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Spatial and temporal chemical variability in the Hillsborough River system

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Abstract

The Hillsborough River originates in the Green Swamp, a principal recharge area of the Floridan Aquifer system. As the river flows to Tampa Bay, its chemistry is influenced by a variety of natural and anthropogenic inputs. Spatial and temporal variations in the river's major ion concentrations, CO_2-system chemistry, and nutrients were examined in a two-year study between 1999 and 2001. At thirteen sampling stations along approximately 87 km of the river, water samples were collected in surroundings that ranged from pristine to urban.

Concentrations of major ions were lowest in the river's headwaters, showed only minor spatial variations mid-river, and sharply increased in tidally influenced waters below the dam on the lower river. The mid-river major ion composition is relatively constant in large part because two of the river's most compositionally distinctive inputs, Blackwater Creek and Crystal Springs, are located well upstream. Below the confluence of Blackwater Creek and river water that is largely derived from Crystal Springs, concentrations of Na^+, K^+, Mg^{2+}, Ca^{2+}, HCO_3^-, F^-, Cl^- and PO_4^{3-} showed spatial variations that were smaller than +/−30%. Only SO_4^{2-} and NO_3^- exhibited strong downstream variations. Sulfate concentrations increased by more than a factor of two, and NO_3^- decreased by more than an order of magnitude.

In contrast to spatial variations in the river's chemistry, temporal variations were quite large. Concentrations of major ions decreased during the rainy season (June–September) by as much as a factor of 3–5, and phosphate concentrations increased by approximately an order of magnitude. The river's CO_2-system also showed strong seasonal variations. River pH and $CaCO_3$ saturation state decreased sharply during periods of high precipitation. $CaCO_3$ supersaturation was observed during the exceptionally dry periods of the study, and undersaturation was observed during periods of high rainfall.

Overall, the Hillsborough River's delivery of solutes to Tampa Bay is greatly influenced by temporal variations in river hydrology, and distinct chemical signatures from the river's tributaries, groundwater sources, and anthropogenic inputs. The river's output of phosphate to the bay, which is exceptionally high during periods of high river-flow, is especially notable.

Keywords: Florida; Major ions; pH; Carbonate; Phosphate; Nitrate; Hillsborough River

1. Introduction

The Hillsborough River is a major freshwater input to Hillsborough Bay and the Tampa Bay estuary. The historic annual discharge for the river (measured at the USGS streamflow gauging station, 02304500) for the period,

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Table 1
USGS rainfall data, Hillsborough River Drainage Basin (September 1999–November 2001) (Southwest Florida Water Management District, 2002)

Sampling months	Rainfall totals by month (cm)			Historical rainfall average (cm)
	1999	2000	2001	(1915–2001)
January	8.31[a]	4.55	3.71	6.45
February	0.64[a]	1.68	1.83	7.57
March	3.07[a]	1.32	17.30	9.58
April	2.67[a]	3.38	0.56	6.53
May	9.09[a]	0.25	1.37	9.75
June	24.82[a]	20.75	21.62	19.46
July	12.29[a]	22.38	25.10	20.85
August	17.42[a]	18.75	16.46	20.62
September	11.61	17.81	30.86	17.63
October	10.52	0.13	3.23	7.42
November	5.92	4.32	0.84	4.85
December	4.01	2.84	2.67[a]	5.92
Annual totals	110.34	98.12	125.55	136.80

[a]These data, which were not obtained in the 9/99–11/01 sampling period, are included for completeness.

1939–1998 was 13.1 m^3/s. The flow from the river (in conjunction with other freshwater inputs in the area) exerts a seasonal influence on the salinity of the bay (Swarzenski, 2001), and concomitant variations are expected in both major ions and nutrients delivered to the estuary. During the period of study, the Hillsborough River basin experienced its worst drought in recorded history (1915–2001). USGS measurements of Hillsborough River streamflow for the period between September 1999 and November 2001 were also below the historical average for the river. The mean annual discharge from the river for the years 1999–2001 was 1.44 m^3/s, and the lowest flow on record (0.27 m^3/s) was recorded in 2000 (United States Geological Survey, 2005). Although yearly rainfall totals (1999–2001) were below the historical averages, monthly precipitation and streamflow (Tables 1 and 2) were consistent with the normal patterns of increases in summer months (April through September) and decreases in winter months (Southwest Florida Water Management District, 2002).

This study was designed to investigate spatial and temporal variations in the Hillsborough River's major ion chemistry as well as variations in key nutrients and CO_2-system variables. Observation of spatial and temporal variations in the river's composition provides insights into the sources of reactive solutes, both natural and anthropogenic, as well as the river's potential influences on Tampa Bay. As this study was conducted during a major drought, the observations obtained in this work should be of special interest in long-term assessments of the impact of climatic variations on the Hillsborough River basin.

2. Background

The Hillsborough River flows approximately 87 km from its source in the Green Swamp to its mouth at Hillsborough Bay. As the river flows toward Hillsborough Bay, water is added from several tributaries and springs. The Hillsborough River's drainage basin includes areas north of Zephyrhills, east of Lakeland, and most of Hillsborough County (Fig. 1).

Crystal Springs (Fig. 1) is the major source of fresh water for the river (Champion and Starks, 2001). It is classified as a second magnitude spring (2.5×10^4–2.5×10^5 cubic meters per day (m^3/day; Spechler, 1995) and, based on averages from 1923 to 1982, historically contributed $\sim1.4\times10^5$ m^3/day of water to the river (Tihansky and Knochenmus, 2001). More recent measurements (1993–1994) indicate the flow has been reduced to $\sim9.1\times10^4$ m^3/day, little more than half the historical flow (Sepulveda, 2001). During times of low precipitation, Crystal Springs may account for up to 80% of the flow in the upper river (Champion and Starks, 2001).

South of Crystal Springs lies a tributary of the Hillsborough River, Blackwater Creek (Fig. 1). Since this tributary drains a large agricultural and phosphate processing area, major ions and phosphate concentrations in Blackwater Creek are unique. Following a

Table 2
Monthly Hillsborough River streamflow at Morris Bridge near Thonotosassa (USGS Station #02303330) and historic monthly averages (United States Geological Survey, 2005)

Sampling months	Average flow by month (m^3/s)			Historical monthly average (m^3/s)
	1999	2000	2001	(1972–2004)
January	3.7[a]	1.7	1.0	6.2
February	3.0[a]	1.7	1.0	6.7
March	2.0[a]	1.2	1.0	8.2
April	1.5[a]	1.0	1.3	4.7
May	1.6[a]	0.9	0.8	2.8
June	3.1[a]	0.8	1.0	4.8
July	5.3[a]	1.1	2.3	8.2
August	4.2[a]	2.5	9.5	12.5
September	2.9	3.5	28.4	17.1
October	3.4	1.8	7.9	7.8
November	2.3	1.1	2.6	4.1
December	1.9	1.1	1.9[a]	6.1

[a]These data, which were not obtained in the 9/99–11/01 sampling period, are included for completeness.
[b]USGS Station #02303330 is located at N 28°05′50″, W 082°18′45″, near monitoring station 5.