PHOSPHORUS RETENTION IN NON-TIDAL PALUSTRINE FORESTED WETLANDS OF THE MID-ATLANTIC REGION

Mark R. Walbridge and Judith P. Struthers
Department of Biology
George Mason University
Fairfax, Virginia 22030-4444

Abstract: We: 1) quantified the areal extent of wetlands by type in Caroline County, VA to estimate the relative importance of non-tidal palustrine forested wetlands as a component of the wetland resources in Virginia's mid-Atlantic coastal plain, 2) used a comparative literature review to identify factors that might be important in controlling P retention in these wetlands, and 3) evaluated three indices that have been used to compare P adsorption potentials in wetland soils. Non-tidal palustrine forested wetlands comprised 66.0% of the 11,372 ha of wetlands in Caroline Co. The majority were either seasonally (4000 ha) or temporarily (1596 ha) flooded wetlands dominated by broad-leaved deciduous species. These wetlands are both small (averaging 5.4 and 2.4 ha in area, respectively) and numerous in this region. Adsorption by Al and Fe (hydr)oxides and precipitation of Al, Fe, and Ca phosphates probably controls dissolved phosphate retention and long-term P storage in these wetlands, although P storage in the woody biomass of aggrading forests may also be important. Phosphorus adsorption isotherms, a single-point phosphorus adsorption index, and concentrations of oxalate-extractable (noncrystalline) Al and Fe have all been used as comparative indices of P sorption potentials in wetland soils, although the latter may represent the best single index of P sorption capacity because of its direct relationship to the mechanisms controlling P adsorption in soil. When using these indices to compare wetland P sorption potentials, it is important to consider differences in soil depth, profile heterogeneity, and bulk density between sites. Actual amounts of phosphate retained by a wetland will also be influenced by the degree of phosphate loading it receives, as determined by hydrology, phosphate sources in the watershed, and the P sorption potentials of surrounding upland soils. Because of the low P sorption potentials of sandy soils in coastal plain uplands, non-tidal palustrine forested wetlands in the mid-Atlantic coastal plain may perform particularly important functions with respect to dissolved phosphate removal and retention on the landscape.

Key Words: aluminum, coastal plain, hydrology, iron, land use, phosphate loading, P sorption capacity, soil chemistry, water quality.

INTRODUCTION

Forest ed wetlands include those wetlands variously described as bottomland hardwood forests (Clark and Benforado 1981, Wharton et al. 1982, McWilliams and Rosson 1990), floodplain and riparian forests (Lowrance et al. 1984, Penka et al. 1985), fringe wetlands (Lugo 1990), riverine wetlands (Brinson 1990), streamside forests (Bell et al. 1978), and swamps (Yarbro 1983, Ewel and Odum 1984). Forested wetlands perform a number of important water quality functions on the landscape, including nitrogen and phosphorus removal (Mitsch et al. 1979a, Yarbro 1983, Brinson et al. 1984, Richardson et al. 1988), amelioration of agricultural runoff (Lowrance et al. 1984, Cooper et al. 1987), and regulation of nutrient exchange between terrestrial and aquatic ecosystems (Cuffney 1988).

With the exception of the Dismal Swamp (Day 1982, Megonigal and Day 1988, Carter 1990), non-tidal palustrine forested wetlands (PFOs) in Virginia have received little attention, particularly with respect to their potential for removing non-point source inputs of phosphorus (P) from surface, subsurface, and ground waters. Past studies have examined the geomorphologic structure and/or vegetational composition of these wetlands (e.g., Hack 1957, Parsons and Ware 1982, Osterkamp and Hupp 1984). More recent studies have focused on sediment and trace element dynamics (Hupp et al. 1993, Puckett et al. 1993).

Elucidation of the P retention functions of non-tidal PFOs in Virginia's lower piedmont and coastal plain could be particularly important because of the potential impact of these functions on the quality of water entering the Chesapeake Bay (cf. Computer Sciences Corp. 1991) and because these wetlands are currently threatened both by increasing development in this region and by changes in the criteria used to delineate...
jurisdictionally protected wetlands. Coastal plain regions are frequently characterized by sandy soils, particularly in upland areas, while finer-textured clays tend to accumulate along floodplains and in riparian zones (cf. Schlesinger 1991). Because the geochemical mechanisms (e.g., adsorption and precipitation) that remove phosphate from soil solutions are associated primarily with these clay particles (Stevenson 1986), non-tidal palustrine forested wetlands in coastal plain regions may perform particularly important functions with respect to dissolved phosphate removal and retention on the landscape.

Our study had two objectives: 1) to estimate the relative importance of non-tidal palustrine forested wetlands as a component of the wetland resources in Virginia's mid-Atlantic coastal plain, and 2) to identify factors that might be important in controlling P retention in these wetlands. To accomplish our first objective, we quantified the areal extent of wetlands by type in Caroline Co., VA as representative of Virginia's mid-Atlantic coastal plain using a combination of National Wetlands Inventory (NWI) data and updated digital information provided by the Virginia Council on the Environment. We addressed our second objective by a comparative literature review of the factors controlling P retention in forested wetlands. Richardson (1985) suggested a simple index for comparing the P adsorption capacities of wetland soils. Here, we also suggest additional factors that should be included when comparing P adsorption potentials in wetland soils.

WETLAND RESOURCES IN CAROLINE CO., VA

Caroline Co. comprises an area of approximately 362,508 ha and lies primarily in the mid-Atlantic coastal plain. Although the Rappahannock River, which forms the northern border of the county, is tidally influenced below Fredericksburg, Caroline Co. is primarily a landlocked county. Wetland distributions in coastal counties may show increased importance of tidal wetlands, but estimates of wetland distributions for Caroline Co. should be comparable to other landlocked coastal plain counties in VA.

We used Virginia Council on the Environment (VCE) digital data for wetland distributions by type in the lower 42% of Caroline Co. (C. Powers, pers. comm.), and combined these data with similar distributions indicated on National Wetlands Inventory (NWI) maps for the remaining 58% of the county. When available, VCE data were used in preference to NWI data because the VCE data are more recent and are considered more accurate (C. Powers, pers. comm.).

For the NWI data, wetland areas by type were determined from appropriate NWI maps using an ER-DAS Geographic Image Processing System, Version 7.4 software (ERDAS, Inc., Atlanta, GA) and a 386 microcomputer. Wetland areas were calculated by averaging two estimates per wetland, one drawn in a clockwise direction, the other counterclockwise. Many temporarily flooded, broad-leaved deciduous palustrine forested wetlands (PFO1As) on the NWI maps are represented as linear features (lines following stream drainages). We estimated the areas of these wetlands by multiplying linear measurements times an estimated average width of 6m.

Wetland classifications follow the U.S. Fish and Wildlife Service system (Cowardin et al. 1979). Where appropriate, category designations were updated based on information provided by the USFWS regional office in Massachusetts (G. Smith and D. Foulis, pers. comm.). Deep water habitats, unconsolidated bottom (UB) areas with water depths greater than 2 m at mean low water, were excluded from our analysis. Since these are difficult to identify from aerial photography, we followed the USFWS convention for including or excluding UB areas as wetlands (D. Foulis, pers. comm.). All palustrine UBs were assumed to be wetlands, lacustrine UBs and riverine UBs represented as polygons were assumed to be deepwater habitats, and riverine UBs represented as linear features were assumed to be wetlands.

The combined NWI and VCE databases indicate that there are approximately 11,372 ha of wetlands in Caroline Co., VA, roughly 3.1% of the total county area (Table 1). Non-tidal palustrine forested wetlands (PFOs) account for 66.0% of the total wetland area and 94.1% of all wetlands in the county are non-tidal palustrine wetlands. Tidal palustrine wetlands account for an additional 5.4%; most of these are also forested. Palustrine wetlands completely dominate the wetland resources of Caroline Co. (Table 1).

Of the estimated 7505 ha of non-tidal palustrine forested wetlands in Caroline Co., the majority (4000 ha) are seasonally flooded wetlands dominated by broad-leaved deciduous tree species (PFO1Cs); most of the remaining non-tidal palustrine forested wetlands (1596 ha) are temporarily flooded wetlands dominated by broad-leaved deciduous trees (PFO1As) (Table 2). PFO1C and PFO1A wetlands in Caroline Co. are both small, averaging 5.4 and 2.4 ha in area respectively, and numerous. Since many PFO1A wetlands are drawn as linear features on the NWI maps, our method of estimating areas for these wetlands may have caused us to underestimate their areal extent.

Based on the combined NWI and VCE databases, only a small percentage of each type of non-tidal palustrine forested wetland seems to have suffered impacts from drainage, impoundment, or beaver activity, although impacts to PFO1F wetlands (semiperma-