Coastal groundwater discharge – an additional source of phosphorus for the oligotrophic wetlands of the Everglades

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Abstract

In this manuscript we define a new term we call coastal groundwater discharge (CGD), which is related to submarine groundwater discharge (SGD), but occurs when seawater intrudes inland to force brackish groundwater to discharge to the coastal wetlands. A hydrologic and geochemical investigation of both the groundwater and surface water in the southern Everglades was conducted to investigate the occurrence of CGD associated with seawater intrusion. During the wet season, the surface water chemistry remained fresh. Enhanced chloride, sodium, and calcium concentrations, indicative of brackish groundwater discharge, were observed in the surface water during the dry season. Brackish groundwaters of the southern Everglades contain 1–2.3 μM concentrations of total phosphorus (TP). These concentrations exceed the expected values predicted by conservative mixing of local fresh groundwater and intruding seawater, which both have TP < 1 μM. The additional source of TP may be from seawater sediments or from the aquifer matrix as a result of water–rock interactions (such as carbonate mineral dissolution and ion exchange reactions) induced by mixing fresh groundwater with intruding seawater. We hypothesize that CGD maybe an additional source of phosphorus (a limiting nutrient) to the coastal wetlands of the southern Everglades.

Introduction

All coastal aquifers with a hydraulic connection to the sea are susceptible to seawater intrusion (Bear et al., 1999). The interface between freshwater and seawater in coastal aquifers was first identified by Du Commun (1828), half a century earlier than the more widely cited Ghyben–Herzberg principle (Ghyben, 1888; Herzberg, 1901). A systematic study of seawater intrusion in the 1950s in south Florida formed a set of benchmark papers on the subject (Cooper, 1959; Kohout, 1960, 1964). The most significant finding of these studies was the recognition that the freshwater–seawater interface was not sharp as described by the Ghyben–Herzberg principle, but formed a zone of mixed water composition termed by many in the field as a ‘mixing zone’ (Fig. 1a; Back et al., 1986; Price & Herman, 1991). Brackish water in this mixing zone is circulated along with the freshwater to the sea (Cooper, 1959). If the groundwater discharge occurs beneath overlying marine or estuarine waters it is termed submarine groundwater discharge (SGD; Younger, 1996; Fig. 1a). However, the position and extent of the mixing zone and the flux of its associated brackish
groundwater discharge is governed by many factors such as rainfall, groundwater withdrawals, irrigation and evapotranspiration on the freshwater side, with tides, waves, and changes in sea level on the seawater side (Kohout, 1960; Bear et al., 1999). Along many of the worlds developed coastlines, the combined effects of increased groundwater withdrawals and sealevel rise results in enhanced seawater intrusion into the freshwater coastal aquifers (Konikow & Reilly, 1999), thereby shifting the discharge of brackish groundwater inland (Fig. 1b). We wish to define a new term, coastal groundwater discharge (CGD) to describe the discharge of brackish to saline groundwater to coastal areas including coastal wetlands and streams (Fig. 1b).

The discharge of this brackish groundwater can have a significant impact on the ecology of dominantly freshwater coastal wetlands and streams. CGD has the potential to alter the salinity of wetland soils and surface waters, to be a source of water, and to deliver dissolved constituents like nutrients and dissolved toxins. Such discharge also can be an important determinant of the productivity of coastal systems, as they are often nutrient limited and groundwater tends to be enriched in nitrogen and phosphorus compared to oligotrophic surface waters.

The potential for brackish groundwater discharge to the surface water of the Everglades as evidenced by a comparison of groundwater and surface water levels was presented earlier (Price et al., 2003). The objective of this paper is to provide geochemical evidence of the discharge of brackish groundwater to the overlying surface water of the coastal Everglades. Furthermore, this paper demonstrates that the brackish groundwater contains elevated concentrations of phosphorus. Phosphorus limits primary producer biomass, animal biomass, the structure of the primary producer community, the structure of the microbial community and the structure of animal community of the coastal Everglades (Armitage et al., 2005, 2006; Gil et al., 2006). We propose that the enhanced productivity of the freshwater–marine ecotone of the coastal Everglades as compared to either freshwater or marine end-members may be fueled by the P delivered by CGD.

**Site description**

The Everglades occupies most of the south Florida peninsula and discharges into Florida Bay and the Gulf of Mexico (Fig. 2). The topography across the Everglades is extremely flat, and contributes to an exceptionally low hydraulic gradient ($5 \times 10^{-6}$) and poorly defined watershed boundaries. The Surficial Aquifer System (SAS) in south Florida consists of Miocene to Holocene age siliclastic and carbonate sediments and varies in thickness from 50 to 82 m (Fish & Stewart, 1991; Reese & Cunningham, 2000). The Biscayne Aquifer forms the top of the SAS and is the principal water supply for human development in South Florida. Its thickness increases across the study site in a southeasterly direction from a feather edge in northwestern Shark Slough to over 65 m thick along the southeastern coastline (Fish & Stewart,