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On the *Gymnodinium* Red Tide in Jinhae Bay

鎭海灣의 *Gymnodinium* 赤潮에 關하여

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1981年 夏季중 鎭海灣에서는 3次에 걸친 大規模의 赤潮가 있었다. 이들 赤潮는 그 規模나 原因種, 濃度, 머문期間에 있어 南海岸에서 그 類例가 없었던 惡性赤潮였다. 그로 因한 水産物 被害額만도 약 17億3千4百萬으로 추정되었다.

1次赤潮는 7月 18, 19日부터 시작되어 7月末까지 계속되었으며, 2次는 8月中旬에 그리고 3次는 9月初旬에 있었다. 主 原因種은 渦鞭毛藻의 一種인 *Gymnodinium* sp. 로서 外部形態로 보아 1965年 日本 大村灣에서 있었던 赤潮의 原因種인 *Gymnodinium* 65年度型과 類似하였으나 확인할 수는 없었다. 赤潮時의 水色은 暗褐色이었고 細胞量은 주로 表面에서 水深 약 2 *m* 層까지 농밀하여 심한 경우 透明度는 0.1 *m* 이었다. 最高세포數는 약 20萬 cells/*ml* 이었고 이때 클로로필-a 量은 약 1,000 *mg*/*m*³ 이었다. 溶存酸素量은 2∼3 *ml*/*l* 인 경우가 많았고 最下 1 *ml*/*l* 이 발견되었다. 1次赤潮 後期엔 養殖굴 및 홍합의 폐사가 나타났고 2次赤潮가 사라진 8月 16, 17日에는 게, 고동, 새우類 등과 양태류, 볼락, 까나리 등의 死體가 潮流에 밀려 海岸에서 발견되었다.

금번 赤潮의 특징은 原因種이 惡性인 *Gymnodinium* sp. 이고 내년에도 再發할 수 있는 可能性이 있다는 점이다. 發生原因은 日本 大村灣 赤潮의 경우처럼 多雨後 高溫의 지속과 底泥중 多量의 硫化物이 主要因子라 추측된다.

Introduction

During the summer from the middle of July to the middle of September 1981 huge red tides occurred three times in Jinhae Bay, one of productive shellfish farm areas in the southern coastal sea of Korea. It was malignant in its size, density, period and a causative organism. Such red tides have been never previously seen in Korean coastal waters.

Red tides have frequently occurred in Jinhae Bay. For eight years from 1972 to 1979 more than 50% out of 104 red tides in the southern coastal waters occurred in Jinhae Bay (Park, 1980). Causative organisms were mainly diatoms but flagellates appeared as dominant species since the late 1970's (Park, 1980; Cho, 1979, 1978; KORDI, 1980). Main causative organism of the red tide in Jinhae Bay during summer 1981 was also a flagellate, *Gymnodinium* sp., which was similar in shape to *Gymnodinium* type-'65 occurred in Omura Bay in Japan in 1965.

Damage due to the red tide in Jinhae Bay in 1981 was estimated to be 1,734 million won, equivalent to US$ 2.25 million.

Materials and Methods

Ten stations in total were fixed in Jinhae Bay

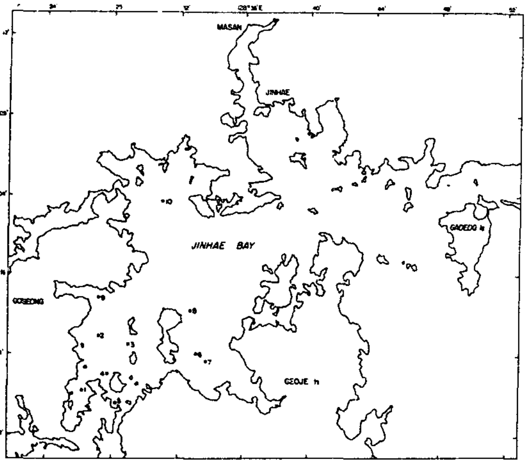

Fig. 1. Map showing the sampling stations for phytoplankton and oceanographical data during the summer 1981.

as shown in Fig. 1. Transparency by Secchi disc and water temperature by an electric thermometer were recorded in the field. Waters for dissolved oxygen, chlorophyll-a and phytoplankton counting were sampled by Van Dorn sampler. Dissolved oxygen was determined by Winkler's method (APHA *et al.*, 1975) and chlorophyll-a was measured by spectrophotometer, UV-200S (Strickland and Parsons, 1968). Phytoplankton cells were enumerated and classified under Shimazu microscope equipped with an automatic camera.

Results

1. Phenomena of red tide

Red tides occurred three times in 1981; the first one in July, the second in August and the third in September. They were distributed almost all the area except the central part and the mouth of the bay (Fig. 1). Colour of the surface waters was brown in general and dark brown in patches. Transparency with Secchi disc was less than 0.1*m* when the red tide was severe.

The first red tide appeared around July 18 and continued till the end of that month. For the first three or four days diatoms such as *Chaetoceros* group dominated and *Gymnodinium* sp. was found only 1% on July 22 as shown in Table 1. Chlorophyll-a in the 1*m* layer from surface in places excluding patches was 3—6*mg*/*m*³ and 25—84 *mg*/*m*³ in patches at all stations shown in Fig. 1.

Table 1. Dominant organisms and their percentages among total phytoplanktons during the red tide period in Jinhae Bay in summer 1981

Date		Dominant organisms	%
July	20—22	*Chaetoceros* spp.	70
	24—30	*Gymnodinium* sp.	99
	31	*Gymnodinium* sp.	41
Aug.	1—2	*Ceratium fusus*	42
	3—8	*Ceratium fusus*	47
		Gymnodinium sp.	39
	14	*Gymnodinium* sp.	37
		Nitzschia seriata	36
	24	*Nitzschias seriata*	86
Sept.	5	*Gymnodinium* sp.	71
	9	*Skeletonema costatum*	56

Fig. 2. A red tide organism, *Gymnodinium* sp., occurred in the waters of Jinhae Bay in summer 1981. Cell size is about 25 μm in transdiameter. A cell in block is enlarged.

Sampling was carried out every three hours at station 5 from July 24 to August 3. *Gymnodinium* sp. shown in Fig. 2 was found as a dominant species from July 24 and almost no other species was discovered during the first red tide period (Table 1). Maximum number of cells was 224,600

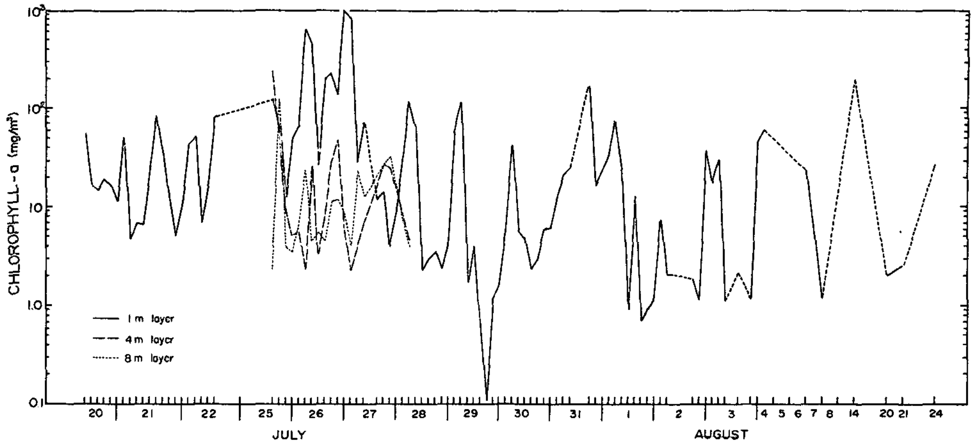

Fig. 3. Quantities of chlorophyll-a in accordance with time and water depth at station 5 in Jinhae Bay from July 20 to August 24.

cells/*ml* on July 24 and at the second peak was 177,600 cells/*ml* with 1,060 *mg/m*³ in chloro phyll-a on July 27 as shown in Fig. 3.

The second red tide occurred on August 14 and disappeared after four days. The dominant species were *Gymnodinium* sp. and *Nitzschia serriata.*

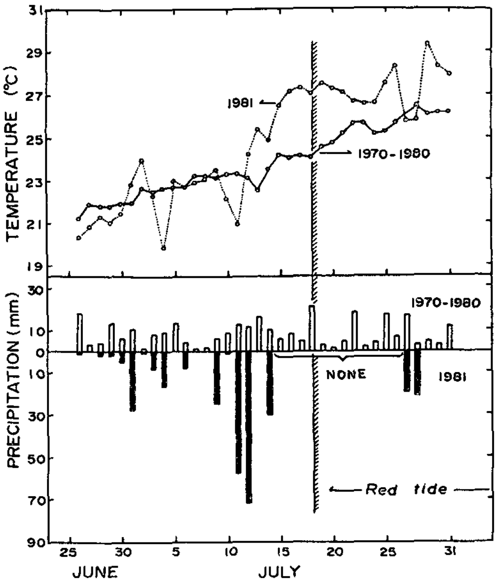

Fig. 4. Air temperature and precepitation before and after the first red tide occurred in Jinhae Bay during summer 1981.

Chlorophyll-a was 180 *mg/m*³. Water colour was dark brown and the water was sticky and smelly. The third red tide was found on September 5 and lasted for a week. Water colour was brown. Then, *Gymnodinium* sp. was dominant and it consisted about 71%. Chlorophyll-a was 57 *mg/m*³. On September 9, the dominant species was changed into *Skeletonema costatum*, and *Gymnodinium* sp. was composed of only 3% although phyto- plankton density was still high; that is, 35—270 *mg/m*³ in chlorophyll-a.

2. Environments

Temperature in the surface water and one meter layer above the bottom were 28.5°C and 14.4 °C respectively at station 7 at 13:00 p.m. on July 21. A thermocline existed between two and three meters under the surface water and temperature difference was 5°C between two layers. The thermocline disappeared on July 26 but difference of temperature between the surface and the bottom waters was about 7°C and it continued till the end of that month. There was a typhoon on July 31 and then such wide difference was narrowed to 3°C.

Oxygen content in the bottom waters during the first red tide and the second red tides was 2-3 *ml/l* but it dropped to less than 2 *ml/l* after the second red tide (Table 2). On September 9, it was found that oxygen content in the bottom-waters was normalized; say over 3.5 *ml/l*.

Precipitation for three months from March to May was only 144 *mm*, which is a third of the same period in the normal year. High temperature was kept till June 24 with very little rainfalls, and after heavy rainfalls very high water temperature, 28—30°C without rainfalls continued before and after the first red tide (Fig. 4).

3. Fisheries Damage

Dead oysters and mussels cultured by off-bottom method were found on July 26. Mussels cultured near the shore died completely and some oysters appeared to be dead from July 26. Mortalities of oysters and mussels were found 5%

Table 2. Dissolved oxygen(*ml/l*) at station 5 during the red tide period. Crosses in the table indicate over 3 *ml/l*

Date		Time	Layer		
			1 *m*	4 *m*	8 *m**
July	25	19:30	+	+	2.64
	26	10:30	+	+	2.30
		19:30	+	+	2.68
		22:30	+	+	2.20
	27	01:30	1.51	+	+
		04:30	1.63	+	+
	28	01:30	+	+	2.83
		04:30	1.73	+	+
	29	07:30	+	+	2.20
		13:30	2.02	+	+
Aug.	1	10:30	+	+	2.90
	2	04:30	+	+	2.94
		07:30	+	+	2.61
	18	16:30	2.45	2.93	2.55
	21	12:30	1.66	1.45	1.06
	24	15:30	+	2.58	1.67

* layer 1*m* above bottom

and 50% respectively in the off-shore farms by August 4 and a rotten smell in the culture ground was serious. On August 17 and 18, dead fishes, crabs, shells and shrimps were landed by tidal currents. Mortalities of oysters and mussels increased to 6% and 70% respectively by August 24. It was impossible to estimate how much ark shells cultured in the bottom died.

According to an official statistics by Fisheries Department, total damage was assumed to be 1,734 million won, equivalent to US$ 2.55 million.

Discussion and Conclusions

A main causative organism, *Gymnodinium* sp. was found for the first time in the Korean sea waters in 1980 (KORDI, 1980). It was very similar in shape to *Gymnodinium* type-'65 found in Omura Bay in Japan in summer 1965 (Iizuka and Irie, 1966). The periods from the begining to disappearence and densities of the causative organism of both red tides were almost the same (Iizuka and Irie, 1966; Irie and Hamashima, 1969).

The red tide in Jinhae Bay in 1981 was something different from others occurred in the same bay before; that is, red tides by diatoms occurred before the main red tide by *Gymnodinium* sp. It was the same phenomenon that dinoflagellate blooms often follow diatom blooms(Ryther, 1955; Brongersma-Sanders, 1957). During the second red tide, *Noctiluca scintillans* and the species belonging to Tintinnida outnumbered other zooplanktons and it was same status as before (KORDI, 1980; Cho, 1979, 1978).

Low oxygen contents at night was serious and it perhaps would be one of the main effects to kill oysters and mussels, as widely known(Steidinger and Joyce, 1973; Irie and Hamashima, 1969).

According to Iizuka(1972), the *Gymnodinium* type-'65 red tide in Omura Bay might be classified into "July red tide" associated with the inflow of fresh water in rainy season. Thus, "July red tide" is so-called "rainy red tide" associated with the rainy season(Iizuka and Irie, 1969). Correlation of heavy rainfall with initiation of red tides was noted early in the history or red tide research (Slobodkin, 1953; University of Miami Marine Lab. 1954). Both the *Ceratium* and the

Gonyaulax red tides in Jinhae Bay in 1977-1978 also occurred after heavy rainfalls (Cho, 1979, 1978) but it was not sufficient to explain that heavy rainfall was the main causative factor because red tides did not frequently occur in other bays near Jinhae Bay.

Waters in Jinhae Bay contained high nutrients, especially phosphorus (Park, 1975) and it increased year by year (Cho, 1978). High nutrient levels, particularly those associated with waste discharge, are often suggested as the causative factors of phytoplankton blooms. It was, however, unable to find a relationship between total phosphorus levels and red tide outbreaks (Bein, 1957).

Bottom muds contained high organic matters and sulfide compared to other farms near Jinhae

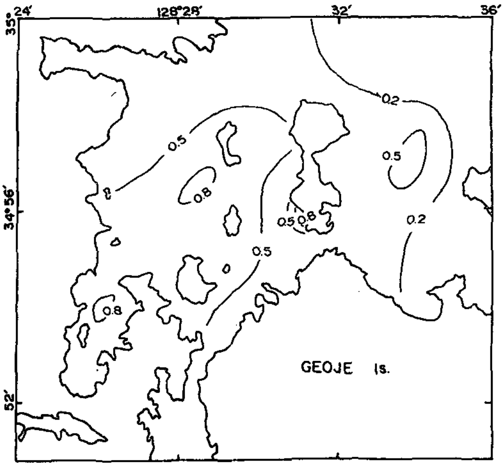

Fig. 5. Distribution of sulfide (*mg/g* dry mud) in the superficial mud in Jinhae Bay during summer 1981. After Cho *et al.*, 1981.

Bay(Fig. 5) (Cho and Kim, 1978; Cho *et al.*, 1981). A study on the culture *Gymnodinium* type-'65 in a medium suggested that the supply of inorganic nutrients into the sea waters was essential to the outbreak of red tide but the sea waters of Omura Bay might contain the growth promoting substance which was not included in the composition of the medium used (Hirayama, Iizuka and Yoneji, 1972). In an other study Hirayama and Numaguchi(1972) found that sodium sulfide added to the medium in low concentration exhibited the growth promoting effect and concluded that the dissolution of anaerobically decomposed product of bottom mud into sea water should be one of the causes of the outbreak of the red tide in Omura Bay, and it was confirmed by Iizuka and Nakashima (1975) that apparent photosynthesis of the organisms belonging to genus *Gymnodinium* was promoted by the addition of sodium sulfide in any concentration.

It is, however, uncertain what causative effects of red tide in Jinhae Bay at present are although the author supposes that it might be a combination of continuous high temperature, calmness of sea waters after a great quantity of rainfalls and high contents of organic matters and sulfide in the bottom muds.

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