NUTRIENTS AND DISSOLVED ORGANIC MATTER IN THE ALTAMAHA RIVER AND LOADING TO THE COASTAL ZONE

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Abstract. Ammonium (NH_4^+), nitrate+nitrite (NO_x), dissolved inorganic phosphorus (DIP) and dissolved organic carbon, nitrogen and phosphorus (DOC, DON and DOP) were measured in the Altamaha River and several tributaries during a two year period from September 2000 through September 2002. Temporal variations in concentration as well as nutrient and dissolved organic matter loading from the Altamaha to the coastal zone were determined.

Loading rates were heavily dependent on river discharge, as was the form of nitrogen. All measured dissolved compounds in the Altamaha River were significantly correlated with river discharge ($p<0.05$) with the exception of NH_4^+. Concentrations of DOC, DON, DOP and DIP increased during periods of high flow, while levels of NO_x dropped. This resulted in NO_x dominating dissolved N loading during low river discharge, and DON increasing in importance during periods of high flow. Overall rates of C, N and P loading were much greater during high discharge times. Although loading rates of N were greater during high discharge, the shorter residence time in the coastal zone and the higher fraction of DON may alleviate some of the impacts of loading during high flow. Longer residence times and the availability of NO_x for rapid uptake may contribute to coastal eutrophication during periods of low flow.

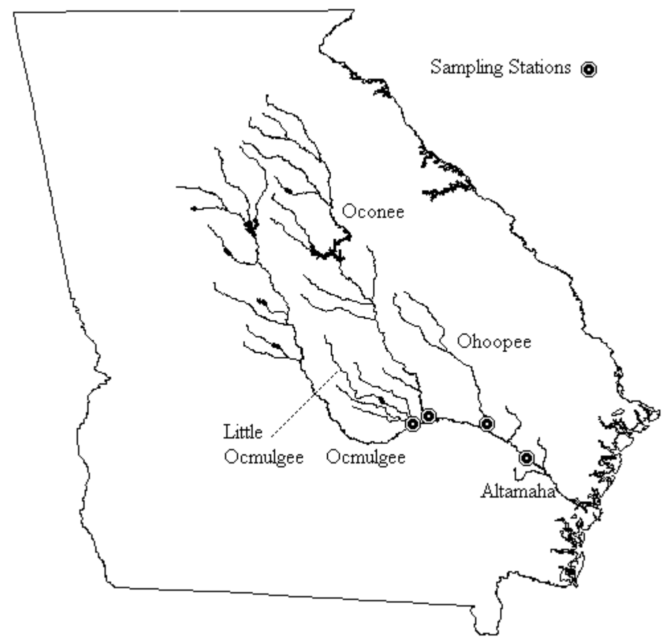

Figure 1. Sampling site map for the Altamaha, Oconee, Ohoopee, Ocmulgee and Little Ocmulgee Rivers (the Ocmulgee and Little Ocmulgee sampling sites are indistinguishable at this scale).

INTRODUCTION

Changing land-use has altered the biogeochemical signatures and flow patterns of many rivers. Development within the watersheds of rivers impacts both the river and the coastal zone (Howarth et al. 1996). Loading of nutrients and organic matter from rivers can cause and/or exacerbate eutrophication, harmful algal blooms, fish kills, reduce water quality, disrupt the heterotrophic / autotrophic balance and/or drive system-scale changes in production and trophic structure of estuaries (Nixon 1995; Paerl et al. 1998).

The Altamaha River in Georgia (Fig. 1) drains one of the largest basins on the East Coast (33,000 km^2), and the coastal zone of the Altamaha is an important and productive fisheries area. Although the watershed of the Altamaha remains relatively undisturbed, development and water withdrawal pressure has increased in recent years in the basin. The Altamaha River was placed on the American Rivers Organization's 2002 list of most endangered rivers (www.americanrivers.org).

Despite the size of the Altamaha River and the importance of the Altamaha Sound coastal zone, relatively little is known about loading rates from the river. In this study, we monitored nutrient and dissolved organic matter concentrations in the Altamaha River and several tributaries over a two-year period and calculated rates of loading.

METHODS

Table 1. Nutrient and Dissolved Organic Matter Concentrations and Ranges (mM) and Dissolved Organic Matter Molar Ratios

River	N		NH_4^+	NO_x	DIP	DON	DOP	DOC	DOC:DON	DOC:DOP
Altamaha	84	Mean	1.9	17.3	0.6	28.9	0.5	441	15	786
		Range	0.1 - 6.7	0.2 - 48.3	0.1 - 1.1	10.7 - 46.0	0.0 - 1.3	148 - 946		
Ocmulgee	14	Mean	2.7	34.0	0.7	27.3	0.6	345	13	540
		Range	0.9 - 6.0	0.1 - 69.2	0.0 - 1.8	13.5 - 47.5	0.3 - 0.9	127 - 896		
Oconee	14	Mean	2.9	14.3	0.8	31.4	0.9	338	11	378
		Range	0.6 - 8.5	5.3 - 29.8	0.1 - 2.2	17.9 - 60.5	0.0 - 2.0	237 - 657		
Ohoopee	14	Mean	2.3	13.4	0.7	38	0.6	825	22	1336
		Range	0.8 - 5.3	1.2 - 35.8	0.4 - 1.4	15.1 - 71.1	0.0 - 1.3	255 - 1521		
Little	14	Mean	2.3	3.7	0.3	40.6	0.8	897	22	1089
Ocmulgee		Range	0.7 - 4.9	0.5 - 14.3	0.0 - 0.7	13.9 - 66.7	0.0 - 2.8	263 - 1759		

Water samples were collected approximately weekly from the Altamaha River near Jessup, GA (Fig. 1) from September 2000 to October 2001, and approximately monthly until August 2002. The Ohoopee, Oconee, Ocmulgee and Little Ocmulgee Rivers were sampled just above their confluences with the Altamaha River (Fig. 1) approximately quarterly for the duration of the study.Water was filtered (GF/F) and stored at 4 °C until analysis. Ammonium (NH_4^+) was analyzed by standard colorimetry (Solorzano 1969). Nitrate+nitrite (NO_x) and dissolved inorganic phosphorus (DIP) were determined on a Lachat Instruments QuickChem 8000 autoanalyzer (Lachat methods 31-107-04-1-A and 31-115-01-1-H, respectively). Dissolved organic carbon (DOC) was measured by high-temperature catalytic oxidation on a Shimadzu TOC 5000 after acidification (pH<2) and sparging with CO_2 free air. Dissolved organic nitrogen (DON) was analyzed by high-temperature catalytic oxidation on a Shimadzu TOC-5000 coupled to an Antek Instruments 7020 NO analyzer (Álvarez-Salgado and Miller 1998). Dissolved organic phosphorus (DOP) was analyzed as DIP after evaporation, high-temperature combustion and hydrolysis (Monaghan and Ruttenberg 1999).

Altamaha River discharge data was obtained from the United States Geological Survey (www.usgs.gov, station 2226000). Loading rates for dissolved nutrients and organics from the Altamaha River were calculated from river discharge data (Fig. 2) and measured concentration data.

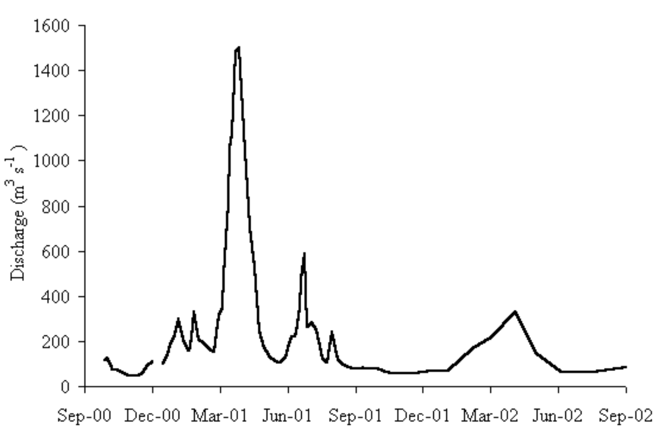

Figure 2. Altamaha River discharge at Doctortown, GA during the study period (from www.usgs.gov station 2226000).

RESULTS

Concentrations of nutrients and dissolved organic matter from the Altamaha River and several major tributaries are summarized in Table 1. NO_x generally dominated the inorganic nitrogen in the rivers, with NH_4^+ contributing a small fraction. NO_x concentrations up to 50 μM were observed in the Altamaha River (Table 1). The Ocmulgee had significantly higher and the Little Ocmulgee significantly lower NO_x than the Altamaha River ($p<0.01$). DIP concentrations were generally low (<1 μM), and did not exceed 3 μM.

Both DON and DOC concentrations were higher in the Ohoopee and Little Ocmulgee Rivers than in the Altamaha ($p<0.05$). DON and DOP contributed significantly to the total dissolved N and P pools in these rivers, with concentrations similar to DIN and DIP, respectively (Table 1). The average dissolved organic matter C:N and C:P molar ratios were higher in the Ohoopee and Little Ocmulgee Rivers and lowest in the Oconee River (Table 1).

There was significant interannual variation in

Table 2. Regression Coefficients and Statistics for Concentration (μM) Against the Natural Log of Discharge (m^3 s^{-1}) in the Altamaha River

	NH_4^+	NO_x	DIP	DON	DOP	DOC
Slope	NS	-4.67	0.11	3.08	0.13	208.3
Intercept	NS	41.32	0.02	12.98	-0.12	-623.6
R^2	0.02	0.09	0.19	0.06	0.09	0.65
P-value	0.28	0.006	<0.001	0.030	0.008	<0.001

NS – not significant

Altamaha River discharge over the course of this study (Fig 2). River discharge during the spring and summer 2001 was higher than the following year.

All dissolved constituents measured in the Altamaha River during this study were significantly correlated with river discharge (natural log transformed) with the exception of NH_4^+ (Table 2). Concentrations of DIP and of all the dissolved organics increased with increasing river flow, while NO_x concentrations decreased (Table 2).

Due to the discharge patterns in the Altamaha (Fig. 2) and the different relationships of NO_x and DON to river discharge (Table 2), there was a shift in the dominant form of dissolved nitrogen supplied to the coastal zone during this study. During the initial approximately seven months, DON concentrations consistently exceeded DIN (Figure 3). Subsequently, DON and DIN levels were variable, and by the fall and winter of 2001 DIN exceeded DON (Fig. 3).

Loading of nutrients and dissolved organics to the coastal zone from the Altamaha River was calculated from concentration data and flow rates. Loading rates were highly dependent on river discharge, with higher rates of loading during periods of high discharge (Fig 4). Total yearly loading rates were calculated for the two years of this study (Sep 2000 – Aug 2001 and Sep 2001 – Aug 2002). Due to the very different flow regimes between these two years (Fig. 2), total yearly loading was markedly different (Table 3). With the exception of NO_x, loading of nutrients and dissolved organics dropped by at least half from the first year to the second (Table 3).

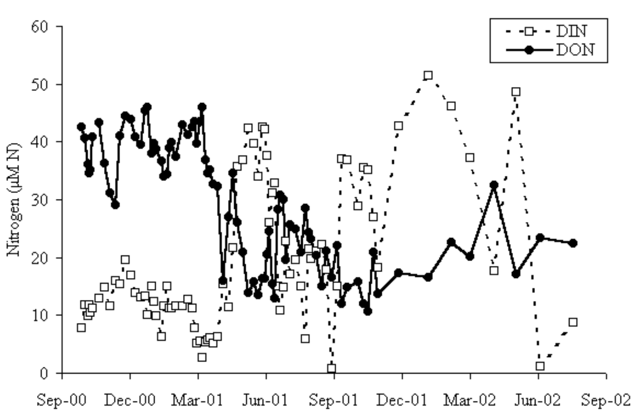

Figure 3. Dissolved organic nitrogen and dissolved inorganic nitrogen (NOx + NH_4^+) in the Altamaha River.

DISCUSSION

Concentrations of inorganic nutrients in the lower Altamaha River are similar to but lower than many other rivers of the southeast Atlantic coast (Dame et al. 2000). The watershed of the Altamaha River remains relatively undeveloped, so anthropogenic loading of nutrients to the Altamaha and its tributaries is limited. The slightly higher NO_x concentrations in the Ocmulgee (Table 1) may be due to more advanced development and higher population density of this watershed and its proximity to the cities of Atlanta and Macon.

The Ocmulgee and Oconee Rivers, with origins in the Piedmost region of Georgia, contribute to the bulk of the Altamaha River volume. The Altamaha, Ocmulgee and Oconee Rivers have similar nutrient and

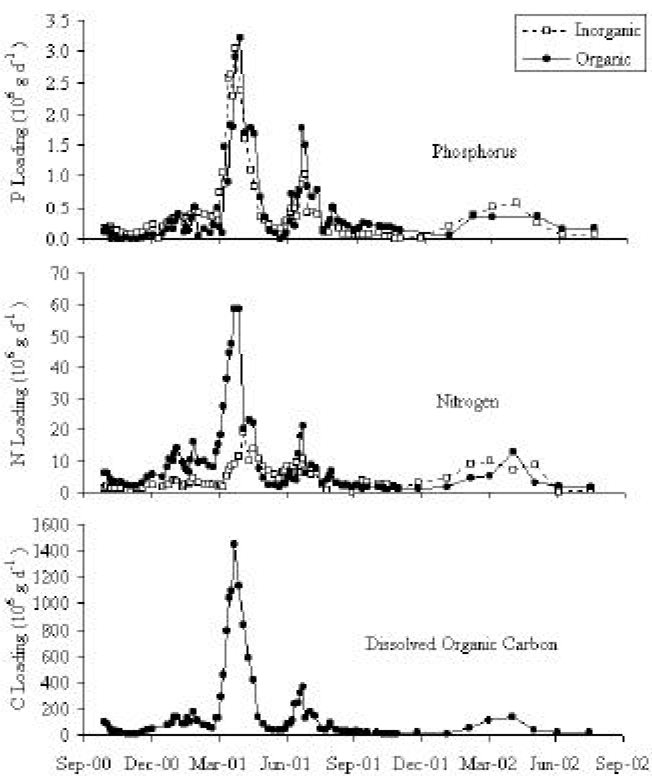

Figure 4. Loading rates of dissolved inorganic and organic phosphorus and nitrogen and dissolved organic carbon from the Altamaha River.

Table 3. Calculated Altamaha River Loading Rates for Two Years (10^6 g yr^{-1}).

Year	NH_4^+	NO_x	DIP	DON	DOP	DOC
Sep 00 - Aug 01	243	1420	191	4049	181	72957
Sep 01 - Aug 02	78	1291	53	948	88	12133

organic matter signatures, although the Altamaha does appear to have somewhat higher DOC and organic C:N and C:P ratios (Table 1). This may be the influence of the coastal plain 'black-water' Little Ocmulgee and Ohoopee tributaries which both have high DOC (Table 1).

Loading rates of nutrients and dissolved organics from the Altamaha River to the coastal zone is largely driven by river discharge (Fig. 4). Concentrations of DIP and of all the dissolved organic compounds are positively correlated with discharge (Table 2). Loading rates were much higher during the first year of this two-year study (Table 3) due to a very different flow regime in the Altamaha River (Fig. 2).

Although loading rates of most measured constituents are higher in the first year, NO_x loading is similar in both years (Table 3). NO_x is inversely correlated with river discharge, and while absolute loading rates of NO_x remain somewhat higher during periods of high discharge (Fig. 4), the relative contribution of NO_x is much higher during low discharge. This shift in the form of dissolved nitrogen input to Altamaha Sound has major implications for productivity in the coastal zone.

The flushing time of the Altamaha River Estuary is relatively short, on the order of one week on average, but highly dependant on river discharge (Alber and Sheldon 1999). As river discharge drops and flushing time of the estuary increases, plankton populations may increase rather than be flushed from the system (Howarth et al. 2000). In the Altamaha, lower discharge is correlated with higher NO_x concentrations (Table 2), which is available for phytoplankton uptake. Therefore as river discharge drops, environmental conditions become suitable for phytoplankton blooms to develop in the coastal zone.

Although nutrient concentrations in the Altamaha River system are lower than many other rivers on the East Coast of the United States (Dame et al. 2000), there does appear to be some impact of development in the watershed. Perhaps the greatest threat to the Altamaha coastal zone is not nutrient loading, but increased water withdrawal that will decrease flushing times. If the dominant form of nitrogen shifts to NO_x during lower flows caused by water withdrawals as we have seen in this study for lower flows due to climate variation, phytoplankton blooms and eutrophication of the coastal zone may occur with ecosystem wide impacts.

Further monitoring of the Altamaha River and its tributaries is needed to establish a long-term trend in nutrient and organic matter loading to the coastal zone. This will allow us to fully assess the health of the system and to document future trends. Proper management of water withdrawal and nutrient loading in the Altamaha River watershed is vital to sustaining the river, Altamaha Sound and the coastal zone.

ACKNOWLEDGMENTS

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