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Abstract

Title	The Influences of Typhoon on Nutrient Dynamics and Hypoxia in Atsumi Bay, Japan

(800 words)

Investigations on nutrients have occupied an important role in the oceanographic research, since the interaction among nutrients and planktonic organisms is the key to elucidate the biological productivity of oceans. The Atsumi Bay is a watershed area in the middle of Japan which is strongly affected by seasonal changes associated with typhoon following rainfall event. The Atsumi Bay has become highly eutrophic, and the nutrient enrichment has induced intense red tides almost every year during summer. Increased water pollution accompanied by red tides and hypoxia has been frequently observed in the estuaries of Japan. The purposes of this study are to study the spatial and temporal variability of nitrogen and phosphorus form; to assess the impacts of freshwater inflow on the nutrient concentrations; to clarify the physical characteristics of the Atsumi Bay estuary by water movement before and after a typhoon; to examine the chemical environmental effects caused by typhoon; and to examine the nutrient uptake by the enhancement of phytoplankton after typhoon.

The present thesis, "The Influences of Typhoon on Nutrient Dynamics and Hypoxia in Atsumi Bay, Japan" is based on the intensive sampling and analysis of nutrients and Chlorophyll *a* (Chl *a*) concentrations collected at 18 stations covering 3 transects (Toyo, Shio and Umeda Rivers transects) in the Atsumi Bay estuary. Field samplings were carried out during the summers of 2010 (July to November) and 2011 (July to September). At the same time, a conductivity-temperature-depth (CTD) sensor was deployed to measure vertical profiles of the dissolved oxygen (DO, mg/L), temperature (^{o}C) and salinity (psu) at depth intervals of 0.1 m. Continuous measurements of DO and salinity were also conducted, during the summers of 2010 and 2011.

The result during study period revealed that the maximum of surface TN and TP concentrations in the study area reached a value of 2.62 and 0.67 mg/L respectively. Both of these highest concentrations were observed at St-18 along the Umeda River transect, respectively on July 2010 and September 2011 due to the rainfall event. These values were about 4 and 13 times the Japanese water quality standard for the Atsumi Bay, in which the limits of total nitrogen and total phosphorus concentrations for the coastal waters were $\leq$ 0.6 mg/L and $\leq$ 0.05 mg/L, respectively.

During normal condition (no rainfall), the concentrations of nutrient in the bottom layer were higher than that in the surface layer due to the hypoxic condition in summer represented by the low DO concentrations. However, higher concentrations of nutrients appear in the surface layer after rainfall event due to discharge of the freshwater which is bring more nutrient concentrations from the river. Although there is no rainfall event, the surface concentration of nutrient was higher along the Shio river and the Umeda river transects. It was caused by the high concentration of nutrient

in freshwater entering this side, especially from the Umeda River. The high nutrient concentration was caused by the Umeda River being located near one of the major agricultural areas in Japan; it was achieve 45.61% agricultural area comparing to the Toyo River which achieve 79.38% forest.

In order to clarify the impact of typhoon on the nutrient concentration and the enhancement of phytoplankton, we selected eight stations along the Toyo River transect from the 18 sampling stations distributed in the Atsumi Bay to analyze the nutrient, Chl *a*, salinity and dissolved oxygen (DO), before and after the six typhoon from 25 surveys during the summers of 2010 and 2011. By examining those evidences related to typhoon event, we summarize that each typhoon has its own effects, depends on the factors influencing those typhoons. The heavy rainfall associated with the typhoons Chaba, Ma-On and Roke increased discharges of freshwater. After typhoon event, a large quantity of nutrient loading from freshwater enters the estuary and then use by phytoplankton for growth. It is evidenced by the decrease of the surface salinity (which spread over the surface layer of the estuary). Strong winds associated with the typhoon Talas caused turbulence in the water column. It was sufficient to mix surface and bottom layers and hence to change the hypoxic conditions in the bottom layer.

To elucidate the impact of a typhoon on phytoplankton uptake related to nutrient concentration change, we first selected sampling period (pre- and post-typhoon) during typhoon Ma-On (summer 2011). We measured pre- and post-typhoon nutrient concentrations and recorded vertical profiles of the salinity and Chl *a* at eight and five stations, respectively, along the Toyo River and Umeda River transects. This study documented the effects of the typhoon Ma-On on the decrease of the surface water concentrations of the Dissolved Reactive Phosphorus (DRP) at all stations. It was also reflected a shift to P limitation after the typhoon and was caused by a combination of the phytoplankton uptake and mixing of freshwater and seawater. We estimated the phytoplankton uptake by using Chl *a*:N:P stoichiometry. By combining these estimations with changes caused by mixing of the freshwater and seawater along the Toyo River transect, we estimated that the phytoplankton uptake accounted for 100% and 84–100% of the changes in DRP and Dissolved Inorganic Nitrogen (DIN), respectively, not otherwise explained by mixing effects. In addition, uptake of the DIN and DRP by the phytoplankton in the Toyo River transect was higher than in the Umeda River transect.