DOI: 10.31398/tpjf/24.1.2016A0007

Spatio-Temporal Distribution and Abundance of Phytoplankton in Manila Bay

Norvida C. Gatdula, Valeriano M. Borja, Jane Abigail Santiago and Elsa F. Furio*

Aquatic Ecology Section
Capture Fisheries Research and Development Division
National Fisheries Research and Development Institute

*Corresponding Author: efurio2010@yahoo.com

Abstract

Understanding the dynamics and production of phytoplankton may contribute to the elucidation of the status of fishery resources and may be the key for better fisheries management since phytoplankton is at the base of the food chain. The changes and succession of phytoplankton community structure in Manila Bay was studied by conducting hydrobiological survey every other month from January 2012 to November 2015. It was determined from this study that diatoms dominated the phytoplankton composition all throughout the survey period and the total phytoplankton density was generally highest during southwest monsoons. Dinoflagellates and cyanobacteria, on the other hand, were relatively most dense during tradewinds. Although causative species for harmful algal blooms and fish kills were present, only the bloom of red *Noctiluca scintillans* was observed in January 2014 albeit no harmful implication to consumers was reported. Phytoplankton typically converged in the coasts of the bay, particularly at the eastern portion, but it is noteworthy to say that the sporadic pattern seen maybe attributed to the presence of their predators. The dramatic drop in the phytoplankton densities seem to coincide with the spawning of *Sardinella fimbriata* and *Sardinella gibbosa.*

Keywords: phytoplankton, Manila bay, ichthyoplankton, Sardinella fimbriata, Sardinella gibbosa

INTRODUCTION

Management of fisheries resources is likely to succeed if there is a genuine appreciation of the environment. The elements that are vital to the preservation and conservation of fish must be taken into account so that scientific decisions may be made not only for management but for the marine habitat's eventual revitalization.

The deterioration of the water quality to a highly eutrophicated state of Manila Bay was due to the increased anthropogenic activities along its surrounding coastal areas (Chang et al., 2009). Water quality is affected by the physico-chemical and hydrobiological parameters. The biological components of the said parameters include phytoplankton, a community of microscopic alga that is at the base of the food web. They are an important resource that supports the higher trophic levels in the bay (MBRRA, 2004). Generally, increase in phytoplankton density is actually a beneficial condition to the fisheries (Legendre 1990) since they fuel the production of the food of fish. However, the algal bloom may become so dense that they become the cause of fish kills due to oxygen depletion and the cause of shellfish poisoning to humans (Hallegraeff 2002).

Phytoplankton, as a primary producer, can be an indicator of ecological problems (MBRRA, 2004). Algal monitoring is a very useful tool in surveillance of harmful algal blooms and early warning for shellfish toxicity (Aune et al. 1995). Because of this, studies of phytoplankton in Manila Bay were either usually limited to the areas previously affected by toxic shellfish poisoning and fish kills or conducted in a short survey period–phytoplankton was included in the study as a support parameter in an attempt to prove or disprove the hypothesis. With the many changes in the ecosystem, there were claims that there is a decline in the phytoplankton population, but there are no concrete data to support this (Bidaure, 2009). Nonetheless, an investigation was made to know the extent of the phytoplankton population change. This information may lead to a cohesive understanding of the dynamics of the present marine environment. This study shall assess the changes and succession in phytoplankton community structure and correlate the results with the studies on the distribution of ichthyoplankton and spawning of *Sardinella* spp.

MATERIALS AND METHODS

Collection of phytoplankton samples was done in Manila Bay (lat. 14°53′ N, long. 120°76′ E) every two months starting January 2012 up to November 2015. Plankton net (ca. 20 µm mesh size, 30cm mouth diameter, 1m long) was vertically towed from surface waters down to 10m depth throughout the water column of the 16 established stations (Figure 8.1). Plankton samples were placed in Nalgene bottles, treated with 10% buffered seawater-formalin solution for its preservation and stored in a cooler on board prior to its analysis.

In the laboratory, the volume of samples was measured using a graduated cylinder. A 1 ml aliquot sample was taken for light microscopy using Sedgewick Rafter counting chamber. Quantitative and taxonomic analysis of phytoplankton was done using the method of Omura *et al.* (2012).

RESULTS

Phytoplankton population was composed of diatoms, dinoflagellates, and cyanobacteria (Figure 8.2). Diatoms dominated the phytoplankton community throughout the survey period. There were 15 families of dinoflagellates, 24 families of diatoms and 1 species of cyanobacteria (Table 8.1). *Thalassiosira* sp., *Skeletonema* spp. and *Chaetoceros* spp., were the most dominant species among the diatoms while *Ceratium* spp., *Protoperidinium* sp. and *Noctiluca scintillans* dominated the dinoflagellates population. *Trichodesmium* spp. also occurred in densities high enough to be included in the list of 10 most dominant species (Figure 8.3). Relative abundance of all species from 2012 to 2015 are shown in Table 8.1.

By and large, phytoplankton was most dense during the southwest monsoon (July and September) (Figure 8.4). On the other hand, the

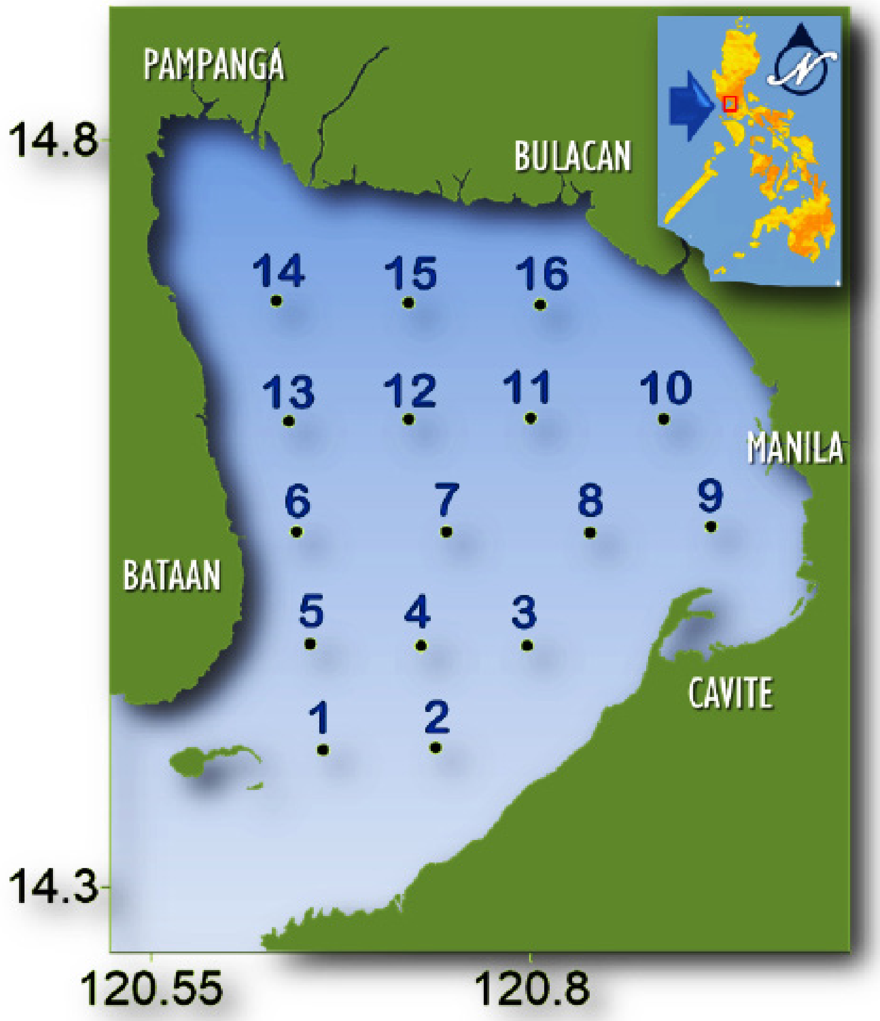

Figure 8.1. Sampling stations for hydrobiological surveys in Manila Bay (2012-2015)

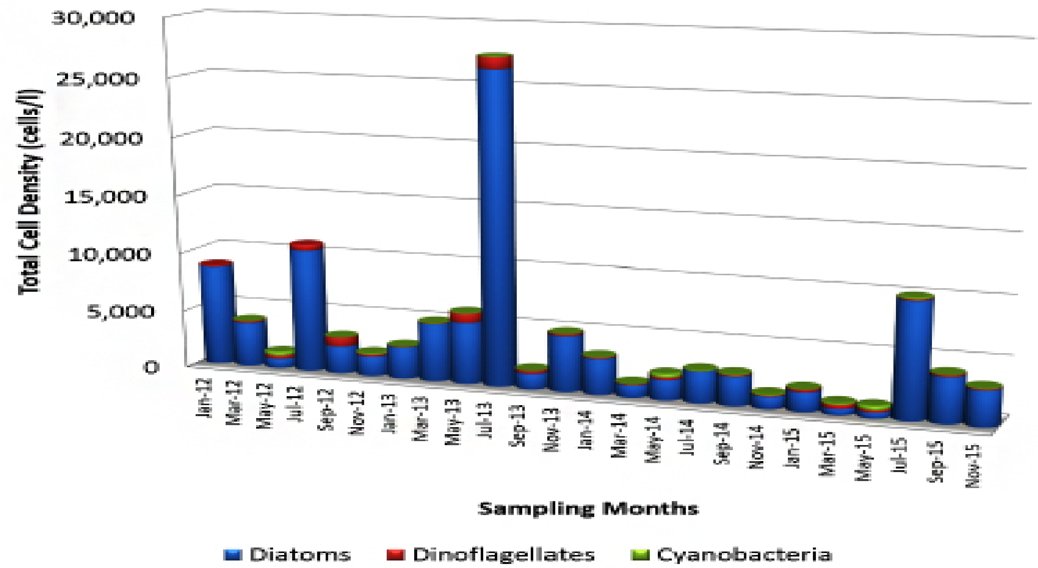

Figure 8.2. Densities of Diatoms, Dinoflagellates and Cyanobacteria in Manila Bay (2012-2015)

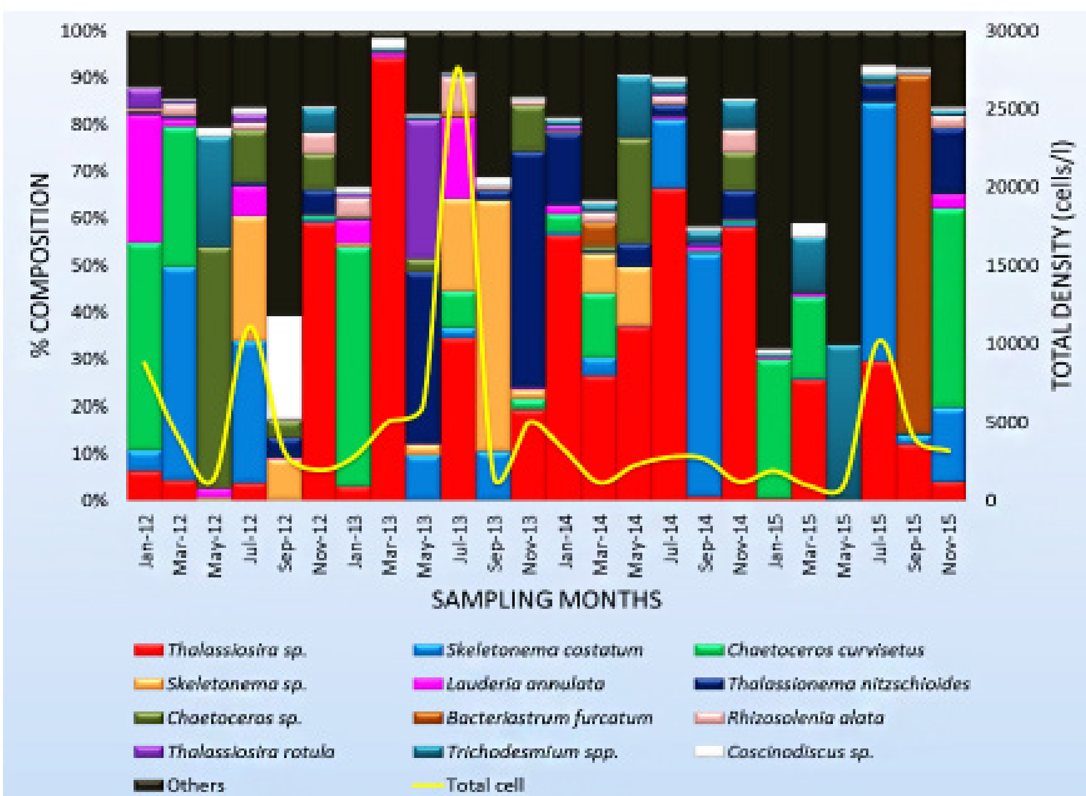

Figure 8.3. Twelve most dominant phytoplankton species found in Manila Bay (2012-2015)

Table 8.1. List of phytoplankton identified in Manila Bay 2012-2015. (a) Diatoms; (b) Dinoflagellates and Cyanobacteria

Family	Species	Family	Species
DIATOMS			
Asterolampraceae	*Asterolampra sp.*	Hemiaulaceae	*Climacodium frauenfeldianum*
Bacillariaceae	*Bacillaria paxillifera*		*Eucampia sp.*
	Nitzschia sp.		*Hemiaulus hauckii*
	Pseudo-nitzschia sp.		*Hemiaulus indicus*
Catenulaceae	*Amphora sp.*		*Hemiaulus membranaceus*
Chaetocerotaceae	*Bacteriastrum delicatulum*		*Hemiaulus sinensis*
	Bacteriastrum elongatum		*Hemiaulus sp.*
	Bacteriastrum furcatum	Hydrodictyaceae	*Pediastrum sp.*
	Bacteriastrum hyalinum	Lauderiaceae	*Lauderia annulata*
	Bacteriastrum sp.		*Lauderia sp.*
	Chaetoceros castracanei	Leptocylindraceae	*Leptocylindrus sp.*
	Chaetoceros coarctatus	Lithodesmiaceae	*Ditylum brightwellii*
	Chaetoceros compressus		*Ditylum sol*
	Chaetoceros constrictus	Naviculaceae	*Navicula sp.*
	Chaetoceros convolutus	Pleurosigmataceae	*Pleurosigma sp.*
	Chaetoceros costatus	Rhizosoleniaceae	*Dactyliosolen fragilissimus*
	Chaetoceros curvisetus		*Dactyliosolen phuketensis*
	Chaetoceros debilis		*Guinardia cylindrus*
	Chaetoceros decipiens		*Guinardia striata*
	Chaetoceros didymus		*Rhizosolenia alata*
	Chaetoceros laevis		*Rhizosolenia cylindrus*
	Chaetoceros pseudocurvisetus		*Rhizosolenia hebetata*
	Chaetoceros sp.		*Rhizosolenia imbricata*
Cocconeidaceae	*Cocconeis sp.*		*Rhizosolenia robusta*
Corethraceae	*Corethron sp.*		*Rhizosolenia setigera*
Coscinodiscaceae	*Coscinodiscus granii*		*Rhizosolenia simplex*
	Coscinodiscus sp.		*Rhizosolenia sp.*
Dictyochaceae	*Dictyocha fibula*		*Rhizosolenia styliformes*
	Dictyocha speculum	Skeletonemataceae	*Skeletonema costatum*
Eupodiscaceae	*Odontella aurita*		*Skeletonema sp.*
	Odontella longicruris	Stephanopyxidaceae	*Stephanopyxis sp.*
	Odontella mobiliensis		*Streptotheca tamesis*
	Odontella sinensis	Thalassionemataceae	*Thalassionema frauenfeldii*
Fragilariaceae	*Asterionella gracialis*		*Thalassionema nitzschioides*
	Asterionella japonica	Thalassiosiraceae	*Thalassiosira mala*
			Thalassiosira rotula
			Thalassiosira sp.

Family	Species	Family	Species
DINOFLAGELLATES			
Ceratiaceae	*Ceratium biceps*	Gymnodiniaceae	*Gymnodinium sanguineum*
	Ceratium boehmii	Noctilucaceae	*Noctiluca scintillans*
	Ceratium breve	Oxytoxaceae	*Oxytoxum elegans*
	Ceratium declinatum		*Oxytoxum scolopax*
	Ceratium deflexum	Podolampadaceae	*Podolampas bipes*
	Ceratium dens		*Podolampas elegans*
	Ceratium falcatiforme		*Podolampas spinifera*
	Ceratium falcatum	Prorocentraceae	*Prorocentrum gracile*
	Ceratium furca		*Prorocentrum micans*
	Ceratium fusus		*Prorocentrum sigmoides*
	Ceratium humile	Protoperidiniaceae	*Protoperidinium claudicans*
	Ceratium inflatum		*Protoperidinium compressum*
	Ceratium macroceros		*Protoperidinium crassipes*
	Ceratium massiliense		*Protoperidinium denticulatum*
	Ceratium teres		*Protoperidinium depressum*
	Ceratium trichoceros		*Protoperidinium divergens*
	Ceratium tripos		*Protoperidinium mite*
	Ceratium vultur		*Protoperidinium oceanicum*
Dictyochophyceae	*Dictyocha fibula*		*Protoperidinium pallidum*
	Dictyocha speculum		*Protoperidinium pentagonum*
Dinophysiaceae	*Dinophysis caudata*		*Protoperidinium pyriforme*
	Dinophysis hastata		*Protoperidinium quinquecorne*
	Dinophysis miles		*Protoperidinium sp.*
	Dinophysis ovata		*Protoperidinium steinii*
	Dinophysis rotundata	Pyrocystaceae	*Pyrocystis fusiformis*
	Ornithocercus magnificus		*Pyrocystis sp.*
	Ornithocercus steinii	Pyrophacaceae	*Pyrophacus horologium*
Goniodomataceae	*Alexandrium spp.*		*Pyrophacus steinii*
	Alexandrium tamiyavanichii		
	Goniodoma polyedricum	**CYANOBACTERIA**	
Gonyaulacaceae	*Gonyaulax digitalis*	Microcoleaceae	*Trichodesmium spp.*
	Gonyaulax jollifei		
	Gonyaulax spinifera		

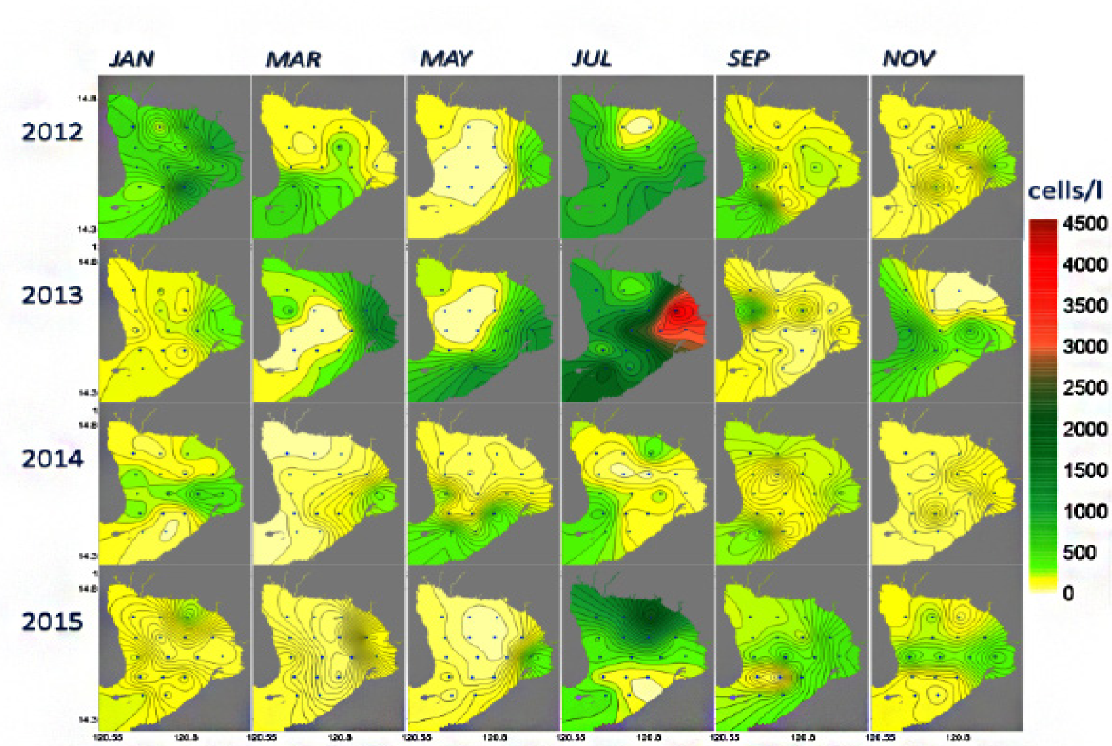

Figure 8.4. Spatiotemporal abundance of phytoplankton in Manila Bay (2012-2015)

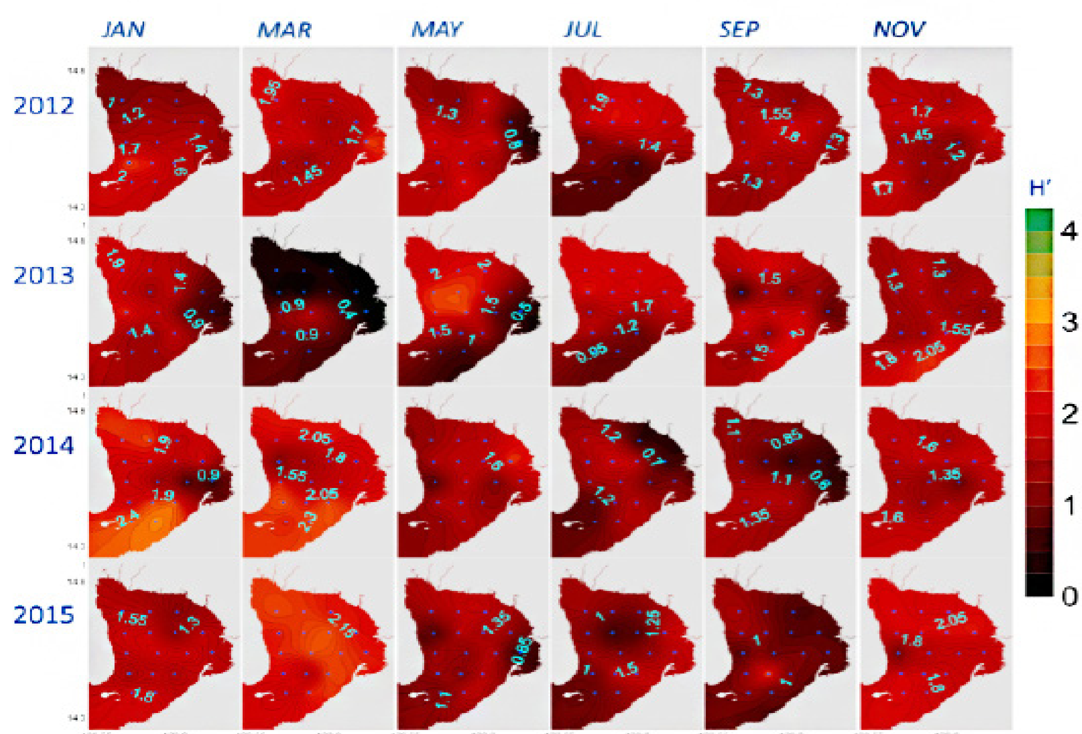

Figure 8.5. Spatiotemporal diversity index (H′) of phytoplankton in Manila Bay (2012-2015)

density of dinoflagellates and cyanobacteria increased during tradewinds or Southeast (SE) Monsoon. The highest record of phytoplankton abundance was observed in July 2013 while the lowest was recorded in March 2015.

The coast of Manila Bay was where phytoplankton often abounds. It is usually observed in the eastern portion of the bay at Manila area which characteristically had the highest phytoplankton concentrations (Figure 8.4). These accumulations seemed to 'flush out' into the mouth of the bay located in the southwestern side on the succeeding months of sample collections. This could be the effect of the double-gyre horizontal water circulation system in Manila Bay located on the western side and eastern side (Yniquez *et al*., 2000). Aggregations on the northern portion of the bay were rare.

Phytoplankton communities were typically more diverse in the northwestern, western and southeastern parts of the bay (Figure 8.5). The lowest diversity was recorded on March 2013 while the highest was on March 2015. November had the most fairly moderate diversity (0.9 – 2.3) albeit the inconsistencies at what portions of the bay these occur. The phytoplankton species diversity indices (Shannon-Weiner Index) measured in the bay within the span of four years (2012 – 2015) ranged from 0.1 to 2.8, an indication that the bay has a low to moderate species diversity.

DISCUSSION

The identified phytoplankton species from this study is lower compared to the 61 genera that were identified by Bidaure in the same bay (1999). The result of the phytoplankton composition and dominant species echo the results of Azanza and Miranda (2001). However, in the present study, *Coscinodiscus* sp. was bumped into the last place by *Lauderia annulata, Thalassionema nitzschioides, Chaetoceros sp., Bacteriastrum furcatum, Rhizosolenia alata, Thalassiosira rotula*, and *Trichodesmium* spp. (Figure 8.3) in terms of total abundance for the whole duration of the survey. Although species known to cause harmful algal bloom were present (*Alexandrium tamiyavanichii, Noctiluca scintillans, Dinophysis* spp., *Nitzschia* spp.), their densities did not reach densities high enough to cause an alarm. However, a short-lived bloom of red *Noctiluca scintillans* was observed on January 2014 at the eastern portion of the bay. The appearance of red *N. scintillans* coincided with the coldest temperature (17.66°C) recorded during the survey. *Trichodesmium* spp. is a cyanobacterium known to form blooms which cause fish mortality. Several species possess neurotoxin similar to anatoxin-a (Rorig et.al. 1997). Thus, this species should be kept in check.

It can be said that the prevalence of dinoflagellates during tradewinds or SE monsoon is an indication that they thrive in warmer water temperature. However, during an exceptionally hot water surface temperature of 35.59°C in May 2014 (Sy *et al*., unpublished, also included in this chapter), dinoflagellates community were relatively lower. Perhaps the temperature exceeded the required optimum for most of the dinoflagellates' growth as in the laboratory experiment conducted by Boyd *et al*. (2013), where the maximum tolerated temperature of the dinoflagellates, *A. sanguinea,* is only 35°C while *P. donghaiense* is only 30°C. Even though the phytoplankton exhibited thermal adaptation in the study of Padfield *et al*. (2012), it took about 10 generations of culture before the phytoplankton finally adapted to the temperature increase. In this regard, the abrupt increase in the water temperature may also have triggered the decrease in the population.

No remarkable values of temperature, salinity, dissolved oxygen (DO), silicates, chlorophyll-*a* and nutrients in July 2013 to explain the extraordinary increase in the phytoplankton density (Vergara *et al*., unpublished, also included in this chapter). In fact, the abundance may even be the culprit for the dissolved oxygen depletion in the water column since it recorded the lowest DO value for the said year. Afterall, phytoplankton can also modify the aspects of its physical environment (Jenkinson and Wyatt, 1993).

Interestingly, the study of Harvey et al. (2012) about the fleeing behaviors of phytoplankton away from predators seemed to be one of the factors for the phytoplankton distribution when the occurrence of the zooplankton and fish larvae is factored in. Phytoplankton was observed to be usually abundant at the opposite side of the adjacent portion of the bay where zooplankton and fish larvae are distributed (Jose, *et al*., and Tobias *et al*., unpublished, also included in this chapter). This perspective might explain the intermittent pattern in the phytoplankton distribution even though the physicochemical parameters of the bay was relatively consistent with the seasons.

Obviously, the possibility of prey-predator factor cannot also be discounted on this especially since phytoplankton diet provides the reserve material needs of the highly opportunistic feeder, sardines (Garrido and van der Lingen, 2014). The decrease in the density of the phytoplankton was observed to correspond with the major peak of the spawning seasons of *Sardinella gibbosa* from October to December and *Sardinella fimbriata* from October to December and February (Bendaño, 2016). There was also a drop in the density during the minor peaks in March, April, and August for *S. gibbosa* and from May to June for *S. fimbriata*. It appears that *S. gibbosa* is a more voracious eater than *S. fimbriata* because phytoplankton density can recover more easily after the minor peak of the latter. Needless to say, although the spawning of these species occurs all year round, the peak for spawning appears to commence at the height of the phytoplankton population. Unfortunately, the survey periods for phytoplankton sampling did not cover the exact months of the spawning peak of these two species to be able to infer the relationship.

Species diversity indices are also a good indicator of pollution in the aquatic ecosystem. Diversity index value greater than 3.00 indicates clean water. Values in the range of 1.00 to 3.00 are characteristics of moderately polluted water and values less than 1.00 characterize heavily deteriorated condition (Mason, 1998). With the recorded diversity index value ranges of 0.1 to 2.8, Manila bay can be classified as moderately heavy to heavily polluted. Diversity is better during northeast monsoon though especially just before the onset of tradewinds.

REFERENCES

Aune, T. Dahl, E. and Tangen K. 1995. Algal monitoring, a useful tool in early warning of shellfish toxicity? 6th Proceedings International Conference on Harmful Algae (765-770)

Bendaño, A.P., Rivera, E.L., Lopez, G.D.V., Bognot, E.C., Gonzales, F.L., Torres, F.S.B.Jr., Santos, M.D., 2016. Reproductive Biology of Common Small Pelagic Fishes in Manila Bay, Philippines. 7th Fisheries Scientific Conference. 29-30 September 2016; CFRDD-03(78)

Bidaure, W., 2000. Phytoplankton in the Manila Bay waters: their ecological and economic importance, Canopy International, 2000 September to October; 26(5)

Boyd, P. W., Rynearson, T. A., Armstrong, E. A., Fu, F., Hayashi, K., Hu, Z., Hutchins, D. A., Kudela, R. M., Litchman, E., Mulholland, M. R., Passow, U., Strzepek, R. F., Whittaker, K. A., Yu, E., and Thomas, M. K. 2013. Marine

Phyto plankton Temperature versus Growth Responses from Polar to Tropical Waters – Outcome of a Scientific Community-Wide Study. PLoS One.; 8(5): e63091

Chang, K.H., Amano, A., Miller, T.W., Isobe, T., Maneja, R., Siringan, F.P., Imai, H. and Nakano, S. 2009. Pollution Study in Manila Bay: Eutrophication and Its Impact on Plankton Community. In Interdisciplinary Studies on Environmental Chemistry — Environmental Research in Asia, Eds., Y. Obayashi, T. Isobe, A. Subramanian, S. Suzuki and S. Tanabe. (261–267)

Garrido, S. and Van der Lingen, C.D., Feeding Biology and Ecology. Biology and Ecology of Sardines and Anchovies 2014, Ed. Ganias, K.(122-189)

Harvey EL, Menden-Deuer S. 2012. Predator-Induced Fleeing Behaviors in Phytoplankton: A New Mechanism for Harmful Algal Bloom Formation? PLoS ONE 7(9): e46438 DOI: 10.1371/journal.pone.0046438

Jenkinson, I.R., Wyatt, T. 1993. Does bloom phytoplankton manage the physical oceanographic environment? 6th Proceedings International Conference on Harmful Algae. (603-608)

Manila Bay: Refined Risk Assessment, 2004

Mason, C.F. 1998. Biology of Freshwater Pollution. Langman scientific & technical press. U.S.A.

Omura, T., Iwataki, M., Borja, V.M., Takayama, H., Fukuyo, Y. 2012. Marine phytoplankton of the western pacific.

Padfield, D., Yvon-Durocher, G., Buckling, A., Jennings, S., Yvon-Durocher, G. 2015. Rapid evolution of metabolic traits explains thermal adaptation in phytoplankton. Ecology Letters,; DOI: 10.1111/ele.12545