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Atmospheric nitrogen deposition: magnitudes, seasonal variation and potential impacts on Yaeyama coral reefs

Toshihiro Miyajima[1*], Chikage Yoshimizu[2], Takahiro Yamamoto[3], Ichiro Tayasu[2], Toshi Nagata[1], Naoko Morimoto[1], Atsushi Watanabe[3], Kazuo Nadaoka[3]

[1]The University of Tokyo, [2]Kyoto University, [3]Tokyo Institute of Technology

Roughly half of nitrogen (N) emitted anthropogenically to the atmosphere is said to be deposited on the coastal sea, with deposition rates depending on the proximity to pollution sources and the wind regime. Ecological impacts of N deposition would be particularly large in originally oligotrophic coastal areas including coral reefs. However, few studies have ever been conducted on N deposition on reef areas. We studied wet deposition of dissolved inorganic nitrogen (DIN) on coral reefs around Yaeyama Islands (southwestern Japan) that are close to large pollution sources (Continental China and Taiwan). Rain waters were collected at 11 coastal sites surrounding Ishigaki and Iriomote Islands during 12 survey periods spanning from March 2009 to January 2011 and analyzed for DIN concentration and related parameters. The deposition rate of DIN was usually high in winter (up to $>$100 uM as concentration in rain water) and low in summer (normally $<$10 uM). However, ephemeral increases to $>$50 uM have been observed in summer months of 2009. In most case 50% - 80% of the rainwater DIN was nitrate, with the rest being ammonium. Concentrations of nitrate and ammonium were correlated to each other (r = 0.908). Rainwater pH was often as low as 4.3 in winter. The delta-^{18}O of deposited nitrate was typically high (70 - 80 permil vs. VSMOW), although it was as low as 50 permil when the deposition rate was lowest, indicating at least two pollution sources with different isotopic signatures. We are now identifying source locations and transport pathways of atmospheric DIN using both wind regime simulation by the regional meteorological model and the O/H isotopic compositions of rainwaters. On the annual basis, the calculated DIN deposition rate on Shiraho reef area (well-studied fringing reef of Ishigaki Island) was roughly comparable to the biological nitrogen fixation rate estimated from literature data, when only direct precipitation to the reef area was considered. The range of delta-^{15}N of deposited nitrate (-3 to +3 permil vs. atm. N_2; -1.4 permil on average) was also similar to that of N delivered by biological N_2 fixation (-2 to 0), which makes it difficult to discriminate the provenance of N for reef biota using the tissue delta-^{15}N. The high DIN deposition rates would cause eutrophication of the water column of reef areas, which might benefit temporarily reef corals that can utilize DIN. However, eutrophication also leads to higher abundance of phytoplankton, which may enhance the larval survival of crown-of-thorns starfish and consequently lead to coral degradation. The influential area of atmospheric N deposition extends far offshore compared to that of terrestrial nutrient loading due to rivers and groundwaters. Close examination of ecosystem responses of coral reefs to the atmospheric N deposition is needed in future studies.

Keywords: coral reefs, eutrophication, East China Sea, transboundary pollution