Pollution Study in Manila Bay: Eutrophication and Its Impact on Plankton Community

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Abstract—Eutrophication and chemical pollution due to human activities have seriously affected coastal ecosystems during the last three decades. Manila Bay is one typical example suffering from such pollution problems. In the present study, the distribution of plankton community was investigated in June 2008 in relation to abiotic environmental parameters (salinity, temperature and dissolved oxygen concentration) and pollution factors particularly nutrient concentrations. The dissolved oxygen concentrations near bottom were lower than 3 mg l^{-1} inside of the bay. Average concentrations and standard deviations of dissolved inorganic nitrogen, nitrate, nitrite and ammonium in near surface were 0.90 ± 0.53, 0.10 ± 0.16 and 8.00 ± 1.35 μM, respectively. Northeastern area near Metro Manila showed higher concentrations of nitrogen. Phosphate and silica showed higher concentrations near northern shore with average concentrations of 0.92 ± 0.34 and 28.87 ± 9.53 μM, respectively, over the bay. From the results, Manila Bay is thought to be highly eutrophicated with high nitrogen concentration particularly ammonium. Among phytoplankton, the centric diatom, *Stephanopyxis* spp. were dominant, and they occupied 44% of total phytoplankton biomass. The small Cyclopoida *Oithona* spp. occupied 42% of total mesozooplankton abundance. Consequently, the plankton community of Manila Bay showed a structure composed of higher microbial activity and primary production but lower secondary production, particularly with lower mesozooplankton abundances.

Keywords: eutrophication, Manila Bay, nutrients, phytoplankton, zooplankton

INTRODUCTION

Coastal ecosystem is extensively exposed to anthropogenic contamination since

it receives inputs from terrestrial, riverine, marine and atmospheric sources. The developments of urban areas around coastal areas and consequent increase in the levels of anthropogenic pollutants from the catchment area cause serious water quality deterioration problems worldwide, particularly in Asian regions having larger populations and higher precipitation compared with other regions of the world (Islam and Tanaka, 2004). Eutrophication due to the increase of anthropogenic nutrients loading, mainly nitrogen and phosphorus, from watersheds has been a central environmental issue along many marine coastal areas over a decade (Nixon, 1995). It causes an increase of phytoplankton biomass and turbidity and decrease of submerged grasses, thus inducing bottom-water hypoxia due to deterioration of excess organic matter (Fisher *et al*., 2006). Massive increase of certain phytoplankton genera causing phenomenon like red tides and changes in physicochemical parameters in coastal ecosystem can have serious impacts on flora and fauna, consequently modifying the structure and function of coastal marine food web.

Manila bay is semi-closed bay system, and more than 10,000,000 people live in the catchment area of the bay. Its abundant natural resources have been the primary source of livelihood for people in the areas surrounding the bay. The bay has suffered from serious water quality deterioration due to the rapid increase in population and industrialization in the watershed. Substantial increments in organic loads entering the bay through excessive urban emissions of nutrients (nitrogen and phosphorus) and heavy metals, increase incidences of hypoxia and anoxia, frequent blooms of harmful microalgae and persistent red tides caused by dinoflagelalate (Prudente *et al*., 1994; Azanza *et al*., 2004; Furuya *et al*., 2006; Hayashi *et al*., 2006; Jacinto *et al*., 2006; Reichardt *et al*., 2006; Urase *et al*., 2006). Despite the studies that have concentrated on pollution of the bay especially on water quality and harmful algal bloom issues, only very few studies are available on the structure and function of plankton community of the bay and its interactions with environmental pollution.

To examine the spatial and temporal trends of various pollutants within Manila Bay and their biomagnification through the food chain to human, we have carried out a survey in Manila Bay focusing on 1) spatial and temporal trends of persistent organic pollutants and heavy metals, 2) food-web approach by analysis of plankton and fish (community structure and bioaccumulation of pollutants), and 3) temporal and spatial distribution of plankton community in relation to the distribution of pollutants and eutrophication. In the present study, we show brief results of Manila Bay survey in June 2008 with a focus on the basic physicochemical parameters including nutrients distribution in the bay. We present here the composition and distribution of phytoplankton and mesozooplankton in the bay, and discuss the ecological status of Manila Bay.

MATERIALS AND METHODS

The survey was carried out in both dry season (January 2008) and rainy season (June and November 2008). We collected Expand CTD (CTD) data from
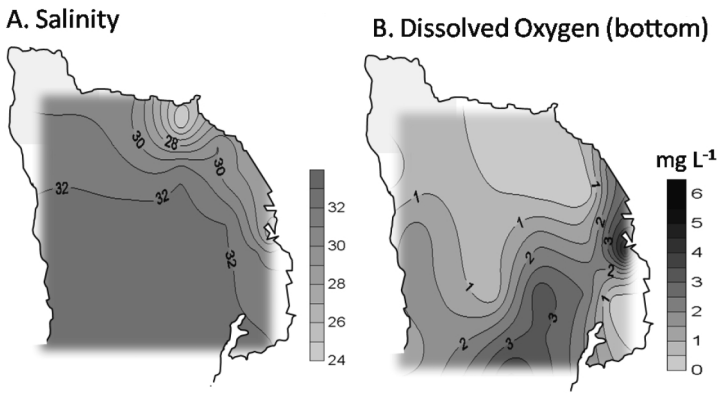
Fig. 1. Horizontal distribution of salinity (A) and dissolved oxygen concentration (B) in Manila Bay during June 2008.

34 sites and chemical and biological data from 24 sites over the bay. For the measurements of nutrient concentrations, we collected water from 5 m depth using a 6 liter Van Dorn sampler, and filtered the water through a Whatman GF/F glass fiber filter (Whatman Inc., Clifton, NJ, USA). The filtrate was kept frozen (–20°C) until analysis. Dissolved inorganic nitrogen (nitrate-N, nitrite-N and ammonia-N), soluble reactive phosphorus (phosphate-P), and silica (SiO_2–Si) concentrations were measured by colorimetric analysis with a continuous flow system (Auto Analyzer 3, BRAN + LUEBBE (Murphy and Riley, 1962; Raimbault et al., 1990)). Mesozooplankton was collected by vertical net towing (160 μm mesh size). The compositions of phytoplankton (conversion from cell counts into carbon biomass, Menden-Deuer and Lessard, 2000) and mesozooplankton (individual numbers), and their distributions are also briefly discussed in the present paper.

RESULTS AND DISCUSSION

Average water temperature in the bay during the June survey was 29.3°C and thermal stratification was not strong. The differences between surface and bottom water temperature were lower than 3°C. Salinity near the bay mouth was around 33‰, but lower than 30‰ near the shore (Fig. 1A) due to freshwater inflow from rivers. Dissolved oxygen concentration (DO) in the bottom was lower in most sites inside of the bay, but increases along the bay mouth (Fig. 1B). Particularly low DO at the bottom was observed in northwest region of the bay.

Average concentrations of dissolved inorganic nitrogen, nitrate (NO_3–N), nitrite (NO_2–N) and ammonium (NH_4–N) in near surface (5 m depth) were 0.90, 0.10 and 8.00 μM, respectively. However, the concentrations vary widely among the sampling sites. Nitrate, nitrite and ammonium levels showed different distribution patterns with high nitrate and nitrite levels near Metro Manila and
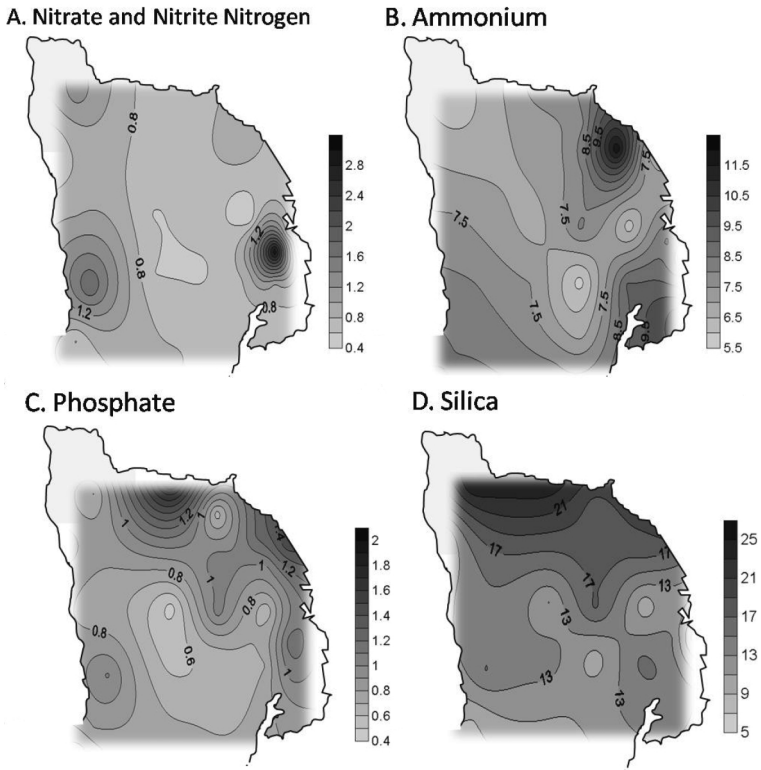
Fig. 2. Horizontal distribution of nutrients (μM l^{-1}), nitrate and nitrite (A), ammonium (B), phosphate (C), and silica (D) in Manila Bay during June 2008.

with the highest concentration of 3.04 μM in the mouth of Pasic River. Ammonium levels were higher than other species of nitrogen with a range between 6 to 12 μM, with the highest concentration observed near northeastern shore (Figs. 2A and 2B). On the other hand, phosphate and silica showed higher concentrations near northern shore with average concentrations over the bay of 0.92 and 28.87 μM, respectively (Figs. 2C and 2D).

From these results, Manila Bay can be considered as highly eutrophicated with nitrogen species, particularly with ammonium. High nutrient concentrations near the shore having high inflow from rivers indicate that the main sources of nutrients are the rivers. However, the differences in the distribution of nutrients suggest that main sources of nutrients depend on the land use pattern of the catchments. Compared with previous studies on the nutrient concentrations of Manila Bay from 1993 to 2004 (Furuya *et al*., 2006; Jacinto *et al*., 2006), the concentrations of nitrate and phosphate in the present study are lower than their results. Since seasonal variations of nutrients cycling in bay areas is very large (Hayashi *et al*., 2006), extensive monitoring is necessary to evaluate the status
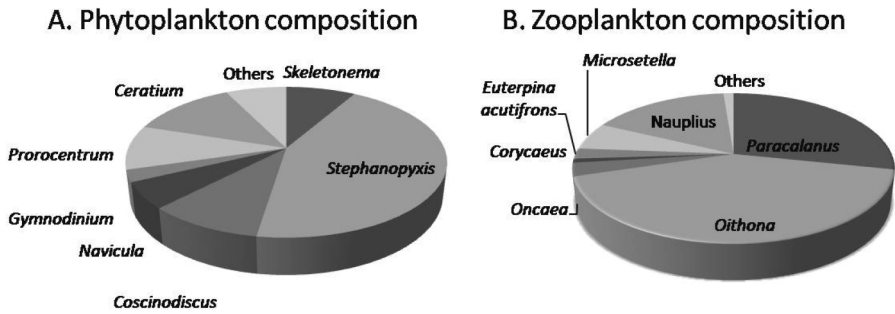
A. Phytoplankton composition

B. Zooplankton composition

Fig. 3. Composition of phytoplankton (A) and mesozooplankton (B) in Manila Bay during June 2008.

A. Total phytoplankton biomass

B. Mesozooplankton (Oithona spp.) abundance
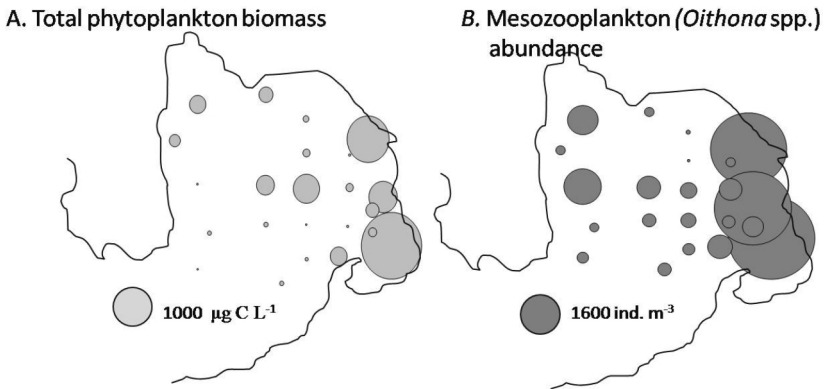

1000 μg C L^{-1}

1600 ind. m^{-3}

Fig. 4. Horizontal distribution of phytoplankton biomass (mg C l^{-1}) and zooplankton abundance (ind. l^{-1}) in Manila Bay during June 2008.

and eutrophication in Manila Bay.

During the survey, green *Noctiluca* (*Noctiluca scintillans* containing the photosynthetic green flagellate as an endosymbiont) dominated the plankton community in all the sites. It has been reported that *N. scintillans* forms persistent red tide in the bay and their abundance often exceeds 5000 ind. l^{-1} (Furuya *et al.*, 2006). Among phytoplankton, the centric diatom, *Stephanopyxis* spp. were dominant, occupying 44% of total phytoplankton biomass (Fig. 3A). Dianoflagellate, *Ceratium* and diatom, *Coscinodiscus* occupied 13 and 10% of phytoplankton biomass, respectively. Among mesozooplankton, small Cyclopoida, *Oithona* spp. occupied 42% of total zooplankton abundance (Fig. 3B). Among Calanoida, the coastal species, *Paracalanus* spp. was dominant. They occupied 28% of total mesozooplankton abundance, and 74% of calanoid abundance. Other common coastal species, *Acartia* spp. took only 4% of calanoid abundance, and

the species belonging to the genus *Temora* was rarely found throughout the study in all the sites. *Oncaea* and *Corycaeus* also showed low abundances throughout the study.

Both phytoplankton and zooplankton abundances showed highly heterogeneous distribution patterns over the bay (Fig. 4). During June 2008 survey, they were abundant near the eastern shore and very low at the center and bay mouth. Distribution patterns of phyto- and mesozooplankton abundances were quite different among genus. However, during our previous survey in January, both phytoplankton and mesozooplankton showed different compositions and distribution patterns (data not shown). Thus, it is likely that their distributions are highly variable among seasons as well vary with species.

As conclusion, it can be stated that Manila Bay is highly eutrophicated with excessive nitrogen and phosphorus loading from surrounding areas. This might lower the dissolved oxygen concentration in the bottom, particularly in inner bay area. Such environmental condition of the bay might also alter the structure and function of the plankton community with excessive increase in primary production. The bloom of green *Noctiluca* and the dominance of the small Cyclopoida species *Oithona* in mesozooplankton community are typical characteristics of eutrophicated bay ecosystem, and they might have been closely related to excessive food supply and increase of bottom hypoxia (Uye, 1994; Sriwoon *et al.*, 2008). It is known that heterotrophic microbial food web is promoted by nutrient enrichment (Andersson, 2006). Although we did not show our results of microbial food web analyses in the present paper, higher abundances of bacteria and heterotrophic nanoflagellates were observed throughout our research.

Consequently, the plankton community of Manila Bay exhibits a structure composed of higher microbial activity and primary production but lower secondary production, particularly with lower mesozooplankton abundances with dominance of small species. It has been suggested that the food web efficiency (mesozooplankton production per basal production including primary production and bacterial production) decreases with increasing nutrient levels that can lead to increasing loss process in the food web due to the presence of more trophic levels and respiration steps in it (Andersson *et al.*, 2006). The ecological status of Manila Bay regarding the structure and function of plankton community shows how eutrophication drives ecosystem functioning to undesirable direction. However, the plankton community in Manila Bay showed highly variable distributions over time and space. Our knowledge on the food web dynamics in highly eutrophicated ecosystems is still limited. We are going to analyze their distributions in detail to determine their major driving forces. Our further study also includes extensive examination of spatial and temporal trends of micro- and mesoplankton communities and their trophic interactions to obtain a more comprehensive view of pollutants in Manila Bay and their potential link and risk to humans as well as further ecological understanding of food web dynamics.

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