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Bloom of *Trichodesmium* (Oscillatoriales, Phormidiaceae) and seasonality of potentially harmful phytoplankton in San Pedro Bay, Leyte, Philippines

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Abstract: Since 1983, San Pedro Bay in the Philippines had been reported to be the site of episodic *Pyrodinium bahamense* var. *compressum* blooms that caused paralytic shellfish poisoning in its nearby coastal communities. This bay is also subjected to numerous storms; the strongest was super typhoon Haiyan in November 8, 2013. For the first time, the seasonal dynamics of potentially toxic and harmful phytoplankton in this bay is elucidated. This is also the first record of a bloom of the cyanobacteria, *Trichodesmium erythraeum* that reached 70 000 colonies/L in April 2013 in this area. There were other 19 potentially toxic and harmful phytoplankton encountered during the sampling period. These consisted of a haptophyte, *Phaeocystis globosa,* the diatom *Pseudo-nitzschia* and 17 dinoflagellates. Seven of these harmful algae had densities high enough to be traced through time. Normally, diatoms abound during the dry season. But *Pseudo-nitzschia* increased in abundance during the wet season of 2012 and 2013. The dinoflagellates and *Phaeocystis globosa* behaved as expected and exhibited a relative increase in cell density during the rainy season of both years too. High nutrient availability during this season must have influenced the behavior of the phytoplankton despite differences in temperature and light intensity among seasons. Other notable but rare harmful species found only in plankton net tows during the study were *Pyrodinium bahamense* var. *compressum, Alexandrium tamiyavanichii*, *Cochlodinium polykrikoides,* and *Noctiluca scintillans.* Rev. Biol. Trop. 64 (2): 897-911. Epub 2016 June 01.

Key words: *Trichodesmium*, *Pseudo-nitzschia*, harmful dinoflagellates, HAB, nutrients, storm, San Pedro Bay, Leyte, Philippines.

Episodes of *Pyrodinium bahamense* var. *compressum* blooms that cause paralytic shellfish poisoning (PSP) have been reported in San Pedro Bay since 1983. In January 1983, toxic bloom of *Pyrodinium bahamense* var. *compressum* affected 300 km of coastlines of Samar and Leyte including this bay. The red-tide repeated in 1987 and 1988 (Bankoff, 2003; Gonzales, 1989). Human fatalities accompanied some of these blooms historically. The latest recorded bloom was in October 2007 (LMBTC, 2007). Laboratory analyses of shellfish samples at that time from Cancabato Bay showed positive results for saxitoxin beyond the regulatory limit of 40 micrograms saxitoxin equivalent/100 grams meat (LMBTC, 2007). Last November 2012, all coastal waters in Eastern Visayas region including San Pedro Bay covering Palo and Tanauan, and Cancabato Bay in Tacloban City, were declared free from this toxic red tide (BFAR, 2012).

There are two other harmful algae previously recorded in the bay. *Nitzschia navis-varingica* was detected in San Pedro Bay in 2004 and was found to produce the major toxins, domoic acid and isodomoic acid B (Kotaki et al., 2005). *Pseudo-nitzchia* spp. were also present (Yap-Dejeto, Cobacha, & Cinco, 2008; Yap-Dejeto, Omura, Cinco, Cobacha, & Fukuyo, 2013).

It is not clear until now how species of phytoplankton behave annually in tropical marine waters. Recent studies have proven that changes and successions of phytoplankton communities do occur in coastal tropical areas seasonally (Franco-Herrera, Castro, & Tigreros, 2006). Harmful phytoplankton are few; however, these species can cause small or large-scale shellfish and fish kills (Sellner, Doucette, & Kirkpatrick, 2003) and even human deaths when they form blooms. Hence, monitoring of phytoplankton composition is important to understand their formation and to predict occurrences of harmful algal bloom incidents that directly affect commercial shellfish production, mariculture industries and overall food safety.

San Pedro Bay is located in the center of the Philippines and confined within the coastlines of Leyte and Samar islands. It includes the narrow San Juanico Strait and a shallow U-shaped embayment, Cancabatoc Bay. It then spreads out through the Pacific Ocean. A characteristic feature of this bay is its relatively shallow depth averaging only 20 m. Its total area is 625 km^2 (Campos, 2003); and parts of the bay are mariculture zones for fish and shellfish, and is also an important fishing ground for people in its coastal communities. Thus, updated information on the water quality of the bay is important.

The Philippine Atmospheric Geophysical Astronomical Services Administration (PAGASA) classifies Leyte Island under Type IV of the Corona system of classification. This is characterized by even distribution of rainfall throughout the year and short dry season from February to March (DOST-PAGASA, 2011). This bay is also subjected to numerous typhoons; the strongest was typhoon Haiyan in November 8, 2013. Ecological studies of this bay will thus provide a glimpse of possible effects of climate change in phytoplankton ecology in a marine ecosystem.

This paper aims to elucidate the seasonal succession of harmful phytoplankton in San Pedro Bay, Leyte, Philippines from 2012-2013; and to conduct a thorough search of potential harmful phytoplankton in the system. This is the first study of this kind that has been done in this Philippine region (Visayas).

MATERIALS AND METHODS

Sampling strategy: Three representative stations in San Pedro Bay were established. Station 1 (11°13’270” N - 125°02’471” E) at 8-10 m depth was located near Dio Island, Station 2 (11°15’46” N - 125°04’5” E), 2.3-4 m deep, located within Cancabato Bay and Station 3 (11°17’22” N - 124°58’30” E), 11-15 m deep, located along the San Juanico Strait (Fig. 1). A GPS unit (Handheld Garmin 76) was used to record the coordinates of the stations which were then traced and plotted using Manifold®. Station 1 is located near Dio Island, far from coastal settlements. Station 2 is located within the shallow and restricted Cancabato Bay near residential and mangrove areas. Station 3 is along the San Juanico Strait, which harbors a mariculture area and a number of fish cages.

A quantitative data of phytoplankton was recorded to represent the three (3) climatic seasons in the Philippines i.e., the rainy season (June-November), the cold dry season (December-February) and hot dry season (March-May). Monthly collections were done from January to March 2012, and August to December 2012. Bimonthly collections were done from April to December in 2013. Samples for qualitative assessment were taken 1-m below the surface using a 20 µm mesh size (aperture diameter: 30 cm, length: 1m) plankton net, while that for phytoplankton counts were from a 2-L vertical alpha water sampler (WILDCO).

Physico-chemical analysis: Physical variables were assessed *in situ.* Temperature, salinity, light intensity and depth readings were recorded using a mercury-filled centigrade field thermometer, ATTAGO refractometer, EXTECH light meter and a calibrated rope, respectively. Current velocity was estimated through drift method using a fabricated Holey Sock drogue. Secchi Disc Transparency (SDT; turbidity of the water column) was estimated. Measurements for pH and amount of dissolved

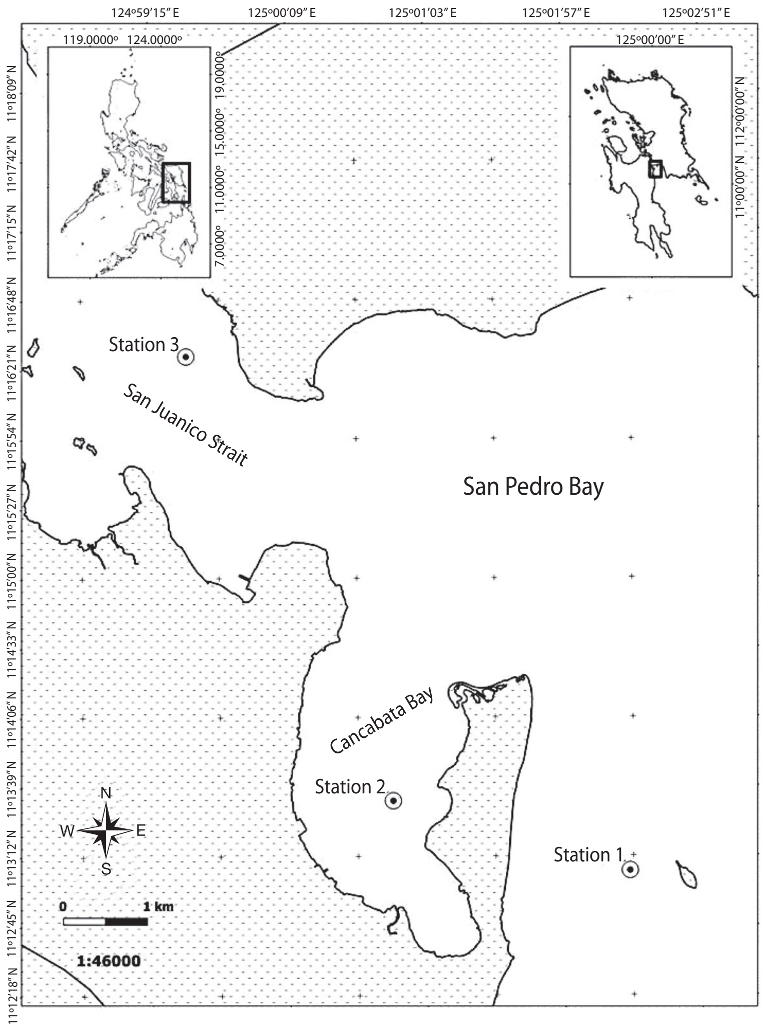

Fig. 1. The inner portion of San Pedro Bay showing the location of the three sampling stations.

oxygen were taken using a EUTECH Multiparameter Handheld Meter (PCD 650).

For nutrient analyses, water samples were filtered using 47-mm Whatman GF/C glass-fiber filters (1.2 µm pore size). The filtered samples were stored in acid-washed bottles and were frozen. The prepared samples were then sent to the Chemical Oceanography Laboratory of the Marine Science Institute of University of the Philippines, Diliman for analysis. Nitrate, nitrite and phosphate concentrations were measured by the use of SKALAR SANS ++ segmented flow analyzer D5000 following Strickland and Parsons (1972).

Phytoplankton species identification: Phytoplankton samples were settled for at least 48 hours with two settling phases of at least 24 hours. The 1L samples for quantitative analysis were fixed with Lugol's solution and settled for at least 24 hours to obtain about 200 mL sample. These were then transferred to 250 mL graduated glass cylinders to settle for at least another 24 hours. Capillary tubing's were used to siphon upper layers of each settling phase to finally obtain about 50 mL final concentrated phytoplankton sample (USEPA, 1994 with modifications). One (1) mL of the 50 mL concentrated sample was then dispensed into a gridded Sedgwick-Rafter counting chamber and was examined in triplicate under a light compound microscope at 40x-400x magnification. The harmful phytoplankton species present were identified using identification guides and keys of Omura, Iwataki, Borja, Takayama and Fukuyo (2012), Larink and Westheide (2006), Botes (2003), Tomas (1997) and Yamaji (1984). The number of cells counted in three replicates was averaged in order to calculate cell density per species. Cell density was obtained by multiplying the averaged cell density counted in one-mL to the concentrated volume of sample.

Data treatment: Monthly cell densities and physico-chemical parameters from the three stations were averaged to obtain the mean monthly data. Pearson's correlation coefficients and p-values were calculated using Windows Excel 2013 and Pumpkin Helmet© package (2014) in R version 3.1.2.

RESULTS

Physico-chemical parameters: The monthly and seasonal variation of the physical parameters obtained during the two year study period, 2012 and 2013, is shown in figure 2. Mean monthly water temperatures varied over a relatively narrow range during the two consecutive years from 26.8 to 31.0 °C. Lowest temperatures were recorded during the cold dry season of both sampling years while highest temperatures were recorded during the rainy months of June and August 2013. Salinity varied from 29 to 35 ppt within small amplitude, with the highest value recorded during the cold dry season of 2012 and 2013. pH values were all relatively alkaline and did not vary much across all the sampling months of both years.

Dissolved Oxygen (DO) concentrations of most sampling months were greater than the minimum value of 4 mg/L set by ASEAN water quality criteria (ASEAN, 2008). The least current velocity (0.2 m/s) was in Station 1 in December 2013 and greatest current velocity (0.78 m/s) was in Station 3 in January 2012. Mean light intensity measurements ranged from 691 to 1 216 µmol photons/m^2.s. High temperatures and light intensities were during the rainy season of both years. Transparency measurements, on the other hand, fluctuated between 0.19 to 4.6 m.

Mean soluble inorganic nitrogen (NO_2; NO_3) and soluble reactive phosphate (PO_4) concentrations in selected months of 2012 and 2013 are shown in figure 3. Concentration of nitrates (4.36-5.5.43 µm) and phosphates (3.09 µm) were high during the rainy season of 2012 particularly in the months of August and October. In contrast, nitrite concentration during the same months was low (0.4 µm).

Toxic and harmful phytoplankton composition and seasonal cell density: A total of 20 potentially toxic and harmful phytoplankton taxa were identified during the study period (Table 1) which consists of one cyanobacterium, one diatom, one haptophyte and 15 dinoflagellates belonging to the following divisions: (17) Dinophyta, (1) Bacillariophyta, (1) Cyanophyta and (1) Haptophyta. *Dinophysis* spp., *Prorocentrum* spp, *Protoperidinium* spp., *Pseudo-nitzschia* spp., and *Trichodesmium erythreaum* were the most abundant taxa observed over the 2-year period leaving the other phytoplankton taxa recorded rare and in low cell numbers. General phytoplankton number in 2012 increased during the rainy season with an average total cell density of 30 000 cells/L, contrary to year 2013 in which the total phytoplankton number increased substantially during the hot dry season (average of 75 000 colonies & cells/L) dominated largely by *Trichodesmium* (70 000 colonies/L). Dinoflagellates increased during the rainy season of both years.

Shown in figure 4 are the seasonal fluctuations in abundance of harmful microalgae that were found in San Pedro Bay over the last two years. As observed, these apparent upturn in abundance of the recorded harmful diatoms and cyanobacteria occurred during the rainy season for both years. Low diatom cell densities

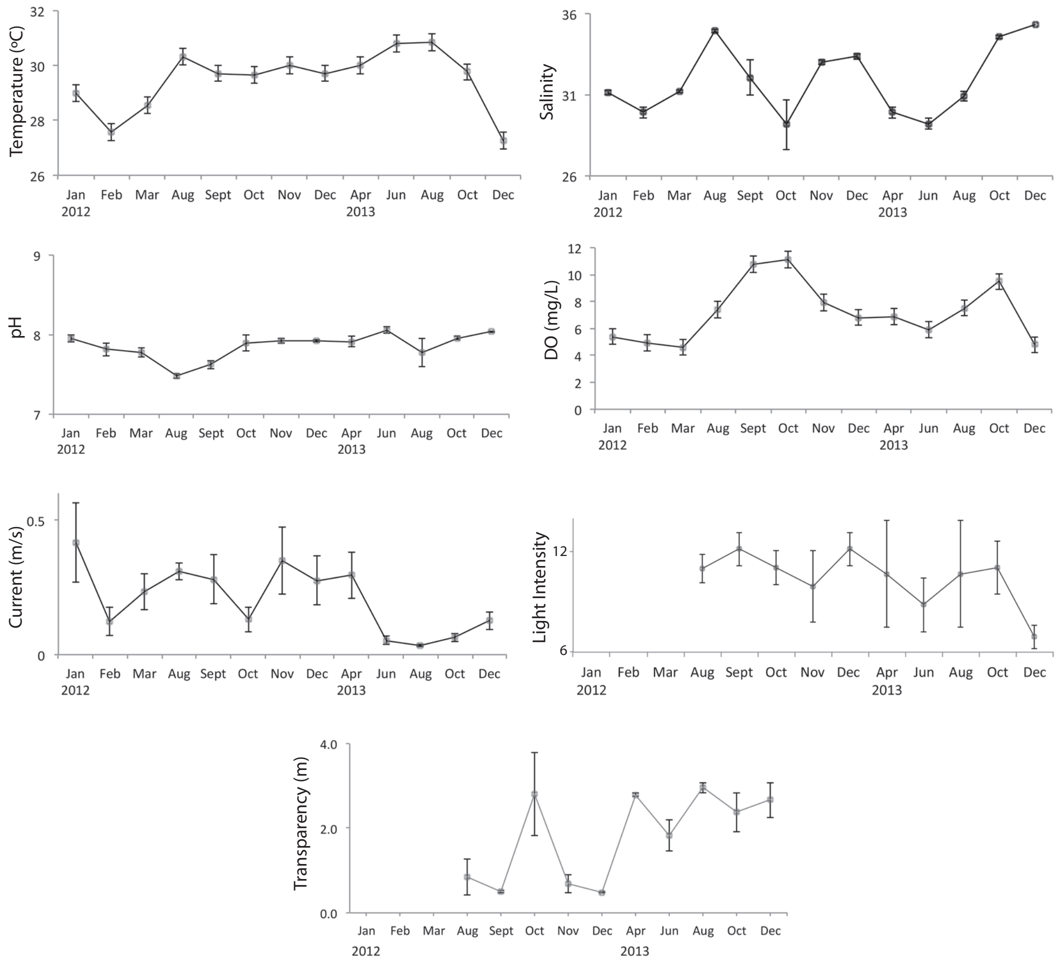

Fig. 2. Mean temporal variations of physico-chemical parameters obtained during 2012 and 2013 sampling months in San Pedro Bay in al. Bars indicate the standard error of each mean. Transparency is from Secchi disk depth. Unavailable data values are indicated by broken lines.

occurred during the rest of the years. But for the month of April 2013, *Trichodesmium* escalated into a peak reaching an average total of 70 000 colonies/L.

Shown in figure 5 is the graphic representation of the seasonal fluctuations in abundance of dinoflagellates which frequently occurred in the samples obtained from 2012 to 2013. By August, the density of the harmful dinophytes that were frequently recorded in most stations and sampling months (*Dinophysis* spp., *Gymnodinium* sp., *Prorocentrum* spp., and *Protoperidium* spp.) increased remarkably (highest at 3 300 cells/L) as compared to their previous and succeeding recorded cell numbers (undetected to 50 cells/L). Dinophytes that were found rare and in very few cell numbers (*Alexandrium tamiyavanichii*, *Cochlodinium polykrikoides*, *Noctiluca scintillans*, and *Pyrodinium bahamense* var. *compressum*) were spotted mostly during the rainy season especially during the months of June and August

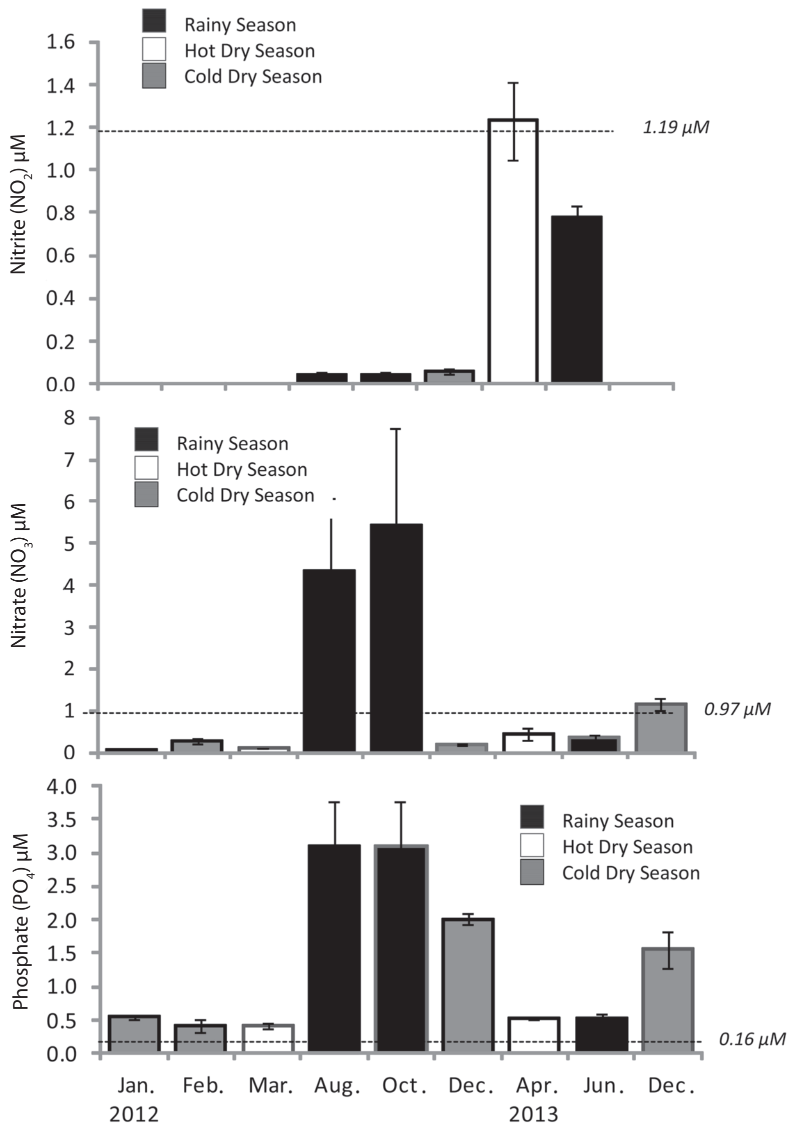

Fig. 3. Mean concentrations of Nitrates, Nitrites and Phosphates during selected sampling months of 2012 and 2013 in San Pedro Bay. Standard error of each mean is represented by vertical error bars. Unavailable data values for Nitrite are indicated by blank spaces in the graphs. The ASEAN water quality criteria for aquatic life protection for nutrient concentration is indicated by black dashed line.

TABLE 1
Potentially toxic and harmful phytoplankton species found in San Pedro Bay from year 2012-2013
(S=Sept, O=Oct, D=Dec, F=Feb M=Mar)

Genus/Species	Months/Year	Stations	Impact
Dinophyceae			
Alexandrium tamiyavanichii	Aug-13	1 & 2	PSP (GEOHAB, 2010)
Cochlodinium polykrikoides	Aug-13	1, 2 & 3	Fish mortality (Gárate-Lizárraga, Lopez-Cortes, Bustillos-Guzman & Hernandez-Sandoval, 2004)
Dinophysis spp.[1]	Aug S D Jan F M-12 Jun Aug D-13	1, 2 & 3	DSP (Le, Nguyen & Fukuyo, 2012)
Gymnodinium sp.	Aug S O M-12 Jun Aug D-13	1, 2 & 3	PSP (Larsen & Nguyen, 2004)
Noctiluca scintillans	Apr Jun Aug-13	1 & 2	Fish mortality (Cardoso, 2012)
Prorocentrum spp.[2]	Aug S O D Jan F M-12 Apr Jun Aug O D-13	1, 2 & 3	Fish mortality (Aligizak, Nikolaidis, Katikou, Baxevanis & Abatzaopoulos, 2009)
Protoperidinium spp.[3]	Aug S O D Jan F M-12 Apr Jun Aug O D-13	1, 2 & 3	Azaspiracid Poisoning (AZP) (Gribble, Nolan & Anderson, 2007)
Pyrodinium bahamense var. *compressum*	Aug-13	1	PSP (Usup, Ahmada, Matsuoka, Lim & Leaw, 2012)
Bacillariophyceae			
Pseudo-nitzschia spp.	Aug M F-12 Jun Aug O-13	1, 2 & 3	ASP, toxic substance (Anderson et al., 2010)
Cyanophyceae			
Trichodesmium erythraeum	Aug O M-12 Jun Aug O D Apr-13	1, 2 & 3	Harmful to marine fauna (Sheridan et al., 2002)
Haptophyceae			
Phaeocystis globosa	Aug O M D Jan-12 Aug O D-13	1, 2 & 3	Haemolysis, Foam-forming (Smith et al., 2013)

[1]D. tripos, D. oblongum, D. miles, D. caudata; [2]P. minimum, P.micans, P. sigmoides, [3]P. pellucidum, P. pallidum, P. divergens, P. depressum, P. conicum

(Table 1). Station 2 harbored the most dense potentially harmful algae, followed by station 3, then station 1 (Fig. 4 and Fig. 5).

DISCUSSION

In tropical and subtropical areas, diatoms usually dominate or form blooms during the summer season where there is relatively high temperature and light intensity (Philips et al., 1997). However, in this study, higher temperatures and light intensities were observed during the rainy season of both years. This was accompanied by peaks in abundance of the diatom *Pseudo-nitzschia* spp. during this season. There was even a moderate negative relationship calculated between *Trichodesmium erythraeum* and light intensity (Pearson's r= -0.3, p= 0.03). Studies indicated that this diazotroph is inhibited by intense light (Ho, Chu, & Hu, 2013; Bell & Fu, 2003). This could mean that light was too strong for phytoplankton in this area during these years.

Instead of diatoms, a cyanobacterium bloomed during the hot dry season of 2013. There was a sudden increase in abundance of *Trichodesmium erythraeum* particularly in April which contributed to the high nitrite content of the water body during the same month. A strong positive relationship (Pearson's r= 0.6, p= 0.009) was shown with nitrite concentration and *Trichodesmium* density. *Trichodesmium*

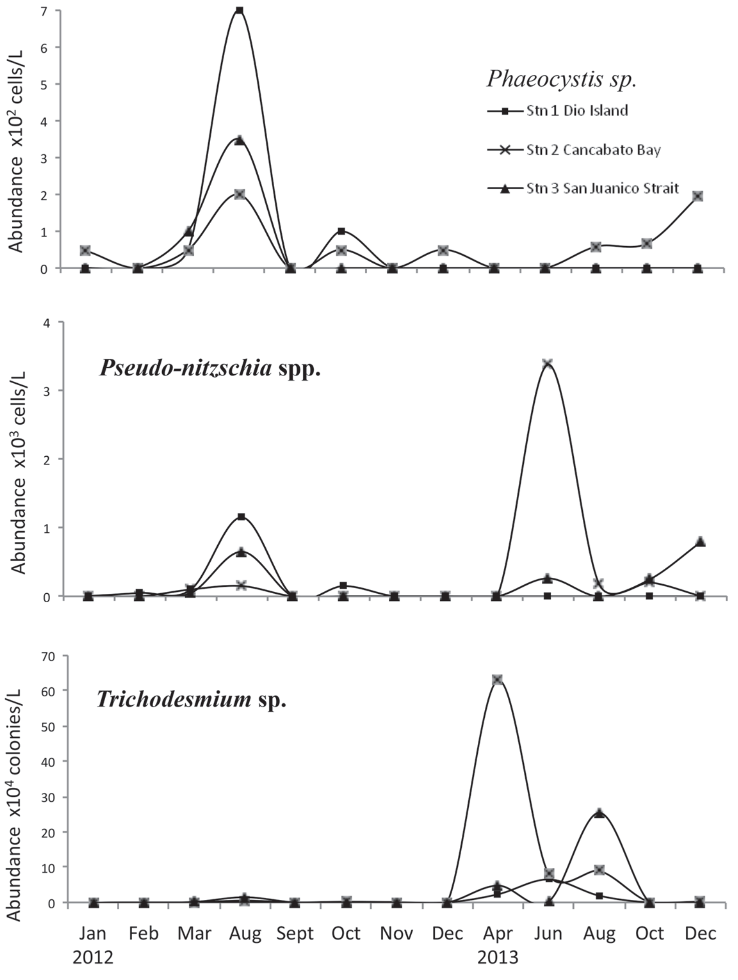

Fig. 4. Seasonal dynamics of the potentially toxic and harmful haptophyte, *Phaeocystis* sp. (x10^2 cells/L)*,* the diatom, *Pseudo-nitzschia* sp. (x10^3 cells/L) and cyanobacterium, *Trichodesmium* sp. (x10^4 colonies/L) in San Pedro Bay from 2012 to 2013.

is a filamentous and colonial nitrogen fixing cyanobacteria, pervasive in tropical and subtropical regions of the world's oceans. Its presence is more prominent in nitrogen poor water and easily seen during blooms (Capone, Zehr, Paerl, Bergman, & Carpenter, 1997). These blooms release carbon, nitrogen and other nutrients into the environment which contributes to nutrient loading (Capone et al., 1998).

Generally, *Trichodesmium* is dangerous as a food source for other organisms. Only few specialized animals feed on it actively. Some strains of *Trichodesmium* produce toxins causing mortalities in some copepods, oysters and fish. Some blooms were found to produce toxins leading to clupeotoxism in humans after ingestion of fish contaminated by *Trichodesmium*-toxins (Post, 2005). There were no reports of fish mortalities in the bay however. The bloom was more pronounced in the semi-enclosed Cancabatoc Bay (Station 2) where 70 000 colonies/L were noted. Mariculture areas were found in Station 1 which harbored less cyanobacteria (2 300 colonies/L).

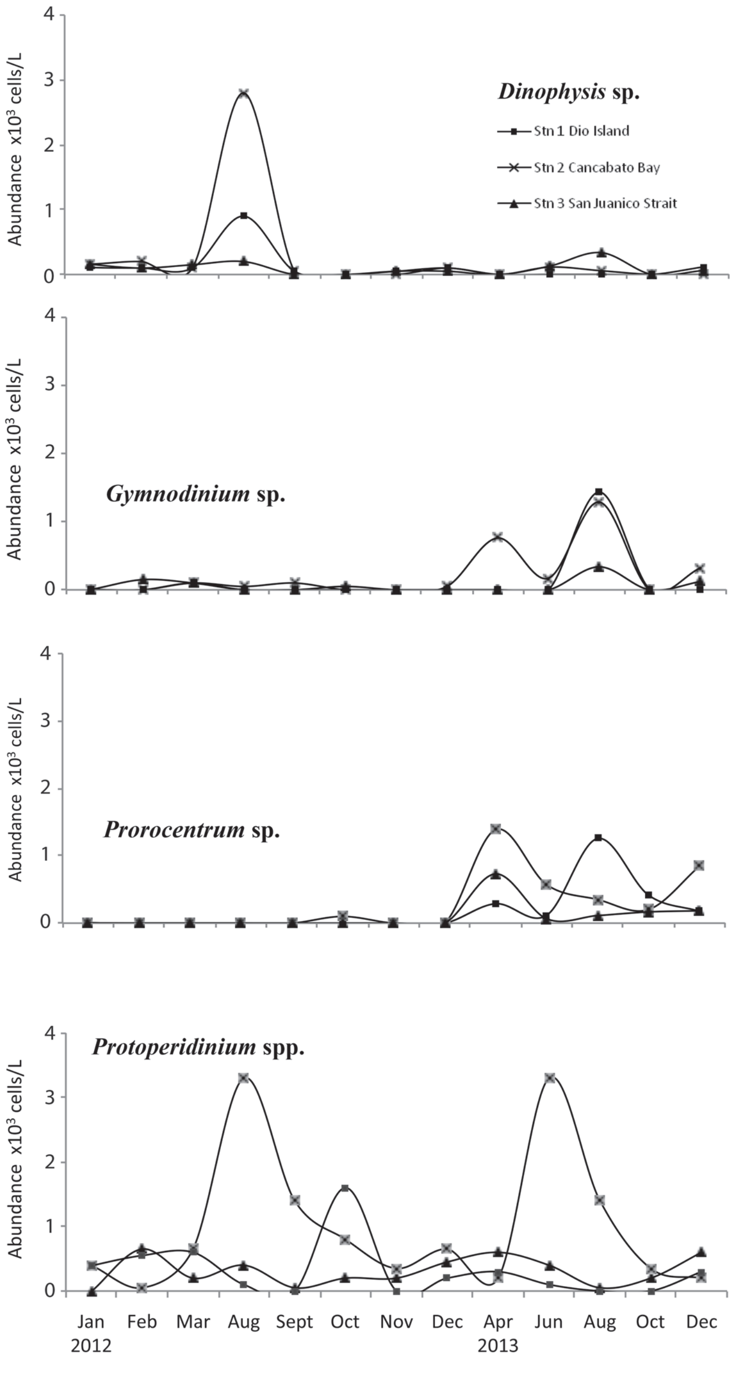

Fig. 5. Seasonal dynamics of potentially toxic and harmful dinoflagellates with higher cell densities in San Pedro Bay from 2012 to 2013.

Anthropogenic activities in the area partly resulted in phosphate loading through fertilizer pollution, waste disposal and aquaculture activities, reducing growth limitations from limited phosphate, and brought the increase *Trichodesmium* bloom occurrences (Bergman, Sandh, Lin, Larsson, & Carpenter, 2012). The increased nitrite concentration in April must have resulted from this bloom. Nitrogen fixation process by *Trichodesmium* in daytime is still partially understood (Bergman et al., 2012). Nitrogen fixation converts dinitrogen (N_2) to ammonia (NH_3) which is then assimilated by the algae, or will be further nitrified to nitrite and nitrate. Nitrate is preferred by the cyanobacteria (Qingfeng, Hong, & Post, 2000) and other marine plants, thus leaving elevated nitrite. Nitrite might have also come from regeneration of nutrients when the bloom started to die off. Other sources of nitrite concentration in the area might be influenced by the contribution of nutrients coming from agricultural run-offs, septic and sewage discharges and decaying fish feed and fish waste.

Intense light did not favor the growth of dinoflagellates during the dry season which may be due to effect of high UV radiation and temperature (Lesser, 1996). In the results, dinoflagellates showed an increase in abundance during the rainy season of both years in which relatively lower light intensity and temperatures were observed. *Dinophysis* spp., *Gymnodinium* sp., *Prorocentrum* spp., and *Protoperidinium* spp. peaked during the rainy season of 2012 and 2013 with relatively high cell densities ranging from 400 to 3 500 cells/L. High nutrient availability during the season might have a strong influence on both diatoms and dinoflagellates inducing both groups to increase in abundance during the same season. Peaks of nutrient concentrations are accompanied by increase in phytoplankton numbers particularly in August of both years.

High nutrient input in Station 2 within the Cancabato bay explains the continued high total cell density of phytoplankton in the area (Macanip & Yap-Dejeto, 2012; Oracion & Yap-Dejeto, 2011). The shallow and restricted morphology of this bay increases contact with nutrients in the bottom and susceptibility to nutrient-related algal problems and risk of bloom formation (Anderson, 2005).

Aquaculture activities such as cage and fish pen farming present in Station 3, also affect nutrient loading. These anthropogenic inputs have changed the nutrient pool in that area which, in turn, may or may not create a favorable environment for HAB species. Inorganic nutrients released can affect phytoplankton in upper waters. Fish farming activities contribute to the release of inorganic nutrients (NH_4 and PO_4), particulate organic nutrients, and dissolved organic nutrients (Olsen & Olsen, 2008). One potential threat of aquaculture to environment is the effect of bio-deposits such as fish feces and uneaten feed. These impacts include physiological effects to fish caused by low dissolved oxygen levels in the water column, toxic effects of H_2S and ammonia from bio-deposit degradation, and toxic effects of harmful algal blooms related to eutrophication (Degefu, Mengistu, & Schagerl, 2011).

Station 3 was second to Station 2 in terms of potentially toxic and harmful phytoplankton abundance. In comparison with Stations 2 and 3, Station 1 has relatively low total phytoplankton cell density. This station is far from coastal settlements, there are no fish cages, and thus low amounts of nutrients are loaded into the area. Hence it registered the lowest phytoplankton abundance among all three stations.

Episodic environmental events, such as typhoons, induce extensive ocean-atmosphere interactions which have profound influences on phytoplankton ecology (Chung, Gong, & Hung, 2012). The occurrence of typhoon Haiyan on November 8, 2013, caused severe devastation in Eastern Visayas including San Pedro Bay. The sampling for December was conducted a month after the typhoon and water was observed to have high transparency, low DO concentration and low phytoplankton abundance. Total phytoplankton was only 14 000 cells/L. This is contrary to reports of increased phytoplankton density after a typhoon (Chung et al., 2012). Accounts of people and based on first hand observation, during the onslaught of Haiyan, a storm surge covered the city. The water coming in was murky, almost black in color. This must have been mostly silt and sewage. It also must have brought inland most of surface coastal phytoplankton. There was, however, an increase in nitrate concentration (1.14 μM) which might be due to the increase land run-off and mixing of nutrients from the bottom sediment through the water column.

The high dissolved oxygen concentrations during the rainy season at 189-265 mm (DOST PAGASA 2000-2012) reflect the high rate of rainfall experienced this season. Rainfall increases interaction of water and air which increases dissolved oxygen. More interaction of water and air was achieved through increased mixing of water brought by high rate of river discharge into the ocean due to rainfall (Wehmeyer & Wagne, 2011). High input of rainwater, in return, decreased the salinity of seawater considerably but only during the rainy season of 2012. In 2013, however, the increase in salinity suggests that there is low input of rainwater, 82 mm (DOST PAGASA 2013) or freshwater in the area and high DO levels might have been due to wind-assisted surface mixing, with wind velocities from 4.4-6.7 kph (WeatherOnline, 2015) or photosynthesizing algae and not necessarily the inflow of freshwater during the season (Ladipo, Ajibola, & Oniye, 2011).

Usually, in colder waters, there is high concentration of oxygen since oxygen dissolves more easily in cold temperatures (Jones, 2011). However, in the tropics, temperature is subject to less seasonal variation reflecting less change of temperatures between sampling seasons. The lowest temperature recorded in this bay was only at a relatively warm 26.8 °C. This explains the low DO concentration during the cold dry season of both years, specifically in stations 1 and 3 during the months of February and March 2012, and in all stations during the month of December 2013 (4.6-4.9 mg/L). Phytoplankton profiles remained at low levels during this time too. In addition, absence of mixing brought by little rainfall and flow, decreases interaction of air and water thereby decreasing oxygen solubility which happened here during the hot dry season.

During the rainy season, the relatively higher transparency (uppermost at 2.96 m) and current velocity (0.3 m/s) might have influenced the amount of light that penetrated the water column as well as the DO concentration during the season. High current velocity induces mixing of the water column, which increases dissolved oxygen concentrations (Jones, 2011) while high transparency values indicate high amount of light, that can penetrate the water column conducive for diatom growth.

The spike of phosphate (3.1 μM) in August and October of 2012 was unusual. It should be noted that in August 2012, an earthquake with magnitude 7.6, epicenter 10.83 °N, 126.71 °E occurred (PHIVOLCS, 2012). Sediments must have been resuspended due to the activities of the seafloor near the Philippine trench. Increase in phosphate after an earthquake was also documented in Izmit Bay, Turkey (Okay et al., 2001). Nitrate (4.3-5.4 μM) also increased during this time. But by December, this has been consumed by primary producers and was back to 0.19 μM. Phosphate, however, was still at 2 μM in December 2012 and slowly decreased in the subsequent months ahead. Then typhoon Haiyan occurred in November 2013 and again phosphate concentrations were raised to 1.6 μM in December 2013. Other sources of phosphate in this bay are the presence of cage and pen fish farming in Station 3, and influx of municipal wastewaters consisting of soap and detergent, wastes from mangrove ecosystems and discharge of raw human and animal feces in Station 2. These accumulated factors might have contributed to the release of wastes that are high in phosphate content.

The toxin-producing *P. bahamense var. compressum* was still detected in the bay but in lower cell densities. In 2011, its Atlantic counterpart, *Alexandrium* was first seen in the bay (Oracion & Yap-Dejeto, 2011). There was a *Noctiluca scintillans* bloom during October 2007 in this bay. *Noctiluca* has also been reported to bloom in Manila Bay (Furuya et al., 2006). *Gymnodinium* sp. is common but never reached bloom proportions. This species may be *G. catenatum*, the same species found in Manila Bay (Fukuyo et al., 1993). There are five *Pseudo-nitzschia* species so far recorded in the bay: *P. brasiliana, P. micropora, P. pseudodelicatissima* and *P. pungens* (Yap-Dejeto et al., 2013).

The results of this study show that the taxonomic composition and abundance of harmful and potentially toxic phytoplankton in San Pedro Bay still vary seasonally. The relative consequence of light, temperature, DO concentration, but most importantly, nutrient availability was found to influence the spatial and temporal patterns observed in the abundance and composition of harmful phytoplankton.

Thus, a total of 20 potentially toxic and harmful phytoplankton taxa were identified consisting of one cyanobacterium, one haptophyte, one diatom and 17 dinoflagellates. *Trichodesmium erythraeum* bloom was observed during the month of April in Station 2 reaching 70 000 colonies/L. *Phaeocystis globosa* had the least cell density (820 cells/L) this was followed by *Protoperidinium* spp. (8 600 cells/L) and *Prorocentrum* spp. (4 200 cells/L). Other notable but sporadic harmful species found only in plankton net tows were *Alexandrium tamiyavanichii*, *Cochlodinium polykrikoides, Noctiluca scintillans*, and *Pyrodinium bahamense* var. *compressum*. Rainy season brought in the most number of harmful and potentially toxic phytoplankton due to high nutrient concentration. Among stations, Station 2, in Cancabato Bay, showed high relative abundance of harmful and potentially toxic phytoplankton.

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RESUMEN

Proliferación de *Trichodesmium* (Oscillatoriales: Euphorbiaceae) y estacionalidad de fitoplancton potencialmente dañino en Bahía San Pedro, Leyte, Filipinas. Desde 1983, la Bahía de San Pedro en Filipinas ha sido reportada como un sitio de proliferación de *Pyrodinium bahamense* var. *compressum* que causó intoxicación paralítica en sus comunidades costeras cercanas. Esta bahía también está sometida a numerosas tormentas; entre las más fuertes se presentó un súper tifón en Haiyan, el 8 de noviembre 2013. Por primera vez, se explica la dinámica estacional del fitoplancton potencialmente tóxico y dañino en esta bahía. Este es también el primer registro en esta área de una proliferación de cianobacterias (*Trichodesmium erythraeum*) que alcanzó 70 000 colonias/L en abril 2013. Durante el periodo de muestreo se presentaron otras 19 proliferaciones de fitoplancton potencialmente tóxicas y dañinas. Estos consistían en una haptófita, *Phaeocystis globosa*, la diatomea *Pseudo-nitzschia* y 17 dinoflagelados. Siete de estas algas nocivas tenían densidades suficientemente altas como para ser rastreadas a través del tiempo. Normalmente, las diatomeas abundan durante la estación seca. Pero *Pseudo-nitzschia* aumentó en abundancia durante la temporada de lluvias de 2012 y 2013. Los dinoflagelados y *Phaeocystis globosa* se comportaron como se esperaba y exhibieron un aumento relativo de la densidad celular durante la temporada de lluvias en los dos años. La alta disponibilidad de nutrientes durante esta temporada debe haber influido en el comportamiento del fitoplancton a pesar de las diferencias en la temperatura y la intensidad de la luz entre estaciones. Otras especies nocivas notables, pero raras que se encontraron sólo en las redes de arrastre de plancton durante el estudio fueron: *Pyrodinium bahamense* var. *compressum*, *Alexandrium tamiyavanichii*, *Cochlodinium polykrikoides* y *Noctiluca scintillans*.

Palabras clave: *Trichodesmium*, *Pseudo-nitzschia*, dinoflagelados nocivos, HAB, nutrientes, tormenta, San Pedro Bay, Leyte, Philippines.

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