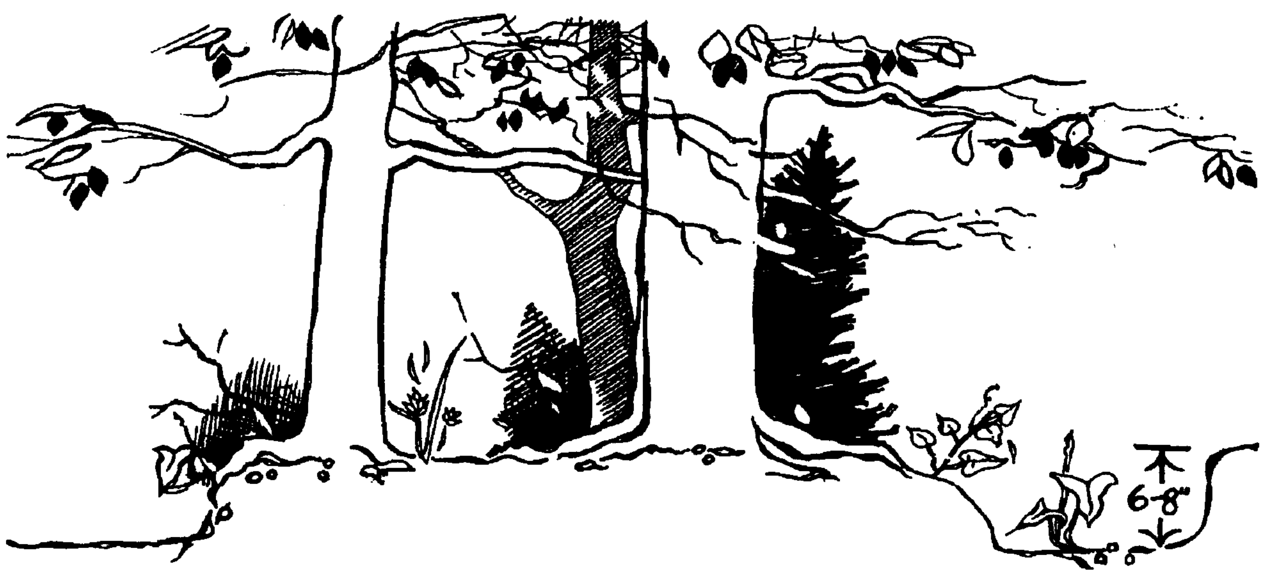

Figure 2. The microtopography of tidal freshwater swamps is an interdigitating pattern of hummocks and hollows. Hummocks are composed of a dense network of tree roots that also support woody subcanopy species and less flood tolerant herbs. Hollows are almost always saturated and support only the most flood tolerant herbaceous species. Both hummocks and hollows are composed primarily of organic matter (peat) and lie at about the extreme upper end of the tidal range.

ductivity of the organic muck (peat) on which the swamps reside.

Trees and shrubs are restricted to hummocks which all lie at about the same elevation, approximately 6-8 inches above that of the hollows. Hummocks are composed of a dense network of tree roots and small rootlets; therefore, tree roots are the hummocks. Hollows are almost continually saturated, but hummocks are rarely flooded to their surfaces and so provide a much less stressful environment for plant growth than adjacent hollows. However, even the intensity of flooding in the hollows is not overly stressful for all plants because many herbaceous species grow in them.

Vegetation

Tidal freshwater swamps contain fewer species of canopy trees than do most nontidal swamps because relatively few tree species can tolerate the intensity of flooding that occurs in them. Trees that survive the rigorous, tidally-induced flooding conditions appear to allocate so much energy to overcome the stresses imposed upon them that both growth rates and crown development are reduced. Thus, canopy trees in tidal swamps are generally smaller in stature than trees growing in nontidal swamps.

Differences in flooding intensity between swamps also determine the species composition of the forest (defined by the relative abundance or cover of component species). In tidal swamps

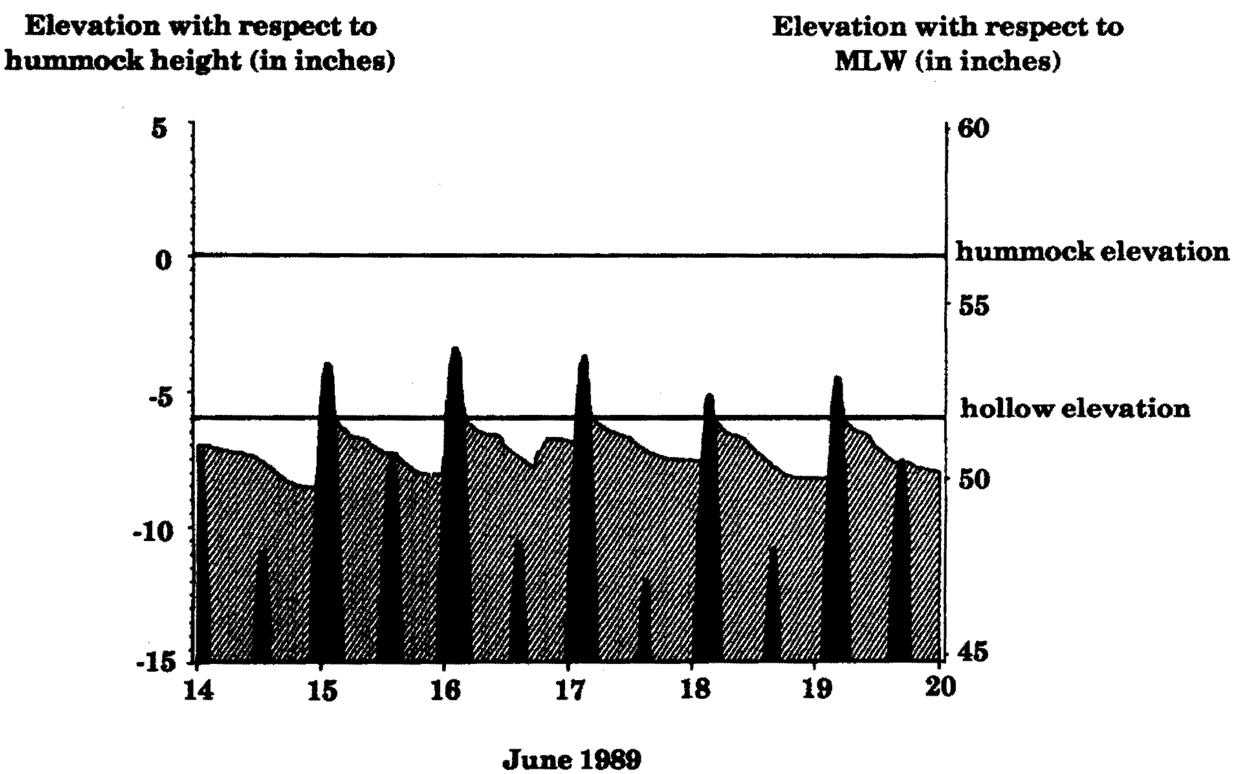

Figure 3. Typical weekly flooding regime of a tidal freshwater swamp along the Pamunkey River. The upper horizontal line is located at the elevation of the hummocks; the lower horizontal line at the elevation of the hollows. The solid fill represents the tidal fluctuation of the river, the hatched and solid fill together represent groundwater height. Note that for the indicated time period (neap tide conditions), the higher high tide each day forces the water table to rise above the elevation of the hollows, while the lower high tide of the day only impedes the rate of drop in the water table. During spring tides (twice/month), both high tides of the day usually force the groundwater to flood the hollows. Only rarely (less than 1% of the time) do the hummocks become completely inundated by water.

where hummocks comprise 35% of the forest floor on average and the average depth of the water table is 6-7 inches below the hummock surfaces, ashes (*Fraxinus spp.*) and swamp blackgum (*Nyssa biflora*) share dominance in the canopy. Such swamps are classified as ash-blackgum swamps.

Bald cypress (*Taxodium distichum*) is sometimes important in tidal swamps, but primarily in stands along the Chickahominy River. Only two stands with bald cypress occur along the Pamunkey River. In both stands, bald cypress shares dominance with ash and swamp blackgum. Except for the prevalence of bald cypress, these two stands are compositionally similar to the other ash-blackgum stands both in canopy and understory vegetation.

The conspicuous absence of bald cypress along the Pamunkey River is surprising. It is possible that bald cypress was once much more prevalent along the Pamunkey, but was logged out long ago. However, remnant cypress stumps could not be found nor do reliable records exist concerning the pristine condition of these forests.

In swamps in which conditions are less wet (where the average water table depth is 9-11 inches), hummocks comprise about 75% of the forest floor on average. Under these conditions, red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*) dominate the canopy. It is the reduced importance of the ashes and the increased importance of sweetgum and red maple that differentiates maple-sweetgum swamps from the wetter ash-blackgum swamps (Table 1).

Due to the interdigitating pattern of hummocks and hollows in tidal swamps and the fact that trees are restricted to the hummocks, trees in tidal swamps tend to grow further apart on average than do trees growing in nontidal wetland forests. The sparse distribution of canopy trees in conjunction with the reduction in crown breadth (a response to flooding stress) allows much light and light of variable intensity to reach the forest floor. This may be why the understory of tidal freshwater swamps is so luxuriant and rich in species. In fact, the understory of tidal swamps appears to contain more species of herbaceous plants and more shrub and understory tree species than any other temperate forest ecosystem yet studied by scientists.

The subcanopy tree stratum (composed of shrubs such as spicebush and various viburnum (honeysuckle family) species and understory trees such as swamp dogwood, ironwood, and various holly species) contains 25 species with 8-10 species often occurring together within one half acre. The herbaceous layer is much richer in species and harbors more than 75 species at the time of peak biomass in July. Because herbaceous species composition changes continuously throughout the growing season, tidal swamps support even more herbaceous species on an annual basis. The interplay of light and flooding provides many heterogeneous habitats and a variety of niches within a small area. Thus, the herbaceous layer of tidal freshwater swamps is shared by obligate and facultative wetland species, shade tolerant bottomland hardwood species, shade intolerant freshwater marsh species, and shade generalists, all regulated by variances in tidal flooding heights of only a few inches.

Toward the most upriver reaches of tidal excursion, where the river narrows to approximately 25 yards in width, the swamps are probably flooded near the surface only in the early spring. Later in the growing season, tidally forced groundwater fluctuations occur 18-26 inches below ground. Such swamps, classified as seasonally flooded tidal swamps, vary in composition, are devoid of hollows, and possess a closed canopy much like that of nontidal swamps. The canopies of these seasonally flooded swamps also possess many more tree species than ash-blackgum and maple-sweetgum tidal swamps (probably due to the less stressful flooding regime), but contain fewer understory species (perhaps due to the more closed canopy).

Changes in sea level could have important implications for tidal swamps. Sea level is rising in the Chesapeake Bay area and has been rising throughout the last 18,000 years. Tidal swamps maintain themselves as sea level rises by building upward (as long as the water is fresh) and by retreating upriver and inland (essential for escaping saltwater intrusion).

Table 1

Vegetation of tidal freshwater swamps. Swamp-types are based upon the composition of the canopy. Numbers are importance values (IV). For canopy trees IVs are based upon the average of relative basal areas and relative densities, for subcanopy species IVs are based upon relative densities, and for herbs IVs are based upon the average of relative coverages and relative frequencies of occurrence. BA= basal area.

	Ash-blackgum (n=12)	Ash-blackgum (Bald cypress subtype) (n=2)	Maple-sweetgum (n=6)
CANOPY			
Mean BA (ft^2/acre)	154.2	135.6	138.2
Mean density (#/acre)	339	273	255
Importance Value:			
Fraxinus spp.	41.5	19.7	13.2
Nyssa biflora	35.5	22.6	19.7
Acer rubrum	20.2	30.9	36.5
Liquidambar styraciflua	0.4	3.0	21.6
Taxodium distichum	0.1	21.2	–
Other species (n)	3.0 (8)	2.6 (2)	9.0 (11)
SUBCANOPY			
Mean Density (#/acre)	1,329	1,761	1,236
Relative Density:			
Lindera benzoin	22.3	21.2	3.6
Ilex verticillata	19.7	7.6	11.2
Carpinus caroliniana	11.0	6.8	9.0
Viburnum dentatum	7.3	2.5	8.2
Alnus serrulata	10.0	0.9	5.6
Ilex opaca	7.8	13.6	22.0
Magnolia virginiana	1.7	9.0	8.7
Other species (n)	20.2 (14)	38.4 (7)	31.7 (11)
HERBS			
Importance Value:			
Polygonum arifolium	20.9	14.9	2.5
Carex bromoides	8.9	13.2	8.0
Peltandra virginica	6.9	2.8	3.8
Saururus cernuus	5.9	7.3	10.9
Murdannia keisak	5.1	1.2	0.2
Uniola latifolium	3.1	–	–
Cinna arundinacea	3.1	3.2	1.3
Carex tribuloides	2.2	2.7	0.6
Carex intumescens	1.8	–	15.3
Boehmeria cylindrica	1.7	4.8	3.3
Mitchella repens	1.4	4.1	5.1
Carex crinita	1.1	1.8	2.9
Other species (n)	37.9 (44)	44.8 (25)	44.1 (31)

In order to build upward, tidal swamps must accumulate biomass (trunks, limbs, leaves, etc.) at a rate sufficient to pace that of the rising sea level. Trees that die and fall over, provide a surface on which the less flood tolerant trees and herbs can colonize. As the colonizing trees grow, they develop a thick root mass around and within the decomposing trunks. Eventually all that is left are the colonizers, raised (as hummocks) above the general surface level of the swamp (the hollows). If sea level rises too rapidly, not only does the accumulation of biomass slow relative to sea level rise, but the absolute rate of biomass accretion slows due to the increased stress imposed by flooding. Even when tidal swamps are unable to rise vertically in pace with a rapid sea level rise, they can move upriver as the sea advances inland.

Tidal freshwater swamps lie at one end of a temperate estuarine flooding continuum; at the other end lie the tidal saltwater marshes. Under the scenario of a rising sea level, the natural progression in an estuary is from terrestrial forest to tidal saltwater marsh. As tidal waters encroach upon terrestrial forests near the river, upland vegetation is replaced by more flood tolerant swamp vegetation and its composition changes to that of a seasonally flooded tidal swamp. As sea level rises further and conditions become more wet, maple-sweetgum tidal swamps replace the seasonally flooded tidal swamps. Under still wetter conditions in the wake of a further rise in sea level, the maple-sweetgum swamps are replaced by ash-blackgum tidal swamps. As conditions become too wet for trees and the river starts to become slightly saline (about 0.5 ppt), tidal freshwater marshes replace the ash-blackgum swamps. Tidal freshwater marshes are replaced by tidal oligohaline marshes and then by tidal saltwater marshes as sea level rises still higher and saline water intrudes further into the estuary.

Conclusions

The tidal swamps of the lower Chesapeake Bay, although small in areal extent, may be important to the biological integrity of the estuary. These swamps not only contain a rich and unique assemblage of plant life, but they may provide essential habitat for spring spawning anadromous fishes and overwintering waterfowl.

Flooding regime has been shown to be the most important environmental factor controlling the distribution and relative abundances of plant species growing in freshwater wetlands. In tidal freshwater swamps, the flooding regime is controlled by the tides. Although tide heights can fluctuate by as much as 4 feet in some tidal swamps, vegetation patterns are regulated by variations in the average belowground flooding levels of only a few inches at the extreme upper range of tidal influence.

Tidal freshwater swamps may be rare because there are few areas where the delicate balance between physical factors and biomass accumulation can be maintained. When a tidal swamp is unable to accumulate biomass at a rate sufficient to pace local sea level rise, it will not persist on the landscape.

The influences of man at both the regional and global levels could potentially upset the delicate balance necessary for the survival of tidal swamps. A removal of timber from tidal swamps could slow or prevent biomass accumulation in them. Regional subsidence of the ground due to the withdrawal of groundwater from underlying aquifers and thermal expansion of the oceans in response to global climatic warming could accelerate the rate of local sea level rise, making it less likely for tidal swamps to build vertically at a sufficient rate.

Even if a tidal freshwater swamp can build vertically at a rate sufficient to pace sea level rise, it will eventually succumb to the intrusion of saltwater. In order for tidal freshwater swamps to persist on the landscape over the long-term they must retreat upriver or inland as sea level rises. With the continued encroachment of man onto the coastal landscape, suitable areas for the continued colonization of tidal swamps (as well as for other tidal wetlands) are becoming increasingly limited. A loss of tidal swamps would further degrade the biological integrity of Chesapeake Bay.

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