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Seasonal Distribution of Harmful Algal Bloom Species in East Coast of Sabah, Malaysia

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ABSTRACT

In the east coast of Sabah, no Harmful Algal Bloom (HAB) case has been reported although *Pyrodinium bahamense* var. *compressum* had been reported a decade ago. Therefore, this study was performed to evaluate the current situation of HAB in the east coast of Sabah. Samples were collected during northeast monsoon and southwest monsoon at 3 sites (St. 1, St. 2 and St. 3). Physical and chemical parameters such as nutrients (phosphate and nitrate), salinity, pH, temperature and dissolved oxygen were measured. Rainfall data were obtained from Meteorological Department, Sabah. Eight potential HAB species were identified. *Ceratium furca* dominated the area during both monsoons. Monsoons did not significantly affect the occurrence of HAB species. Based on location, St. 3 has high cell density of HAB and high nutrient concentration. Aquaculture activity and river effluents near St. 3 were believed to contribute to this high nutrient concentration. The presence of potential HAB species indicates that the east coast of Sabah may experience HAB problem in the future if factors triggering the bloom are not managed well.

Key words: Harmful algal bloom, *Ceratium furca*, aquaculture, monsoon

INTRODUCTION

Sabah, Malaysia particularly in the west coast of Sabah has experienced HAB problems for the last 3 decades. The events have affected the economy of the state and brought fear to the local community. The causative organisms were *P. bahamense* var. *compressum* and *Cochlodinium polykrikoides* (Adam *et al*., 2011). *Pyrodinium bahamense* var. *compressum* was first reported in the coastal waters of Sabah in 1976 (Roy, 1977). Since it was first reported, many human illnesses have been recorded (Ting and Joseph, 1989). *C. polykrikoides* was first reported in 2005 and the occurrence of this species has been associated with fish mortality in aquaculture (Anton *et al*., 2008).

In Asian countries, monsoons have been suggested to play an important role in increasing nutrient concentration. Three known monsoon seasons are the southwest monsoon (SWM), northeast monsoon (NEM) and intermonsoon. Heavy rainfall during monsoon is believed to bring high nutrients through rivers and land run-offs (Buyukates and Roelke, 2005; Lee and Lee, 2006; Jalal *et al.*, 2011). In the Straits of Malacca, high chlorophyll a concentration was observed during NEM (Tan *et al.*, 2006). In the west coast of Sabah, heavier rain was reported during SWM compared to NEM (Adam *et al.*, 2011). In this area, blooms of HAB species namely *C. polykrikoides* and *Gymnodinium catenatum* were reported during both monsoons. However, *P. bahamense* var. *compressum* was prolific during NEM (Adam *et al.*, 2011).

To date, HAB problems have only been recorded along the coastal water of the west coast of Sabah. No reports on HAB have been recorded from the east coast of Sabah although the presence of *P. bahamense* var. *compressum* had been reported in 1998 (Anton and Suibol, 1999). Due to the recurrent problems of HAB in the west coast of Sabah, more research has been carried out in this area. With the understanding of negative effects of HAB problems, up-to-date data on the occurrence of HAB problem in the east coast of Sabah are needed to evaluate the potential of HAB problem. Currently, the east coast of Sabah is considered safe for aquaculture activities. Therefore, this study was carried out during NEM and SWM to determine the occurrence of commonly reported HAB species i.e., *P. bahamense* var. *compressum*, *C. Polykrikoides* and other potential HAB species in the west coast of Sabah. Therefore, physical and chemical factors including nutrients (nitrate and phosphate) were measured. Information gained from this study is important to give the current status of HAB in the east coast of Sabah which is crucial to the fishery activities in the area.

MATERIALS AND METHODS

In the east coast of Sabah, 3 transects with 2 sampling stations were located at Lahad Datu, Semporna and Tawau (Fig. 1). Samplings were carried out in August and September during the southwest monsoon (SWM) and January and December during the northeast monsoon (NEM). At each station, 1 L of phytoplankton sample was taken using water sampler and preserved with Lugol's iodine. In the laboratory, these samples were concentrated into 50 mL. Cell density of HAB species was determined by counting using Sedgwick Rafter cell under light microscopy. The species

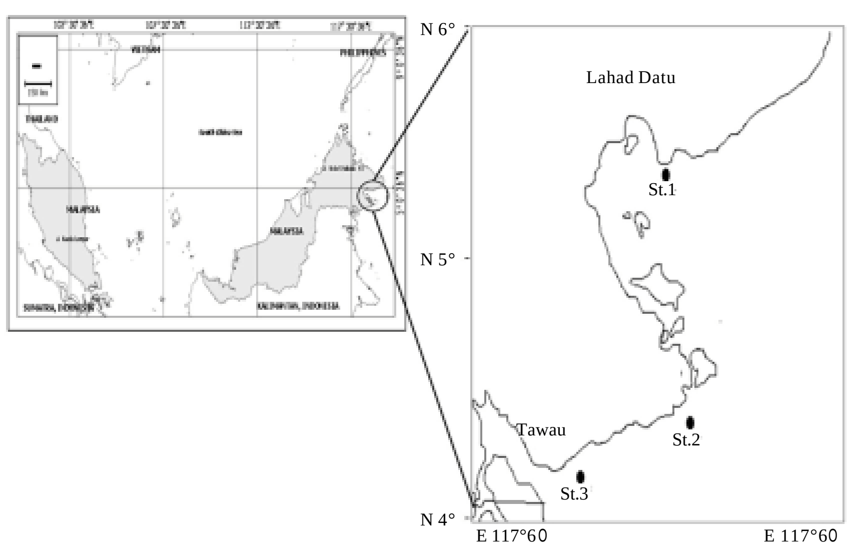

Fig. 1(a-b): Map of Malaysia showing the, (a) East coast of Sabah and (b) Location of study sites, St: Sites were identified as HAB species based on previous reports. Water samples were also collected for nutrient analysis including nitrate and phosphate. Nutrient concentrations were determined using standard method by Parsons *et al.* (1984). Physical and chemical parameters such as dissolved oxygen, temperature, salinity and pH were measured *in situ* using Hydrolab. Statistical analyses (one-way ANOVA) were done using SPSS (Statistical Package for the Social Science) version 15.

RESULTS

In this study, eight potential HAB species were identified in these three locations with the mean total cell density of 30.40×10^3 cells L^{-1} (Table 1). Total cell density of HAB species at St. 3 was significantly different ($p<0.05$) from St. 1 and St. 2. During SWM, the cell density of HAB species recorded was higher compared to NEM with the value of 38.0×10^3 cells L^{-1} and 24.5×10^3 cells L^{-1}, respectively (Table 1). Among the three stations, St. 3 scored the highest total cell density with 51.75×10^3 cells L^{-1} (Table 1). *C. furca* was observed having the highest percentage at all stations and during both monsoons (Table 1). Other potential HAB species recorded having high percentages were *Ceratium fusus* and *Prorocentrum micans* (Table 1). Phosphate and nitrate concentrations were highest at St. 3 with the value of 9.94±0.74 and 11.26±0.84 μM, respectively (Table 2). Statistical analysis showed that there was no significant difference observed for the physical and chemical parameters between stations ($p>0.05$) except for nutrient. No significant difference was also found between monsoons for nutrient concentrations ($p>0.05$). Total cell density of potential HAB species was positively correlated with nitrate concentration. Total rainfall for the

Table 1: HAB species recorded in Northeast of Sabah during sampling period

HAB species	Mean count ($\times10^3$ L^{-1})	Sites (%) 1	2	3	SWM (%)	NEM (%)
Ceratium fusus	4.083	1	9	20	20	20
Ceratium tripos	0.791	5	6	1	3	4
Chaetoceros sp.	1.500	8	0	0	3	2
Dinophysis caudata	1.718	11	0	3	2	8
Ceratium furca	12.938	22	27	59	30	45
Prorocentrum micans	5.041	27	33	9	26	6
Prorocentrum sigmoides	2.500	16	12	5	7	14
Pseudo-nitzschia sp.	1.833	8	12	4	9	0
Total No. of HAB ($\times10^3$ L^{-1})	30.400	18.25	16.5	51.75	38.0	24.5

HAB: Harmful algal bloom, SWM: Southwest monsoon, NEM: Northeast monsoon

Table 2: Mean seawater parameter in the study sites

Parameter	Sites 1	2	3	SWM	NEM
Phosphate (μM)	8.45±0.62	6.12±0.46	9.94±0.74	0.57±0.21	1.47±0.72
Nitrate (μM)	5.55±0.41	7.00±0.52	11.26±0.84	0.45±0.27	0.38±0.18
Temperature (°C)	29.90±0.40	30.00±0.30	29.70±0.30	30.20±0.30	29.50±0.30
Salinity (psu)	33.00±0.40	32.20±0.10	33.00±0.80	33.10±0.40	32.50±0.60
Dissolved oxygen (DO) (mg L^{-1})	5.60±1.30	6.80±0.80	5.80±0.60	6.10±1.20	5.60±1.10
pH	8.00±0.10	8.10±0.10	8.10±0.10	8.20±0.10	8.10±0.10

HAB: Harmful algal bloom, SWM: Southwest monsoon, NEM: Northeast monsoon

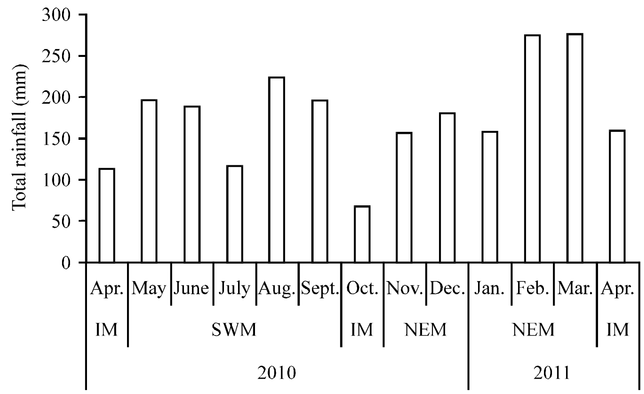

Fig. 2: Total rainfall (mm) during SWM, NEM and intermonsoon (IM) for 2010 and 2011 in the east coast of Sabah, SWM: Southwest monsoon, NEM: Northeast monsoon

year 2010 and 2011 in the east coast of Sabah showed that during NEM, the rainfall was higher compared to SWM (Fig. 2).

DISCUSSION

In this study, the two HAB species viz., *P. bahamense* var. *compressum* and *C. polykrikoides* that were commonly reported to occur in the west of Sabah (Adam *et al.*, 2011) were not observed. Therefore, current study indicates that the east coast of Sabah is safe from HAB problem caused by these species. Previously, Anton and Suibol (1999) had reported *P. bahamense* var. *compressum* in Lahad Datu, east coast of Sabah. Occurrence of *P. bahamense* var. *compressum* has only been reported in tropical countries and has a specific requirement to grow (Wang *et al.*, 2008; Adam *et al.*, 2011). This species was not present in the three stations indicating that the environmental condition was not suitable for the species to grow or the species was present but in insignificant number thus decreasing the chance to be detected. In the west coast of Sabah, blooms of *C. polykrikoides*, a fish killer, has been observed through satellite images expanding from the south towards the north of west coast of Sabah before reaching Palawan, Philippines (Azanza *et al.*, 2008). Occurrence of this species was recorded in tropical and temperate countries e.g., in the Philippines (Azanza *et al.*, 2008) in Pettaquamscutt River Estuary, Rhode Island (Tomas and Smayda, 2008) and in South Sea of Korea (Lee, 2008). The wide distribution and the high tolerance of this species to the environment increased the possibility of this species to occur in the east coast of Sabah. In terms of the physical and chemical parameters and frequency of *P. bahamense* var. *compressum* and *C. polykrikoides* between the east and west coast of Sabah, it was found that the west coast of Sabah has higher frequency of HAB than the east coast of Sabah (Table 3). The west coast of Sabah also has higher nutrient concentration (nitrate and phosphate) compared to the east coast of Sabah. Other parameters such as temperature, salinity and pH were more or less similar. The differences in nutrient concentration at these two sites may explain the absence of algal bloom in east coast of Sabah, particularly for *P. bahamense* var. *compressum* and *C. polykrikoides*. Lee (2006) and Lee and Lee (2006) have reported the significant effects of nutrient in triggering *C. polykrikoides* blooms. Eight potential HAB species found in the study area were *Ceratium furca, C. fusus, C. tripos, Dinophysis caudata, Pseudo-nitzschia* sp., *Chaetoceros* sp., *Prorocentrum sigmoides* and *P. micans*. Among these species, the most abundant species were *P. micans* and *C. furca*. In Black Sea, Turkey, *P. micans* has been

Table 3: Comparison of physicochemical parameters and frequency of common HAB species in the east and west coast of Sabah

Parameter	East coast (this study)	West coast
P. bahamense var. *compressum*	No report	Rare (Adam *et al*., 2011)
C. polykrikoides	No report	All year round (Adam *et al*., 2011)
Phosphate (µM)	1.02±0.56	1.91±0.41 (Weliyadi, 2012)
Nitrate (µM)	0.60±0.31	29.59±5.48 (Weliyadi, 2012)
Temperature (°C)	29.9±0.4	30.2±1.1 (Adam *et al*., 2011)
Salinity (psu)	32.7±0.5	29.8±2.1 (Adam *et al*., 2011)
pH	8.1±0.1	8.4±1.1 (Adam *et al*., 2011)
Heavy rain	NEM	SWM (Adam *et al*., 2011)

reported as a potential mass species (Turkoglu and Koray, 2004). *C. furca* has been reported to cause red tide in Japanese coastal area (Fukuyo *et al*., 1990) and in Tolo Harbour, Hong Kong (Wong *et al*., 2010). In Hong Kong, the blooms of *C. furca* were reported to reach to 35,000 cell mL^{-1} covering up to 2.6 km^2 and have caused the swimming route to be changed to avoid risk on human health (Wong *et al*., 2010). In Malaysia, blooms of *C. furca* have been reported in the west coast of Peninsular Malaysia (pers. com.). Other potential HAB species that were commonly observed in the study sites viz *P. micans* and *C. fusus* have been reported to cause red tides in Japanese coastal waters (Fukuyo *et al*., 1990).

In the east coast of Sabah, heavy rain was observed in NEM compared to SWM (Table 3) and the heavy rain was believed to bring high nutrients. However, in this study, nutrient concentrations and total HAB species were not significantly different between NEM and SWM. During SWM, total HAB cell density recorded was a little bit higher i.e., 38.0 cells L^{-1} compared to NEM, 24.5 cells L^{-1}. During both monsoons, *C. furca* dominated the area followed by *C. fusus*. This condition contributed to the high cell number of HAB species recorded. This shows that these species can better adapt in the environmental condition compared to other HAB species. Unlike *C. fusus*, *C. furca* has an efficient ability to perform vertical migration and this gives advantages to the species to get sufficient nutrient from water column and sediment (Baek *et al*., 2009). Other HAB species may have different environmental condition requirement in order to grow in high number. Study on *Scrippsiella trochoidea* showed that nutrient is not a triggering factor in the formation of bloom of this species (Yin *et al*., 2008). Among the three stations, total density of HAB species at St. 3 was significantly high compared to other stations. Phosphate and nitrate concentrations were highest at St. 3 with the values of 9.94±0.74 and 11.26±0.84 µM, respectively. This station was situated near the river and tiger prawn (*Penaeus monodon*) farming. Waste from this aquaculture farm was believed to contribute to the high nutrient concentration thus leading to high number of HAB species. As reported by Heisler *et al*. (2008), the increase in nutrient level will trigger the development of many HABs. High nutrient concentration was reported at stations located near marine fish farm (Mantzavrakosa *et al*., 2007) and near river estuary (Shapoori *et al*., 2009). River was known as the main source of eutrophication where nutrients were released from variety of sources such as domestic sewage (Periyanayagi *et al*., 2007). Total cell density of potential HAB species was positively correlated with nitrate concentration. Saravi *et al*. (2008) have also reported that phytoplankton growth was limited by nitrogen. The alteration of physical, chemical and biological factors may affect phytoplankton occurrences (Ananthan *et al*., 2008) and composition (Agboola *et al*., 2011). Shah *et al*. (2008) have reported that the seasonal variation of phytoplankton in Southwest Coastal waters of Bangladesh was affected by temperature, salinity, nitrate and phosphate.

CONCLUSION

Eight potential HAB species were identified at the east coast of Sabah. The two common HAB species in the west coast viz. *P. bahamense* var. *compressum* and *C. polykrikoides* were not found. *C. furca* dominated the area followed by *C. fusus*. Both monsoons had no effects on the distribution of HAB species. St. 3 that was located near aquaculture farm and river estuary had significantly high cell density of HAB compared to other stations. Aquaculture activity and river effluents are believed to contribute to the high nutrient concentration at this station. Although the two common HAB species in the west coast of Sabah were not found in the study site, the presence of other potential HAB species indicates that the east coast of Sabah may experience with HAB problem if factors triggering the bloom are not managed well.

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