Distribution and cycling of carbon in the Tana River Basin (Kenya), from headwaters to the Tana River delta.

Introduction

Data compilations on carbon fluxes in freshwater systems invariably indicate that tropical regions are severely undersampled. Large-scale studies on carbon processing along the flowpath of river basins have to date been concentrated on a very limited number of systems, e.g., the Orinoco basin, the Ganges-Brahmaputra, and an extensive body of work on the Amazon river basin.

In this study, we present data on various biogeochemical characteristics of a tropical river basin (Tana river, Kenya), along the flowpath from high-altitude headwater streams in perennial catchment areas, down to the lower river meandering through semi-arid plains. Using a large suite of parameters both on particular and dissolved carbon pools and nutrients, we present a first basin-wide view on the inputs and processing of carbon in this tropical river basin.

Sites

The Tana River originates in the vicinity of Mt. Kenya and is the longest river system in Kenya (~1000 km), with a catchment area of ~120,000 km². The three main perennial headwater regions are located in high-altitude regions, i.e., the Aberdare range, the S and E slopes of Mt. Kenya, and the Nyambene Hills. A number of hydroelectric power dams have been constructed along the river since the late 1960’s, the largest of which is Masinga Dam. Sampling took place in February 2008, i.e. during dry season (low river flow) conditions. Samples were taken in the three headwater regions, along several points on the main Tana river, and surface water was taken at 4 sites along a transect on the largest of the reservoirs, Masinga Dam.

Surface water and soil samples at selected locations were analysed for a wide range of physico-chemical and biogeochemical parameters – the focus here is on carbon pools and their stable and radiocarbon isotope composition.

Bacterial carbon sources in suspended matter, soils and river sediments

Effects of Masinga Dam

- Surface waters of Masinga Dam appear highly productive, with much lower pCO2 (376 ± 57 pm) compared to the main river, high δ13C (-11.3 ± 3.1 ‰), and low δ15N (-19.2 ± 0.6 ‰).
- POC is dominated by phytoplankton biomass with low δ13C, while DOC appears to retain its original δ13C signature, suggesting high turnover rates of phytoplankton-derived DOC and low reactivity of terrestrially-derived DOC.
- Comparison of nutrient concentrations in the main inflow and outflow indicates a high degree of nutrient retention: TN: 30%, NH4+: 20%, NO3-: 40% and Si: -40%.
- δ13C/δ15N below Masinga Dam relatively low (-25.2 ‰), reflecting a contribution of reservoir phytoplankton. This signature rapidly shifts to -21.5 ‰, with a concurrent loss of POC (%POC/POC from 4.6 to 2.3 ‰), consistent with rapid selective loss of δ13C-depleted phytoplankton.

Methane

- CH4 concentrations in headwater streams ranged typically between 25 and 92 nmol, except for Murgungo river (314 nmol) and Mburiti river (415 nmol), above atmospheric equilibrium (<3 nmol).
- In the main Tana river, CH4 concentrations were relatively high downstream of Masinga Dam (40.5 ± 13.6 nmol lower than the reservoir (372 nmol), and much higher in surface waters of the reservoir (51 ± 7 nmol), suggesting a high CH4 oxidation activity (or emission to the atmosphere) despite the likeness of CH4 production in its anoxic waters.
- Along the middle and lower course, CH4 concentrations range between 54 and 387 nmol, with the highest concentration observed in the Tana Delta.

PCO2 and indicators of aquatic metabolism

- Although no direct metabolism rate measurements were made during this survey, several patterns suggest that in-stream primary production can be significant, even in the highly turbid waters of the middle and lower Tana River:
  - δ13C was high in all tributaries, Masinga Dam, and typically only slightly undersaturated along most of the Tana River.
  - δ15N was consistently lower than the value expected for equilibrium with atmospheric O2 (~24.5‰) but ranged between +19 and +29.3‰, suggesting contributions by isotopically light CO2 from photosynthesis (δ13C between -5.6 and 2.7‰).
- pCO2 in headwater streams ranged between 110 and 1020 ppm, and ranged between 560 and 686 ppm along most of the main Tana River, except in Masinga and towards the tidal delta (3570 and 1540 ppm, resp.). While generally overestimated, these pCO2 levels are in the lower range of those observed in other tropical river systems.

Distribution and sources of POC and DOC

- In agreement with the increase in TSM, POC increases drastically along the main Tana River, from 0.6 mg L-1 downstream of Masinga to 5 mg L-1 at the lowest station sampled.
- In contrast, DOC concentrations along the river continuum are remarkably stable at 0.98 ± 0.14 mg L-1, leading to a large shift in DOC/POC ratios from 1.5 to 0.2 along this transect.
- Variations in DOC/POC are inversely related to TSM (as expected), but relationships are different for tributaries and main Tana River.
- River basin has mixed C3-C4 vegetation. At high altitude, C4 plants are restricted to a few tussock-forming species in the Aberdare, at lower altitudes grasses in savanna are exclusively C4. Soil samples encompass the full range of C3-C4 continuums (28.3% to 13.5%).
- δ13C-POC varied between -26.5 and -22.7 ‰ for tributaries, between -25.2 and -21.2 ‰ along the main Tana river, and much more negative in Masinga (-29.0 ± 0.3 ‰) where it reflects dominance of phytoplankton.
- δ18O-DOC ranged between -27.7 and -21.8 ‰ in tributaries, within a narrow range of between -24.0 and -22.7 ‰ along the Tana main river, and showed no marked depletion in δ13C Masinga Dam (-23.9 ± 0.3 ‰).
- Thus: δ18O-DOC and δ13C-POC clearly uncoupled and showed a relatively weak relationship.