Nutrient Flux in a Landscape: Effects of Coastal Land Use and Terrestrial Community Mosaic on Nutrient Transport to Coastal Waters

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ABSTRACT: Long-term interdisciplinary studies of the Rhode River estuary and its watershed in the mid-Atlantic coastal plain of North America have measured fluxes of nitrogen and phosphorus fractions through the hydrologically-linked ecosystems of this landscape. These ecosystems are upland forest, cropland, and pasture; streamside riparian forests; floodplain swamps; tidal brackish marshes and mudflats; and an estuarine embayment. Croplands discharged far more nitrogen per hectare in runoff than did forests and pastures. However, riparian deciduous hardwood forest bordering the cropland removed over 80 percent of the nitrate and total phosphorus in overland flows and about 85 percent of the nitrate in shallow groundwater drainage from cropland. Nevertheless, nutrient discharges from riparian forests downslope from croplands still exceeded discharges from pastures and other forests. The atomic ratio of nitrogen to phosphorus discharged from the watersheds into the estuary was about 9 for total nutrients and 6 for inorganic nutrient fractions. Such a low N:P ratio would promote nitrogen rather than phosphorus limitation of phytoplankton growth in the estuary. Estuarine tidal marshes trapped particulate nutrients and released dissolved nutrients. Subtidal mudflats in the upper estuary trapped particulate P, released dissolved phosphate, and consumed nitrate. This resulted in a decrease in the ratio of dissolved inorganic N:P in the estuary. However, the upper estuary was a major sink for total phosphorus due to sediment accretion in the subtidal area.

Introduction

The landscape of the mid-Atlantic coastal plain of North America is a mosaic of different hydrologically-linked ecosystems. Agricultural uplands are major sources of nutrient discharges from coastal plain watersheds (Correll 1983, 1987; Jordan et al. 1986a). Upland forests also release nutrients, but at much lower rates than agricultural lands (Correll 1983; Weller et al. 1986). In contrast, other ecosystems such as riparian forests (Correll and Weller 1989), flood plain forests, freshwater swamps (Brinson et al. 1984; Yarbro et al. 1984), and tidal marshes (Correll 1981; Jordan et al. 1983; Jordan and Correll 1985; Jordan et al. 1986b) act as nutrient sinks. Whether these ecosystems trap or release nutrients may depend on how much nutrient they receive from uphill ecosystems. For example, riparian forests are often located downhill of agricultural lands in the coastal plain. Typically the concentration of nitrate in agricultural drainage waters is dramatically reduced as it moves through these riparian forests and before it reaches the adjacent stream channel (Lowe et al. 1984a; Jacobs and Gilliam 1985b; Cooper et al. 1986; Correll and Weller 1989).

Hydrologically-linked ecosystems interact through the flux of water-borne sediments and nutrients. Nutrients discharged from many upland ecosystems pass through lowlands and a continuum of freshwater and brackish wetlands on their way to estuaries and the sea. Understanding the dynamics of such nutrient flows requires knowledge...
Fig. 1. The upper Rhode River and eight subwatersheds where nutrient fluxes were measured. Dotted lines are watershed boundaries (from Jordan et al. 1986a).

of the effects of land use on nutrient discharge and of the effects of uphill ecosystems on downhill ecosystems.

There have been many studies of nutrient cycling and flow through specific ecosystems, but few studies of nutrient flows through landscapes containing several different kinds of ecosystems. In this we provide a synthesis of our long-term studies of nitrogen and phosphorus flux through a complex coastal landscape containing many different hydrologically-linked ecosystems.

Site Description

The study site is the Rhode River estuary and its watershed, located east of Washington, D.C. on the western shore of Chesapeake Bay (38°51’N, 75°36’W). We studied eight subwatersheds comprising 2,286 ha which drain into a tidal creek at the head of the Rhode River (Fig. 1). Overall, the studied watersheds were 62% forest, 23% croplands, 12% pasture, and 3% freshwater forested swamp (Correll 1977), but land use differed from subwatershed to subwatershed (Table 1). The soils are rich in nutrients and consist of fine sandy loams of sedimentary origin (Correll 1983). An impermeable clay aquiclude forms a continuous layer just above sea level, creating perched local aquifers within each subwatershed (Chirlin and Schaffner 1977). The forests are deciduous and mostly of the tulip poplar association (Brush et al. 1980). The croplands are predominantly in corn production. The upper part of the Rhode River consists of 23 ha of shallow (less than 1 m deep) tidal mudflats and creeks bordered by 22 ha of high tidal marshes.