Phytoplankton community occurring in the southern coast of Myanmar especially focusing on potentially harmful dinoflagellates

Myanmar has been one of the world’s top ten countries for capture fisheries. In particular, marine capture fisheries in Myanmar have constantly increased since the late 1990s to recent year. This constant growth in marine fisheries relies on the high productivity of the coastal environment. Meanwhile, concerns have been raised as to whether such growing fishing pressure is within the sustainable level of the productivity in this area. At the same time, coastal development in Myanmar is proceeding at a rapid pace; marine finfish and shrimp culture farms, and many fisheries industries are operating in the coastal areas. These coastal developments, along with the drastic economic progress in Myanmar, might lead to eutrophication of coastal areas and subsequent harmful algal bloom (HAB) events. For estimating fish productivities and risks of HAB, phytoplankton surveys are essential. However, despite such concerns, very few phytoplankton studies from the Myanmar coasts have been reported. Therefore, to understand the phytoplankton community structure in Myanmar coast, field surveys have been carried out in the foremost marine fishery area, Tanintharyi coastal region in Myanmar. Since the southwest monsoon (rainy season; June to October) is the main source of climatic variation in Myanmar, the surveys had been conducted before and after the rainy season. Field surveys were carried out thrice: May 2010, December 2010 and March 2012. The first survey was carried out around the Mali and Kadan Islands, and the second and third surveys were carried out around the Kadan Island. Based on the results of these surveys, detail taxonomic lists of diatoms and dinoflagellates were established, and their seasonal occurrences were discussed in relation to the oceanographic structures. This study comprises not only the field surveys and also the laboratory culture experiments using some harmful dinoflagellate strains isolated from the corresponding area. (Chapter 1)

Chapter 2. Phytoplankton occurrences in southern Myanmar coast in pre- and post-monsoon seasons

Sixty-four species of diatoms were listed, including 57 species in the December survey and 52 species in the March survey. In the December survey, massive diatoms blooms were detected at St.2 with high density of *Bacteriastrum* spp. (50,500 cells/L) and *Chaetoceros* spp. (40,500 cells/L) as dominant species. The massive occurrences of diverse diatoms species in this season can be explained by; the flooding of nutrient-rich terrestrial water into the coastal areas in prolonged rainy weather during the southwest monsoon, and drift of these terrestrial waters to the entire coastal area due to the shift to the northeast wind. Total 100 species of dinoflagellates comprising 57 species in the May survey, 26 species in the December survey and 67 species in the March survey were listed. These diverse dinoflagellate occurrences in the May and March surveys were probably due to the oligotrophic environment in the late dry season. In the March survey, red-tide of
*Prorocentrum rhathymum* was detected near the St.6, the northeast part of Kadan Island, and this species was also detected at the same area of May survey. The oceanic species such as *Ornithocercus* spp., *Podolampas bipes*, and *O. magnificus* were found together with the neritic species (e.g. *Prorocentrum* spp., *Gonyaulax* spp. and *Alexandrium tamiyavanichii*) in the May and March surveys. The simultaneous occurrence of such oceanic and neritic species explained that the characters of the oceanic waters mixing with the coastal waters in this coastal area. In this study, 44 dinoflagellate cyst types including 12 autotrophic and 32 heterotrophic types were recorded. High diversities of heterotrophic cysts were characteristic of the Myanmar coast.

**Chapter 3. Occurrences of potentially harmful dinoflagellates**

A total of 21 species of potentially harmful dinoflagellates were identified in the previous chapter. Among them, 10 species were reexamined with detail morphological observation and DNA analyses. In regard to red-tide forming species, *Prorocentrum micans*, *P. shikokuense*, *P. sigmoides*, *Ceratium fusus*, *C*. *furca*, *Alexandrium affine*, *Gonyaulax polygramma*, *Scrippsiella troichoidea* and *Noctiluca scintillans* were confirmed. In regard to the shellfish poisoning causative species, paralytic shellfish poisoning (PSP) causative species such as *Alexandrium tamiyavanichii* and *Gymnodinium catenatum*, yessotoxins (YTXs) production species of *Gonyaulax spinifera* and *Lingulodinium polyedrum*, diarrhetic shellfish poisoning (DSP) causative species of *Dinophysis caudata*, *D. miles*, *D. rotundata*, *D. infundibulus*, and potentially okadaic acid (OA) producing species of *Prorocentrum rhathymum* were confirmed. They mainly occurred in the May and March surveys, and this late dry season should be regarded as to potentially cause HAB events.

**Chapter 4. Growth characters of three red-tide forming species (*Prorocentrum rhathymum*, *P. shikokuense*, *Alexandrium affine*) at different temperatures**

This study is based on the finding of red-tide at St. 6 in the March survey. This red-tide is noteworthy by comprising three different harmful dinoflagellate species shown in the chapter title. To investigate possibility of such red-tide extension in the corresponding area, it is important to understand their growth physiology. Temperature experiments were carried out at four different temperature regimes (15°C, 20°C, 25°C, 30°C). The results of *A. affine* exhibited the low tolerant to low temperature (15°C) hence it was more adapted to tropical environment. The optimal growth (0.46 day⁻¹) was occurred at temperatures 20°C and 25°C. In compare with other studies, the results of *A. affine* showed more tolerant of temperature regimes than some other *Alexandrium* species. *P. rhathymum* and *P. shikokuense* exhibited the strong tolerant to the temperature ranges from 15°C to 30°C. The optimal growth of *P. rhathymum* (0.62 day⁻¹) was occurred at temperature 25°C. This result agrees with a finding of the red-tide of *P. rhathymum* reported from the Gulf of California. The optimal growth rate of *P. shikokuense* (0.87 day⁻¹) was occurred at temperature 15°C. The result of optimum temperature showed significant difference of *P. doghaiense* (junior synonym of *P. shikokuense*) in the East China Sea, regardless to the genetic identity of these local strains.

**Chapter 5. Occurrence of dinoflagellate cysts in the surface sediment, and finding of toxic *Gymnodinium catenatum* and *Alexandrium tamiyavanichii* from coastal water of Selangor, Malay Peninsula**

Selangor district, west coast of Peninsula Malaysia is an important area for blood cockle culture industry. This coastal area faces to the Strait of Malacca and leads to the southern Andaman Sea, connecting to Myanmar coast. In regard to HAB expansion from or to the Myanmar coast, and to a future model of HAB risk management in shellfish culture fields, both phytoplankton and cysts of harmful dinoflagellate species were observed in this study, as a multi-nations cooperative research. Total of 43 cysts types comprising 10 autotrophic and 33 heterotrophic types were found. In the plankton and cyst samples, PSP causative species of *Gymnodinium catenatum* was detected. The cysts of *G. catenatum* were detected at 11 stations in the September and 8 stations in the December survey. The average density of *G. catenatum* cyst was high (<0.6 cysts g⁻¹ dry weight sediment) in St. A (Northern part of Selangor area) to comparing with other stations. In total dinoflagellate cyst assemblage, *G. catenatum* cyst is a minor component and its density is still low. This indicates yet scarce
occurrence of plankton cell *G. catenatum* in the Selangor coast at the moment. The occurrence of another PSP causative species, *A. tamiyavanichii* was not confirmed in the cyst surveys, however, their plankton form was found. The detection of toxic dinoflagellates, *G. catenatum* and *A. tamiyavanichii* from the cockle culture grounds suggests the PSP risks present in Selangor district. In addition, the wide distribution of *G. catenatum* cysts may also suggest diffusion risks of *G. catenatum* cysts by the fisheries activity.

In this study, detail lists of diatom and dinoflagellate species were firstly established based on three surveys conducted in the southern Myanmar coast. They were based on the latest taxonomic criteria and expected to contribute future planktological study in the area. The results are surmised as; diverse occurrence of diatoms after the rainy season (southwest monsoon) due to the extensive terrestrial water inflow to the ocean, and followed by luxuriant occurrence of dinoflagellates in the late dry season. In the view of dinoflagellate diversity, it is interesting that typical ocean species and neritic species can occur simultaneously in the coast. This can be explained by a significant extension of the Indian Ocean water driven by southwest monsoon. Extension and mixture of both rich terrestrial water and oceanic water would largely contribute high ocean productivity in the Myanmar coast.

In the same time, rather diverse occurrence of harmful dinoflagellate species were found: they comprised several red-tide forming species and toxic species of PSP and DSP. Actually, a red-tide phenomenon was encountered in the March survey, and the tide consisted of three potentially harmful species, namely *A. affine*, a potentially toxic species, *P. rhathymum*, a fish-kill species, and *P. shikokuense*, a species forming notable red-tide in the East China Sea. The culture experiment using these culture strains revealed they exhibited rather high cell division under a broad range of temperature, and agreement or disagreement in the temperature tolerance of other localities in the red-tide affected areas, indicating similar awareness (e.g. routine monitoring or evaluation of fish kill) will be needed but considered local strain character.

In the potential risks due to dinoflagellates, PSP risk should be mostly regarded. There were certainly notorious species of *A. tamiyavanichii* and *G. catenatum* in the area, and people consume shellfish at there. They were also revealed to distribute first time in the near shellfish culture ground in Selangor area (west coast of Peninsular Malaysia), and the risk would surface in near future.

Although Myanmar has still limited the phytoplankton study, the understandings of this study notified that the phytoplankton studies should be continued in Myanmar water for sustainable fisheries production and future HAB risks management.