Seasonal variation in dissolved and particulate nutrient delivery from two subtropical mangroves to outer ocean

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Estuarine mangroves enhance longitudinal mixing of seawater and freshwater and actively exchange nutrient materials such as carbon (C), nitrogen (N) and phosphorus (P) with the water phase. Mangrove vegetation takes up and fixes atmospheric CO_2 by photosynthesis, and some of the fixed carbon is sequestered within the sediment for a long term, while the other part is released later as respired CO_2 and detrital organic C (OC) into river and sea water and eventually exported to the outer ocean. The released OC fuels heterotrophic animal and microbial communities inside and around the mangrove, and the exported CO_2 locally enhances ocean acidification in coastal ecosystems. Mangroves are also known as a nutrient filter that captures and removes dissolved inorganic N (DIN) from river water by denitrification, thereby preventing N loading to coastal ocean. In subtropical mangroves, inherent biological activities of mangrove ecosystems, such as photosynthesis, remineralization, and denitrification, as well as external nutrient inputs to mangroves through river waters or atmospheric deposition, can vary widely depending on seasons. However, knowledge about seasonal variability of ecosystem functioning of mangroves is still very limited, especially for subtropical ones. We investigated biogeochemical properties of two subtropical estuarine mangroves of Ishigaki Island, Okinawa, Japan, with an emphasis on seasonal variability. Intensive water sampling was conducted at mangrove-ocean interfaces and several streams flowing into the mangroves in different seasons (March, June, September, and December), and concentrations and isotopic compositions of dissolved and particulate constituents were determined to create and compare the salinity-property diagrams. Mangroves were always a net source of dissolved inorganic C (DIC) to the water phase. The $\delta^{13}C$ of DIC in the brackish zone was more negative in warmer seasons, indicating temperature dependence of soil respiration. Nitrate dominated in DIN in river waters. Dissolved inorganic P (DIP) usually behaved conservatively across the salinity gradient, while the mangroves seemed to be a net sink for nitrate and a net source of nitrite and ammonia. The ratio of DIN to DIP was the lowest in March. In most cases, the weight ratio of particulate organic C (POC) to chlorophyll *a* exceeded 500, indicating the predominance of detrital organic matter produced within the mangroves. The ratio of POC to particulate N (PN) was the highest and the $\delta^{13}C$ of POC was the most negative in December. The $\delta^{15}N$ values of both nitrate and PN in the brackish zone was higher in warmer seasons, which suggested that denitrification in the watershed and the mangrove depended on temperature. Our results suggested that the ecosystem functioning of subtropical mangroves vary significantly between different seasons, and that such a seasonal variation could be due to seasonal changes in both internal metabolic activities and external factors such as hydrology and nutrient loading from the watershed. We discuss these characteristics of subtropical mangroves in comparison with mangroves under different geographical and climate conditions.

Keywords: Mangrove, Dissolved inorganic carbon, Dissolved inorganic nitrogen, Particulate organic matter, Salinity gradient, Stable isotope ratio