Red Tides and Paralytic Shellfish Poisoning in the Philippines

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Introduction

Toxic marine dinoflagellate blooms have been recognized for many years to have a significant impact on the utilization of shellfish resources and human health because of the problem of paralytic shellfish poisoning (PSP), which occurs in many areas of the world and seems to be intensifying and spreading (Prakash et al. 1971; Taylor and Seliger 1979). Less than 20 dinoflagellate species are known or thought to produce toxins (Steidinger 1979).

Many filter-feeding shellfish, such as clams, mussels, and scallops, feed on several of these red tide forming toxic dinoflagellates and accumulate the toxins in their tissues without themselves being affected (Prakash et al. 1971; Twarog 1974; Hashimoto 1979). As a consequence, it may become a serious problem when the affected shellfish are eaten by warm-blooded animals that are particularly sensitive to the toxin. In extreme cases, several species of clams and mussels may prove fatal if eaten by man. To date, research efforts to develop an antidote for the toxins have been relatively unsuccessful (Yentsch and Incza 1980) and the only effective control measure is the closure of the affected areas to shellfish gathering.

Paralytic shellfish poisoning has long been known as a serious problem in four regions of the world, namely Europe, North America, the Pacific coast, and Asia (Twarog 1974). There are medical records of over 1650 cases of this food poisoning worldwide, which have resulted in at least 300 fatalities (Dale and Yentsch 1978). Jay (1970) asserted that paralytic shellfish poisoning in man has a mortality rate close to 10% and as much as 22% in some areas.

Most recently, red-tide outbreaks were reported in tropical Indo-Pacific countries such as Papua New Guinea (1972 until early 1976), Brunei and Sabah (March-May 1976) and the Philippines (mid-1983).

The major species involved in the tropical Indo-Pacific red tides was the armoured, bioluminescent dinoflagellate *Pyrodinium bahamense* Plate 1906, which was recently reclassified as *Pyrodinium bahamense* var. *compressa* Böhm 1931 (Steidinger et al. 1980), a species that is closely related to *Protogonyaulax* (= *Gonyaulax* spp.) (Fig. 1), and was unreported in the region before 1971 (Maclean 1979). The organism was first described from Waterloo Lake, a small, shallow, saline lagoon in Nassau, Bahamas, in 1906 (Beales 1976) and its previous known distribution was restricted to the tropical and subtropical waters of the Carribean Sea (particularly Jamaica and Puerto Rico), eastern Pacific Ocean, Red Sea, Persian Gulf, and North Atlantic Ocean (Wall and Dale 1969) where it was reported to be nontoxic (Beales 1976). It has now, however, been found to be responsible for fatal paralytic shellfish poisonings in Papua New Guinea (Worth et al. 1975), Brunei and Sabah (Beales 1976), and the Philippines (Estudillo 1984).

Harmful dinoflagellate blooms of *Pyrodinium bahamense* var. *compressa* and the paralytic shellfish poisoning it causes were experienced for the first time in Philippine waters when they occurred along the coast of Eastern Visayas northwestward to the coast of Masbate and Sorsogon during the period from late June to early September 1983 (Fig. 2). In the latter part of September, cases of paralytic shellfish poisoning involving one fatality were reported in Western Visayas.

Severely affected by the red tide were the mariculture project farms in Maqueda Bay and Villareal Bay (western Samar), where green bay

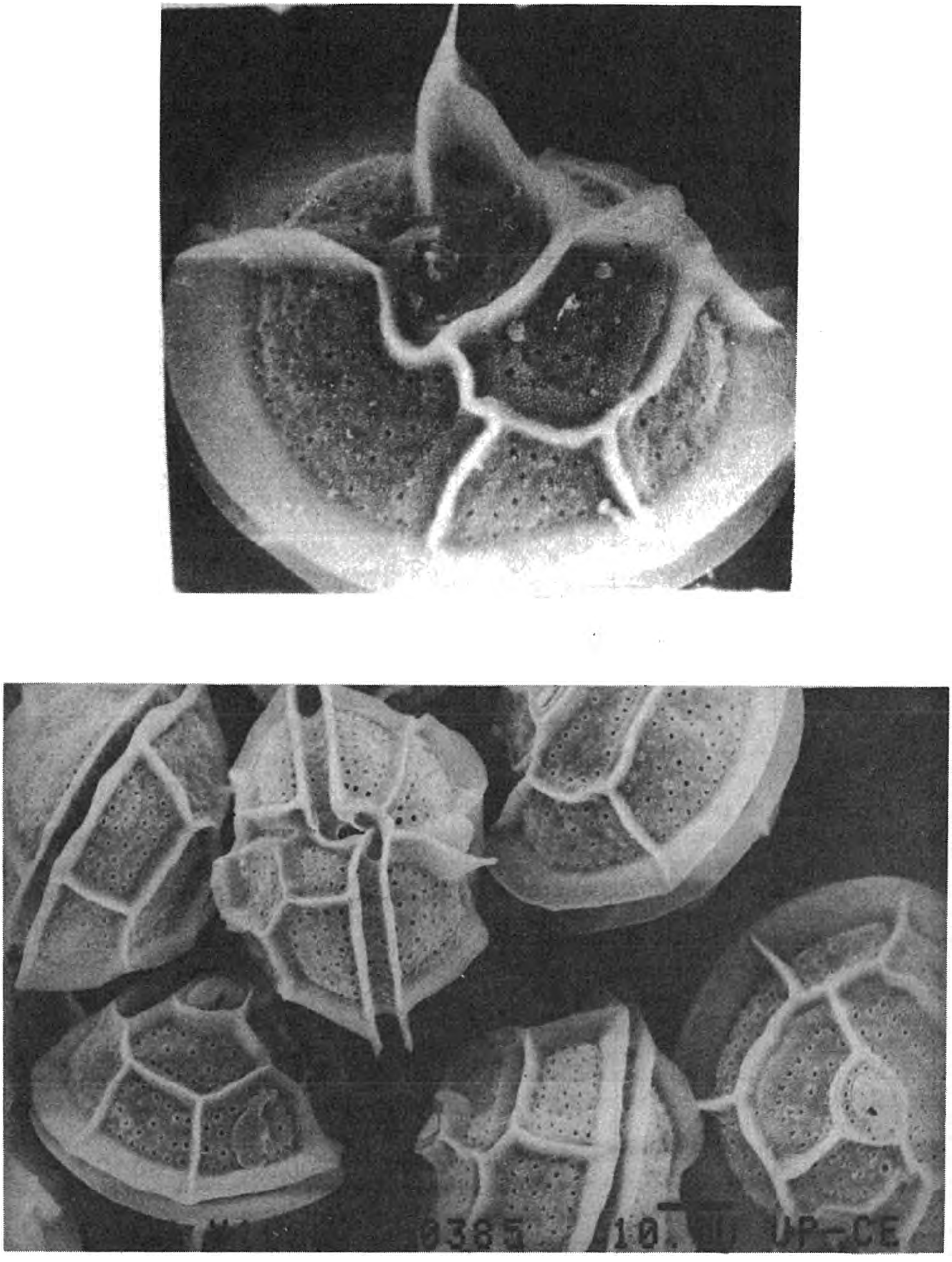

Fig. 1. Pyrodinium bahamense *var.* compressa *Böhm 1931 taken by scanning electron microscope (through the courtesy of the Research Institute for Tropical Medicine and the U.P. College of Engineering).*

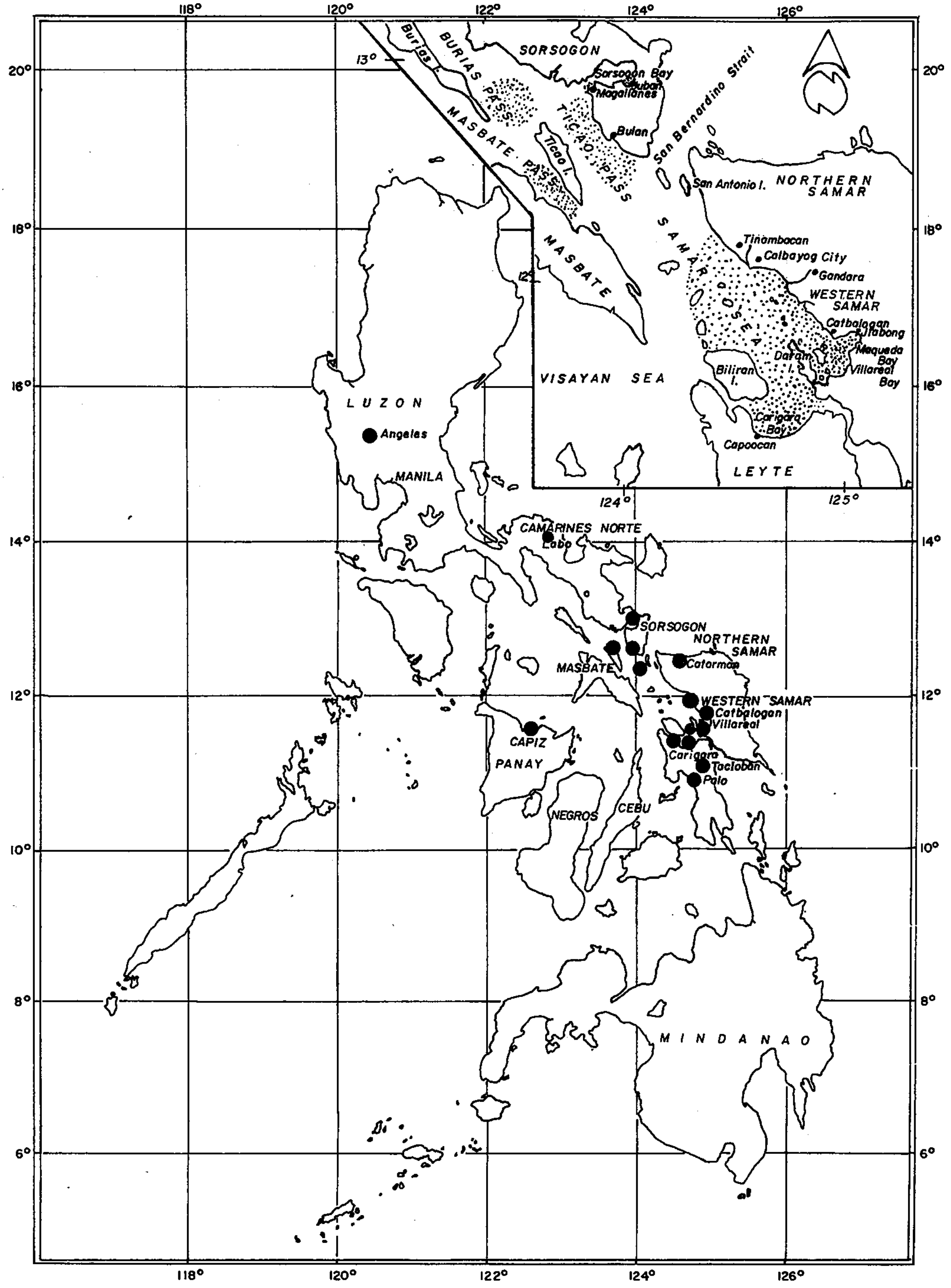

Fig. 2. Map showing the red tide survey area. Shadowed circles indicate areas where paralytic shellfish poisoning cases have been reported. Areas affected by the Pyrodinium *blooms (red tide) are stippled.*

mussels (locally called "tahong") or *Perna viridis* Linne (= *Mytilus smaragdinus*) are being cultured. Commercial harvest, sales, and consumption of mussels and other shellfish were banned for almost 8 months, which resulted in great economic loss. Paralytic shellfish poisoning reports have also shown that many people had been taken ill: a total of 278 cases were reported involving 21 deaths, most of them were due to the ingestion of the green mussels from Maqueda Bay and Villareal Bay.

The extensive toxic dinoflagellate blooms in Eastern Visayas and along the nearby coast provided an opportunity for the Bureau of Fisheries and Aquatic Resources (BFAR) to monitor and investigate the blooms.

This paper deals with the type of monitoring and investigative work conducted from 22 July 1983 until the blooms of the toxic dinoflagellate completely disappeared from the waters of the affected areas and from the gills and viscera of the mussels. The results of the toxicological analysis carried out on the mussels are also presented in this paper.

Methodology

Two aerial observations were carried out to assess the location, configuration, and possible spreading of the red tides. These were carried out using light aircraft from the Eastern Command of the Philippine Air Force in Tacloban City. In addition to these, sighting reports from commercial Philippine Airline flights were also recorded.

Eighteen oceanographic stations were established in Carigara Bay and the eastern and southern parts of Samar Sea where water samples were collected at standard depth intervals of 2m in the upper 10-m layer and every 5 m thereafter using Nansen reversing water bottles provided with protected and unprotected reserving thermometers. Temperature readings were recorded at each depth and water samples were collected and analyzed for salinity and dissolved oxygen employing the Knudsen-Mohr and modified Winkler methods respectively.

Tansparency readings were taken using the standard Secchi disc. Sea surface and meteorological observations were also recorded.

Vertical plankton hauls were made using a closing plankton net measuring 30 cm in mouth diameter, 110 cm in total length, and with a 90 μm mesh size. Five sets of plankton data, according to sampling depths, were obtained, i.e., 5-0, 15-10, 25-20, 35-30, and 35-0 m, or from near the bottom to the surface if the depth of the station is shallower than 35 m. The samples collected were preserved in 10% formalin solution.

Plankton samples were examined for toxic dinoflagellates using a Nikon bacteriological microscope (model SC). Counting was carried out on a 1 mL aliquot part placed into a Sedgwick-Rafter counting chamber. Numerical estimates were made based on the diameter of the mouth of the net, sampling depth, and volume of the plankton samples. Counts were then converted to number of *Pyrodinium* cells per litre of water filtered by the net.

Regular plankton samplings (both vertical haul and surface tow) in Maqueda Bay and Villareal Bay and approaches were conducted with the same plankton net, but only for qualitative analysis.

Trawling operations, using a German-type net with dragging time ranging from 15 min to less than 2 hours, were made in Carigara Bay, eastern and southern parts of Samar Sea, and its adjoining waters for the purpose of collecting samples of fish and invertebrates for gut content analysis to determine the extent of contamination and identify potentially toxic seafoods.

Fish and invertebrate collections in the shallow waters of Samar Sea, Maqueda Bay, and Villareal Bay, on the other hand, were made by taking samples from the catch of subsistance fishermen operating in the area. Samples of fish and other marine products were also obtained from the markets and fish-landing centres.

Counting and recording of *Pyrodinium* cells in the gut of fish and invertebretes were carried out by removing the gut/viscera from the fish/invertebrate and dissecting it. The entire gut contents were then placed on a glass slide and spread out. The number of *Pyrodinium* cells were then counted under a microscope and qalified into various categories.

Bioassay tests were carried out on mussel samples collected monthly (or sometimes twice a month) from a number of mussel farms along the coastal area of Maqueda Bay and Villareal Bay. Fresh mussel samples were sent regularly to the Bureau of Research and Laboratories (BRL) of the Ministry of Health in Alabang, Muntinlupa, Metro-Manila, for "mouse bioassay" testing. The calculation of the toxin level in micrograms per 100 grams of shellfish meat, as suggested in the standard assay method of the Association of Official Analytical Chemists (Horwitz 1975), was not possible in the present study due to a lack of paralytic shellfish poison standard solution. Determination of the presence and strength of the toxin in the tissue of mussels was, therefore, attempted (using the Bureau of Research and Laboratories "standard" procedure) in terms of percentage mice mortality and death time. For each monthly test, about 200 mice were injected intraperitoneally with shellfish extract and observed together with the control mice, which were injected with acidified water.

Results and Discussion

Chronological Observations of the Occurrence of Red Tides

The first recorded case of paralytic shellfish poisoning involved two deaths and occurred in the early morning of 21 June after a family of eight ingested mussels collected from Jiabong in Maqueda Bay, where the dinoflagellate bloom was first discovered on 10 July (Fig. 3).

The spreading of the visible red tide was observed on 15 July, apparently associated with typhoon "Bebeng", which occurred from 13-15 July, when maximum rainfall (113.6 mm on 13 July, 109 mm on 14 July, 20 mm on 15 July); maximum wind force (4-8 m/sec) in southwesterly and northwesterly directions; and maximum cloudiness (7.6-8.0 units) were recorded. Tremendous discharge from rivers into the sea was observed during this period. As a result, the red tide spread out and was seen from commercial flights as orange-red patches along the 70-km stretch of western Samar coastline from Villareal to Gandara (Fig. 4).

The peak of the visible red tides occurred in the latter part of July (Fig. 5). The fading of the visible red tides started in early August, which could be due to the continuous sunny days with only occasional rain showers, calm sea surface conditions, minimum wind force (1 m/sec), and variable winds (W, NW, SW, SSW) in the area.

In early August, visible blooms were observed to be absent from the open waters of western Samar and they seemed to concentrate very close to the coastline, particularly near the mouths of river systems. Plankton samples taken along the western Samar coastline from Catbalogan to Tinambacan showed live but somewhat sluggish *Pyrodinium* cells. The chain formation of cells were also observed to be diminishing. The longest chain of the organism observed during its peak occurrence in July was 10 cells, compared with only 6 cells in mid-August (Hermes 1983).

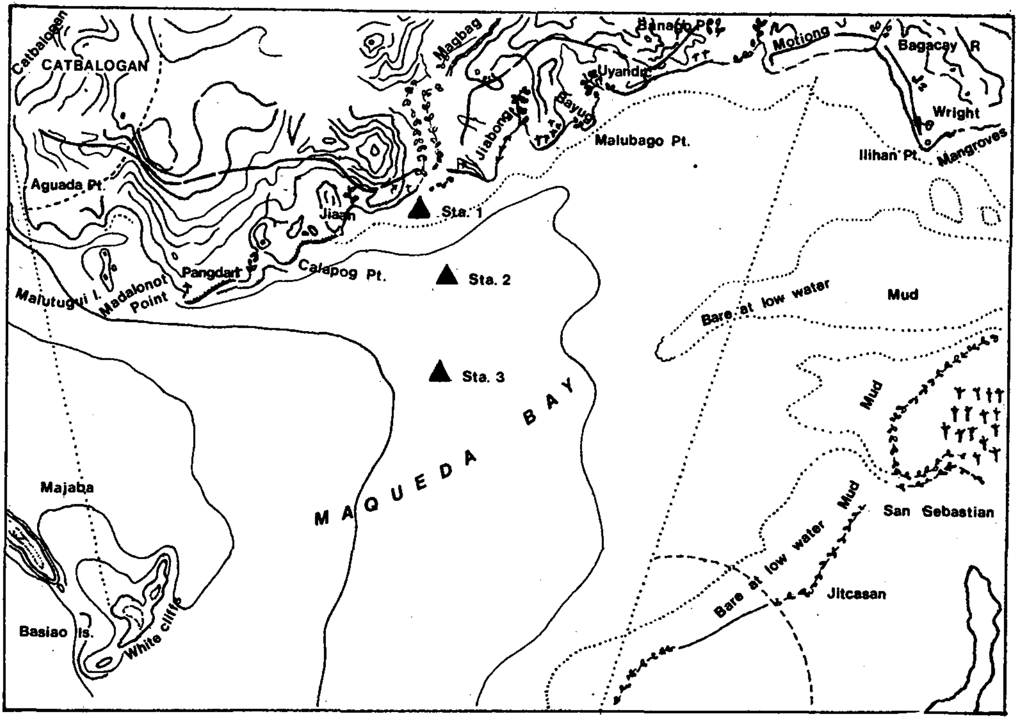

Fig. 3. Locations of plankton stations (dark triangles) on Jiabong side of Maqueda Bay from which toxic dinoflagellate samples were taken, 10 July 1983 (Estudillo 1984).

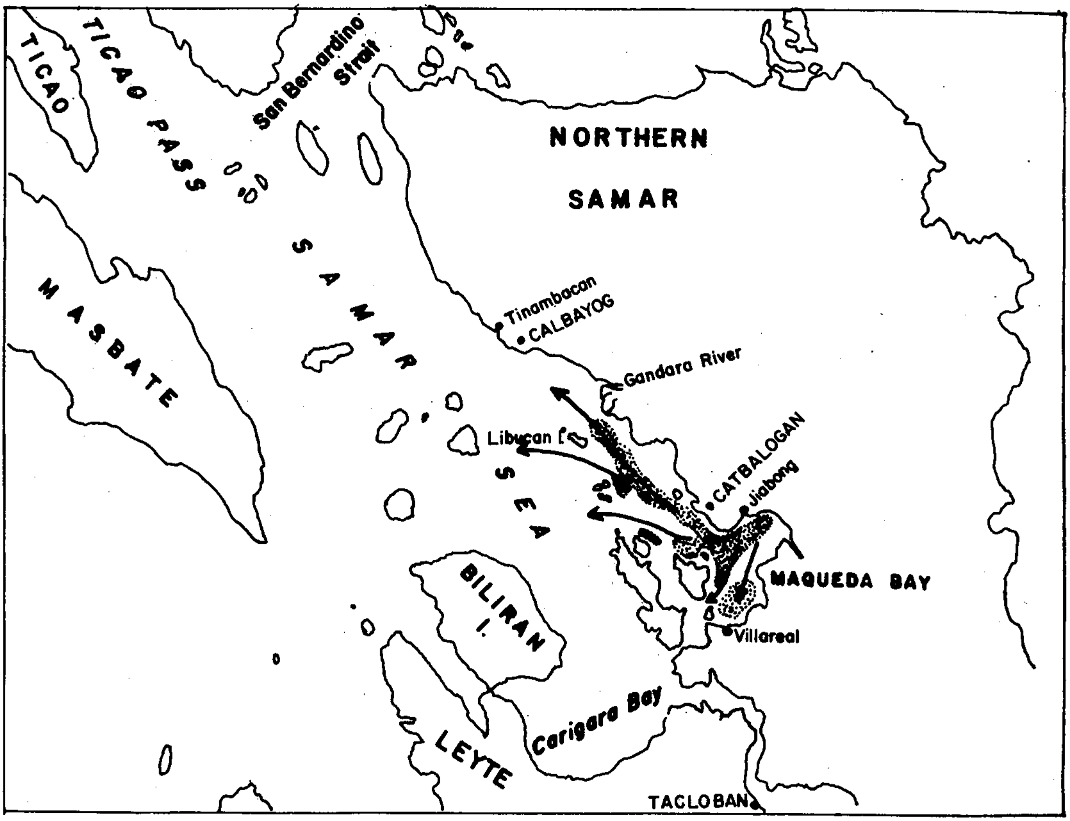

Fig. 4. Distribution of red tide patches (dotted) in Maqueda Bay and approaches from incidental aerial observations — 0900 hours, commercial PAL flight, Tacloban City to Manila, 18 July 1983. Arrows indicate possible movements of dinoflagellate blooms (Estudillo 1984).

During the second week of August, no visible blooms were observed along the western Samar coastline from Maqueda Bay to Tinambacan, except in the area southwest of Tagdarano Island, south of Calbayog City, and near the mouth of the Gandara River, where visible blooms in small patches were noticed.

A plankton sample that was collected near the mouth of the Gandara River showed that *Pyrodinium* comprised about 90% of the total number of plankton organisms. Heavy blooms in patches were also observed at about 1 nautical mile off Biliran Island, between Amambahag Point and Caibiran River (southern part of Samar Sea).

On 13 and 14 August, visible blooms totally disappeared from the southern part of Samar Sea, Carigara Bay, and the entrance of Maqueda Bay. However, plankton samples in Maqueda Bay were still dominated by *Pyrodinium,* followed by *Noctiluca* and *Skeletonema.* On the other hand, *Pyrodinium* completely disappeared from the plankton samples from Zummaraga Channel, except at its entrance where a visible bloom in the form of a streak still remained.

In mid-August, red tide totally disappeared from Maqueda Bay, Villareal Bay, and Samar Sea, but *Pyrodinium* remained a constituent of the plankton population, although in an insignificant quantity.

Plankton samplings were taken at eight stations along the coast of Sorsogon and Ticao Pass that showed the presence of an insignificant number of *Pyrodinium* cells. The dinoflagellate was observed to be present in the gut of the Indo-Pacific mackerel (over 200 cells per individual fish) caught in Ticao Pass (off Bulan, Sorsogon). Slightly discoloured water was noticed on 21 August along the beach of Magallanes, Sorsogon, where a large amount of *Pyrodinium* was found in the plankton sample collected from the area.

The visible blooms and the causative

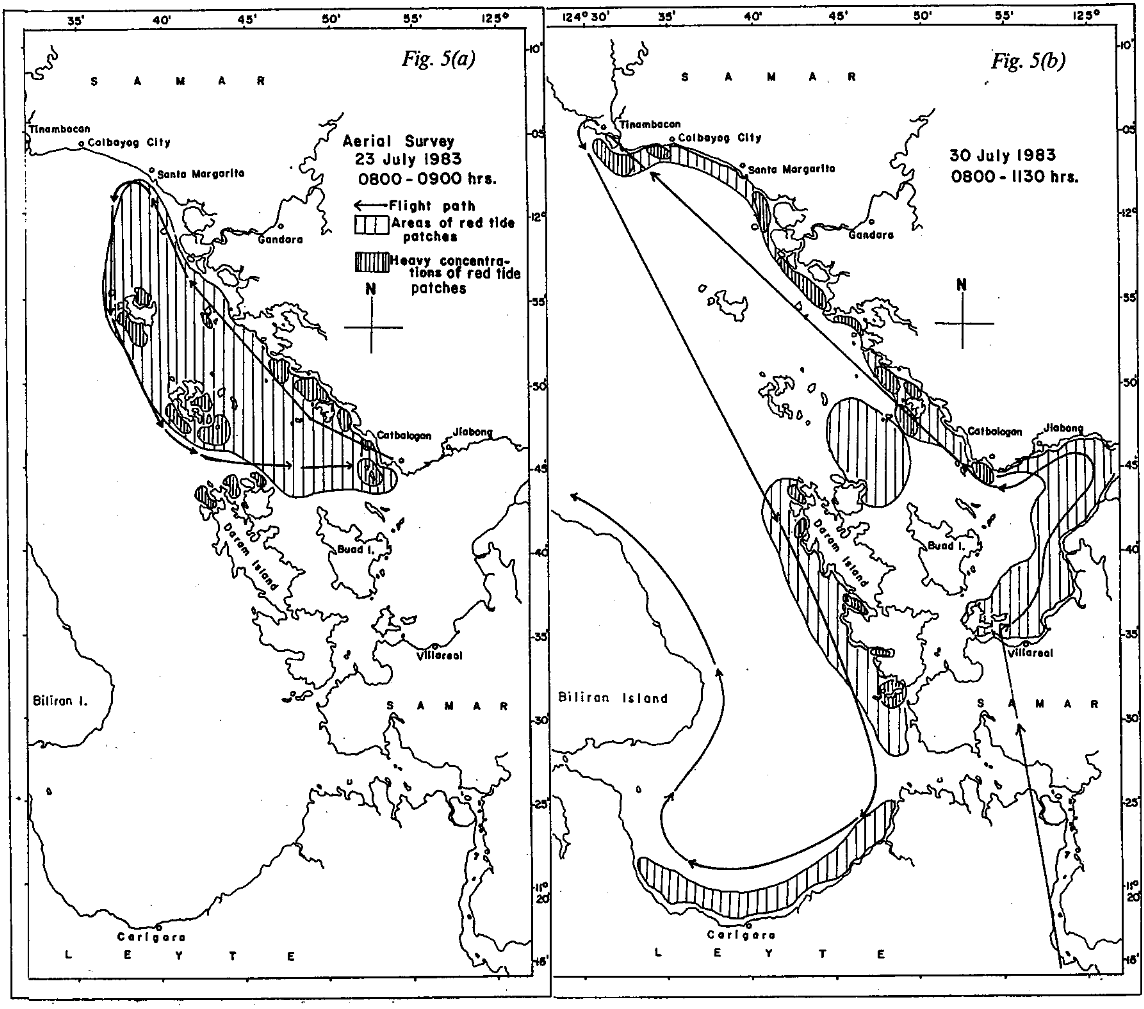

Fig. 5. Distribution of red-tide patches as viewed during aerial surveys on (a) 23 July and (b) 30 July 1983.

dinoflagellate had totally disappeared from Maqueda Bay, Villareal Bay, Carigara Bay, and Samar Sea by the end of August.

On 7 September, follow-up monitoring of Maqueda Bay, Villareal Bay, Samar Sea, and Carigara Bay was conducted and showed once again the complete absence of red tides. Subsequently, blooms of *Noctiluca scintillans* appeared after the toxic red tide blooms. Yellow and greens streaks, or patches of the *Noctiluca* blooms, were observed in Maqueda Bay and Villareal Bay. Blooms of *Noctiluca* were also observed in the eastern Samar Sea, Ticao Pass, and Masbate Pass. Numerous pontellid (blue) copepods were also observed to be very common in the samples. Hermes (1983) also reported a bloom of *Noctiluca* in Visayan Sea, specifically in the northern part of Guimaras Strait and Sorsogon Bay.

On 23 September, cases of paralytic shellfish poisoning were reported in Capiz, northern Panay, that were attributed to scallops (*Amusium pleuronectes*). Shellfish samples were collected from Northern Panay waters and analysis showed that the toxic dinoflagellate was present in the gut of mussels, oysters, and scallops, although in small numbers (with cell counts ranging from 1-20 *Pyrodinium* per individual shellfish). On 12 October, plankton samples were taken at 22 stations from Ayagao Bay, Sapian Bay, and Tinagong

Dagat. All samples taken from Tinagong Dagat were found negative for *Pyrodinium*, whereas those taken from Sapian Bay and Ayagao Bay showed very low levels (from one to seven *Pyrodinium* cells per litre of water). Shellfish collected during the survey were all found to be negative for *Pyrodinium*.

Aerial Survey

The aerial observations were made on the morning of 23 July between 08:00 and 09:00 hours. Figure 5(a) shows the locations of the various red-tide patches or visible blooms observed during the aerial survey. It should be noted that the visible blooms in intense orange-red patches cover practically the entire survey area but heavy concentrations were seen more conspicuously near the coastline.

Another aerial observaton was made on the morning of 30 July between 08:00 and 11:30 hours. Figure 5(b) shows the locations of the observed visible blooms that were generally noted to be very close to the coastline and more prominently near the mouths of river systems.

In Maqueda Bay and Villareal Bay, visible blooms were observed from the shoreline to the 3-fathom contour line. Intense orange-red patches could be seen along a 100-km stretch of the western Samar coastline from Bonoanan, Catbalogan, to Tinambacan. Visible blooms were observed along the entire coast of Daram Island (southern part of Samar Sea), particularly in Sumulit Bay, Cananayan Bay, Domiri Bay, Saa Bay, and around Bascal Island. Visible blooms were also observed along the coast of Carigara Bay, whereas no visible blooms were observed around Biliran Island, northwest of Leyte, and San Pedro Bay.

Observations from commercial flights in early August showed that the visible blooms were still present in Carigara Bay and eastern and central parts of Samar Sea (Hermes 1983). By mid-September, visible blooms had totally disappeared from the areas, as observed by R. Estudillo from commercial flights.

Spatial Distribution of the Dinoflagellate

The distribution of *Pyrodinium*, as observed from plankton collections, covers the coasts of Easten Visayas, provinces of northern Leyte (Carigara Bay), and western Samar (Maqueda Bay, Villareal Bay, Zummaraga Channel, and Samar Sea) northwestward to the coasts of Masbate and Sorsogon (Ticao Pass, Burias Pass, and Masbate Pass) (Fig. 2).

Generally, the dense population during the peak of the dinoflagellate blooms was observed in Maqueda Bay, Villareal Bay, Carigara Bay, and along the coast of western Samar from Catbalogan to Tinambacan. These are obviously the areas where visible blooms tend to concentrate (Fig. 5).

Phytoplankton hauls, to sample specific strata of some of these areas, were made with a 30-cm, 90 μm closing net, the only fine-mesh net available on board the research vessel. The locations of sampling stations are shown in Fig. 6. Three sets of data according to sampling depths were gathered and are presented in Table 1.

It was observed that the concentrations of *Pyrodinium* in the latter part of July varied from a minimum of 59 cells/L at 25-20 m to a maximum of 7134 cells/L at 5-0 m. As expected, a lowering of concentrations in deeper layers was observed; however, this is sometimes inconsistent, which may be due to the effects of diurnal variations in the behaviour of plankton. Generally, the dinoflagellate tends to concentrate in the coastal waters of Catabalogan, at the entrance of Maqueda Bay, and in the northernmost stations (stations 7 and 14). The minimum concentration of the dinoflagellate was observed in the northern part of the survey area and at the entrance of Carigara Bay (Fig. 7).

The concentrations of *Pyrodinium* in August along a transect from Catbalogan to Biliran Island ranged from a minimum of 637 cells/L north of Daram Island to a maximum of 138269 cells/L in the shallow waters off Catbalogan (Table 1). The concentration was observed to increase toward Biliran Island (Fig. 8).

The concentration of *Pyrodinium* at the station occupied during the 13 and 14 August survey was generally higher than those mentioned above, with counts ranging from a minimum of 2251 to a maximum of 123588 cells/L. This is not surprising considering that the sampling was carried out in the entire water column from 35 to 0 m, or from near the bottom to the surface. The highest concentrations were observed at the entrance to Maqueda Bay and between Biliran and Daram Islands and in Carigara Bay (Fig. 9).

The organism was also observed to be present in the plankton samples collected from Cebu City harbour, from the northernmost part of Camotes Sea, and from Sapian Bay and Ayagao Bay in northern Panay. Likewise, it was present in samples taken from the innermost part of Sorsogon Bay in Juban and the entrance of the bay in Magallanes, but absent in the plankton hauls from the bay proper. Counts of the dinoflagellate in all areas mentioned above were insignificant. The locations of these areas are shown in Fig. 2.

The observation that *Pyrodinium* is spreading in the tropical Indo-Pacific region may have some basis. It started during the massive red tides in

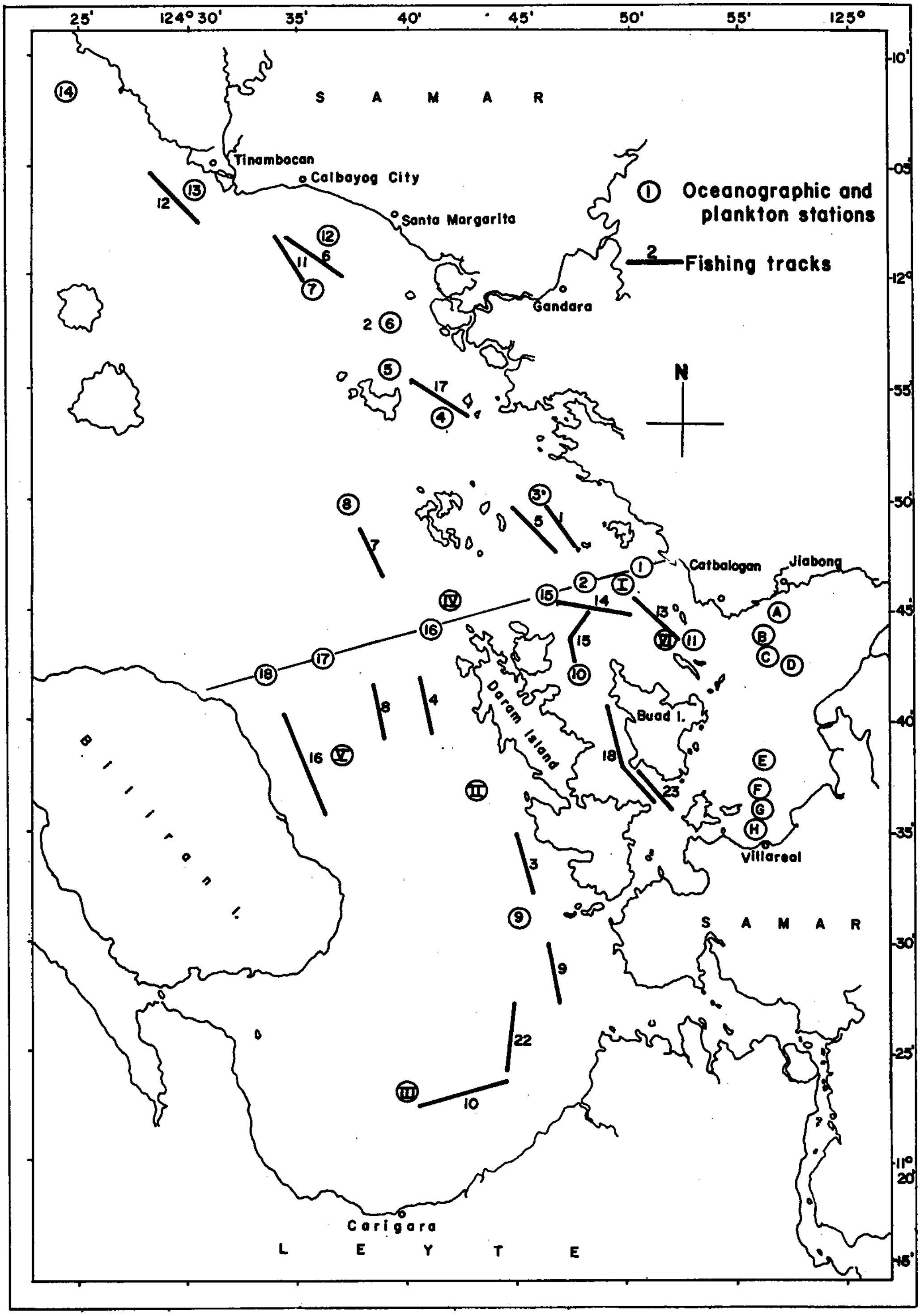

Fig. 6. Map showing oceanogrpahic stations and trawling tracks research vessel Researcher *in the coastal waters of western Samar and Carigara Bay.*

Table 1. Abundance of *Pyrodinium bahamense* var. *compressa* at different layers and different stations in the coastal waters of western Samar and Carigara Bay.

Date 1983	Station No.	Sonic depth (m)	Sampling layers (m)	Cell counts/ L
24 July	1	12	5 — 0	5449
			10 — 5	4013
	2	27	5 — 0	6391
			15 — 10	3369
			25 — 20	1724
	3	15	5 — 0	2080
			15 — 10	1139
	4	18	5 — 0	1635
			15 — 10	3641
25 July	5	27	5 — 0	1932
			15 — 10	1734
			25 — 10	59
	6	11	5 — 0	297
			10 — 5	669
	7	26	5 — 0	7134
			15 — 10	3963
			25 — 20	4013
	8	59	5 — 0	149
			15 — 10	892
			25 — 20	186
	9	40	5 — 0	149
			15 — 10	1932
			25 — 20	59
27 July	10	30	5 — 0	342
			15 — 10	495
			25 — 20	803
	11	11	5 — 0	3418
			10 — 5	1783
1 August	14	68	5 — 0	7285
			15 — 10	892
			25 — 20	885
1 August	1	12	11 — 6	138269
	15	37	35 — 30	1019
	16	48	35 — 30	637
	17	65	35 — 30	892
	18	77	35 — 30	1465
13 August	I	28	25 — 0	11549
	II	46	35 — 0	2251
	III	46	35 — 0	19660
	IV	55	35 — 0	3800
	V	72	35 — 0	17197
14 August	VI	18	15 — 0	123588

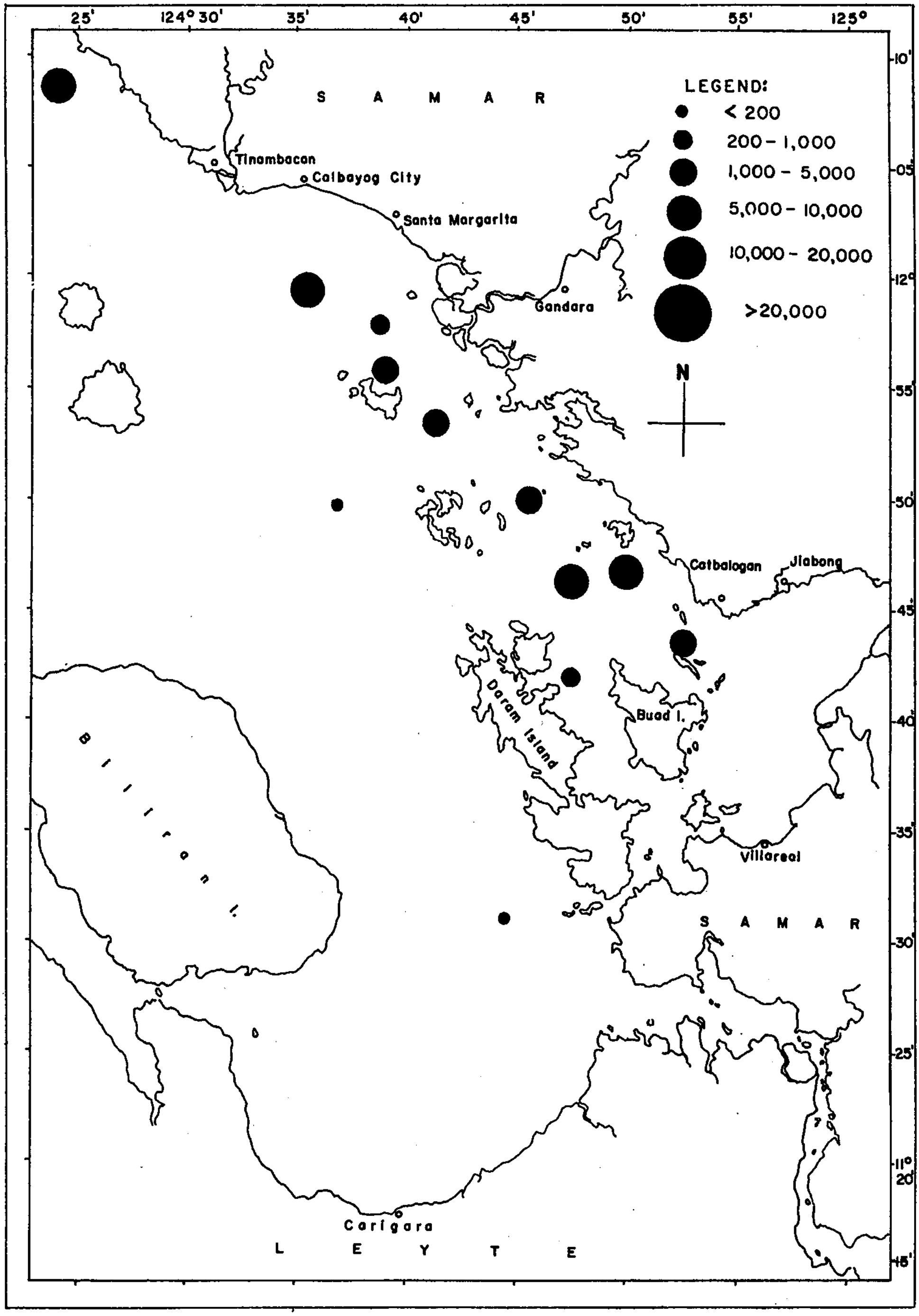

Fig. 7. Relative abundance of Pyrodinium bahamense *var.* compressa *in the coastal waters of western Samar collected by vertical haul from 5 — 0 m from 27 July — 1 August 1983. (Legend shows number of* Pyrodinium *cells per litre.)*

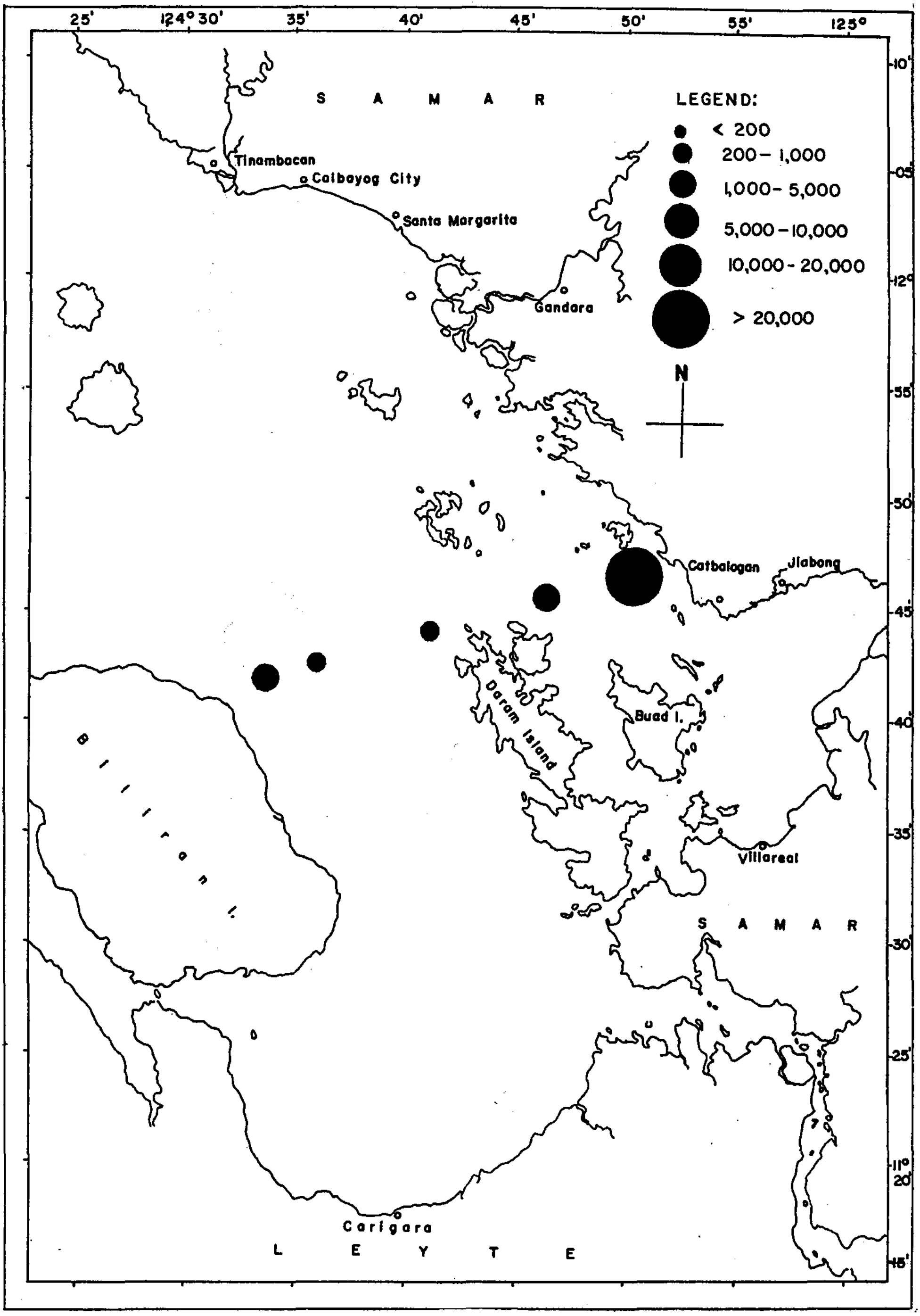

Fig. 8. Relative abundance of Pyrodinium bahamense *var.* compressa *along a transect from Catbalogan to Biliran Island collected by vertical haul from 35 — 30 m on 1 August 1983. (Legend shows number of* Pyrodinium *cells per litre.)*

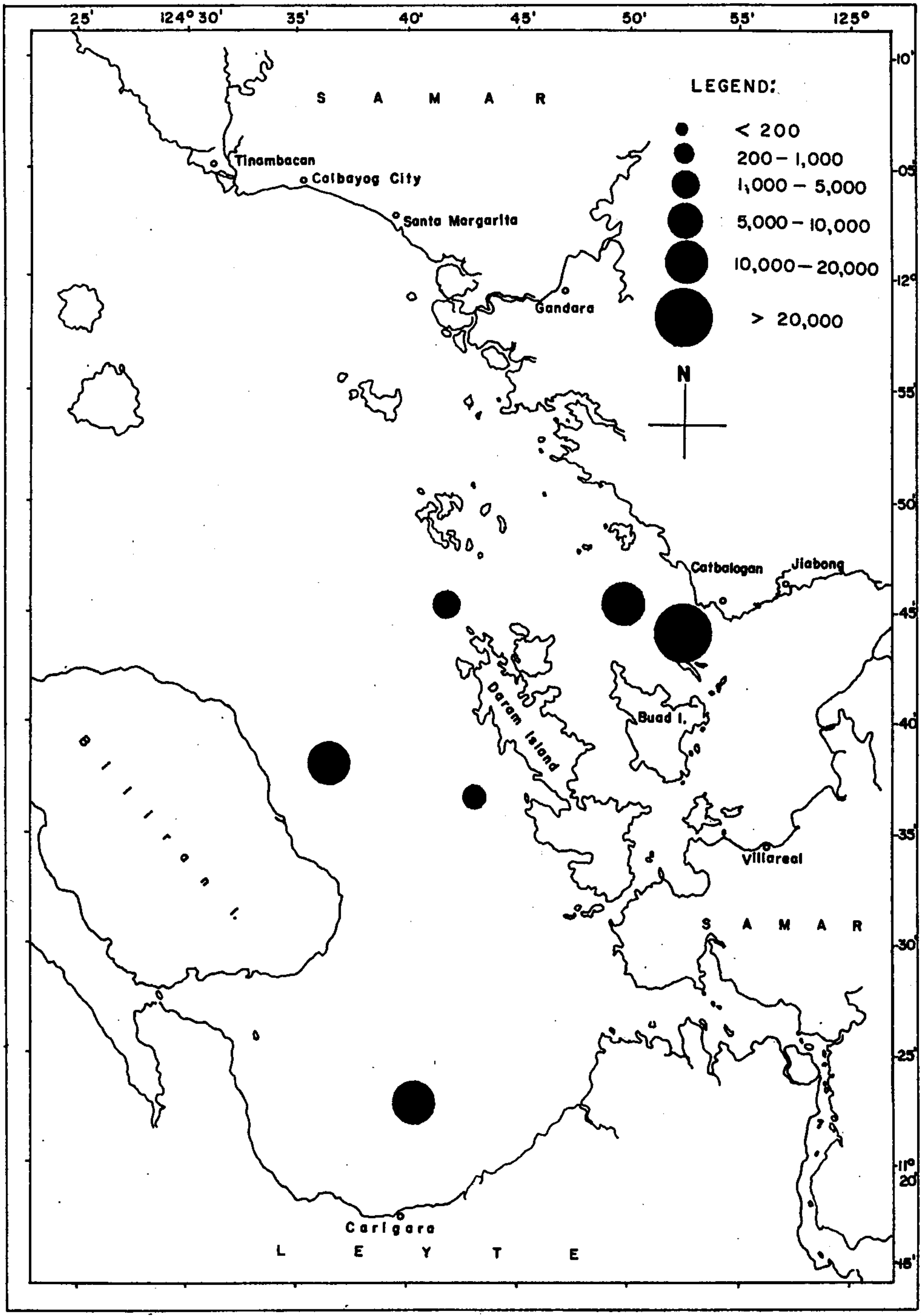

Fig. 9. Relative abundance of Pyrodinium bahamense *var.* compressa *in the coastal waters of western Samar and Carigara Bay collected by vertical haul from near the bottom to the surface (generaly from 35 — 0 m) on 13-14 August 1983. (Legend shows number of* Pyrodinium *cells per litre.)*

December 1975 — February 1976 in Papua New Guinea, which was followed in a matter of a month by the Brunei and Sabah outbreaks in March-May 1976. The Southern Equatorial Current easily accounts for the possible introduction of *Pyrodinium* into the area from Papua New Guinea (Maclean 1979). Similarly, this could also be the reason for the first occurrence of the organism in the Philippines. *Pyrodinium* was also found in Arumizu Bay in Palau Island (Western Pacific) (Harada et al. 1982) and there is a possibility that the organism was introduced into Philippine waters by the North Equatorial Current.

Physical Environment

Results of some of the oceanographic observations obtained during the period from 24 July — 4 August are presented in Table 2. The stations were established in areas where visible blooms were observed to be widespread. The locations of the sampling stations are shown in Fig. 6.

The observed surface water temperature ranged from 29.6-32.5°C. The bottom temperature ranged from 26.4-29.8°C.

The observed surface salinities ranged from 31.15-33.88 ppt, whereas the bottom salinities ranged from 33.73-35.28 ppt.

Both ranges described above are quite similar to those measured in mid-August, i.e., temperatures from 27.6-31.0°C and salinities from 31.9-34.9 ppt (Hermes 1983).

Water temperature and salinity values measured are within the range of the observed values for *Pyrodinium* blooms elsewhere, i.e., 24.4-31.9°C and 24.7-36.8 ppt in Papua New Guinea (Maclean 1977); 24.5-29.4°C and 24.3-32.08 ppt in Brunei (Beales 1976); 27.0-35.0°C and 30.0-36.0 ppt in Jamaica (Buchanan 1971), and 22.2-29.2°C and 30.5-36.5 ppt in Florida (Steidinger and Williams 1970).

Earlier studies of red tide showed that *Pyrodinium* can tolerate salinities as low as 14 ppt for a few days (Buchanan 1971). Laboratory experiments conducted in Papua New Guinea during the 1973 and 1974 blooms showed that the *Pyrodinium* band formed within the salinity range of 28.6 and 31.5 ppt, and can tolerate salinities as high as 40.7 ppt (Maclean 1977). *Pyrodinium* is atypical, having an optimum salinity of around 35.7 ppt (Wall and Dale 1969). This suggests that *Pyrodinium* favours high salinity, as noted above. The lower salinities and reverse temperature gradient associated with river runoff are merely indicators of the source of nutrients and not catalysts of the widespread blooms (Maclean 1977).

Transparency estimates as determined using a Secchi disc ranged from 1.5-12.5m, with exceptionally larger Secchi depths (14 m) at stations 14 (off Binalio Point, Tinambacan) and 18 (northeast of Biliran Island).

In the survey conducted by the University of the Philippines in the Visayas College of Fisheries (UPVCF) team in mid-August, the recorded transparency readings ranged from 5-11 m, which was within the range mentioned above. However, it was a marked decrease from the values observed in 1979 in Samar Sea, when Secchi depths were 15-20 m (Labao 1980).

The observed surface dissoved oxygen ranged from 3.19-5.40 mL/L, whereas the bottom dissolved oxygen ranged from 0.45-3.86 mL/L. The maximum dissolved oxygen values were observed at station 17 (southern Samar Sea). Both surface and bottom oxygen values were generally normal.

The observed prevailing winds at each station on any particular day, as determined by the vessel's instruments, were variable, with wind speeds ranging from 2-18 knots. Generally, the winds blow toward the southeasterly and southwesterly directions. The observations are similar to those recorded by the Catbalogan weather station in Samar. Five sampling stations (stations 1 and 15-18) were occupied on 4 August in a transect from Catbalogan to Biliran Island (Fig. 8) that showed the prevalence of light northeasterly winds (Table 2).

An analysis of wind data for possible correlation with the occurrence of the dinoflagellate bloom will be attempted in the near future. Initial studies showed that wind is at least as important as rainfall in promoting and sustaining *Pyrodinium* blooms (Maclean 1977).

Fishing and Examination of Gut Contents

A total of 49 fishing operations were conducted in areas outside Maqueda Bay (Samar Sea and nearby coast) during the monitoring period that yielded a total catch of 6637 kg of fish and invertebrates. Locations of fishing tracks are shown in Fig. 6. Fishing track nos. 19 and 20 were occupied in an area (Pambujan Bay, northern Samar) not affected by the red tide.

Table 4 shows the *Pyrodinium* concentrations inside the gut of fish and invertebrate samples taken from the trawl catch that were microscopically examined on board. A series of categories has been used and the total number of *Pyrodinium* cells in each category are as follows:

+= 1-20 *Pyrodinium* cells/fish or invertebrate
++= 21-100 *Pyrodinium* cells/fish or invertebrate
+++= 101-200 *Pyrodinium* cells/fish or invertebrate.

Table 2. Physicochemical data of the coastal waters of western Samar and Carigara Bay.

Date 1983	Station Number	Sampling Depth (m)	Transparency (m)	Wind Direction and Speed (knots)	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mL/L)
24 July	1	0	3.6	NW (18)	29.9	31.80	3.58
		2			29.9	—	4.59
		4			30.0	—	3.02
		6			29.6	—	1.74
	2	0	6.0	SSE (10)	30.6	—	4.20
		2			30.1	—	4.00
		4			29.9	—	3.64
		10			29.8	—	2.69
		20			29.4	—	2.18
		25			29.1	—	1.85
	3	0	—	SSW (4)	30.0	33.17	4.31
		2			29.5	33.07	4.31
		4			30.0	33.44	4.20
		7			29.8	34.27	4.26
		10			29.8	35.10	3.76
	4	0	7.8	SE (3)	32.5	—	4.31
		2			32.3	—	4.31
		4			31.0	33.44	4.20
		6			28.5	33.44	3.81
		10			27.3	34.56	3.30
		15			26.5	34.27	3.02
25 July	5	0	5.0	SE (8)	29.6	33.17	3.70
		2			29.7	33.38	3.92
		4			29.7	33.17	3.92
		6			29.9	33.10	3.81
		10			29.5	—	3.02
		15			29.5	34.56	3.02
		20			29.7	34.56	3.64
		25			29.7	34.56	3.86
	6	0	2.5	NE (9)	29.9	30.68	3.75
		2			29.9	33.44	3.47
		4			29.9	33.73	3.14
		6			29.9	34.00	3.19
		10			29.6	34.00	2.86
	7	0	1.5	SE (4)	30.4	31.80	3.86
		2			30.3	32.61	4.87
		4			29.9	33.73	3.70
		6			29.7	33.73	3.75
		10			29.7	33.13	3.53
		15			29.6	33.13	3.86
		20			29.5	33.73	3.42
		25			29.5	33.73	3.42

Table 2. (continued)

Date 1983	Station Number	Sampling Depth (m)	Transparency (m)	Wind Direction and Speed (knots)	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mL/ L)
	8	0	8.0	SE (3)	30.0	—	3.53
		2			30.0	—	3.58
		4			29.9	—	3.70
		6			29.9	—	3.92
		10			29.7	—	4.14
		20			29.2	—	2.58
		30			28.9	—	2.46
		40			27.9	—	2.74
		50			27.6	—	1.90
		58			27.4	—	1.90
	9	0	—	SW (5)	29.8	33.44	3.42
		10			29.7	34.00	3.30
		20			29.4	34.83	2.86
		30			28.6	34.83	2.63
		38			28.3	34.83	2.35
27 July	10	0	9.1	SW (2)	29.7	30.96	3.86
		2			30.0	33.44	3.42
		4			29.9	34.00	3.58
		6			29.6	34.27	2.72
		10			29.9	34.27	3.42
		15			29.6	34.56	2.44
		20			29.0	—	1.74
		28			28.1	—	1.62
	11	0	6.0	NW (5)	30.0	30.41	4.26
		2			29.8	31.80	3.75
		4			29.9	34.00	—
		6			29.7	34.00	2.30
		10			29.6	—	1.62
1 August	12	—	9.0	WSW (1)	—	—	—
	13	—	—	W (4)	—	—	—
	14	—	14.0	NNE (4)	—	—	—
3 August	A	0	—	—	—	30.97	—
	B	0	—	—	—	31.09	—
	C	0	—	—	—	31.80	—
	D	0	—	—	—	32.07	—
	E	0	—	—	—	33.08	—
	F	0	—	—	—	32.79	—
	G	0	—	—	—	32.25	—
	H	0	—	—	—	31.15	—
4 August	1	0	6.1	NE (0)	30.2	33.88	3.19
		2			30.2	33.88	3.14
		4			30.1	34.44	1.76
		6			29.6	34.72	0.78
		10			29.5	34.16	0.45

Table 2. (continued)

Date 1983	Station Number	Sampling Depth (m)	Transparency (m)	Wind Direction and Speed (knots)	Water Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mL/L)
4 August	15	0	12.15	NE (1)	30.3	33.88	3.58
		2			30.2	33.60	3.64
		4			30.2	34.16	4.26
		6			29.8	34.16	3.25
		10			29.4	34.44	2.41
		15			29.3	34.72	1.90
		20			29.0	35.28	1.68
		30			28.7	35.28	1.40
		35			28.6	35.28	1.18
	16	0	9.0	NE (0)	30.7	33.88	4.09
		2			30.2	33.88	4.26
		4			30.2	33.88	5.04
		6			30.0	33.88	4.93
		10			29.5	34.72	3.47
		20			29.0	34.16	3.42
		30			29.1	35.28	2.07
		40			28.5	35.00	2.13
		45			28.1	35.00	2.30
	17	0	3.5	NE (2)	30.4	33.60	5.40
		2			30.1	33.88	5.21
		4			30.0	33.88	5.66
		6			29.9	34.72	4.59
		10			29.7	34.44	4.42
		20			29.3	35.00	4.03
		30			28.8	35.00	3.02
		40			28.0	35.28	2.30
		50			27.3	35.28	2.60
		63			26.7	—	2.63
	18	0	14.0	NE (3)	30.5	—	4.70
		2			33.3	—	4.42
		4			30.2	—	4.40
		6			29.9	—	4.26
		10			29.9	34.16	4.14
		20			29.2	34.72	3.92
		30			28.5	—	2.72
		40			27.8	—	2.97
		50			27.6	34.72	2.52
		60			27.3	34.44	2.46
		70			26.7	34.44	2.74
		75			26.4	34.72	2.52

++++= over 200 *Pyrodinium* cells/fish or invertebrate

The last category (i.e., over 200 cells/fish) extends to thousands or millions of cells per fish.

It can be seen from Table 4 that of the many varieties of food fish, the pelagic group (plankton-feeding fish), represented by five species, namely Indo-Pacific mackerel (*Rastrelliger brachysoma*), sardines (*Sardinella* spp.), Indian mackerel (*Rastrelliger kanagurta*), crevalle (*Selaroides* spp.), and anchovies (*Stolephorus* spp.) contained the most *Pyrodinium* cells. Hard-tail (*Megalaspis cordyla*), caught on two occasions, was also found to contain *Pyrodinium* cells.

Among the demersal fish species, slipmouths (*Leiognathus* spp.) contained the most *Pyrodinium* and even as many as for some of the pelagic fish species. The other fish species occasionally found containing a few *Pyrodinium* organisms included the threadfin bream (*Nemipterus* spp.), goatfish (*Upenoides* spp.), and trigger fish (*Balistes* spp.). Whiting (*Sillago* spp.) and grouper (*Epinephelus* spp.), on one occasion, were also found to contain a relatively high number of *Pyrodinium*. Barracuda (*Sphyraena* sp.) was, on one occasion, found to contain over 200 *Pyrodinium* cells per fish.

Blue crabs (*Portunus* spp.), shrimps (*Penaeids*), and squids (*Loligo* spp.) rarely contained *Pyrodinium*. *Pyrodinium* cells were present in the gut of these edible invertebrates only during the peak of the bloom. The scallops (*Amusium pleuronectes*), which were caught only in some trawling tracks (track nos. 10, 15, and 16), were always found to contain *Pyrodinium*.

Fish and invertebrates caught by gill net, hook and line, baby trawl, and fish corral inside Maqueda Bay and Villareal Bay were sampled on several occasions and were also examined for the presence of the toxic dinoflagellate (Table 3). The fish containing the most *Pyrodinium* cells were also the

Table 3 Concentration of *Pyrodinium bahamense* var. *compressa* in the stomach of different species of fish and invertebrates caught by hook and line, gill net, baby trawl, and fish corral in Maqueda Bay from 27 July — 16 September 1983.

Month (1983)	July			August							September			
DATE	27	28	29	3	9	14	16	23	28	31	5	9	12	16
PELAGIC FISHES:														
Indo-Pacific mackerel (*Rastrelliger brachysoma*)	xxxx		xxx	xxxx		xxxx	xxx							
Sardines (*Sardinella* spp.)			xx	xx		x								
Moonfish (*Mene maculata*)														
Anchovies (*Stolephorus* sp.)														
Indian mackerel (*Rastrelliger kanagurta*)	xxxx	xxxx			xxxx									
Crevalle (*Selaroides* sp.)			xx		xx									
Frigate tuna (*Auxis* sp.)		x												
Hairtail (*Trichiurus lepturus*)														
Leather jacket (*Scomberoides* sp.)														
Round scad (*Decapterus* spp.)						xx								
Hardtail (*Megalaspis cordyla*)	xx													
Mullet (*Mugil* spp.)	xx					xxx								
DEMERSAL FISHES:														
Threadfin bream (*Nempiterus* spp.)		x												
Slipmouth (*Leiognathus* spp.)	xx		x		x									
Lizard fish (*Saurida* spp.)														
Goatfish (*Upeneus* spp.)				x										
Whitings (*Sillago* spp.)	xx			xx										
Croaker (*Sciäenidae*)														
Gerres (*Gerres* spp.)														
Therapon (*Therapon* spp.)	xx		x	x		x								
Trigger fish (*Balistes* sp.)						x								
Grunt (*Pomadasys* spp.)						x								
Grouper (*Epinephelus* spp.)														
Silverside (*Atherina* sp.)	xx			x										
INVERTEBRATES:														
Shrimps (*Peneaus* spp.)				x	xx									
Squid (*Loligo* spp.)														
Crab (*Portunus pelagicus*)														
Scallop (*Amusium pleuronectes*)			xxxx											

Notes: 1.
x = 1 — 20
xx = 21 — 100
xxx = 101 — 200
xxxx = over 200

The four categories used represent the number of *Pyrodinium bahamense* var. *compressa* inside the stomach of fish and invertebrates.

2. All fishes caught by the bottom trawl from 28 August to 17 September 1983 were found to be negative for *Pyrodinium bahamense* var. *compressa*.

Table 4. Concentration of *Pyrodinium bahamense* var. *compressa* in the stomach of differen

Month (1983)	July																				
Date	24	25		27		28			31		· 1			3		4	5	8			
Fishing Track Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17				
Re-Tracking																		1	17	10	4
PELAGIC FISHES:																					
Indo-Pacific mackerel *(Rastrelliger brachysoma)*	xxx	xxxx	xxxx	xx		xxx	xx	xx	x	x	x	xx	xxx	xxx	xxxx	xxxx	xxxx	xxxx	xx	x	x
Sardines (*Sardinella* spp.)	x	xx	xxx		xx	xx	xxx				x			xx			xx	x	x	x	
Moonfish (*Mene maculata*)	x																				
Anchovies (*Stolephorus* spp.)		x									x				x						
Indian mackerel (*Rastrelliger kanagurta*)																					x
Crevalle (*Selaroides* sp.)	xx	x											x								
Frigate tuna (*Auxis* spp.)																					
Hairtail (*Trichiurus lepturus*)	x																				
Shark (*Canchariidae*)																					
Leather jacket (*Scomberoides* spp.)																					
Round scad (*Decapterus* spp.)																					
Hardtail (*Megalaspis cordyla*)																xx		xx			
DEMERSAL FISHES:																					
Threadfin bream (*Nemipterus* spp.)	x																				
Slipmouth (*Leiognathus* spp.)							xxxx									xxx	x				x
Lizard fish (*Saurida* sp.)																					
Flat fish (*Solea humilis*)																					
Goat fish (*Upeneus* spp.)	x	x											xx								
Whitings (*Sillago* spp.)	xxx																				
Croaker (*Scianidae*)	x																				
Flat fish (*Platycephalus* sp.)																					
Siganid (*Siganus* sp.)																					
Gerres (*Gerres* sp.)																			x		
Pomfret *(Apolectus)*																					
Barracuda *(Sphyraena* sp.)		x															xxxx				
Sea catfish (*Arius* sp.)																					
Threadfish (*Polyneumus* sp.)																					
Theraphon (*Theraphon* sp.)																		x			
Trigger fish (*Balistes* sp.)															x			x			
Ray *(Raja sp.)*																					
Grunt (*Pomadasys* sp.)																					
Eel (*Symbranchus* sp.)																					
Snapper (*Lutjanus* sp.)																x			x		x
Grouper (*Epinephelus* sp.)	xxx																				
Porgy (*Lethrinus* sp.)																					
Pomfret (*Stromateus* sp.)		x															x				
Glass fish (*Pentaprion longimanus*)		x																			
INVERTEBRATES:																					
Crabs (*Portunus pelagicus*)	xx																				
Shrimps (*Peneaus* sp.)	xxxx																				
Squid (*Loligo* sp.)	xxx																				
Scallop (*Amusium pleuronectes*)															xx	xxx				x	
Oyster (*Crassostrea* sp.)																					
Total Fishing Time (2,170 mins.)	30	32	42	38	30	30	30	26	27	60	58	56	65	77	30	60	48	24	54	55	47
Total Catch (6,637.24 kgs.)	26	9.5	107.7	31.63	97	129	14	27.5	33.9	88,85	122	123	67	228.05	55	341	83	0.71	17	211	262

NOTES:

1. x = 1 — 20
   xx = 21 — 100
   xxxx = 101 — 200
   xxxx = over 200

The four categories used represent the number of *Pyrodinium bahamense* var. *compressa* inside the stomach of fish and invertebrates.

2. All fishes caught by the bottom trawl from 28 August to 17 September 1983 were found to be negative for *Pyrodinium bahamense* var. *compressa*.

pecies of fish and invertebrates caught by bottom trawl from 24 July — 17 September 1983.

					August																					September	
10		11	13		14			16			18	19	21	22		23		26		27		28	31		6	10	17
					18						19	20	21					22				23					24
7	16	9	10	9	14		13	17	11	12				13	11	8	10	8		12	11		6	11	4	12	
x	xxx		xxx	xxx	xx	xx	xxx		x	xx				xx	xxxx					xxx							
		x		xx	x	x									x	xx				x							
			x					xx	x						x												
x			xxx										xxx			xxxx	x										
			x		x	x		xx	x																		
								x																			
		x			x	x		x	x																		
	xx		x					x	x	x																	
																				x							
	x																										
	xx	x																									
	xxx		xxx														xx										
60	67	115	65	60	61	60	30	15	60	60	30	32	30	60	60	30	30	30	30	35	30	21	60	15	30	30	15
03	35	160	122	102.5	5.1	61	0.5	35	43.8	350	445	108.5	142	251	225	115	105	45	1.0	264	36	3.5	205	40	7.0	137	1214.5

Table 5. Toxin bioassay results from mussel samples (extracted from the toxicity test reports of the Bureau of Research and Laboratories of the Ministry of Health, Metro Manila).

		% Mice Deaths					
Date	Collection Site	Death occurred in minutes	30 minutes to 2 hours	5 hours	17 hours	19 hours	24 hours
1983							
October	Jiabong	100	0	0	0	0	0
November	Jiabong	0	7	0	29*	0	0
8 December	Jiabong	0	0	6.6	0	0	15.9-32
		0	0	32.0**	0	0	89**
		0	0	77.7***	0	0	100***
1984							
4 January	Jiabong	0	0	0	0	90.66	78.0-100
11 January	Jiabong Mussel Farms						
	Jala	0	0	4.0	0	0	58.33
	Gran del Mar	0	0	6.6	0	0	18.57
	Green Ocean	0	0	12.0	0	0	72.72
	Vaquil	0	0	2.66	0	0	89.04
	San Pedro	0	0	4.0	0	0	84.72
	Holy Rosary	0	0	12.0	0	0	80.30
	Sto. Niño	0	0	13.3	0	0	96.92
	Maqueda Bay	0	0	12.0	0	0	87.87
23 January	Ayagao (Capiz)	0	0	0	0	0	0
	Sapian (Capiz)	0	0	0	0	0	0
5 February	Jiabong and Villaeral Mussel Farms						
	Gilbert Uy	0	0	0	0	0	4.0
	San Roque	0	0	0	0	0	2.6
	Amihanan	0	0	17.3	0	0	6.45
	Sta. Rosa I	0	0	16.0	0	0	20.6
	Sta. Rosa II	0	0	5.3	0	0	14.0
	Pacao	0	0	0	0	0	0
	Allied	0	0	0	0	0	0
	Bacarra	0	0	0	0	0	1.3
	Jia-An	0	0	6.6	0	0	15.7
	Cupido	0	0	2.6	0	0	15.7
	Vaquil	0	0	5.3	0	0	2.8

5 March	Jiabong and Villaeral Mussel Farms						
	Sto. Niño	0	0	0	0	0	0
	D' Pioneer	0	0	0	0	0	0
	Amihanan	0	0	0	0	0	0
	El Cupido	0	0	0	0	0	0
	Rabotaso	0	0	0	0	0	0
	Sta. Rosa	0	0	0	0	0	0
	Barsana	0	0	0	0	0	0
	Mahayag Achiever	0	0	0	0	0	0
	Gran del Mar	0	0	0	0	0	0
	Maqueda Bay	0	0	0	0	0	0
18 March	Jiabong and Villareal Bay Mussel Farms						
	Allied	0	0	0	0	0	0
	Amihanan	0	0	0	0	0	0
	Vaquil	0	0	0	0	0	0
	D'Pioneer	0	0	0	0	0	0
	Gran del Mar	0	0	0	0	0	0
	Maqueda Bay	0	0	0	0	0	0
	Pacao	0	0	0	0	0	0
	Sto. Niño	0	0	0	0	0	0
	Sta. Rosa	0	0	0	0	0	0
	San Rafael	0	0	0	0	0	0
	D' Alfa	0	0	0	0	0	0
	Efren	0	0	0	0	0	0
	D' Family	0	0	0	0	0	0
	Neptune	0	0	0	0	0	0
	Percy	0	0	0	0	0	0
	Tony	0	0	0	0	0	0
	Tulay	0	0	0	0	0	0
	Villahanon	0	0	0	0	0	0

0 — animal did not die

* — percentage of death from the remaining 186 mice which manifested illness by immobility (staying at one corner)

** — concentration of the inoculum doubled

*** — concentration of inoculum trebled

pelagic species. The Indo-Pacific mackerel still contained the most. The other food fish examined (both pelagic and demersal fish) were all found to contain low numbers of cells. Demersal species also contained *Pyrodinium* because Maqueda Bay and Villareal Bay are very shallow and *Pyrodinium* were observed to be present in the entire water column.

The scallops (*Amusium pleuronectes*), which were sampled only once in Maqueda Bay, were found to contain more than 200 *Pyrodinium* cells.

It can be seen from Table 3 that all fish caught in Maqueda bay and Villareal Bay within the period from 23 August — 16 September 1983 were found to be negative for *Pyrodinium*, which suggests that during this period the areas was already free from the toxic dinoflagellate.

It can also be seen from Table 4 that all fish caught by bottom trawl within the period from 28 August — 17 September 1983 were found to be negative for *Pyrodinium* and it can also be assumed that during this period the area had been cleared of the toxic dinoflagellate.

From the foregoing observations, it can be stated that Maqueda Bay and Villareal Bay appeared to have been cleared of the dinoflagellate first, as shown by the earlier disappearance of *Pyrodinium* in the gut of fish from these areas.

Unfortunately, no attempt was made to determine the toxicity of these contaminated seafoods due to a lack of facilities and expertise on board. However, the research vessel *Sardinella* collected fish samples in early August by miniature bottom trawl in Maqueda Bay and by purse seine in Samar Sea. The toxicity tests conducted at the UPVCF Department of Fish Processing Technology showed that fish samples from Samar Sea were found to be nontoxic (Hermes 1983).

Conversely, some fishes in Brunei, such as chub mackerels and sardines, were found to be toxic, with a toxin content ranging from 99-478 MU/100 g of whole fish. These species have also caused paralytic shellfish poisoning, but no fatalities were recorded (Beales 1976).

In the Philippines, there was no evidence of massive mortalities of fish and other aquatic animals during the red-tide period although there were some reports of a scattering of a few hundred smaller fish species along the beaches and in the harbour area during the early part of the event. Subsequent underwater observations using SCUBA revealed that no damage has been inflicted either to the fish or invertebrates, such as mussels and other shellfish, crustaceans, and corals.

Examination of the Gut Content of Mussels

During the early part of the monitoring program, a team of biologists from BFAR Central and Regional Offices was formed to concentrate on monitoring mussels in Maqueda Bay and Villareal Bay. The monitoring started on 23 August. At that time, these areas had already been cleared of the toxic dinoflagellate but monitoring continued on a biweekly basis (every Monday and Friday) by collecting samples from a number of mussel farms in the area. The gut of the mussels sampled was dissected and examined for the presence of the dinoflagellate. Counting and recording of the dinoflagellate in the gut of mussels was then carried out.

On 23 August, the mussel samples from Maqueda Bay area were found to be positive (101-200 *Pyrodinium* cells per shellfish) and those taken from Villareal Bay area were also positive (21-100 *Pyrodinium* cells). On 27 August, Maqueda Bay area became positive (21-100 *Pyrodinium* cells) and in Villareal Bay area the number of cells per shellfish was reduced (1-20 *Pyrodinium* cells). On 31 August, samples from Maqueda Bay area were positive (1-20 *Pyrodinium* cells) and samples from Villareal Bay become negative.

Some of the mussel samples taken from Maqueda Bay area still continued to be positive with *Pyrodinium* (1-10 cells) until 19 September.

The same results were obtained from samples collected on 23, 26, and 30 September on 3, 7, and 10 October. Even when mussels were still positive (1-20 *Pyrodinium* cells), BFAR technicians and some mussel farmers started eating mussels, but no paralytic shellfish poisoning or any ill effects were noted.

In spite of the above findings, the local ban on shellfish was extended because studies elsewhere showed that the toxins (or toxic chemical material) remained in the shellfish tissue for about 2 months after the complete disappearance of the causative dinoflagellate in the water. Previous studies reported that mussels accumulate toxins mainly in the hepatopancreas (the so-called digestive or dark gland).

Bioassay Test

The results of the toxin bioassays are shown in Table 5, as extracted from the toxicity test reports of the Bureau of Research and Laboratories of the Ministry of Health. It is difficult to interpret these data, however, because they only provide information on the presence or absence of the toxins. Use of the standard mouse bioassay is important, therefore, because it provides data on toxocity levels and allows comparisons to be made with data from other countries studying the same problem. It was observed in the test in October 1983 (Table 5) that the mussels were still highly toxic when 100% of the mice tested died within a few minutes after injection of the mussel extract. In November, 7% of the mice died within 1 hour, whereas 186 mice (93%) manifested "illness" by immobility. Twenty-nine percent of this number died after 17 hours.

In December, 6.6% of deaths occurred 5 hours after injection. However, the percentage of deaths varied from 15.9-32% after 24 hours. When the concentration of the inoculum was doubled, 32% of the mice died in 5 hours and practically all of the remaining mice died after 24 hours. When the concentration was tripled, 77.7% of the mice died within 5 hours and no survivors were recorded after 24 hours.

The tests revealed that the concentration of the toxin diminished after December. However, the samples collected on 4 January 1984 showed 90% death within 19 hours and from 78-100% after 24 hours.

The collection and bioassay tests were continued and the toxins were still detected in the mussel samples. On 11 January, 2.66-13.3% of the deaths in mice occurred after 5 hours and 18.57-96.92% occurred after 24 hours. On 5 February, 0-17.3% of deaths in mice occurred after 5 hours and from 0-20.6% occurred after 24 hours. By 5 March, samples were found to be negative for the toxin and the ban on mussels was lifted on 15 March 1984.

Follow-up sampling and bioassay tests were conducted on 18 March that showed once again that the inoculum had no effect on the mice used.

The data from bioassay tests showed that green mussels or *Perna viridis* remained toxic for about 6.5 months after the complete disappearance of the toxic dinoflagellate in the water or about 5.5. months after the complete disappearance of the dinoflagellate in the gut of mussels.

Paralytic Shellfish Poisoning

Paralytic shellfish poisoning in the Philippines was probably caused by the same type of toxins involved in cases reported in other tropical and temperate countries, *Pyrodinium bahamense* var. *compressa* being the primary source of the toxins. Harada et al. (1982) identified the toxic substances of this species as gonyautoxin V, neosaxitoxin, saxitoxin, and two unknown toxins coded tentatively as PBT_1 and PBT_2.

During the outbreak of red tide in the Philippines, the symptoms manifested by the patients affected by PSP conformed well with those described in the works of Halstead (1965), Wills (1966), Worth et al. (1975), Beales (1976), and Hashimoto (1979). Generally, the victimcs complained of a tingling sensation of the lips, tongue, mouth, face, and jaw within 30 min after the ingestion of the contaminated shellfish. The sensation progressed to the arms and legs with a feeling of lightness, numbness, and difficulty of movement and breathing. Practically all fatalities suffered nausea and vomiting, and death generally occurred within 17 hours after ingestion of the contaminated seafood.

Table 6 shows the number of reported illnesses and deaths caused by paralytic shellfish poisoning and Fig. 2 shows the areas where cases of poisoning have been reported. As mentioned earlier, some 278 cases with 21 deaths have been recorded. The actual number of victims may be higher because it is the usual practice in remote areas and neighbouring islands not to report incidences of poisoning.

The first deaths attributed to PSP, which occurred before the discovery of the red tide, occurred in the early morning of 21 June, involving a family of eight in Catbalogan, Samar. Two boys, aged 3 and 7 years, of the five children of the family died from respiratory paralysis 11 and 10 hours, respectively, after eating boiled mussels collected from Jiabong. Six other members of the family were also affected and sent to the hospital for treatment. The victims experienced vomiting and body weakness a few hours after supper. Twelve other families in the neighbourhood who also had mussels for their evening meal suffered the same symptoms experienced by the first affected family.

Between the latter part of June and first week of July, more and more cases of mussel poisoning were brought to the hospitals daily. During this period, three deaths attributed to mussel poisoning were reported in Tacloban City.

The incidence of paralytic shellfish poisoning increased after typhoon "Bebeng" hit Samar from 13-15 July. During the typhoon, about 100 pieces of bamboo poles used in mussel culture in Maqueda Bay and Villareal Bay were uprooted, and drifted onto the beaches of western and northern Samar, Sorsogon, and Masbate. Coastal residents who were not aware of the danger feasted on the mussels, which were still attached to the bamboo poles. As a result, as many as 30 poisoning victims were admitted to the hospitals in a single day in Catbalogan, resulting in the death of a 30-year old female from Catbalogan, Samar.

In San Antonio Island, northern Samar, 19 persons were reported to have suffered from paralytic shellfish poisoning following the ingestion of mussels collected from drifting bamboo poles. Of this number, only one person died.

In late July, a 6-year old girl from Barangay Quezon, Bulan, Sorsogon, died and 48 cases of paralytic shellfish poisoning were admitted to the hospital following the ingestion of the same shellfish species.

Table 6. Number of reported illness and deaths caused by paralytic shellfish poisoning (PSP) in the Philippines from 21 June — 23 September 1983.

Location	Number of Illness	Number of Deaths	Fatalities (Age)	Date 1983	Responsibile	Source/Origin
Eastern Central Visayas						
Western Samar						
Catbalogan	95	5	Boy (3)	21 June	Green bay mussels (*Perna viridis*)	Maqueda Bay
			Boy (7)	21 June	Green bay mussels (*Perna viridis*)	Maqueda Bay
			Female Adult (33)	12 July	Green bay mussels (*Perna viridis*)	Maqueda Bay
			Female Adult (30)	16 July	Green bay mussels (*Perna viridis*)	Maqueda Bay
			Girl (8)	31 August	Giant Clam (*Tridacna* sp.)	Approach of Maqueda Bay
Villareal	19	0				
Barangay Borabod (Villareal)	7	2	Boy (3)	1 September	Scallop (*Amusium pleuronectes*)	Near Daram Island (Southern Samar Sea)
			Boy (11)	1 September	Scallop	Near Daram Island (Southern Samar Sea
Northern Leyte						
Tacloban	10	3	*	late June	Green bay mussel	Maqueda Bay
Palo	1	1	Girl (8)	12 July	Green bay mussel	Villareal Bay
Carigara	16	1	Female Adult (44)	8 Aug.	Squid (*Loligo* sp.)	Capoocan (Carigara Bay)
Northern Samar						
San Antonio Island	19	1	*	sometime between 17-23 July	Green bay mussel	Maqueda Bay
Catarman	9	0				
Western Central Visayas						
Northern Panay						
Barangay Barra, Capiz	7	1	Boy (5 1/2)	23 Sept.	Scallop	Olotayan Island (northern Panay)
Masbate						
Monreal, Ticao Island	25	2	Boy (4)	4 Aug.	Green bay mussel	Maqueda Bay
			Girl (8)	4 Aug.	Green bay mussels	Maqueda Bay
Southern Luzon						
Sorsogon						
Barangay Quezon, Bulan	49	1	Girl (6)	late July	Green bay mussel	Maqueda Bay
Juban	0	1	Girl (3)	10 Sept.	Black-lip pearl oyster (*Pinctada margaritifera*)	Innermost part of Sorsogon Bay
Camarines Norte						
Labo	0	2	*	early July	Green bay mussel	Maqueda Bay
Central Luzon						
Angeles City	0	1	*	early July	Green bay mussels	Maqueda Bay
Total reported cases of PSP: 278	257	21				

* No data available

In Monreal, Ticao Island, Masbate, 27 persons were admitted to the hospital and diagnosed as suffering from paralytic shellfish poisoning following the ingestion of mussels collected from drifting bamboo poles. Of this number, two children died.

On 31 August, an 8-year old girl from Barangay Mercedes, Catbalogan, Samar, died 9 hours after eating giant clams (*Tridacna* sp.) and on 1 September all members of a family of nine from Barangay Borabod, Villareal, were admitted to hospital with symptoms of paralytic shellfish poisoning. Two of the children (both boys), aged 3 and 11 years, who ate scallops (*Amusium pleuronectes*) caught in the waters north of Carigara Bay by baby trawlers died after 7 and 10 hours respectively.

On 10 September, a 3-year old girl from Juban, Sorsogon, died after eating black-lip pearl oysters (*Pinctada margaritifera*) collected from the innermost part of Sorsogon Bay and on 23 September at Barangay Barra, Capiz, in northern Panay, a family of eight were admitted to the hospital due to paralytic shellfish poisoning symptoms following the ingestion of scallops collected from the surrounding waters of Olotayan Island. One of the children (a boy), aged 5.5 years, died, whereas all other members of the family completely recovered after 30 hours.

It should be noted that the most toxic shellfish were the green bay mussels (*Perna viridis*), and to a lesser extent the scallops (*Amusium pleuronectes*). The juveniles of pearl oysters (*Pinctada margaritifera*) and giant clams (*Tridacna* sp.) were also implicated in some cases. It is interesting to note that a brachiopod (*Lingula anatina*), locally called "balay" and used as food in the Philippines, was reported to be toxic in the innermost part of Sorsogon Bay. Crustacean species such as crabs (*Portunus* spp.) and shrimps (*Penaeids*) have rarely been reported to be toxic. At least one fatal case had been attributed to the ingestion of squid (*Loligo* sp.).

Based on reported cases, the most hazardous shellfish in North America and Canada are mussels, clams, and scallops of various species, whereas clams (*Anadara maculosa*) and oysters (*Crassostrea echinata*) have been reported as the main source of paralytic shellfish poisoning in Papua New Guinea (Worth et al. 1975). In Sabah, most cases, involving seven fatalities, have also been attributed to clams (Beales 1976; Maclean 1979).

A number of people were admitted to hospital in Samar during the early part of July due to mild paralytic shellfish poisoning symptoms that were attributed to the ingestion of various species of fish. The food fish involved are mainly pelagic species such as mackerels (*Rastrelliger* spp.), sardines (*Sardinella* spp.), anchovies (*Stolephorus* spp.), roundscads (*Decapterus* spp.), mullets (*Mugil* sp.), crevalle (*Selaroides* sp.), whitings (*Sillago* spp.), milkfish (*Chanos chanos*), and slipmouth (*Leiognathus* spp.). Incidentally, these fish contained the most *Pyrodinium* cells (Tables 3 and 4). A number of illnesses due to the consumption of some of these fish species have also been reported in Papua New Guinea and Brunei (Beales 1976; Maclean 1979).

The above intoxication is due to the accumulation by fish of the dinoflagellate toxins, either directly or via the food chain. This intoxication is believed to occur as a result of the ingestion by man of the toxic contents of fish entrails or gills as it is a common practice in Samar and adjacent areas to cook and consume the fish, particularly those mentioned above, with the internal organs still intact. Usually, the fish are cooked with vinegar and in most of the reported cases the patients have eaten fish and shellfish cooked with vinegar. This observation conforms with the findings of Hashimoto (1979) that the toxin of dinoflagellates is stable in an acidic medium and unstable in an alkaline medium.

In one experiment, part of the 6637 kg of fish and invertebrates (including those found earlier to be most contaminated by the dinoflagellate) caught by the research vessel *Researcher* direct from the red tide areas (Table 4 and Fig. 6) were served as food for the 33 officers and crew of the vessel, 15 technical and support staff, 53 shipboard trainees, and 3 instructors from the Fishermen's Training Center. As expected, nobody suffered paralytic shellfish poisoning.

Based on the above findings, BFAR assured the consuming public that all kinds of fish are safe to eat provided that necessary precautions in their preparation are observed, i.e., the fish must be fresh and the gills, viscera, and contents of the abdominal cavity should be removed, and the fish washed thoroughly, preferably in running water.

Portions of the catch of the research vessel were distributed to the people of Catbalogan and Tacloban to allay fears among the general public that the fish were unsafe for human consumption. As a result of the experiment, a ban was not imposed on fish. Shipment of fresh and dried fish, crabs, and shrimps from the affected areas to Manila and adjacent areas was never stopped. Nevertheless, many of the people in the affected areas and neighbouring places refrained from eating fish for about 1 month. Fishing activities consequently dropped. It was only in early August when the people of Samar and Leyte started to eat fish again as a result of the campaign by BFAR, Ministry of Health, and local government authorities to bring back the confidence of the consuming public with regard to eating fish.

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