Contributions to the Understanding of the Bloom Dynamics of *Pyrodinium bahamense* var. *compressum:* A Toxic Red Tide Causative Organism

Rhodora V. Azanza
Marine Science Institute, College of Science
University of the Philippines, Diliman, Quezon City 1101
E-mail: rhod@msi01.cs.upd.edu.ph

ABSTRACT

Pyrodinium bahamense var. *compressum* has been the primary organism responsible for the toxic red tide episodes which have been recurring in Manila Bay, Philippines since 1988. The life history of the species has been elucidated through encystment-excystment studies in vitro, from which its obligatory dormancy has been demonstrated. Cyst-mapping studies have shown that this life stage of the organism occurs relatively higher in the Bataan and Cavite areas where the greater number of red tide occurrences have also been reported. A cyst-based model has been developed as an initial step in understanding the role of physical processes in the development, occurrence/recurrence, and ultimately, advancement of *Pyrodinium* red tides in Manila Bay.

To help mitigate or prevent the negative impacts of toxic red tides, particularly in Manila Bay, regular closure of shellfish harvest in areas affected by *Pyrodinium* bloom should be considered, based on long term monitoring and research data sets.

INTRODUCTION

Pyrodinium bahamense var. *compressum* toxic red tides have been recorded in the Philippines since 1983 when it was first observed in the Samar-Leyte areas. As of 1997, this tropical dinoflagellate has bloomed in several bays (including Manila Bay) in the Philippines and in other countries in the Indo-Pacific area (Corrales and Maclean 1995). Guatemala (Rosales-Loessener 1989), Mexico (Orellana-Cepeda et al. 1997), and Tanzania (Abubakar et al. 1997) have likewise experienced blooms of this organism.

Pyrodinium bahamense was first described from the Bahamas in the Atlantic Ocean by Plate (1906). After reexamining the morphology of the vegetative cells, Steidinger et al. (1980) recognized two varieties, var. *bahamense* and var. *compressum.* Balech (1985) thinks that both varieties are morphologically similar – they integrate and the separation is not needed. *Pyrodinium bahamense* var. *compressum*, however, forms a chain, and in this configuration the cells appear flattened anterior-posteriorly. Variety *compressum* was first discovered in the Red Sea, and all toxic red tides of the species to date has been due to this variety. *Pyrodinium bahamense* var. *bahamense* has never been reported as toxic.

This paper presents a summary of recent contributions on the biology and ecology of the organism from studies conducted in both the field and the laboratory by the Marine Science Institute of the University of the Philippines, Diliman. Emphasis is given on the life history of *Pyrodinium bahamense* var. *compressum* (Fig. 1) and its role in the organism's bloom dynamics.

LIFE HISTORY OF *PYRODINIUM BAHAMENSE* VAR. *COMPRESSUM*

There are gaps in the knowledge of the life history of *Pyrodinium bahamense* (Wall and Dale 1969; Matsuoka 1989;

Key words: *Pyrodinium*, red tides, Manila Bay, paralytic shellfish poisoning

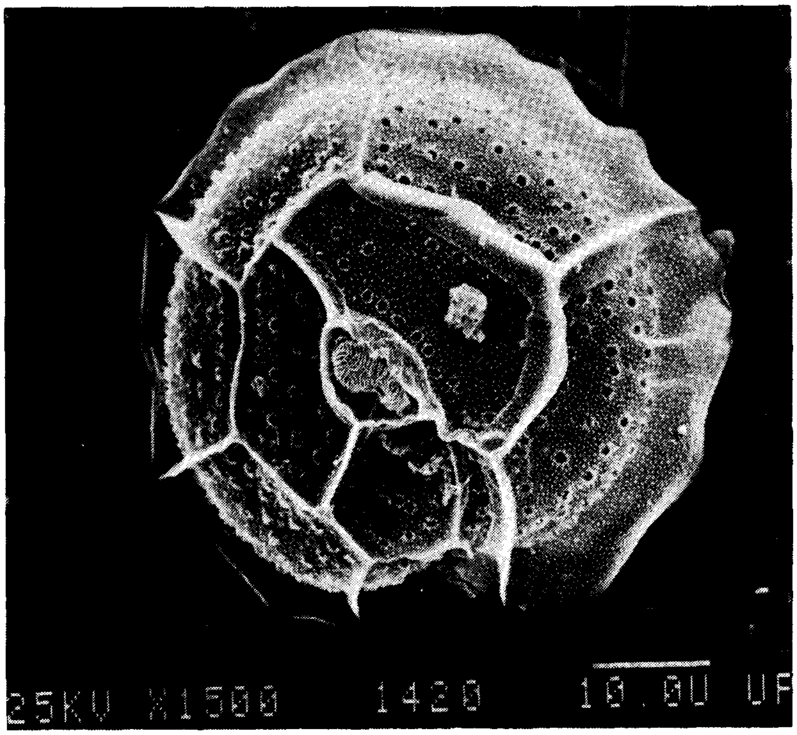

Fig. 1. Scanning Electron Micrograph (SEM) of *Pyrodinium bahamense* var. *compressum*.

Taylor & Fukuyo 1989). The following are the highlights of the results of some pioneering collaborative studies undertaken by the author to help fill these gaps (Azanza-Corrales and Hall 1993; Corrales 1995; Corrales and Martin 1995; Corrales et al. 1995; Usup and Azanza in press).

P. bahamense var. *compressum* form "blooms" in the water column with the cell division (binary fission) of their haploid (N) vegetative stage. These blooms could occur in laboratory culture and in nature if the conditions are favorable. A growth rate of at least one cell division per three days has been established. Some conditions conducive for growth (at a rate of .30/day), as gathered in the laboratory, are the following: salinity of 28-31 ppt, temperature of 28+/-2°C, light intensity of 150-250 $um^{-1}s^{-1}$, and 12L:12D photoperiod (Azanza-Corrales and Hall 1993).

This dinoflagellate produces a planozygote (2N) which is a result of the union of gametes produced usually in the middle or towards the end of the bloom. These motile planozygotes are transformed into non-motile hypnozygotes that are lodged in the sediment of the affected bays. The latter are resistant and could be deposited deeper in the sediment without being damaged. Cysts which are found in the upper part of the sediment and presumably have undergone the resting period of about 3 to 4 months (Corrales et al. 1995), depending on the environmental conditions, could then germinate and serve as the inoculum for the next bloom by first undergoing meiosis, and subsequently, several rounds of binary fission. Temporary cysts different in physiology and morphology from the hypnozygotes could also be formed when conditions are not suitable for growth. These cysts can revert back to the vegetative cell stage that can then undertake division when conditions become favorable (Fig.2).

Fig. 2. Life cycle of *Pyrodinium bahamense* var. *compressum*

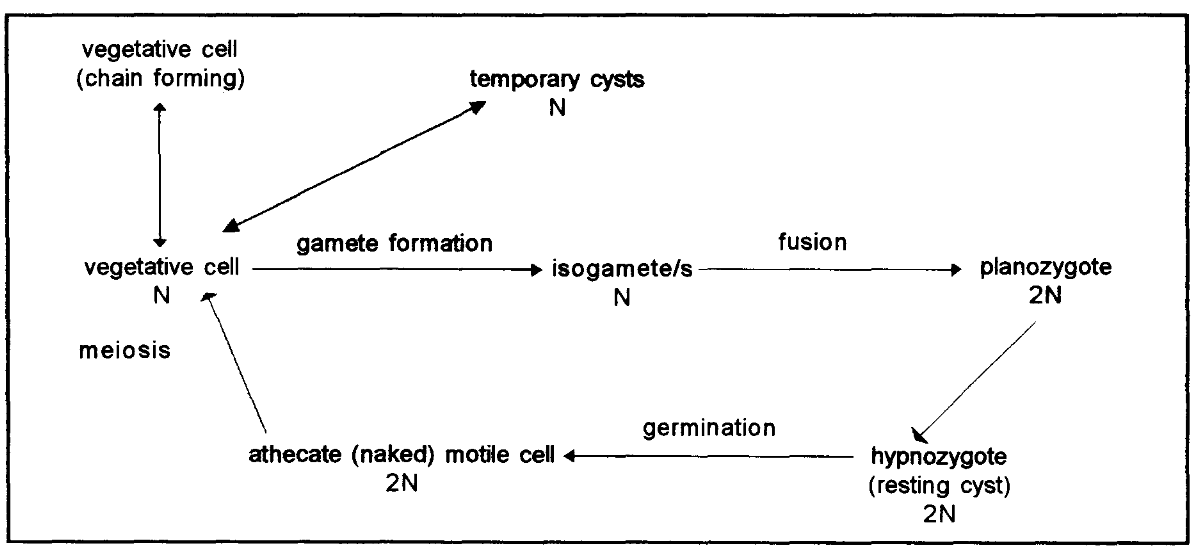

Table 1. *Pyrodinium* cyst density in Manila Bay, Philippines from April 1993 to May 1994.

Month	Bataan	Cañacao	Parañaque	Ternate	Pampanga	Bulacan
Apr 1993	212	256	58	7	66	15
May	366	205	37	15	15	0
Jun	322	183	44	58	44	15
Jul	380	168	58	1	7	7
Aug	439	190	29	77	0	22
Sep	110	249	58	51	0	37
Oct	175	256	51	37	0	22
Nov	22	73	22	44	0	7
Dec	44	73	51	7	15	15
Jan 1994	29	15	22	7	7	22
Feb	51	66	15	0	22	0
Mar	29	22	44	0	7	0
Apr	124	22	7	0	7	0
May	161	102	37	0	7	0
Ave.	176	134	38	22	14	11
(SD)	146	91	17	26	19	11
(SE)	39	24	5	7	5	3

Unit: cyst/ml of wet sediment
Source of data: Corrales and Crisostomo 1996

PYRODINIUM CYST DISTRIBUTION IN THE MANILA BAY, PHILIPPINES

The results of a research conducted in 1993-1994 (Corrales and Crisostomo 1996) showed that *Pyrodinium* cysts were present in six coastal stations in the Manila Bay, where the blooms of the organism have been recurring since 1987. *P. bahamense* mean cyst densities exhibited a variable spatio-temporal pattern. Bataan was the highest, with 176+/-38 cyst/ml; Cañiacao, Cavite, with 134+/-24 cyst/ml, was second; Parañaque, with 38+/-4 cyst/ml, was third; Ternate, Cavite was fourth, with 21+/-7 cyst/ml; the Pampanga Bay, with 14+/-5 cyst/ml, was fifth; and the lowest, with 11+/-3 cyst/ml was Bulacan. Temporal variations in the cyst densities were in phase, although amplitudes of the variability were different. Higher counts have been recorded during the months of April to August; and lowest counts, from November to February (Table 1).

Pyrodinium red tides in these coastal areas of the Bay could therefore be related to the abundance of cysts. The presence of cysts almost the whole year round suggests that they have been deposited from blooms in the overlying or adjacent waters and they represent possible inoculum for these waters.

The following are the practical considerations from these research results: (1) shellfish from these affected areas could be vectors for transfer of cysts, hence, should not be used as seeding materials for culture in other sites; (2) these sites should be closely monitored for shellfish PSP toxicity; and (3) other sites in the Philippines should be studied for presence of *Pyrodinium* and other toxic dinoflagellate cysts.

DEVELOPMENT OF A CYST-BASED MODEL FOR THE *PYRODINIUM* RED TIDES IN MANILA BAY, PHILIPPINES

A descriptive model was prepared as an initial step in understanding the role of physical processes in the development, occurrence/recurrence, and, ultimately, advancement of *Pyrodinium* red tides in the Manila Bay. Variations in the *P. bahamense* cells and cysts were evaluated for one area (Bataan), based on changes in water column stratification as influenced by variations in the surface forcing parameters (wind stress) (Villanoy et al. 1996).

P. bahamense blooms in Manila Bay occur almost regularly from May to September, the Southwest monsoon months (Bajarias and Relox 1996). The concentration of cells and cysts is lowest during the colder months of November to February, the period of the Northeast monsoon (Corrales and Crisostomo 1996).

During the dormant stage (cyst) in the sediment, the same physical mechanisms which control sediment resuspension may be utilized by the organism to move about between the sediments and the water column. The low cyst densities during the northeast monsoon months when the strongest vertical mixing takes place may be a result of the resuspension of sediments and cysts (Villanoy et al. 1996). It could be noted that during this period the water temperature is quite low, and nutrients, such as nitrogen, are less available (Velasquez et al. 1996), thus germination and growth are not favored.

During periods of weak vertical mixing or turbulence, as in the months of the southwest monsoon, cyst densities in the sediment are high due to decreased resuspension and/or increased deposition from the activities of the vegetative cells in the water column. Weak turbulent mixing will promote settling of cysts, provided the settling velocity is greater than the turbulent velocities that will tend to keep the cysts in suspension. It is also during the southwest monsoon that growth, apparently due to availability of nutrients and favorable temperature, is favored (Velasquez et al. 1996). Fukuyo (personal communication), however, believes that germination of *Pyrodinium* cysts can occur in the surface of sediments even without resuspension, and the resulting vegetative cells can move up the water column by means of their flagella.

In 1997 (an El Niño year), the pattern for *Pyrodinium* cell density/occurrence in the bay observed from 1994 to 1997 was not experienced in Manila Bay (Azanza et al. 1997). This shows the major role of the weather system in regulating the environment and consequently, the bloom of this organism. It has been hypothesized earlier that red tides, including those caused by *Pyrodinium*, could increase in intensity and duration during or after an El Niño phenomenon (Maclean 1989; Usup and Azanza in press). However, these claims need to be further substantiated.

SUMMARY AND RECOMMENDATIONS

Pyrodinium bahamense var. *compressum* seems to undertake a life strategy suited quite well for many coastal areas in Manila Bay. The organism's vegetative cell stage usually undertakes division to produce the blooms/red tides in the water column during the months of the southwest monsoon. On the other hand, physico-chemical conditions during the northeast monsoon favor the dormancy of cysts formed from previous blooms and hence, red tides of the organisms are generally not expected or experienced. This pattern could, however, be disrupted during major climatological changes, such as an El Niño year. Areas where there are higher concentrations of their cysts are the most prone to *Pyrodinium* blooms.

To help mitigate or prevent the negative impacts of *Pyrodinium* red tides, particularly in Manila Bay, yearly or regular periods of closure for harvest in areas affected by *Pyrodinium* red tides, based on long term monitoring and research data sets, particularly the toxicity of shellfish, should be considered. It should be remembered, however, that toxicity of the molluscan shellfish in the affected bays would vary not only with the density of the causative organism, but also with the shellfish contamination and detoxification rates and the hydrological conditions in the area. Closure and opening of harvest areas in the bay should be done per subdivision, i.e., areas in Bataan, Cavite, etc., based again on the analysis of toxicity of shellfish. Basic and applied research should be continued particularly in areas beneficial to the affected sectors, such as the producers and consumers of shellfish.

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