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The impact of seepage influx on cation content of a Central Amazonian floodplain lake

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Summary We give the first report on seepage dynamics in an Amazonian floodplain lake, by directly quantifying seepage influx, and qualifying its impact on the hydrochemical seasonality of Lake Camaleão, an island channel lake, which is subject to the 10 m floodpulse of the lower Solimões/Amazon River. The lake shows a distinct seasonal pattern in cation concentrations, with a rise and maximum during its low-water (isolation) phase. To quantitatively and qualitatively clarify the significance of seepage influx, a series of hydrological and hydrochemical variables was recorded in 1998. The observed seasonal pattern in the content of solute cations was similar to results reported for 1995 [G.E. Weber, Causes of hydrochemical seasonality of major cations in Lago Camaleão, a Central Amazonian floodplain lake, Ver. Int. Verein. Limnol. 26 (2) (1997) 408–411.]; when first qualitative evidence for the largely seepage driven process of cation loading was found. Concentration of the monitored Ca, Na, Mg and K, in Lake Camaleão and Solimões were similar during high water. Solute cation content in the groundwater around Lake Camaleão was up to 20 times higher than in lake and river water. With the beginning of falling water, cation concentrations started to rise slightly in Lake Camaleão. Starting with isolation from Solimões River the content of solute cations in the lake rose by approximately 150% within 14 days, then the concentrations had reached their maximum values. This falls in with 14 days of cation rich seepage influx into lake Camaleão. Mean seepage influx rate during this period was 1.45 mm/h, which equals a total influx into Lake Camaleão of 9.7 m^3/min. After 14 days seepage stopped to enter the lake, lake water began to seep into the sediment, (seepage flux inversion), and the rise in cation concentrations in Lake Camaleão came to an end. Based on the water budget and measured cation concentrations of the contributing water fluxes we predicted cation concentrations at the end of the 14 days period of seepage influx into the isolated Camaleão. Observed and expected cation concentrations are fairly close.

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The coincidence of seepage influx and the solute cation increase in the isolated Camaleão, observed twice in 1998 and 1995, gives us strong evidence that cation loading by seepage is the main cause for the lake's characteristic peak of cation concentration during falling water. Our field measurements correspond to values calculated by [K. Furch, Evaluation of groundwater input as major source of solutes in an Amazon floodplain lake during the low-water period, In: Verh. Int. Verein. Limnol. 27, Stuttgart, Germany, 1999.] considering changes in ion concentrations which also point to groundwater as major ion source for Camaleão Lake at low-water period.

Introduction

Extreme seasonal variability of physical, chemical and biological parameters is characteristic of aquatic floodplain habitats (Sioli, 1984). This contrasts clearly with the relative environmental constancy of many other types of Amazonian waterbodies. The causes of abiotic and biotic seasonality in the floodplains are still poorly understood and often left to speculation, because quantification of hydrology and mass transport in particular is difficult and has rarely been attempted. In early studies most attention was paid to biotic nutrient fluxes within floodplain lakes (Piedade et al., 1991). Furch (1984a) and Furch et al. (1983) considered decomposition of macrophyte biomass as the main cause of hydrochemical seasonality in Lake Camaleão, situated 20 km upstream of the confluence of Rio Negro and Solimoes (Fig. 1). However, these studies did not include quantitative assessments of the underlying hydrological processes. Weber et al. (1996) first tried to quantify hydrochemical processes in Lake Camaleão and showed that, except for potassium, biogenic fluxes could not possibly explain the cation loading during drainage. Reports on high cation concentration in groundwater samples on Marchantaria Island (Furch and Junk, 1997) and soils draining well after reemergence (Worbes, 1997), led Weber et al. (1996) to the suggestion, that seepage influx could be the major parameter in cation loading. Seepage of groundwater into lakes and out of lakes is a phenomenon which has been frequently described in the last decade (Mcbride and Pfannkuch, 1975; Winter, 1978; Brock et al., 1982; Sebestyen and Schneider, 2004). Its impact on the dynamics of lakeshore ecosystems has been shown by Connor and Belanger (1981); Loeb and Hackley (1988); Schafran and Discroll (1990, 1993).

In a theoretical case study, Furch (1999) compared samples of cation rich groundwater to lake water quality and concluded, that seepage influx was the most likely cause for the observed cation loading, however, no seepage flux rates or ground water potentials were available in this study, the findings could never be validated. Lesack (1995) presented an empirical seepage model for a floodplain lake further up the Solimões. This model accounts for seepage flux rates and describes the dynamics in detail. However, water quality matters are not the focus of this paper. This is also due to the fact, that the lake observed in this study had a direct connection to the Amazon main stem. Consequently, no dynamics in water quality affect the water body due to continuous mixing with the Amazon water. Lesack's model was transferred to Lake Camaleão by Weber (1997) who suggested that seepage of cation rich groundwater into the lake, might explain the characteristic concentration peaks. Showing, that the end of seepage influx into the lake coincided with the peak cation concentrations in 1995, Weber and Junk (1998) found strong evidence for the dominating role of seepage borne cation loading. However, while this coincidence is a necessary condition for seepage driven cation loading, conclusive empirical proof can only be derived from quantification of seepage influx itself. Thus, the purpose of our study was to quantify seepage influx and verify its significance within the process of cation loading of Lake Camaleão during late drainage and early isolation. Within this context, our study aims at amplifying the knowledge about nutrient dynamics in a particular floodplain lake, representative for a considerable share of the

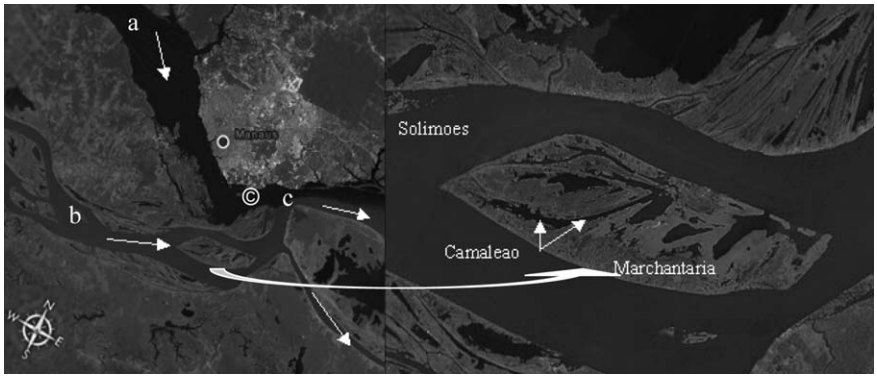

Figure 1 The Marchantaria Island location south of Manaus harbor (©). Solimoes River (b) and Rio Negro (a) confluence is marked with (c).