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Harmful Algal Blooms in Malaysian Waters
(Ledakan Alga Berbahaya di Perairan Malaysia)

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ABSTRACT

Harmful algal blooms (HABs) events have been increasingly reported in the country, not only of the frequency and severity of the events, but also involved more species than previously known. In this paper, a decadal review of HABs events in Malaysia is summarized. Bloom events caused by harmful dinoflagellate species including the shellfish poisoning events were highlighted. Paralytic shellfish poisoning (PSP) is no longer restricted to Sabah coasts and Pyrodnium bahamense. *Bloom of* Alexandrium minutum *was reported for the first time in the Peninsula with six persons hospitalized including one casualty after consuming the contaminated benthic clams. Algal blooms that are associated with incidence of massive fish kills have been reported from both east and west coasts of the Peninsula in conjunction to finfish mariculture loses. The culprits of these bloom events have been identified as the dinoflagellates,* Cochlodinium polykrikoides, Neoceratium furca, Prorocentrum minimum, Noctiluca scintillans *and a raphidophyte,* Chatonella ovata. *In this paper, some of these HABs species were characterized morphologically and genetically, including their toxicity. Therefore, with the increase of coastal utilization and eutrophication, prevention, management and mitigation strategies, such as site selection, moving pens, clay spraying should be adopted to minimize the impact of these natural events.*

Keywords: Diatom; dinoflagellates; harmful algal blooms; Malaysia; mitigation

ABSTRAK

Laporan kejadian ledakan alga berbahaya (HAB) yang kian meningkat bukan sahaja daripada segi kekerapan kejadian, tetapi juga melibatkan lebih banyak spesies yang tidak diketahui sebelumnya. Dalam kertas ini, pelbagai kejadian HAB pada dekad yang lepas telah dirumuskan. Kejadian ledakan akibat dinoflagelat yang berbahaya dan keracunan kerang-kerangan juga dititik beratkan. Keracunan kerang-kerangan yang melumpuhkan (PSP) tidak lagi tertumpu hanya pada perairan Sabah dan Pyrodinium bahamense. *Ledakan* Alexandrium minutum *telah dilaporkan untuk kali pertama di perairan Semenanjung dan menyebabkan enam mangsa keracunan akibat termakan lokan tercemar. Satu kes kematian direkodkan. Ledakan alga juga menyebabkan kejadian kematian ikan secara besar-besaran dan kerugian marikultur di perairan timur dan barat Semenanjung. Organisma penyebab kejadian tersebut telah dikenal pasti sebagai dinoflagelat;* Chlocodinium polykrikoides, Prorocentrum minimum *dan* Noctiluca scintillans *serta satu rafidofit;* Chatonella ovata. *Sebahagian daripada spesies HAB tersebut telah dikenal pasti secara morfologi, genetik dan toksisiti. Oleh itu, dengan peningkatan penggunaan perairan pantai dan proses eutrofikasi, strategi pencegahan, pengurusan dan mitigasi seperti pemilihan lokasi, pemindahan sangkar, penyemburan tanah liat harus diguna pakai dalam usaha meminimumkan impak kejadian semula jadi ini.*

Kata kunci: Diatom; dinoflagelat; ledakan alga berbahaya; Malaysia; mitigasi

INTRODUCTION

Harmful algal bloom (HAB) is a natural phenomenon due to increase in density of microalgal species in the marine and freshwater environments. This incidence is not only causing adverse effects to the natural surrounding environments, but accumulation of algal-origin toxins in filter-feeding shellfish has caused human food poisoning. Massive bloom of microalgae also caused fish kills in the natural or finfishes mariculture by excretion of bioactive compounds or due to hypoxia/anoxia in the surrounding environments.

HABs events have been increasingly reported in the country over the last decade. This may be the cause of increasing utilization of coastal inhabitants, maricultures and other human coastal activities that led to eutrophication of the coastal waters. Industrialization, urbanization and commercial agricultural plantation also led to nutrient run-off and nutrient enrichment in the freshwater and marine coastal systems that subsequently promote algal-bloom.

HABS EVENT IN THE DECADE

For the past decade, several major HABs events have been reported in the country (Figure 1 and Table 1). In 2001, an incident of shellfish intoxication was reported following a massive bloom of a marine dinoflagellate in a semi-enclosed lagoon of Tumpat, the north-eastern of Peninsular Malaysia (Figure 1(a)). The event was widely

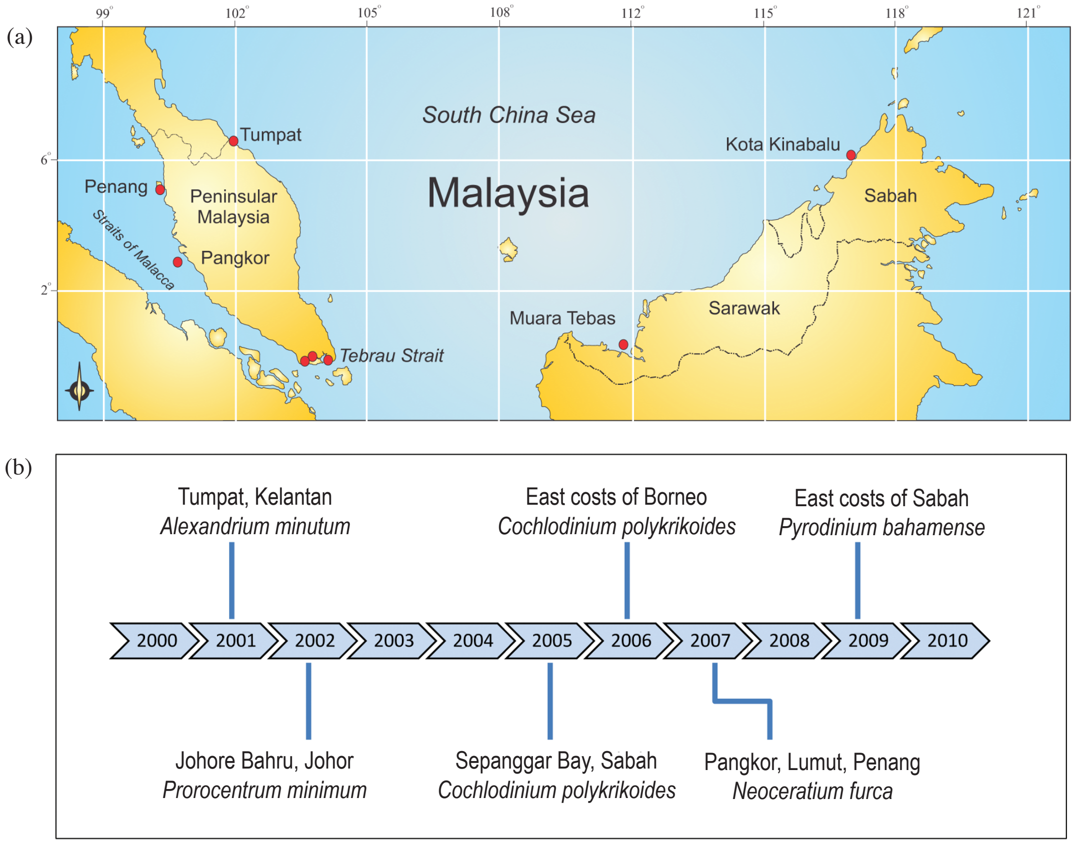

FIGURE 1. Occurrence of HABs in Malaysia from year 2000-2010. (a) Map showing locations of bloom events and (b) a decadal timeline of HABs event in Malaysia

TABLE 1. A decadal summary of harmful algal blooms (HABs) events and related species in Malaysia

Timeline	Harmful microalgae	Location	Impact	References
2001	*Alexandrium minutum*	Tumpat, Kelantan	Six person were hospitalized including one casualty due to PSP	Lim et al. 2004
2002	*Prorocentrum minimum*	Johor Bahru, Johor	Water discoloration	Usup et al. 2002
2005	*Cochlodinium polykrikoides*	Kota Kinabalu, Sabah	Water discoloration	Anton et al. 2008
2006	*Cochlodinium polykrikoides*	Kuching, Sarawak, Kota Kinabalu, Sabah	Water discoloration, some fish kills	Fisheries Research Institute, Bintawa, Sarawak; Anton et al. 2008
2007	*Neoceratium furca*	Pangkor, Lumut, Penang	Water discoloration	Fisheries Research Institute, Batu Maung, Penang
2009	*Pyrodinium bahamense*	Kota Kinabalu and surrounding areas	Shellfish contamination by PSTs with more than 7,000 Mouse Unit; ban of shellfish mollusc harvesting	Fisheries Department, Sabah and Express Daily (2009)

reported in the media with six persons hospitalized and one casualty due to the severe intoxication (Lim et al. 2004). Identity of the organism was confirmed months later as *Alexandrium minutum* (Figure 2(a)) based on cultures and wild specimens collected from the site and lend strong support from the toxin analyses on both the organism and the contaminated clam (locally known as *lokan*) from the area (Lim et al. 2004). Shellfish collection from the lagoon was banned by the Health Department for months after the incident.

A bloom of the same species was also reported coincidentally in Balianao, Northern Philippines which involved human casualty (Bajarias et al. 2003). The occurrence of this species has been reported worldwide. The incident has been reported to occur in most of the neighbouring countries in the region, including Thailand

(Matsuoka et al. 1997), Taiwan (Hwang & Lu 2000), Vietnam (Lim et al. 2007; Yoshida et al. 2000) and the Philippines (Bajarias et al. 2003).

The event has alarmed the relevant authorities on the needs of better HABs monitoring in the country. Current HABs studies in the country are insufficient to safeguard the public health and seafood safety. The incident also highlighted the inadequate monitoring program by relevant authorities. Though it could be costly, it is crucial to ensure the safety of our seafood product, not solely for export purposes, but also for local consumption.

In the subsequent year (2002), Malaysia was hit by another bloom event. Water discoloration in the Tebrau Strait was reported (Usup et al. 2004). Water samples collected from the affected area contained high density of *Prorocentrum minimum* cells (Figure 2(b)). The blooms of this dinoflagellate lasted for months. Fortunately no massive fish kill was reported during the bloom particularly at the nearby local finfish farms. It is noteworthy that the coincident blooms in the Philippines had caused tonnes of milkfish mortality at the affected area (Azanza et al. 2005). The species is a potential toxin producer with rare cases of venerupin shellfish poisoning (VSP) in the Mediterranean waters (Grzebyk et al. 1997). However, no such case of shellfish poisoning has been reported in Malaysia. During the blooms of this species, the rhodophyte; *Chatonella ovata* was found to co-exist in the water column (Figure 2(c)).

Impact of the blooms can be subtle to the marine environments; decomposition of localized blooms creates hypoxic or anoxic condition that subsequently caused fish kills. The bloom event in Penang from 2005-2006 was a lesson-to-learn for lots of aquaculture operators. Most of the finfish farming in the area was meant for export purposes. The aquaculture operators suffered a big blow due to the blooms (red tides) occurred in the areas that lasted for several months. Massive fish kill was reported from the area with losses estimated to not less than RM20 millions (Figure 3 and Sin Chew Daily 2005). Unfortunately the causative organism for the 2005-2006 incidents remained a mystery. Blooms of *Noctiluca scintillans* have been associated with massive fish and marine invertebrate kills (Hwang & Qi 1997) and bloom occurrence of this species in the Straits of Malacca is a common phenomenon (Figure 2(d)). However, inadequate research on this particular species in our waters failed to link the species to incidents of fish kills in the straits. Bloom of the species in high cell density that caused dissolved oxygen depletion in the environment is one of the possible consequences of massive fish/shrimp kills (Ho & Hodgkiss 1992). The species was also reported to accumulate high level of ammonia excreted into the surrounding waters, which likely act as the killing agent (Fukuyo et al. 1990; Okaichi & Nishio 1976). HABs should be taken seriously not only by the relevant authorities but also the industries involved. This is important to ensure growth and sustainability of the industries.

A harmful unarmoured dinoflagellate; *Cochlodinium polykrikoides* was found in samples collected from several locations in the country. Notably that it had never been associated with any bloom events before 2005. However, massive blooms of the species predominated in 2005, not only in the west coasts of Sabah, but the blooms extended to the southern part of Borneo, Muara Tebas in Kuching, Sarawak (Figure 1(a)). The blooms appeared as brown-reddish discoloration observed in the coastal waters of Kota Kinabalu (Sabah Fisheries Department) (Figure 4). The blooms were reported to move upward to the southern Philippines with incidence of fish kills reported in the Palawan Island (Azanza et al. 2008). On the other hand, the blooms in Kota Kinabalu lasted for months in the embayment (Anton et al. 2008). Co-occurrence of this red tide-forming species with other neurotoxin-producing species (*Pyrodinium bahamense*, Figure 2(e); *Alexandrium tamiyavanichii*, Figure 2(f) and *Gymnodinium catenatum*, Figure 2(g) had complicated the management of HABs incidence in the area. In these events, *C. polykrikoides* bloom was reported for the first time in Malaysia.

The dinoflagellate *Neocratium furca* is a marine species that currently gain a lot of research attention. The species is commonly found in Malaysian waters (Figure 2(h)). It has been observed in most of the plankton samples collected throughout the waters. The occurrence of this species with high cell density in Lumut and Pangkor, Perak concerned the country Arm Force whom stationed in the area, particularly of issue on potential health hazard to divers that has direct contact to the bloom organism. Blooms of *N. furca* have been reported to move northward to Penang and subsequently caused fish kill event in Phuket, Thailand (Lidyaprasit per. comm.).

Most recently, *Karlodinium veneficum*, a potentially harmful unarmoured dinoflagellate species, was found in the Tebrau Strait (Figure 2(i)). The species was reported to produce ichtyotoxin and karlotoxin that cause fish kill in several countries (Deeds et al. 2002; Kempton et al. 2002; Larsen & Moestrup 1989; Nielsen 1996). The presence of this species in the Tebrau waters warrants the needs to have more intensive monitoring of the species, especially at sites with finfish aquacultures in the strait. Minor fish kill events in the strait several years back may be due to the species even though no direct evidence is available to support the claim.

SHELLFISH POISONING

HABs event in Malaysia was predominantly related to paralytic shellfish poisoning (PSP), a type of seafood poisoning due to shellfish contamination from a group of neurotoxin, collectively named saxitoxins (STXs). The toxins are produced by several species of marine dinoflagellates, *Pyrodnium bahamense* (Figure 2(e)), *Gymnodinium catenatum* (Figure 2(g)) and several species of *Alexandrium* (Figure 2). *Pyrodnium bahamense* is confined to the coastal waters of Sabah since the first event reported in 1970s (Roy 1977). Over the last three decades, hundreds of poisoning cases including human casualty have been reported almost annually (Usup & Azanza 1998; Usup et al. 2012). In Peninsular Malaysia the first PSP case was reported from Sebatu, Malacca, where the national mussel cultivation project was implemented. Three people were hospitalized and mussels from the areas were banned for years. The organism that responsible for the events was identified as *A. tamiyavanichii* (Figure 2(f)) several years later (Lim 1999). This toxic dinoflagellate species was confined to tropical and subtropical waters, with records from Thailand (Fukuyo et al. 1989), Philippines (Montojo et al. 2003) and Japan (Nagai et al. 2003).

HAB Monitoring and Management

HABs monitoring in Malaysia is currently conducted by the Fisheries Research Institutes (FRI) and the Sabah Fisheries Department (SFD). Shellfish toxicity monitoring was confined to selected locations on the coast of Sabah due to its frequent outbreak of *P. bahamense* blooms. Phytoplankton monitoring in the coastal waters of Sarawak has been undertaken by the FRI, Sarawak. In the Peninsular, monitoring is currently implementing in certain locations, such as Penang and Lumut in the Straits of Malacca, and the Tebrau Straits by the FRI, Penang.

However, sampling interval and frequency of monitoring exercises conducted are not sufficient to monitor the HABs occurrence. Most of the bloom onset and declining occurred within a relatively short duration. Furthermore, monitoring program is hampered by unavailability of trained manpower and expertise in phytoplankton ecology; lack of trained personnel in species identification and enumeration which could lead to misidentification of harmful species. Efforts to strengthen the collaboration among industries, research agencies and institutions involved in HABs studies is crucial to ensure the success of country monitoring program. More locations should be included in the country HABs monitoring program particularly areas with previously known HABs events and areas where shellfish farming activities being established.

HAB Prevention and Mitigation in Malaysia

Due to the rapid growth of finfish aquaculture industries in the country for both domestic consumption and export purposes, it is crucial to adopt and implement HABs prevention and mitigation strategies in the industry. Aquaculture operators should be equipped with knowledge of HABs to minimize the impact of HABs events. Selection of aquaculture sites based on previously known HABs cases and predicting HABs risks will help to avoid unwanted losses to the industry. Generally, site assessment on aspect of hydrography and phytoplankton assemblages should be undertaken by the relevant

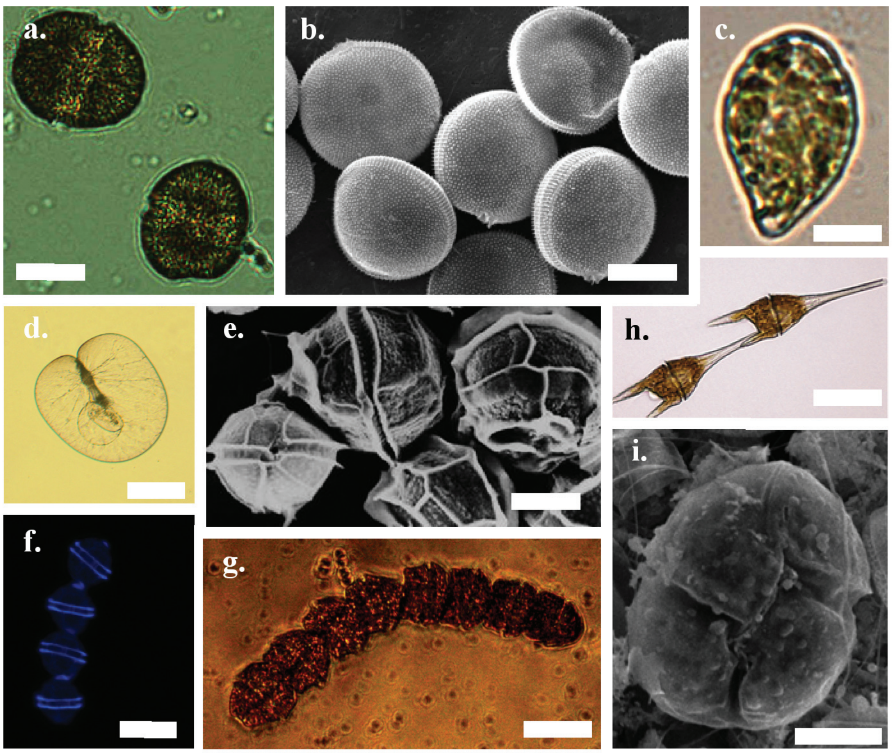

FIGURE 2. Harmful and potentially harmful marine microalgae found throughout the waters of Malaysia. Micrographs of (a) *Alexandrium minutum,* (b) *Prorocentrum minimum,* (c) *Chatenella ovata* (d) *Noctiluca scintillans*, (e) *Pyrodinium bahamense* var. *compressum*, (f) *A. tamiyavanichii*, scale bar = 50 μm, (g) *Gymnodinium catenatum*, (h) *Neoceratium furca*, scale bar = 50 μm and (i) *Karlodinium veneficum*. Scale bar = 10 μm

FIGURE 3. Fish kill event in Penang during year 2005 amounting more than 20 million ringgit of losses (Sin Chew Daily 2005)

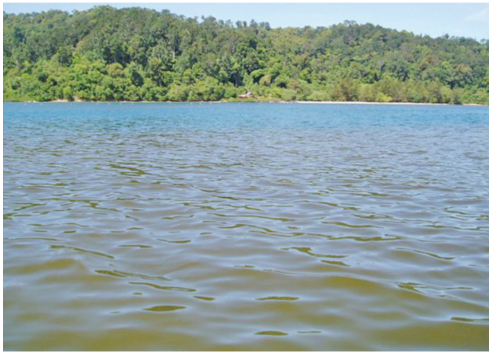

FIGURE 4. Bloom of *Cochlodinium polykrikoides* observed at Pulau Gaya, Kota Kinabalu, 2003 (Sabah Fisheries Department)

authorities and/or industries prior to any aquaculture projects. Sites with no record of potential harmful species and good water exchanges (water movement due to tidal cycle and outside embayment) are preferable, as turbulence may affect the growth of flagellates (White 1976) and assist in dispersal of nutrients from waste waters.

Several other mitigation measures such as aeration and perimeter skirting, moving pens and clay spraying were widely practised in several countries as counter-measure to HABs events at aquaculture sites (Kim 1998; Lim 1989; Rensel & Whyte 2001; Shirota 1989). Perimeter skirting was commonly applied together with other mitigation measure such as aeration. The skirting (plastic sheets) creates a barrier to prevent the farm organisms in the cages/pens to have direct contact with the blooms. The perimeter skirting measure should also be considered couple with management practice such as 'stop feeding' to avoid ammonia accumulation within the perimeters. Fish with feed produced 3-4 times higher ammonia than those unfed (Brett & Zala 1975).

Flocculation application as physical control of algal blooms has been widely used in East Asian countries (Shirota 1989). Clay is the flocculant that commonly used to bind suspended particle (algae cells) and sink to the bottom. Two types of clay, *montmorillonite* and *kaolinite* have proven their efficiency in removal of algal cells (Na et al. 1996; Shirota 1989; Yu et al. 1994). Shirota (1989) showed that clay spraying at 110-400 g m^{-2} was effective in removal of *C. polykrikoides* blooms. Identified suitable local clay with suitable flocculation properties is needed to ensure the success of the mitigation strategies.

Moving pens away from the affected areas has been the measures that widely practiced by aquaculturist (Anderson 1996). However, the cost of moving pens may be substantial and with constraint on the need of suitable refuge areas and possible damage to the pens/cages facilities during the process. Other mitigation measures such as oxygenation or ozone, filter system were not accepted by aquaculturist due to high initial installation cost and limitation on the effectiveness. Detail of other mitigation measures that is not discussed in this paper is available in Anderson et al. (2001).

CONCLUSION

Harmful algal blooms events have been increasingly reported in the country from more locations which involved species that previously not known. However, our understandings of these blooms events and the organisms are still poorly documented. Prevention, management and mitigation strategies that have been reported effective should be adopted by the industries and relevant authorities with the effort to minimize the impact of these events.

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