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Review

Sources of nutrients impacting surface waters in Florida: A review

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ABSTRACT

The promulgation of numeric nutrient criteria for evaluating impairment of waterbodies in Florida is underway. Adherence to the water quality standards needed to meet these criteria will potentially require substantial allocations of public and private resources in order to better control nutrient (i.e., nitrogen and phosphorus) releases from contributing sources. Major sources of nutrients include atmospheric deposition (195–380 mg-N/m^2/yr, 6 to 16 mg-P/m^2/yr), reclaimed water irrigation (0.13–29 mg-N/L, 0.02 to 6 mg-P/L), septic systems (3.3×10^3–6.68×10^3 g-N/person/yr, 0.49×10^3–0.85×10^3 g-P/person/yr) and fertilizer applications (8×10^6–24×10^6 mg-N/m^2/yr). Estimated nitrogen loadings to the Florida environment, as calculated from the above rates are as follows: 5.9×10^9–9.4×10^9 g-N/yr from atmospheric deposition, 1.2×10^8–2.6×10^{10} g-N/yr from reclaimed water, 2.4×10^{10}–4.9×10^{10} g-N/year from septic systems, and 1.4×10^{11} g-N/yr from fertilizer application. Similarly, source specific phosphorus loading calculations are also presented in this paper. A fraction of those nutrient inputs may reach receiving waterbodies depending upon site specific regulation on nutrient control, nutrient management practices, and environmental attenuation. In Florida, the interconnectivity of hydrologic pathways due to the karst landscape and high volumes of rainfall add to the complexity of tracking nutrient loads back to their sources. In addition to source specific nutrient loadings, this review discusses the merits of source specific markers such as elemental isotopes (boron, nitrogen, oxygen, strontium, uranium and carbon) and trace organic compounds (sucralose, gadolinium anomaly, carbamazepine, and galaxolide) in relating nutrient loads back to sources of origin. Although this review is focused in Florida, the development of source specific markers as a tool for tracing nutrient loadings back to sources of origin is applicable and of value to all other geographical locations.

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1. Introduction

Nutrient (nitrogen and phosphorus) loading to waterways from point and non-point sources is an ecological concern and represents one of the most significant water quality issues in surface waterbodies today (Smith et al., 1999). Nutrients are essential to survival of aquatic organisms, but excess nutrient loading to waterbodies can impact designated uses of water (FDEP, 2009; Freeman et al., 2009; Bricker et al., 2007). Despite the water quality protection requirements of the Clean Water Act, eutrophication resulting from excess nutrient loading is considered to be the single largest cause of water quality degradation in US lakes and estuaries (Vitousek et al., 1997). Potential effects of eutrophication in waterbodies are: increased biomass of phytoplankton and macrophyte vegetation, growth of benthic and epiphytic algae, increased blooms of gelatinous zooplankton (marine environment), increased toxins from bloom-forming algal species, reduced carbon available to food webs, loss of commercial and sport fisheries, reduced diversity of habitats, loss of coral reef communities, increased taste and odor problems, dissolved oxygen depletion, increased treatment costs prior to human use, and decreased aesthetic value of the waterbody (USEPA, 2000; Smith and Schindler, 2009). Unintended nutrient loading can also increase the ecological hazard caused by concurrent loading of other anthropogenic contaminant inputs such as heavy metals, pesticides, pharmaceuticals, and hormones (Kelly, 1995; Helgeson and McNeal, 2009). In addition to these ecological concerns, the possibility of a direct correlation between eutrophication and human disease has been reported (Bruno et al., 2003; Townsend, 2003).

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Surface waterbody impairment is a critical ecological concern in Florida, USA. One of the reasons for this concern is that in Florida, surface water accounts for 38% of the drinking water supply (i.e., approximately 4.3 billion gallons per day) of the State (Marella, R. 2010; Borisova and Carriker, 2008). Therefore, considering both ecological and potable water source viewpoints, surface waterbodies need to be protected from nutrient loading to avoid further water quality degradation. Several studies showed evidence that nitrate-nitrite concentrations in many spring discharges have increased from 10 to 350 fold over the past 50 years, with the level of increase closely correlated with the anthropogenic activity and land use changes within the springshed (Panno et al., 2001; FDEP, 2009; Strong, 2004; Katz et al., 1999, 2009). Since surface waterbodies in Florida are often connected to springs, the increased nutrient concentrations frequently documented in the groundwater may cause increased nutrient levels in surface waterbodies (Hornsby and Ceryak, 2000).

As of July 2011, the State of Florida has been implementing a narrative nutrient standard stating that "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna" (62–302.530, FAC). Trophic state indices (TSIs) and chlorophyll-a have been established to assess water impairment (Chapter 62–303.350, FAC). Fig. 1, created using the Verified Impaired Waters GIS file obtained directly from the Florida Department of Environmental Protection (FDEP), shows all of the verified waterbodies impaired for nutrients. Of these 425 nutrient impaired waterbodies; about 27 percent are estuaries and coastal waters, 39 percent are lakes and 33 percent are streams. The majority of the verified impaired waterbodies are located around urbanized areas in the Central and Southwest Districts. However, by area, the Southeast, South and Central districts have the largest percentage of impaired waterbodies at approximately 70%.

The numeric nutrient criteria suggested that the waterbodies in Florida required to be characterized and protected against a more stringent set of nutrient limits (FDEP, 2010a). The final rule for the surface water bodies in Florida is anticipated to be established and adopted in near future. Compliance with such regulations may require wastewater, stormwater, industrial manufacturers, agriculture industries and other contributing entities to provide financial resources as estimated by the USEPA and FDEP (FDEP, 2010a) to mitigate existing impacts. In order to maximize the benefits of future nutrient loading mitigation measures, perspective engineers and researchers should enhance their ability to track waterbody nutrient loads back to their specific sources of origin. Understanding a waterbody's nutrient application points and the fate and transport properties of the nutrient species from their points of origin, will enable an estimation of the relative nutrient contributions from the different sources. Considering the ecological impacts of nutrients and the anticipated numeric nutrient limits, there is a timely need for a review of nutrient source concentration ranges and, their fate and transport properties within the hydrogeologic characteristics of the Florida environment. This review critically summarizes the occurrence and transport of nutrients (nitrogen and phosphorus) with emphasis on: (a) nutrient application and loading rates from a variety of sources, (b) hydrogeologic characteristics of Florida influencing nutrient pathways, (c) factors impacting natural attenuation of nutrients through transport, (d) recent developments in source specific markers to track nutrient sources contributing to a waterbody.

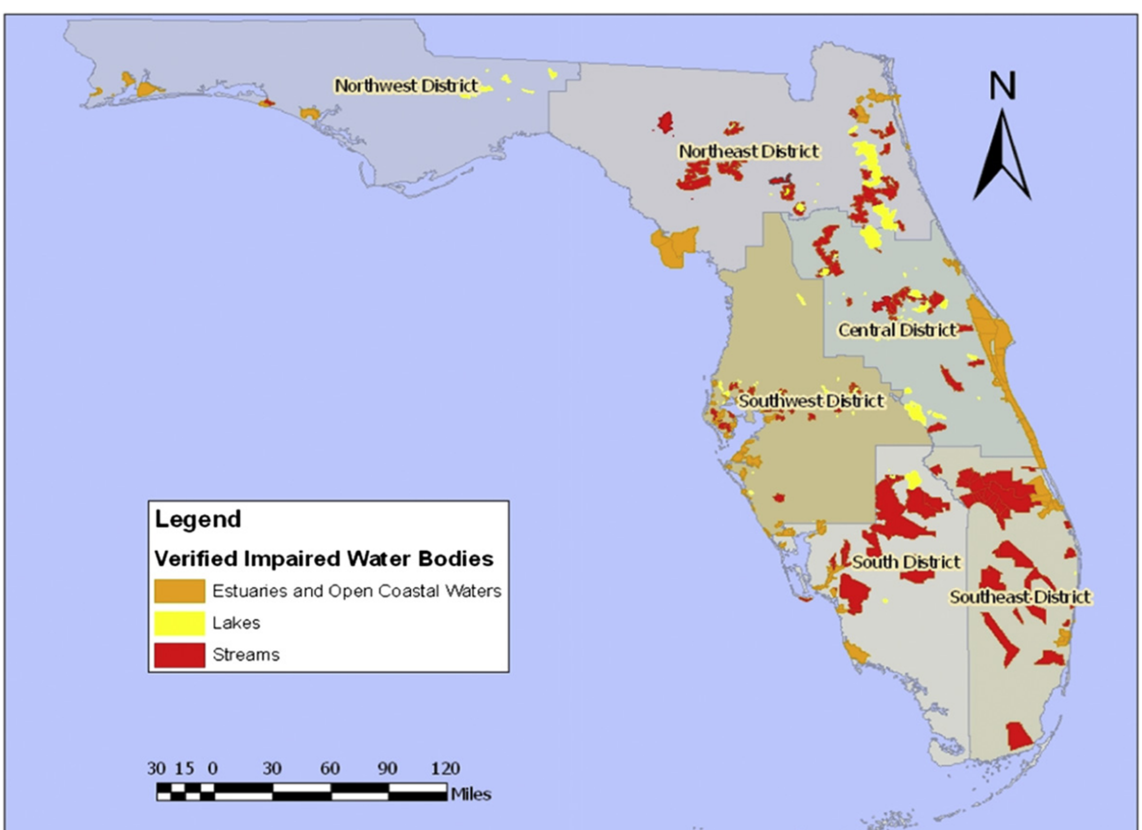

Fig. 1. Distribution of nutrient impaired waterbodies in Florida (Adapted from FDEP GIS database file on verified impaired waterbodies, accessed December, 2010).