Red Tide and Paralytic Shellfish Poisoning in Sabah, Malaysia

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Introduction

The coastal waters of Sabah are subject to sporadic blooming of toxic dinoflagellates. The various toxins from these dinflagellates are accumulated by bivalve molluscs of commercial value, such as clams, mussels, oysters, and cockles, which filter feed on these algae.

Toxic red-tide bloom is a comparatively recent phenomenon in Sabah. The first and by far the worst outbreak occurred in 1976. On 15 January of that year nine cases of suspected shellfish poisoning occurred in Kampung Maruntum, Putatan, near Kota Kinabalu, that resulted in two deaths. On 15 March 1976, 186 victims of what appeared to be mass food poisoning occurred in Sipitang, a village near Brunei, after eating bivalves found dead but freshly washed up onto the beach. One hundred and five people were hospitalized and four children died (Roy 1977).

As early as February 1976, dense patches of red water had been seen by scuba divers near Kota Kinabalu. However, it was not until the occurrence of mass food poisoning in Sipitang after consuming bivalves in early March that the red water and subsequent fish kills that the events were linked.

During the peak of the red tide in late March 1976, nearly the whole of the west coast of Sabah was affected (Fig. 1). Several aerial surveys were carried out during the peak period to monitor the situation. The bloom subsided in the middle of May 1976.

The movement of the red patches was from the southern to the northern part of Sabah and disappeared in the Kudat area. The geographical focal point of interest was the waters around the island of Labuan, which was the area affected most and where red tide blooms occur annually. Since 1981, however, no red tide has been seen or reported.

Recent Cases of Paralytic Shellfish Poisoning

The problems of forecasting toxicity have been further confounded by the recent discovery that shellfish can become toxic without any visible planktonic bloom. Even though no red tide was observed since 1981, certain species of shellfish still remain toxic. On 23 November, 1983, four children died and five others were hospitalized after they had eaten a meal of shellfish (*Atrina* sp.) that were found washed ashore at Kampung Binsuluk, 124 km from Kota Kinabalu.

On 7 January, 1984, two children died after a meal of cockles (*Anadara* sp.) and a certain rare species of rock oysters that had been washed ashore along the beach at Pulau Gaya near Kota Kinabalu. Six others were given emergency treatment.

Again, on 15 March 1984, another five children died and three others were hospitalized following a meal of sea snails (*Oliva* sp.) collected from the beach at Bongawan 58 km from Kota Kinabalu.

Mouse bioassay tests indicated that the shellfish involved in the three incidents were highly toxic and dangerous for human consumption (202-638 $\mu g/100$ g). However, the nature and origin of the neurotoxins have yet to be determined. It has been speculated that the toxins originated from toxic dinoflagellate cysts left behind during previous red-tide blooms (Dale et al. 1978). Unfortunately, Sabah lacks the personnel and means to carry out further research into PSP problems.

Toxicological Work

Mouse bioassays, according to AOAC methods, are being used in all toxin determinations and the standard safety level (400 MU/100 g) is based on Canadian epidemiological studies (AOAC 1975).

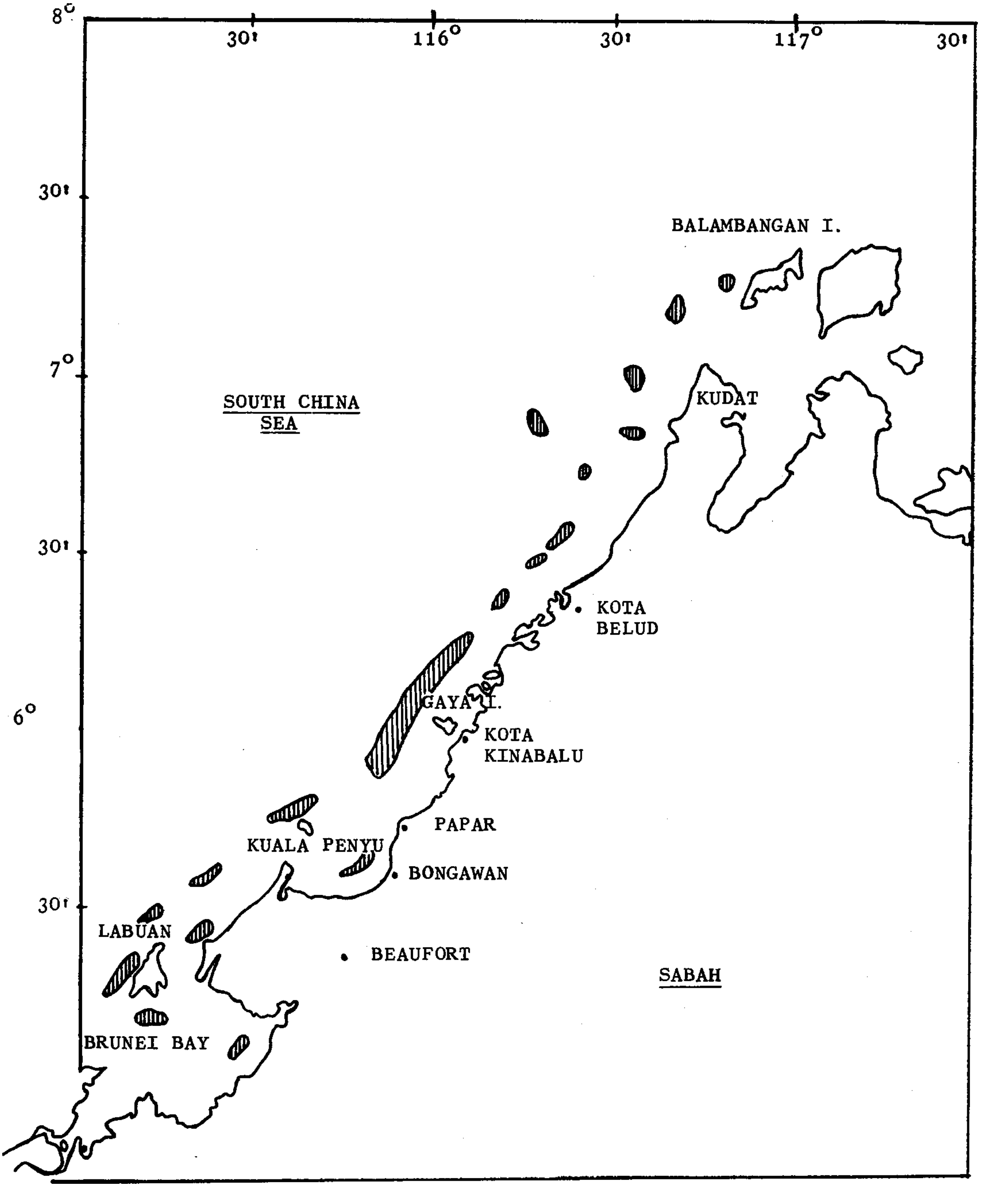

Fig. 1. Areas affected by red tide, March-May 1976.

Table 1. Toxicity levels of paralytic shellfish poison found in fish and cephalopoda following a red-tide occurrence in March 1976.

Genus	Date	Collection Site	Mouse units per 100 g[a]	Remarks
Nemipterus spp.	1.4.76	Near Gaya Island	Not detectable	Entire fish used
Decapterus spp.	1.4.76	Near Gaya Island	Not detectable	Entire fish used
Sciaena sp.	7.4.76	Marudu Bay	Not detectable	Entire fish used — dead fish found floating
Mixed species	11.4.76	Tg. Aru Beach near Kota Kinabalu	Not detectable	Entire fish used — dead fish washed up on shore
Nemipterus spp.	12.4.76	Near Gaya Island	Not detectable	Entire fish used.
Caranx spp.	22.4.76	Near Denawan Island	Not detectable	Entire fish used.
Priacanthus spp.	22.4.76	Near Tiga Island	Not detectable	Entire fish used
Sepia spp.	22.4.76	Near Tiga Island	Not detectable	Entire fish used
Saurida spp.	22.4.76	Near Tiga Island	Not detectable	Entire fish used
Sphyraena spp.	22.4.76	Near Denawan Island	Not detectable	Entire fish used
Pseudorhombus spp.	22.4.76	Near Tiga Island	Not detectable	Entire fish used
Gills from bottom feeders	22.4.76	Tiga Island	175 (5 nos.)	—
Apolectus spp.	2.5.76	Kota Kinabalu (K.K.) fish market	Not detectable	Entire fish used
Stomateus spp.	5.5.76	K.K. fish market	Not detectable	Entire fish used
Arius spp.	12.5.76	K.K. fish market	Not detectable	Entire fish used
Caranx spp.	6.5.76	K.K. fish market	Not detectable	Entire fish used
Gills from filter feeders	6.5.76	K.K. fish market	Not detectable	—
Sardinella spp.	12.5.76	K.K. fish market	Not detectable	Entire fish used
Ilisha spp.	12.5.76	K.K. fish market	Not detectable	Entire fish used
Rastrelliger spp.	12.5.76	K.K. fish market	Not detectable	Entire fish used
Caranx spp.	12.5.76	K.K. fish market	Not detectable	Entire fish used
Stomateus spp.	25.5.76	Kudat fish market	Not detectable	Entire fish used
Rastrelliger spp.	25.5.76	Kudat fish market	Not detectable	Entire fish used
Caranx spp.	25.5.76	Kudat fish market	175 (5 nos.)	Death of mouse disimilar to toxin death
Nemipterus spp.	25.5.76	Kudat fish market	Not detectable	Entire fish used
Sepia spp.	25.5.76	Kudat fish market	Not detectable	Entire fish used
Arius spp.	25.5.76	Kudat fish market	Not detectable	Entire fish used
Megalops spp.	25.5.76	Kudat fish market	Not detectable	Entire fish used
Guts from *Stomateus* spp.	25.5.76	Kudat fish market	Not detectable	—

[a]Numbers in parentheses refer to number of mice used. If number not indicated, 1 mouse was used as the control and 2 mice were used for testing.

However, in emergency cases when mice stocks were running low, young chicks were used as substitutes. The mice used are Porton strain and the conversion factor for this strain has been worked out according to AOAC methods as 1 mouse unit = 0.253 μg toxin. The main purpose of this investigation is to determine the suitability for consumption of marine food organisms found in certain coastal areas.

All results for the toxin testing of seafood over the 1976-1977 period are presented in Tables 1, 2, and 3. Table 4 summarizes some of the more recent analyses. All of the fish and cuttle fish examined (Table 1) showed barely detectable levels of toxin. Of the 15 samples of prawn analyzed (Table 2) only two showed barely detectable levels of toxin. Analysis also showed that none of the lobsters and crabs contained a toxin level in excess of 400 MU/100 g (Table 2). Results in Table 3 indicated that most of the shellfish in affected areas were highly toxic and dangerous for consumption.

Worthy of note is the fact that the sea snail *Oliva* sp. was found to be toxic and was responsible for five fatalities recently (Table 4). This species of

Table 2. Toxicity levels of paralytic shellfish poison found in crustacea following red-tide occurrence in March 1976.

Species	Date	Collection Site	Mouse units per 100 g[a]	Remarks
Portunus pelagicus	4.5.76	Kota Kinabalu (K.K.) market	175 (5 nos.)	Entire body used
	6.5.76	K. K. Market	134 (8 nos.)	Entire body used
	13.5.76	K. K. Market	Not detectable	Entire body used
	18.5.76	K. K. Market	151	Entire body used
	19.5.76	K. K. Market	Not detectable	Entire body used
	22.5.76	K. K. Market	Not detectable	Flesh only
	22.5.76	K. K. Market	288	Gills only
	22.5.76	K. K. Market	328	Guts only
	24.5.76	K. K. Market	Not detectable	Flesh only
	24.5.76	K. K. Market	Not detectable	Guts only
	24.6.76	K. K. Market	Not detectable	Flesh only
	24.6.76	K. K. Market	Not detectable	Gills only
	24.6.76	K. K. Market	234	Guts only
	28.6.76	Brunei Bay	Not detectable	Flesh only
	to			
	1.7.76	Brunei Bay	193 (7 nos.)	Gut only
Mangrove crabs	24.6.76	K. K. Market	Not detectable	Flesh only
	24.6.76	K. K. Market	175 (3 nos.)	Gills only
	24.6.76	K. K. Market	239 (5 nos.)	Gut only
Panulirus versicolor	5.5.76	Labuan processing plant	Not detectable	Cleaned and forzen tail
	5.5.76	K. K. Market	175 (5 nos.)	Entire lobster used
	19.5.76	K. K. Market	Not detectable	Tail only
	19.5.76	K. K. Market	184	Body and legs
	24.5.76	K. K. Market	Not detectable	Tail only
	24.5.76	K. K. Market	175 (7 nos.)	Body only
	25.6.76	Kudat Market	Not detectable	Tail only
	25.6.76	Kudat Market	Not detectable	Body only
Panulirus longipes	5.5.76	K. K. Market	211 (5 nos.)	Entire lobster
	19.5.76	K. K. Market	Not detectable	Tail only
	19.5.76	K. K. Market	177	Head and legs only
Penacidae	March	Frozen tails for export — Labuan	Not detectable	—
	March	Frozen tails for export — Labuan	Not detectable	—
	End March	Frozen tails for export — Labuan	Not detectable	—
	7.4.76	Marudu Bay	Not detectable	Body only
	10.4.76	Frozen tails for export — Labuan	175 (3 nos.)	—
	10.4.76	Frozen tails for export — Labuan	Not detectable	—
	11.4.76	Brunei Bay	Not detectable	Body only
	End April	Frozen tails for export — Labuan	Not detectable	—

Table 2. (continued)

Species	Date	Collection Site	Mouse units per 100 g[a]	Remarks
Penacidae	End April	Frozen tails for exports — Labuan	Not detectable	Tail only
	4.5.76	K. K. Market	Not detectable	Tail only
	5.5.76	K. K. Market	Not detectable	Tail only
	25.5.76	Kudat Market	Not detectable	Tail only
	25.5.76	Kudat Market	268 (5 nos.)	Body only
	24.6.76 to	Brunei Bay	Not detectable	Body only
	28.6.76	Brunei Bay	Not detectable	Body only

[a]Numbers in parentheses refer to number of mice used. If number not indicated, 1 mouse was used as the control and 2 mice were used for testing.

Table 3. Toxicity levels of paralytic shellfish poison found in shellfish following red-tide occurrence in March 1976.

Species	Date	Collection Site	Mouse units per 100 g[a]	Remarks
Anadara spp.	29.4.76	Kuala Kinarut	1552	Entire fish used
	25.5.76	Kudat	175 (3 nos.)	Entire fish used
	2.6.76	Kuala Kinarut	195 (7 nos.)	Entire fish used
	4.7.76	Kota Belud Tamu	175 (5 nos.)	Entire fish used
	13.3.77	Tuaran Tamu — from Gaya Island	Not detectable	Entire fish used
		From Gaya Island	Not detectable	Entire fish used
	23.3.76	Gaya Island	—	Entire fish used
Atrina spp.	4.6.76	Sapangar Island	162 (5 nos.)	Abductor muscle only
	4.6.76	Sapangar Island	4864 (5 nos.)	Mantle only
	4.6.76	Sapangar Island	4873	Body including digestive gland
	16.7.76	Sapangar Island	203 (5 nos.)	Abductor muscle only
	16.7.76	Sapangar Island	731	Mantle only
	16.7.76	Sapangar Island	4160 (5 nos.)	Body including digestive gland
	7.9.76	Sapangar Island	292 (5 nos.)	Abductor muscle only
	7.9.76	Sapangar Island	2588 (5 nos.)	Mantle only
	7.9.76	Sapangar Island	3861 (4 nos.)	Body including digestive gland
	29.9.77	Sapangar Island	Not detectable	Abductor muslce only
	29.9.77	Sapangar Island	225	Mantle only
	29.9.77	Sapangar Island	300	Body including digestive gland
	9.10.77	Tiga Island	Not detectable	Abductor muslce only
	9.10.77	Tiga Island	1440	Mantle only

Table 3. (continued)

Species	Date	Collection Site	Mouse units per 100 g[a]	Remarks
Atrina sp.	9.10.77	Tiga Island	529	Body including digestive gland
Buccinacea (Dog Whelk)	30.5.76	Tg. Aru Beach near Kota Kinabalu	Not detectable	Entire fish used
Donax spp.	29.4.76	Kuala Kinarut	6776	Entire fish used
	2.6.76	Kuala Kinarut	199 (5 nos.)	Entire fish used
Gafranium spp.	29.4.76	Kuala Kinarut	165 (4 nos.)	Entire fish used
	2.6.76	Kuala Kinarut	Not detectable	Entire fish used
Geloina similis	11.6.76	Mengkabong estuary	175 (5 nos.)	Entire fish used
Lambis lambis	30.5.76	Tg. Aru Beach	175 (3 nos.)	Entire fish used
	13.3.77	Tuaran Tamu — from Gaya Island	Not detectable	Entire fish used
Lethophaga spp.	11.6.76	Mengkabong estuary	Not detectable	Entire fish used
Meretrix spp.	29.4.76	Kuala Kinarut	1055 (5 nos.)	Entire fish used
	2.6.76	Kuala Kinarut	175 (3 nos.)	Entire fish used
	6.6.76	Tuaran Tamu	Not detectable	Entire fish used
	28.6.76	Tg. Pajar, Sipitang	Not detectable	Entire fish used
	28.6.76	Tg. Pajar, Sipitang	Not detectable	Entire fish used
	28.6.76	Tg. Pajar, Sipitang	Not detectable	Entire fish used
	28.6.76	Tg. Pajar, Sipitang	Not detectable	Entire fish used
	13.3.77	Tuaran Tamu — from Gaya Island	2140	Entire fish used
	27.3.77	Tuaran Tamu — from Gaya Island	—	Entire fish used
Placuna placenta	5.5.77	Mengkabong estuary	Not detectable	Entire fish used
Saccostrea cucullata	24.5.77	Tawau (east coast)	Not detectable	Entire fish used
	25.5.77	Mengkabong estuary	298	Entire fish used
Telescopium telescopium	11.6.77	Mengkabong estuary	Not detectable	Entire fish used
Giant clam	4.5.77	K. K. Market	149 (7 nos.)	Digestive gland hadn't been removed before sale but filter already had
	6.5.77	K. K. Market	Not detectable	Abductor muscle only
	6.5.77	K. K. Market	Not detectable	Mantle only
Coral-living type clam	4.6.77	Sapangar Island	Not detectable	Abductor muslce
	4.6.77	Sapangar Island	178 (5 nos.)	Mantle and body only
Giant clam	4.6.77	Sapangar Island	311 (5 nos.)	Abductor and mantle only
	4.6.77	Sapangar Island	9920	Other body parts
	23.6.76	K. K. Market	Not detectable	Abductor muscle
Coral-living type clam	23.3.77	Gaya Island	Not detectable	Abductor muscle
	9.9.77	Tiga Island	Not detectable	Abductor muscle only
	9.9.77	Tiga Island	Not detectable	Mantle only
	9.9.77	Tiga Island	Not detectable	Body and digestive gland only
Bunkul[b]	6.6.76	Tuaran Tamu	Not detectable	Entire fish used
Pahat-Pahat[b]	6.6.76	Tuaran Tamu	Not detectable	Entire fish used
Kanjapan[b]	6.6.76	Tuaran Tamu	Not detectable	Entire fish used

[a]Numbers in parentheses refer to number of mice used. If number not indicated, 1 mouse was used as the control and 2 mice were used for testing.
[b]Local Malay name (clam).

Table 4. Toxicity levels in shellfish following recent PSP.

Genus	Date	Collection Site	Mouse units per 100g [a]
Crassostrea sp.	29.11.83	Kulau Penyu	1300
Meretrix sp.	29.11.83	Kinarut	Not detectable
Gafranium sp.	29.11.83	Kinarut	Not detectable
	30.11.83	Pulau Daat	220
	30.11.83	Pulau Papan	Not detectable
Anadara sp.	10.12.83	Kuala Penyu	Not detectable
Crassostrea sp.	10.12.83	Kuala Penyu	1500
Anadara sp.	19.12.83	Kuala Penyu	Not detectable
Meretrix sp.	19.12.83	Kuala Penyu	Not detectable
Crassostrea sp.	12.1.84	Kuala Penyu	600
	14.1.84	Pulau Gaya	2500
Anadara sp.	14.1.84	Pulau Gaya	800
Snail (unidentified)	14.1.84	Pulau Gaya	Not detectable
Crassostrea sp.	16.2.84	Kuala Penyu	262
Anadara sp.	21.2.84	Pulau Gaya	290
	5.3.84	Pulau Gaya	Not detectable
Snail (unidentified)	5.3.84	Pulau Gaya	Not detectable
Oliva sp.	17.3.84	Bongawan	2525
Crassostrea sp.	20.3.84	Kuala Penyu	Not detectable
Anadara sp.	23.3.84	Pulau Daat	Not detectable
Crassostrea sp.	23.3.84	Pulau Daat	Not detectable
	23.3.84	Pulau Papan	Not detectable
Pitar sp.	23.3.84	Kawang	Not detectable
	26.3.84	Kimanis	Not detectable

[a]Numbers in parentheses refer to number of mice used. If number not indicated, 1 mouse was used as the control and 2 mice were used for testing.

shellfish is found buried under 1.25 cm of sand along the beach and its abundance is reported to be seasonal. These sea snails are occasionally washed up on shore and villagers have eaten them in the past without apparent ill effects.

Hydrographic Surveys

Hydrographic surveys were carried out in conjunction with plankton trawl and underwater observations of marine life in coral reefs in areas affected by red tide during March/April 1976. Water samples were collected from various depths, including surface and bottom samples. Parameters examined include pH, temperature, salinity, and dissolved oxygen.

The surface temperature was around 28.5°C, dropping fairly rapidly to 26°C at 5 m depth and 24.0°C at 10 m. There was no further decrease in temperature below this depth. The pH was fairly constant at 8.1.

Surface salinity ranged from 33 ppt near the coast to 35 ppt in the open sea. The vertical gradient of salinity was small and generally an increase of 1 ppt was observed around a depth of 20-30 m, below which it remained fairly constant.

The drop in dissolved oxygen with depth was fairly dramatic. Near Gaya and Sepangar Islands, the surface dissolved oxygen was around 4.1 mL/L. At 20 m it dropped to 3.0 mL/L and at 30 m values were generally less than 0.5 mL/L. At 1 m above the sea floor, dissolved oxygen was practically depleted and values as low as 0.03 mL/L were recorded. Oxygen depletion could either be caused by excessive red-tide blooms, which use up all available dissolved oxygen at night, or by the decomposition of dead marine organisms killed by the red tide.

Underwater Observations after the Occurrence of Red Tides

Underwater observations carried out in March/April 1976 of the coral reefs off Gaya Island, where large patches of red tide had earlier been reported, revealed that virtually all the corals appeared to be dead and were covered with a thick black deposit. Apart from one or two live anemones, no other live invertebrates were seen. Observations revealed dead hydroids, sponges, molluscs, crustaceans, and echinoderms (starfish, sea urchins, and sea cucumbers). No fish were seen below 10 m and a distinct smell of hydrogen sulphide was noticed around 12 m depth and below, indicating anaerobic conditions. The absence of both live and dead fish below 10 m suggests that live fish moved away to more favourable areas as conditions in the vicinity of the red tide deteriorated. A 0.5 hour experimental trawl in the vicinity yielded only about 1 kg of fish. Trawls conducted in other affected areas also yielded very poor catches. However, bottom dwelling sedentary animals, being unable to move, were extremely vulnerable to sudden adverse changes in environmental conditions and many of them might have fed directly on the toxic red-tide organisms and died. The low oxygen values near the sea floor could also have increased the mortalities.

Plankton Studies

Numerous samples of plankton were collected and studied during the several red-tide outbreaks. The samples consisted mainly of surface horizontal hauls using a fine phytoplankton net. Occasionally, surface samples were obtained by simply scooping with a bucket. Several subsurface samples were also collected by divers towing the plankton net by hand at the appropriate depth where dense clouds of phytoplankton were seen. Other samples were collected by simply opening polyethylene bags under water by divers. Microscopic examination of the samples revealed that most samples consisted mainly of one particular species of dinoflagellate. Samples collected from dense patches of red water contained only this species and nothing else. The species was positively identified by Prof. F.J.R. Taylor and later confirmed by Dr. K.A. Steidinger as *Pyrodinium bahamense* var. *compressa,* the same species that was found in New Guinea (Maclean 1979).

Monitoring of Red Tides

The 1976 red tide caught Sabah totally unprepared. Few people in Sabah had heard of red tide before. Through valuable experience gained from the first and subsequent red-tide outbreaks, however, the Department of Fisheries is now ready to cope with the situation with more confidence. The most urgent problem was and still is the determination of the suitability for consumption of marine food, particularly shellfish from previously affected areas. As in most countries affected by toxic red tides, the department has PSP surveillance programs using standard procedures for the bioassay of toxin levels and a standard quarantine level based on Canadian epidemiological studies. Admittedly, there is little that can be done to prevent or control the outbreak of red tide; however, should any sign of an impending outbreak be detected, the general public could be given early warning, thus eliminating any unnecessary loss of lives.

Conclusion

Further studies need to be carried out by qualified personnel into the reasons why some species of shellfish become toxic from time to time even though no red tide is seen or reported. More specifically, the origin and nature of the toxins should be investigated. The possibility of resting cysts as the source of toxins should be fully investigated. Hopefully, such research can shed further light onto the problem of PSP forecasting in this region.

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