Harmful Algal Bloom in Iligan Bay, Southern Philippines

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ABSTRACT

We report the first occurrence of harmful algal bloom (HAB) caused by a non-toxic dinoflagellate, *Cochlodinium* sp. in Philippine waters, particularly, in Kalangahan Pt.-Manticao Pt., Iligan Bay on March 13-18, 2002. Two patches of *Cochlodinium* sp. bloom, associated with fish kills in Kalangahan Pt.-Manticao Pt., Iligan Bay, caused localized water discoloration from the usual ocean blue to rusty brown or reddish brown to blackish. The first patch, located near fish-aggregating device (FAD) areas, spanned 2 km wide, while the second patch, located near a fish corral, spanned 500 m wide. These patches occupied the water column from surface to 5 m depth, but a thick mat formed at 0.5 m to surface. Patches decreased as the bloom began to decline. The observed dead demersal and pelagic fishes coincided with highest bloom density of 3.1×10^4 to 3.8×10^4 cells ml^{-1} of *Cochlodinium*. Dissected gills and stomach contents of fishes killed in HAB-affected areas did not reveal any indication of clogging of gills by *Cochlodinium* sp. Fishes covered by the "shading effect" of *Cochlodinium* bloom may have suffered anoxia or asphyxation due to oxygen depletion. No poisoning of people who consumed the dead fishes was reported. Laboratory analyses revealed lower DO values, 2.4 to 0.5 mg L^{-1} from 2400 to 0600 hr; 14N:1P ratio; air-water temperature ranged from 28-29 ^oC; pH 7.89-8.29; and salinity, 33-35^o/oo. *Favella* sp., a tintinnid grazer of dinoflagellate was developing in the area at the termination of the *Cochlodinium* bloom on March 18.

Keywords: HABs, discoloration, *Cochlodinium* sp., fish kill, *Favella* sp.

INTRODUCTION

Harmful algal blooms (HABs) or "red tides" as known traditionally, refers to localized natural phenomena, which occur in polluted, warm sea, river, lake, or lagoon. Discoloration of the water could be observed as red, reddish brown, rusty brown or chocolate, maroon, blue, and yellowish brown (Taylor, 1987; Smayda, 1997). This water discoloration happens when HAB-causing organisms such as dinoflagellates, diatoms, or cyanobacteria reach a bloom density, i.e., cellular abundance of the causative species, that exceeds 10^3 cells ml^{-1} (Sournia, 1995). Based on the reported HABs in other parts of the world, the bloom density ranges from 9×10^3 to 2.50×10^8 cells L^{-1} (or 9 to 250 x 10^3 cells ml^{-1}) (Holmes et al., 1967; Tracey, 1988; Sotto & Young, 1995; Bajarias & Relox, 1996; Wiadnyana et al., 1996). In certain areas in the Asia Pacific, most HABs have been reported to occur due to eutrophication, favorable wind and weather conditions,

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and the advent of ENSO (El Niño Southern Oscillation) (Maclean, 1989). Yet the HAB or “red tide” phenomenon is not completely understood. Further research studies are still needed to understand the dynamics of HABs (Azanza & Taylor, 2001). HABs have negative impacts on health, economy, and ecology (Maclean, 1989; Corrales & Gomez, 1990; Smayda, 1997; Azanza & Taylor, 2001). In the Asia-Pacific Region, four negative impacts of HABs affecting fishery resources were recorded in 72 incidents in a span of 60 years. These are fish kills (53%), paralytic shellfish poisoning (42%), shrimp kills (4%), and ciguatera fish poisoning (1%) (Corrales & Maclean, 1995).

Mindanao State University (MSU) Naawan officials received a report on the occurrence of water discoloration in Lugait and Manticao municipalities in the province of Misamis Oriental from Mr. Aldin Gabe, Manager, Semaña Hatchery, on March 13-14, 2002. This was followed by a report of fish kill in some coastal towns of the province on March 14, 2002. Acting on these reports, MSU Naawan immediately organized a research task force to investigate the phenomenon.

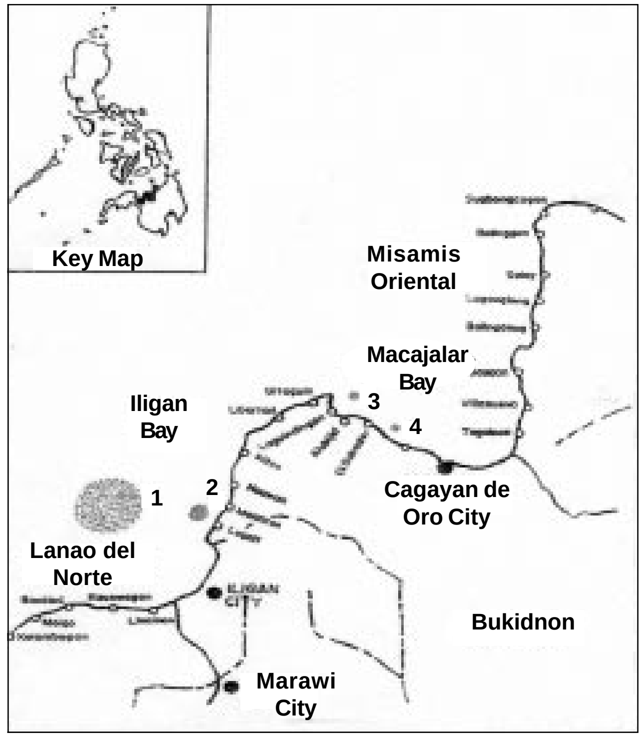

Fig. 1. Map of Iligan Bay showing harmful algal bloom sites (circular blackened areas along neritic and oceanic zones): (1) Patch in FAD area; (2) Patch near fish corral area in Lugait-Manticao Pts.; (3) Patch in Tubajon Pt.; (4) Patch in Molugan Pt.

METHODOLOGY

The monitoring of the alleged fish kill and water discoloration started with field interviews of ten (10) fishers, living along the coastal barangays of Iligan Bay, initially in Kalangahan, Biga, Paitan, Punta Silum, Poblacion Manticao, and Maputi (Fig. 1). Similar interviews of five (5) fishers were also conducted in Tubajon and Molugan, in adjacent barangays in the western side of Macajalar Bay, Misamis Oriental. The interviewees’ ages ranged from 29 to 56 years old, all male, and all engaged in fishing activities only. The collection of water samples was focused in Lugait-Punta Silum-Manticao coastal area, where the reddish-brown to blackish water covered a relatively large area (approximately 8 km span according to fishermen’s estimation on March 13, 2002). Water was sampled using a Nansen water sampler at 0, 1, 2, 3, 4, and 5 m depth in duplicate. Additional surface water was sampled using 1L and 500 ml plastic bottles. Water samples from Nansen water sampler were placed in 1L and 500 ml plastic bottles to determine: (1) phytoplankton population density, by microscopic counting with a modified Sedgwick-Rafter counting chamber; (2) pH, by a PAM 210 (Copenhagen) pH meter; (3) salinity, by an ATAGO S/MILL (Japan) refractometer; (4) nutrient analysis, by standard methods: cadmium reduction method for NO_3-N and stannous chloride method for PO_4-P (Franson, 1995); and (5) air-water temperature readings, by a thermometer. DO was likewise, measured using a WTW (Germany) oximeter. Gills and stomach of dead fishes were dissected and analyzed to determine the presence or absence of *Cochlodinium* sp. on the corresponding organ tissues, which may indicate clogging of gills and filtering of *Cochlodinium* sp. by fishes.

RESULTS AND DISCUSSION

There was an observed localized discoloration of seawater in Iligan Bay, particularly in Kalangahan Pt. and Manticao Pt. on March 13-14, 2002. The discolored water formed two patches: one patch was observed

Table 1. *Cochlodinium* sp. population densities during a harmful algal bloom (HAB) occurrence in Iligan Bay.

Date	Density (Cells mL^{-1})	Location from shoreline (Km)	Span/Remarks (Km)	Impact
March 13	5 - 10	6*	8*	-
14	31,000 - 38,000	4*	2*	Fish kill
15	2,500 - 7,200	3**	0.5**	-
16	800 - 4,800	2**	0.1**	-
17	0	-	-	-
18	0	-	-	-

*Fisherman's estimation
**MSU-Naawan estimation

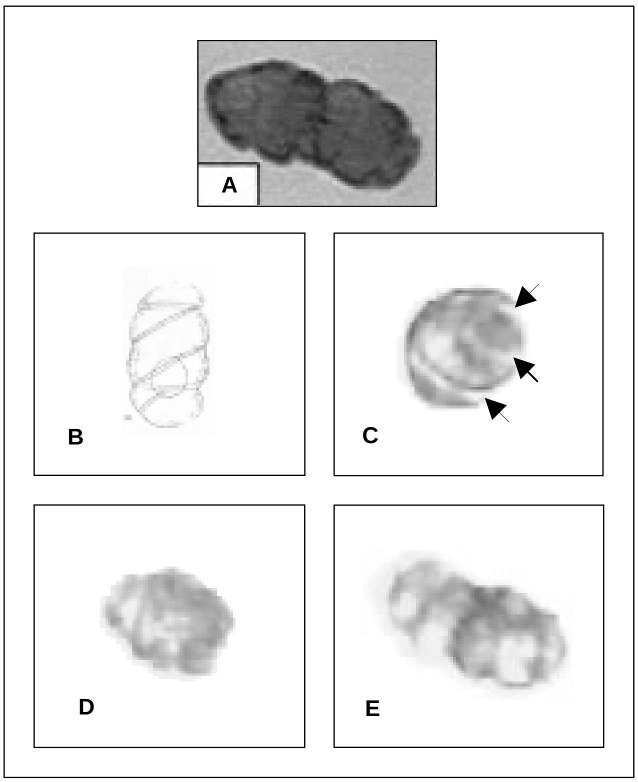

Fig. 2. (A) *Cochlodinium* sp. (LM, enlarged from 100x = 220x; scale: 100x); (B) line drawing of the cell; (C) very motile cell arrows indicate cell furrows; (D) cell starting to feed; and (E) cell fully immobile and extended while feeding; (B) to (E) cells documented with a microscope-mounted video camera.

about 2 km from the shoreline of Manticao Pt., where FADs were located, and the other was observed 500 m from the shoreline near a fish corral (Fig.1). The first patch spanned about 2 km wide while the other one was about 100 m wide. Patches decreased as the bloom began to decline (Table 1). The causative organisms of the bloom was found to be a dinoflagellate, *Cochlodinium* sp. (Fig. 2). This species is characterized by a large displacement of the median girdle and a spiral sulcus, with apical and antapical loops (Kofoid & Swezy, 1921; Schiller, 1937; Wood, 1968) (Fig. 3). This *Cochlodinium* species contracts and extends its apical and antapical pellicular loops while swimming and feeding. The body is subovate to ellipsoidal, with a length of 36-54 µm. *Cochlodinium* sp. HAB transformed the color, from the usual ocean blue to rusty brown or reddish brown to blackish, of some patches in Iligan Bay. These patches were observed to occupy the water column from the surface to 5 m depth, but a thick mat formed at 0.5 m to surface. The thick 0.5 m to surface matting consequently formed "shading effect" on the pelagic and benthic fishes below it. In this ecological scenario, there could be a competition for DO demand by fishes during the *Cochlodinium* HAB, and the dead fishes in localized HAB span could have suffered anoxia due to oxygen depletion. Oxygen depletion means that DO value is below the ASEAN marine water quality criteria value for the protection of aquatic life which is 4.0 mg L^{-1}. DENR (1990) critical DO values ranged from 5.0 mg L^{-1}. Values below this range becomes unsuitable for most aquatic life.

Likewise, due to vertical migration of *Cochlodinium* sp. at night till dawn to a depth of approximately 10 fathoms (16.62 m), as observed by fishermen spear-fishing in Tubajon Pt., Macajalar Bay, the dinoflagellate could have been a competitor to DO consumption of fishes in the area. Fishermen recounted that corral fishes went out of their burrows and were weak and sluggish. However, no fish kills were observed in Tubajon, unlike in the coastal areas of Lugait, Punta Silum, Manticao, and Maputi, where dead demersal and pelagic fishes (Table 2) were collected in the shoreline on March 14, 2002. Dead fishes in these coastal areas were collected by fishermen and eaten broiled or raw. There was no reported poisoning of people who consumed the fish.

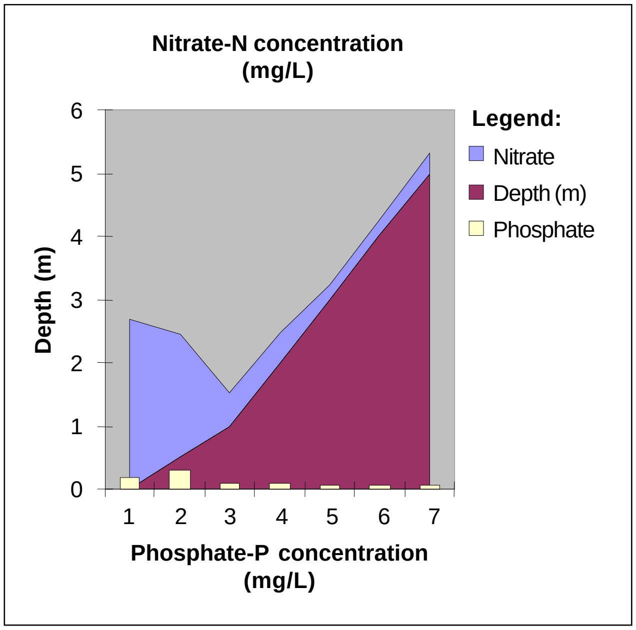

Fig. 3. Nitrate-N and Phosphate-P concentrations at 5 m to surface collected at 0900 hr at a bloom patch located 2 km from the shoreline.

The observed fish kill in Iligan Bay coincided with highest bloom density of 3.1×10^4 to 3.8×10^4 cells ml^{-1} of *Cochlodinium* sp. (Table 1) on March 14, which is higher than the reported bloom density of $2,000 \times 10^4$ $cells^{-1}$ (or 2.0×10^4 cells ml^{-1}) (Holmes et al., 1967).

Fish kills are one of the consequences of HABs (Maclean, 1989; Corrales & Maclean, 1995). A similar incident of *Cochlodinium* sp. bloom was observed in Australia in 1989 during which mass wild fish kills was reported by Sarjeant (1989). Fishes covered by the “shading effect” of the *Cochlodinium* bloom may have suffered anoxia or asphyxation (respiratory failure) due to oxygen depletion.

Cochlodinium was not reported as a toxic species (Taylor, 1987; Matsuoka & Fukuyo, 2002). *Cochlodinium* is a harmful, but not toxic, dinoflagellate. *Cochlodinium* sp. is different from other dinoflagellates like *Gambierdiscus toxicus*, which cause tropical fish contamination and inflect ciguatera fish poisoning to humans. Those who consume the fish suffer from gastrointestinal (diarrhea, abdominal pains, nausea, and vomiting) or neurological symptoms (numbness and tingling of hands and feet; cold objects feel hot to the touch; difficulty in balance; low heart rate and blood pressure; rashes; and death, in extreme cases) (Sarjeant, 1989; Lewis & Holmes, 1993). It is also different from the HAB-causing organism, *Prorocentrum minimum*, associated with the Bolinao fish kills (Fuertes, 2002). *Prorocentrum minimum* was reported to cause diarrhetic shellfish poisoning in North Sea-Netherlands (Kat, 1979). The *Cochlodinium*-caused fish kills in Iligan Bay did not manifest any of the symptoms specified for humans consuming the dead fishes. Based on interviews of fishermen in the Mapalad, Paitan, Lugait, Kalangahan, and Manticao areas, residents ate the dead fishes on March 14, 2002 (Table 2). None of them felt any of the symptoms of poisoning. In short, there was no deleterious health impact on humans. Dissected gills and stomach contents of frozen fishes killed in the HAB affected areas did not reveal any indication of clogging of gills by *Cochlodinium* sp. However, mechanical damage leading to death of larvae of the American oyster, *Crassostrea virginica* shellfish, which resulted from collisions (bumping) with *Cochlodinium heterolobatum* bloom, was reported by Ho & Zubkoff (1979).

The nutrient analyses revealed a mean of 2.678 (nitrate) and 0.190 mg L^{-1} (phosphate) (Fig. 3), with nitrate:phosphate ratio of 14:1 comparable to the 16:1 (N:P) ratios of the *Pyrodinium* bloom in Zambales (Corrales et al., 1995). These data indicate that the *Cochlodinium* sp. bloom used up more nitrates in the discolorized water patches. Air-water temperature

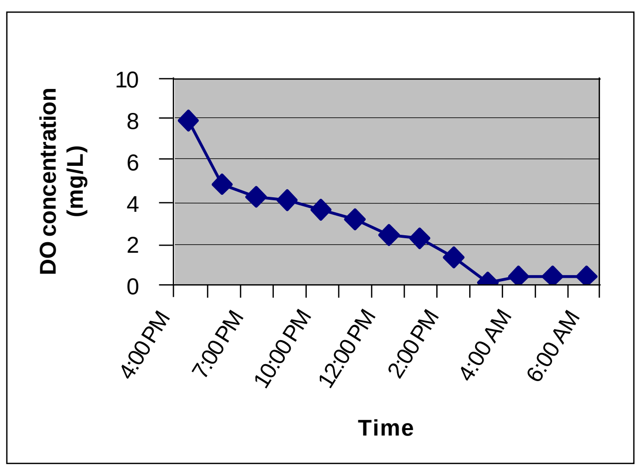

Fig. 4. DO monitoring of water samples from 1600 to 0600 hr at a bloom patch located at 2 km from the shoreline.

Table 2. Respiratory organs that could be affected due to clogging by filtering *Cochlodinium* sp.***

Municipalities/ Local name of resources	Scientific Name	Respiratory organs
Paitan & Lugait		
Lapulapu, Pugapu	*Epinephelus* sp.	gills
Molmol	*Scarus* sp.	gills
Mamsa	*Caranx* sp.	gills
Danggit	*Siganus* sp.	gills
Tabogok (small octopus) Kugita (big octopus)		High oxygen requirement provided by one pair of gills without cilia; water exchange by radial muscles in mantle wall and expel water forcibly through a funnel.
Kalangahan		
Bolinao	*Stolephorus* sp.	gills
Uburan	*Muraenesox* sp.	gills
Barungoy	*Cyoselurus* sp.	gills
Swasid	*Hemiramphus* sp.	gills
Maputi		
Ba-at	Holothuria	Respiratory tree (analogous “gill rakers” in fishes) for respiration and excretion. Gas exchange in skin and tube feet.

***Based on interviews. Likewise, the fishermen in the municipalities of Tubajon and Molugan observed weak fishes. Dead fishes were not observed by fishermen in Macajalar Bay on March 11,13, and 16 when harmful algal bloom (HAB) occurred in these areas.

ranged from 28-29 ^{o}C; pH, 7.89-8.29; and salinity, 33-35 ^{o}/oo. DO measurement registered lower values, 2.4 to 0.5 mg L^{-1} (Fig. 4), from 2400 to 0600 h. At the termination of the *Cochlodinium* bloom on March 17, population of *Favella* sp., a tintinnid grazer of dinoflagellate, was developing in the area.

Cochlodinium sp. was not reported to form cyst or hypnozygotes (Sarjeant, 1974; Taylor, 1987; Matsuoka & Fukuyo, 2000); thus, seed population for the recurrence of the species depends on its vegetative stage. So far, this paper is the first documented outbreak of *Cochlodinium* sp. in Philippine waters.

RECOMMENDATION AND ACTION PLANS

1. Conduct of information drive on HABs in Mindanao;

2. Establishment of fish kill “hotline” – Zonal Centers/ BFAR;

3. Immediate formation of fish-kill task force and fish-kill contingency plan at the regional level;

4. Adequate funding of monitoring and surveillance activities and establishment of facilities for environmental monitoring at the regional level; and,

5. Review of policies on the illegal use of chemicals (which may add to the nutrient build-up in Northern Mindanao waters) in fishing.

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