Sustained eutrophic conditions in mariculture areas of Bolinao and Anda, Philippines as seen using biogeochemical indices including oxygen isotope of phosphate

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Long-term time series of nutrients in a monitoring station in Bolinao, Philippines showed persistently eutrophic conditions even after regulation in number of fish farm structures from 2002. Regulation was implemented following a massive fish kill that occurred in the coastal waters of Bolinao in the same year. To elucidate the reasons for this sustained eutrophication and determine their implications to management for the mitigation of recurring algal blooms, hypoxia and fish kills, the nutrient dynamics of nitrogen (N) and phosphorus (P) was studied for Bolinao and its adjacent coastal town of Anda.

Detailed spatial and temporal analysis of nutrients in the water column, sediments, and possible end member sources of nutrients to the mariculture area was conducted. Based on the results, mariculture areas exhibited high concentrations of dissolved inorganic nitrogen (DIN) especially ammonium (NH_4^+), and dissolved inorganic phosphorus (DIP) primarily due to decomposition of uneaten and undigested fish feeds, and fish excretions. Compared to the Redfield ratio (N/P of 16), these materials are enriched in P relative to N, resulting in low N/P ratios (~6.6) of the regenerated nutrients. DIP in the water was higher during the dry season than the wet season possibly due to enhanced accumulation of regenerated nutrients inside the embayment during the dry season due to the flow pattern. Temporal analysis of satellite images showed that while fish farm structures in Bolinao have been regulated, the structures in Anda continued to increase in number. This has contributed to fish farm-derived organic matter and regenerated nutrients enriched in P that can get advected to Bolinao waters with the residual currents during the dry season. These factors sustained the DIP enrichment and created an N-limited condition that is highly susceptible to sporadic algal blooms whenever N is supplied from freshwater input during the wet season.

Analysis of the ratio of the oxygen isotopes of phosphate ($\delta^{18}O_p$) from different environmental samples showed that rivers (14.4 ±0.2 ‰) and fish feed (21.8 ±0.4 ‰) are two contrasting end-member sources of phosphate to the mariculture areas. Sediment porewater (21.3 ±0.2 ‰) has a similar isotopic signature as fish feeds suggesting that porewater DIP mainly come from decomposed feeds. Water samples from mariculture areas showed $\delta^{18}O_p$ close to fish feed end-member values that vary depending on season and tidal variation.

Keywords: phosphorus, eutrophication, fish feed, nutrient ratios, mariculture, oxygen isotope ratio of inorganic phosphate

