Journal of Physics: Conference Series

PAPER • OPEN ACCESS

The Monitoring of Harmful Algae Blooms in Sabah, Malaysia

To cite this article: S J Jipanin *et al* 2019 *J. Phys.: Conf. Ser.* **1358** 012014

The Monitoring of Harmful Algae Blooms in Sabah, Malaysia

S J Jipanin[1,3,] S R Muhamad Shaleh[1]*, P T Lim[2], C P Leaw[2] and S Mustapha[3]

[1] Unit for Harmful Algal Blooms Studies, Borneo Marine Research Institute, University Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia
[2] Likas Fisheries Complex, Department of Fisheries Sabah, 88400 Kota Kinabalu, Sabah, Malaysia
[3] Bachok Marine Research Station, Institute of Ocean and Earth Sciences, University of Malaya, 16310 Bachok, Kelantan, Malaysia

E-mail: sittirae@ums.edu.my

Abstract. The first record of harmful algae bloom (HAB) in Sabah was in 1976 where 202 victims were reported to be suffering from Paralytic Shellfish Poisoning (PSP) and 7 deaths. The causative organism was *Pyrodinium bahamense*, a dinoflagellate which produces saxitoxin. Since then, Department of Fisheries Sabah has been doing monitoring to safeguard seafood safety, especially shellfish harvested for food consumption. *Cochlodinium polykrikoides* bloom for the first time in Sabah in year 2005 where Kota Kinabalu and Tuaran experienced fish kill. Since then, other HAB species such as *Gymnodinium catenatum, Gonyaulax polygramma* and *Noctiluca scintillans* were identified in waters of Sabah. Sabah is the only state in Malaysia in which the monitoring program is done consistently throughout the year since 1976. Samples were collected once or twice a month, according to high and low risks areas which have been identified, most of which are in the west coast. The collection frequency may be increased depending on the situation such as whether there is an outbreak of red tide or PSP in the area. Due to this effort, PSP cases involving the public have declined during the last 40 years without duly affecting the income of fishermen and the fisheries industry. After successfully implementing toxin monitoring between 1984 to 2013, it recurred back in 2013 when 3 deaths were reported. The purpose of this paper is to review all HABs incidences that occured in Sabah over the last few years from January 2000 – December 2017.

1. Introduction

Harmful algal bloom (HAB) occur when there is an increase of phytoplankton abundances in natural marine or freshwater environments. It causes toxic or harmful effects on people, fish, shellfish, marine mammals and birds. Some microalgae species produces toxins and bioaccumulate in shellfish and cause harm to people who consume them. Other species of microalgae causes fish kill by clogging their gills and they die from lack of oxygen.

Paralytic shellfish poisoning (PSP) is caused by consuming bivalve mollusks (mussels, clams) which are contaminated with saxitoxins (STX). PSP toxins accumulated in shellfish because of filtration of toxic algae produced by several dinoflagellates (including *Alexandrium, Gymnodinium* and *Pyrodinium*). The first PSP case in Sabah caused by *Pyrodinium bahamense* was recorded in 1976 where 202 victims were reported to be suffering from PSP and seven deaths [1]. Paralytic shellfish poisoning was only confined to the west coast of Sabah until 1990. In early 1991, Peninsular Malaysia experienced the first recorded red tide event, where three people became ill after consuming farmed mussels from Sebatu, Malacca caused by *Alexandrium tamiyavanichii*. West coasts of Sabah have been experiencing HABs annually for the past four decades since then. The presence of HABs in Sabah occurs sporadically since 1976, but the pattern of occurrence was different from district to district. The east coast of the state is considered low risk area as no occurrence had happen before. The west coast is considered a high-risk area for HAB and PSP.

First record of bloom in Sabah caused by *Cochlodinium polykrikoides* was in 2005 [2] where Kota Kinabalu and Tuaran experienced fish kill. Sabah Fisheries Station which was situated in Tanjung Badak, Tuaran suffered a huge loss due to the mass fish mortality. Other fish cage farmers in Kota Kinabalu and Tuaran areas were caught unprepared during the bloom. However, no data on scale of damage was obtained. In 2014, Tanjung Kupang, Johor, massive fish kills were caused by *Karlodinium australe* bloom which has never been reported as toxic. Reported losses were amounting to RM150,000 according to fish cage operators.

The purpose of this paper is to review all HABs incidences that occured in Sabah over the last few years from January 2000 – December 2017.

2. Red tide monitoring system

Red tide monitoring has been conducted by Department of Fisheries Sabah (DOFS) since 1976 to safeguard seafood safety, especially shellfish harvested for food consumption. Table 1 shows summary of coastal fisheries district offices in Sabah. The red tide monitoring area covers all the Sabah coasts and has been regularly conducted at 69 monitoring stations (under the responsibility of 13 fisheries district offices) since 1976 (Figure 1). Sabah is the only state in Malaysia in which the monitoring program is done consistently throughout the year since 1976. Red Tide and Public Health lab which is situated in Likas Fisheries Complex is the main laboratory to conduct PSP and HAB analysis under the supervision of Sabah Biosecurity Fisheries Division. DOFS have been collaborating with Ministry of Health Sabah (MOHS) in monitoring, mitigating and managing red tide occurrences in Sabah to take care of the public health and protect the local fisheries industry. Due to this effort, PSP cases involving the public have declined during the last 40 years without duly affecting the income of fishermen and the fisheries industry.

Table 1. Summary of fisheries district offices in Sabah, Malaysia.

Fisheries district offices	Station	Level of risk	Latitude	Longitude
Sipitang	1	High risk	N05°01.761’	E115°26.955’
Beaufort	2		N05°21'29.5"	E115°44'42.6"
Kuala Penyu	3		N05°34.864’	E115°37.220’
Papar	4		N05°33.657’	E115°50.796’
Kota Kinabalu	5		N06° 00’54.8”	E116° 06’16.1”
Tuaran	6		N06°08.327’	E116°10.130’
Kota Belud	7		N06°22.179’	E116°20.122’
Kudat	8		N07°06.519’	E117°05.224’
Kota Marudu	9		N06°36.154’	E116°51.076’
Sandakan	10	Low risk	N05°49.907’	E118°07.475’
Lahad Datu	11		N04° 56. 842’	E118° 21.073’
Semporna	12		N04°31'17.8"	E118°37'29.3"
Tawau	13		N06°16.945’	E118°10.592’

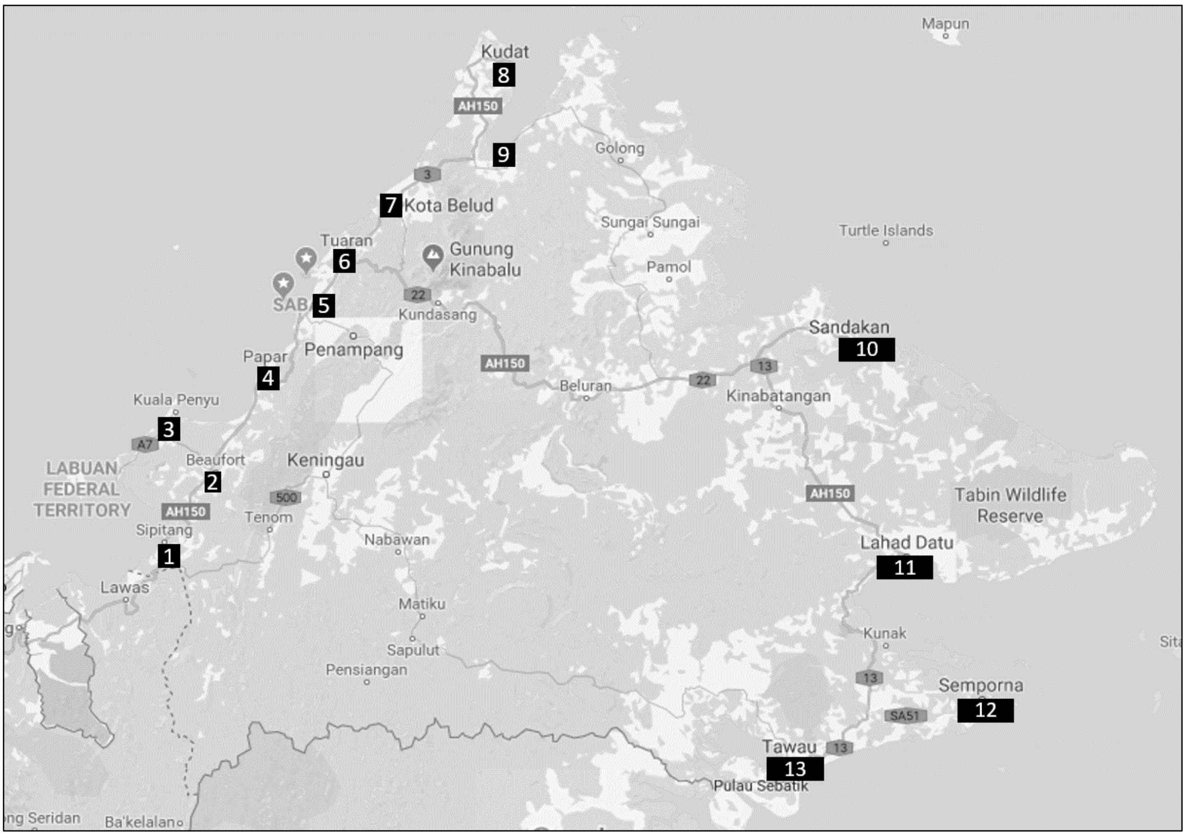

Figure 1. The 13 strategic coastal fisheries district offices along the Sabah coast that has been conducting monitoring since early 1976.

DOFS is primarily in charge of routine red tide monitoring. Thirteen strategic coastal fisheries district office are responsible for HAB monitoring, mainly targeting potential areas where there have been frequent red tides. Sampling was done once a month for low risk areas (East Coast of Sabah – 4 sites) and twice a month for high risk areas (West Coast of Sabah – 9 sites). All samples were collected by the appointed personnel from respective district offices and sent to Likas Fisheries Complex for analysis. In addition, once there is PSP case, MOHS joins the red tide monitoring program by collecting and sending HAB or PSP samples to DOFS laboratory for analysis. Table 2 shows the red tide monitoring program conducted by agencies in Sabah where three types of red tide monitoring have been conducted since 1976.

Table 2. Red tide monitoring program in Sabah.

Type of monitoring	Main objectives	Monitoring parameter	Responsible agency	Monitoring frequency
Monitoring of *Cochlodinium*	To forecast early warning of *Cochlodinium* blooms	-Phytoplankton species (abundance) -Cell density -Water color	DOF Sabah	Monthly/ weekly (during red tide)
Monitoring of *Pyrodinium*	To forecast early warning of *Pyrodinium* blooms		DOF Sabah	Monthly/ weekly (during red tide)
Monitoring of shellfish poisoning	To check abundance of toxic species and poisoning level in the shellfish meat	-Toxic species (PSP) -Cell density -Water color -Toxin level	DOF Sabah and MOH Sabah	Monthly/bi-weekly (when poison is detected)

3. Red tide alert system

Presently, the Assistant Director of Sabah Biosecurity Fisheries Division will issue out letter to the respective fisheries district offices to increase monitoring frequency as early precautionary measure when the cell densities of *P. bahamense* and *C. polykrikoides* exceeds 1,000 cells/L. The fisheries district office will also inform the District Officer, village heads, chairman of village community and district Health Office to take necessary precaution to refrain from eating shellfish from affected district. When both cell densities of *P. bahamense* exceeds 7,000 cells/L and collected shellfish sample toxicity level from the same area exceeds 80 µg Poison/100 g meat, the Director of DOFS will issue a press statement to advise the public from consuming any type of shellfish or bivalves from the affected areas, besides banning of selling and collection of shellfish. For *C. polykrikoides*, once the cell densities exceed 5,000 cells/L, the Assistant Director of Sabah Biosecurity Fisheries Division will issue out letter to the respective fisheries district offices to increase monitoring frequency and the district offices will take immediate action to notify fish cage farm operators to take precautionary measure such as harvesting of fish or to move their cage away from affected areas. Warning will be lifted once cell density and PSP toxicity level are lower than the safety limit for three consecutive weeks. Table 3 summarizes the red tide warning standards in Sabah since 1976.

Table 3. Red tide warning standards in Sabah.

Warning class	Scale	Cell density (cells/L)
Red tide attention	HAB blooms and potential fishery damages	*P. bahamense*: over 1000 *C. polykrikoides*: over 1000
Red tide alert	HAB blooms and fishery damages	*P. bahamense*: over 7000 *C. polykrikoides*:over 5000
Warning lift	HABs are extinct, no risk of fisheries damages	When cell density lower than safety level for 3 consecutive weeks.

4. Materials and Method

Environmental data of pH, dissolved oxygen (DO) and temperature were recorded in-situ at two meters depth from surface using Hydrolab Quanta Multi-Probe Meter (OTT Hydromet, Germany).

Phytoplankton samples were collected vertically with a 2.5 L Van Dorn water sampler at 1 m and 3 m water depth. Sedgewick-rafter counting chamber was used for cell counting and species identification. Qualitative and quantitative analysis of phytoplankton was performed using a normal light microscope (Leica Microsystems, Wetzlar, Germany). The smallest algae were counted under 40x and the larger ones under 10x. The bloom density was determined by direct cell counts of target species [3].

Mouse-bioassay (MBA) was adapted since 1976 until to date according to AOAC (Association of Official Analytical Chemists) Official Method 959.08 to determine PSP toxicity level [4]. Strain of mice used were Balb C and cultured in Likas Fisheries Complex prior analysis. Stock of mice were sometimes an issue and DOFS is in the process of using LC-MS/MS analysis in the future. Before this, all results were expressed in MU/100 g and since 2015, results were expressed as µg Poison/100 g meat. Any value above 80 µg/100 g meat was considered hazardous and unsafe for human consumption.

5. Results and discussion

During the red tide events on March - April 1976, surface temperature was reported around 28.5 °C with pH was constant at 8.1. Surface salinity ranged from 33-35 ppt and dissolved oxygen was around 4.1 mL/L [5]. No environmental data was obtained until 2016. Environmental data was collected on September 2017 in Kota Kinabalu where surface temperature ranged from 23.6-25.5°C. Range of pH and dissolved oxygen were recorded at pH 7.23-8.55 and 4.57-6.95 mg/L respectively. No surface salinity data was taken.

5.1. Red tide events

A total of 3279 red tide events (Figure 2), of which 1752 events (53.4%) were caused by *P. bahamense* (PB) from 2000 to 2017. Starting from 2004 until 2017, there were 1527 events (46.6%) caused by fish killing species, *C. polykrikoides* (CP). Both events occurred mainly along the east coast of Sabah namely Tuaran, Kota Kinabalu, Kuala Penyu, Sipitang and Papar. In year 2005, there were 351 samples observed present with *P. bahamense* cells and the highest numbers of cell densities recorded was 2.3 x 10^6 cells/L on March 2005 in Sipitang. *C. polykrikoides* cells were found present in 471 samples on the same year and the highest number of cell densities was 139 x 10^3 cells /L also on March 2005 in Kota Kinabalu. Unfortunately, no environmental data was collected during these events.

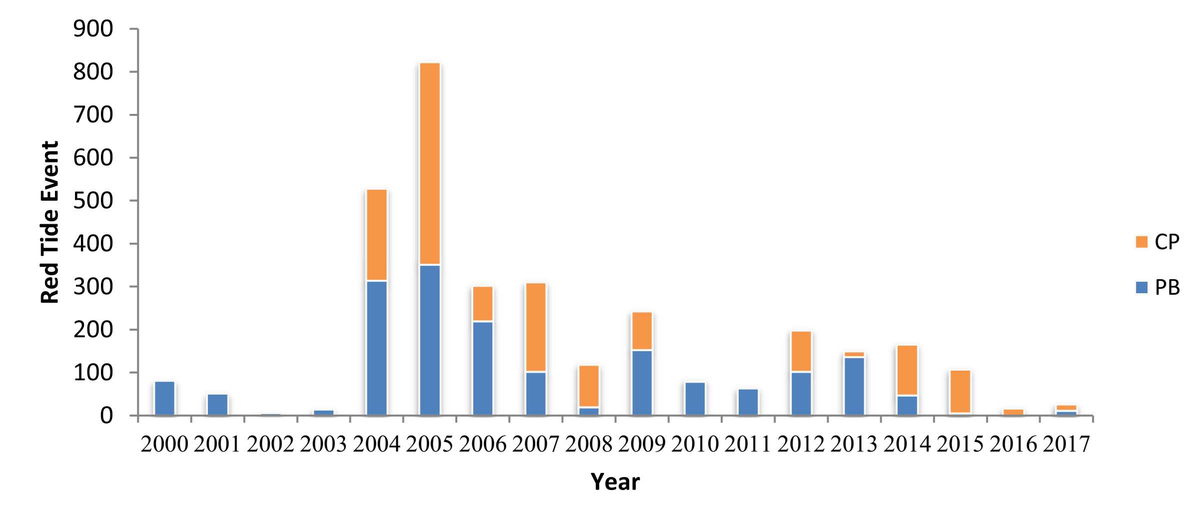

Figure 2. Number of red tide events in Sabah waters since 2000; *C. polykrikoides* (CP): *P. bahamense* (PB).

5.2. Red tide seasons

The monthly variations of red tide events in the coastal water of Sabah over the years is shown in figure 3. Sabah is under the influence of monsoons namely northeast monsoon from November to March, southwest monsoon from May to September and inter-monsoon (April and October). From 2000 to 2017, more than 70% (2,142 events in total) of the red tide events occurred during wet season. The greatest number of red tide events has occurred in January (25%) and the lowest was found in November (2%). During dry season, the number of red tide events started to increase from May (74 events in total), reached the highest in August (183 events in total) and started to fluctuate until October (85 events in total). While for wet season, it started to increase from November (64 events on total), highest in January (756 events in total) and lowest in April (259 events in total). The overall trend of red tide events can be seen in both seasons and started to increase after inter-monsoon. Numerous of studies had been done on triggering factors of *Pyrodinium* blooms such as nutrient concentrations, water parameters, monsoon season and geomorphology of the locations [6]. [7] stated that these monsoons have been reported to be responsible for the *Pyrodinium* blooms, particularly in Sabah. [8] found out that *P. bahamense* occurred during both northeast and southwest monsoon periods, but no clear combination of environmental conditions was observed. Rainfall was found to trigger the occurrence of *C. polykrikoides* blooms after one or two days caused by high amount of nutrients through run-off [9].

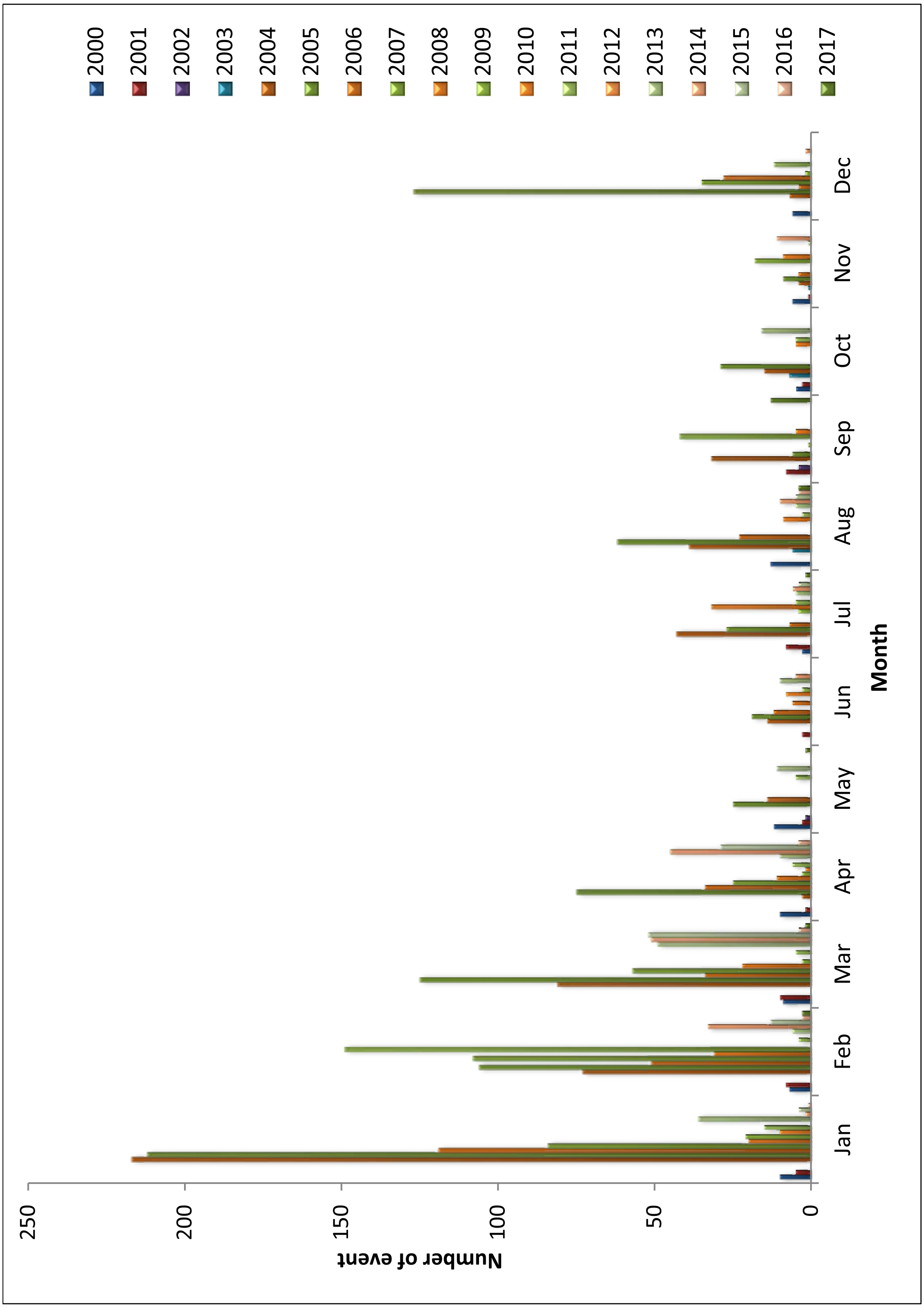

Figure 3. Monthly variations of red tide events in year 2000 to 2017.

Table 4. Types of plankton identified in waters of Sabah, Malaysia.

HAB species	Location	Year	References
Pyrodinium bahamense	Kota Kinabalu	1976	[1]
Gymnodinium catenatum	Kota Kinabalu	2003	[11]
Cochlodinium polykrikoides	Kota Kinabalu	2005	[2]
Gonyaulax polygramma	Kota Kinabalu	2014	[10]
Noctiluca scintillans	Kudat	2014	Department of Fisheries Sabah

5.3. Historical occurrences of HABs in Sabah

Since 1976, *Pyrodinium bahamense* have become a very important HAB species in west coast of Sabah for causing death. DOFS has been conducting various programs in creating awareness and educating the public on the impacts of PSP and HAB such as talks in schools, including participation in exhibitions and seafood festivals. After successfully implementing toxin monitoring between 1984 to 2013, it recurred back in 2013 when 4 deaths were reported (Table 5). Public warnings via newspapers and radio had been issued on December 2012 where samples tested were 660 MU/100 g. Posters and leaflets were also distributed by MOHS on educating and awareness of the implications of PSP. The public had been warned in refraining to consume any types of shellfish, ban of collecting and selling shellfish had been issued to fishermen and industry. In case of any poisoning, they were reminded to go to the nearest healthcare to seek treatments. Shellfish which were sold for local consumption were not obliged to send their samples for PSP test prior to selling. Only those which need to be exported must send their products to be tested as it is one of the requirements in health certificate application. Shellfish samples were bought from local market or fishermen for monitoring purpose by DOFS. Shellfish from other areas were also collected and transferred to another area for cultivation or selling purposes.

Since 2005, *C. polykrikoides* blooms have become common at the west coast of Sabah especially in Kota Kinabalu and Tuaran where fish cage culture industries grew rapidly. However, after the *Cochlodinium* blooms incidence most of them shifted to the east coast of Sabah. In February 2014, maximum cell densities of *C. polykrikoides* was 6×10^6 cells/L in Tuaran. Fortunately, no fish kill was reported. The recent bloom of *C. polykrikoides* was detected at Kota Kinabalu in September 2017 at density of 146×10^3 cells/L. The bloom lasted for 3 days and no fish kill was reported. During bloom of *Cochlodinium*, the public became panic and worried whether to consume fish and as a result affecting the sales of fish in markets. Due to this matter, DOFS has been doing extra effort in educating the public regarding the differences of non-toxic algal bloom (fish killer) and red tide (harmful to human). Early prevention measurement such as to train fish cage operators to identify *C. polykrikoides* cells has been proposed.

6. Conclusion

From this long-term data, monitoring of harmful algal bloom events prove to be successful when the relevant authorities and experts work hand in hand in identifying, mitigating and minimizing the impact of red tide. The exact triggering factor, which causes P. bahamense and C. polykrikoides cells to bloom throughout the year in west coast of Sabah, has not been fully understood. It is important to understand so the bloom can be forecasted earlier and to achieve this, records of environmental data such as temperature and nutrients, or other contributing factors such as pollution is crucial. New species of plankton is emerging from time to time and without trained personnel in species identification and enumeration, this could lead to misidentification of toxic species.

Table 5. Historical occurrences of HABs and related socio-economic impact in Sabah.

Timeline	Harmful algal bloom	Location	Impact	References
1976	*P. bahamense*	Kota Kinabalu, Sabah	202 hospitalized, 7 deaths, water discoloration	[1]
1983	*P. bahamense*	Beaufort, Sabah	5 hospitalized, 4 deaths, water discoloration	Department of Fisheries Sabah
1984	*P. bahamense*	Kota Kinabalu, Sabah	9 hospitalized, 7 deaths, water discoloration	Department of Fisheries Sabah
2003	*G. catenatum*	Kota Kinabalu, Sabah	Water discoloration	[11]
2004	*C. polykrikoides*	Kota Kinabalu	Water discoloration, fish kill	Department of Fisheries Sabah
2005	*C. polykrikoides*	Kota Kinabalu	Water discoloration, no fish kill	[2]
2006	*C. polykrikoides*	Kota Kinabalu	Water discoloration, some fish kill	[2]
2009	*P. bahamense*	Kota Kinabalu, Sabah	Water discoloration	Department of Fisheries Sabah
2013	*P. bahamense*	Kota Kinabalu, Sabah	64 hospitalized, 4 deaths, water discoloration	Department of Fisheries Sabah, Department of Health Sabah
2014	*G. polygramma*	Kota Kinabalu, Sabah	Water discoloration, no fish kill	[10]
2014	*N. scintillans*	Kudat, Sabah	Water discoloration, some fish kill	Department of Fisheries Sabah
2015	*N. scintillans*	Kota Marudu, Sabah	Water discoloration, no fish kill	Department of Fisheries Sabah
2017	*C. polykrikoides*	Kota Kinabalu, Sabah	Water discoloration, no fish kill	Department of Fisheries Sabah

References

[1] Roy R N 1977 Red tide and outbreak of paralytic shellfish poisoning in Sabah *Medical Journal of Malaysia* **31** 247–251

[2] Anton A, Teoh P L, Mohd-Shaleh SR and Mohammad-Noor N 2008 First occurrence of *Cochlodinium* in Sabah, Malaysia *Harmful Algae* **7** 331–336

[3] Reguera B, Alonso R, Moreira A, Méndez S and Dechraoui-Bottein M-Y 2016 *Guide for designing and implementing a plan to monitor toxin-producing micro-algae 2nd Edition* (Paris: UNESCO)

[4] AOAC 2012, Official Methods of Analysis of AOAC International, 19th edition (Gaithersburg, MD: AOAC International)

[5] Joseph W T S and Ting T M 1984 *Red tide and paralytic shellfish poisoning in Sabah, Malaysia Proc. of a consultative meeting held in Singapore* ed White *et al* (Singapore: Southeast Asian Fisheries Development Center and International Development Research Centre) pp 35–42

[6] Tilstone G H, Figueiras F G and Fraga F 1994 Upwelling-downwelling sequences in the generation of red tides in a coastal upwelling system *Mar. Ecol. Prog. Ser*. **112** 241–253

[7] Usup G, Ahmad A and Ismail N 1989 *Biology, Epidemiology and Management of Pyrodinium Red Tides Proc. of the Management and Training Workshop Bandar Seri Begawan, Brunei*

Darussalam 23-30 May 1989 ed Hallegraeff GM and Maclean JL (Manila: Fisheries Department) p 97
[8] Usup G and Yu K L 1991 Effects of meteorological factors on toxic red tide events in Sabah, Malaysia *Marine Ecology* **12** 331–339
[9] Mohammad-Noor N, Weliyadi, Aung T, Adam A and Hanan D S M 2014 Effects of Meteorological Conditions on the Occurrence of *Cochlodinium polykrikoides* and *Pyrodinium bahamense* var. *compressum* in Coastal Waters of Kota Kinabalu, Sabah, Malaysia *Sains Malaysiana* **43** 21–29
[10] Lim H C, Lim P T, Leaw C P and Teng S T 2014 An unprecented bloom of *Gonyaulax polygramma* in Kota Kinabalu, Sabah, Malaysian Borneo *Harmful Algae News* **49** p 9 www.ioc-unesco.org/hab
[11] Mohammad Noor N, Adam A, Soler J M F, Anton A and Muhamad Shaleh S R 2008 *First Record of Toxic Gymnodinium catenatum off the West Coast of Sabah, Malaysia Proc. of the 13th Int. Con. on Harmful Algae*, ed Ho *et al* (Hong Kong: International Society for the Study of Harmful Algae and Environmental Publication House) pp 243–245

Acknowledgement
The authors wish to thank the officers and staff of Likas Fisheries Complex for their continuous hard work in helping with the sample analysis. This study was financially supported by the Department of Fisheries Sabah.