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Seasonal changes of the phytoplankton chlorophyll *a* and their relation to the suspended solid in Thale Sap Songkhla, Thailand*1

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Abstract : Standing stock and seasonal changes of phytoplankton chlorophyll *a* at seven stations in Thale Sap Songkhla, Thailand, were investigated in relation to the Secchi disk depth and suspended materials from August 1991 through November 1993. The lake water was yellow-brown in color due to high concentrations of suspended materials throughout the year. The difference in the Secchi disk depth was big in the dry season compared with that in the rainy season. The levels of suspended solid in the lake were generally high during the rainy season at most stations. However, the patterns of seasonal change in the amount of suspended solid were not always the same among the stations. The ignition loss of suspended solid was less than 40 % at all stations throughout the year indicating the high proportion of the inorganic materials in the suspended solid in this lake. The amount of chlorophyll *a* in water seemed to be in the range from 1 to 10 $\mu g/l$ in this lake except the rare bloom of phytoplankton observed in December 1991. The level of chlorophyll *a* concentrations in Thale Sap Songkhla corresponds to those of mesotrophic and/or of moderately eutrophic waters.

1. Introduction

Songkhla Lake is a lagoonal coastal lake in southern Thailand, including three waters, Thale Noi, Thale Luang and Thale Sap Songkhla, from north to south between 7°50′N and 7°08′N and from west to east between 100° 07′ E and 100° 37′ E which are connected by narrow channels. A narrow canal connects Thale Sap Songkhla, the southernmost lake, with the open sea, the Gulf of Thailand, at its southeastern end. Distinctive gradient of salinity is, therefore, a common phenomenon in this lake system.

Thale Sap Songkhla which covers an area of 176km^2 is shallow with a mean depth of 1.4m and filled with brackish water (LIMPADANAI, 1977; Lake Biwa Res. Inst. and Int. Lake Environ. Com., 1988), however, the present depth is probably less due to rapid sedimentation partly caused by soil erosion from nearby watershed. This lake is known for its high productivity of fish, shrimps and crabs, and now is utilized intensively for the aquaculture of seabass. The lake accepts much suspended materials and municipal drainage flowing in from the surrounding area especially from the Hat Yai area. Thus, the eutrophication of this lake has been progressed rapidly and the lake is now moderately eutrophic.

A series of research was carried out in the framework of a cooperative research program "Ecosystem Dynamics of Songkhla Lake under Human Impact" between Japan and Thailand. The present paper describes the results of three years research concerning the standing stock and seasonal changes of phytoplankton chlorophyll *a* at seven stations in Thale Sap Songkhla in relation to the Secchi disk depth and suspended materials.

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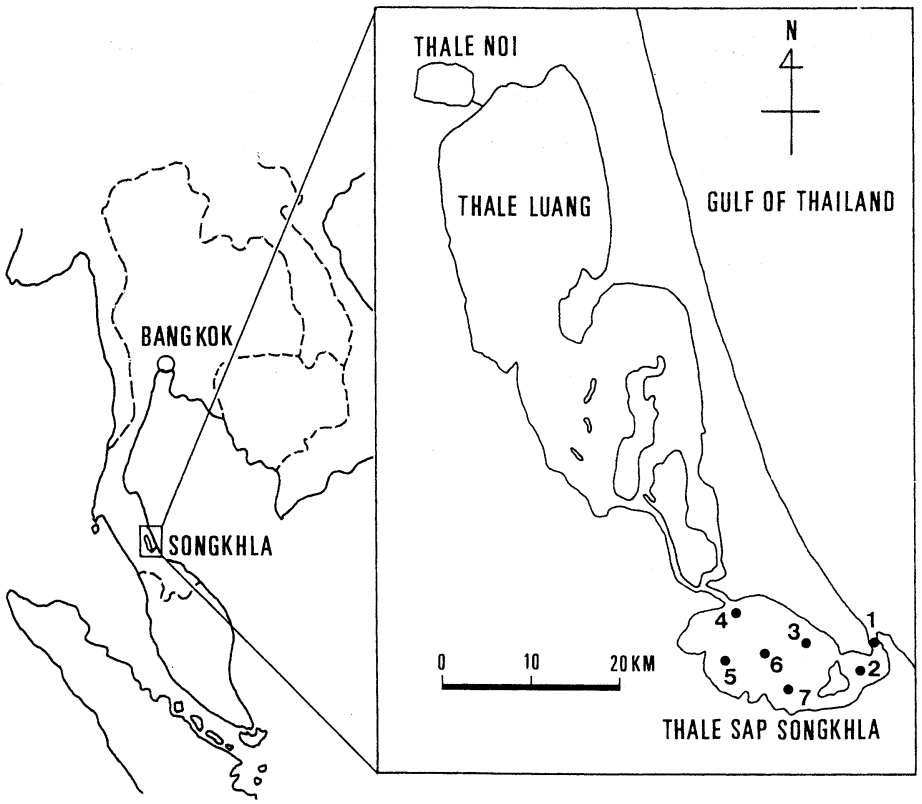

Fig. 1. Map of Songkhla Lake and the sampling stations in Thale Sap Songkhla.

2. Material and method

Routine observations were carried out from August 1991 through November 1993, every two months in the first year and every three months in the second year. In spite of its large surface area, Thale Sap Songkhla is very shallow, around 1m at most stations. Water samples were collected mainly from the surface layer (0.5m) with a Van Dorn type and/or Kitahara type water samplers at seven stations (Fig.1).

Each water sample was filtered through a glass fiber filter (Whatman GF/C, 47mm in diameter) which was precombusted at 450 ℃ for 2 hrs and weighed, and the filter with suspeded materials on it was re-weighed after drying overnight in a drying oven at 85 ℃. The amount of suspended solid (SS) was determined as the difference of dry weights before and after the filtration of water samples. After determination of SS, the filter was ignited again in a Muffle furnance (ST-20, Thomas Sci. Co., Ltd, Japan) at 450℃ for 2hrs and weighed again after cooling, and the percent decrease of dry weight was regarded as the ignition loss (IL). The amount of particulate organic material was calculated by multiplying SS with IL.

As an index of the standing stock of phytoplankton, concentrations of chlorophyll *a* in the water samples were determined. For this purpose, water samples were filtered through glass fiber filters (Whatman GF/C), and the filters were kept in a deep freezer for later analyses. Pigments were extracted from the filters with 90% acetone. Absorbances of the extracts were measured at 750, 664, 647 and 630nm with a spectrophotometer model LKB-ULTROSPEC (Medico Co., Ltd., England), and the chlorophyll *a* concentrations were calculated by the equation of JEFFREY and HUMPHREY (1975).

The transparency of water was measured with a Secchi disk (20 cm in diameter) at each station.

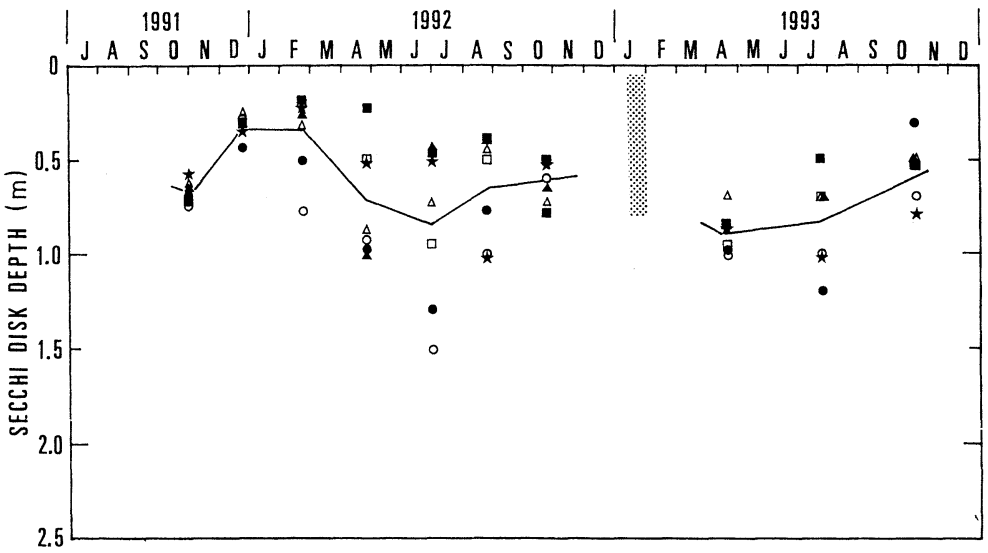

Fig. 2. Seasonal changes of the Secchi disk depth at Stns. 1–7 in Thale Sap Songkhla. The line is for average of the seven stations. ○, Stn. 1; ●, Stn. 2; ★, Stn. 3; △, Stn. 4; ▲, Stn. 5; □, Stn. 6; ■, Stn. 7; ▒, no data due to strong wind.

3. Results

The Secchi disk depth (transparency) was highest, 1.5 m, in June 1992 at Stn. 1 and lowest, 0.19 m, in February 1992 at Stn. 7. Seasonal changes of the Secchi disk depth at seven stations (Stns. 1–7) are shown in Fig. 2. Readings of the Secchi disk depth was generally deeper in the outer part (Stns. 1–2) than in the inner part of the lake (Stns. 3–7). Differences of the Secchi disk depth at the seven stations were big in dry seasons while those in the rainy seasons were relatively small. In average, the Secchi disk depth ranged from 0.34 m to 0.89 m. Clear pattern, higher in the dry season and lower in the rainy season, was observed in average Secchi disk depth throughout the year. These facts suggest that much suspended solid inflowing in the lake from surrounding watershed might strongly affects reduction of Secchi disk readings at all stations especially in the rainy season.

Seasonal changes of the amount of suspended solid in the water at Stns.1–7 are illustrated in Fig. 3. A clear pattern of seasonal change of suspended solid, high in the rainy season and low in the dry season, was observed at Stn. 1. The level of suspended solid was generally higher (49.72–192.66 mg/l) in the rainy season and lower (31.13–96.50 mg/l) in the dry season at Stn.1. The trends similar tot hat of Stn. 1. were obtained at Stns. 2, 4 and 6, but the trends were different at Stns. 5 and 7. A Stn.7, the suspended solid was highest, 152.4 mg/l, during the dry season in 1992. Contrarily, the seasonal change was not clear at Stn. 3 where the depth of water was shallowest among the seven stations. The ranges of variation were quite big at Stns. 1, 2, 5 and 7 as compared with those at other stations.

Variations in the ignition loss of suspended solid were big with stations and with seasons ranging from 7.1 % to 38.6 % (Fig. 4), however, the difference in the average values of ignition loss at the seven stations was rather small within the range from 17.9 % to 23.4 %. The pattern of seasonal changes of the ignition loss was also similar among the seven stations. The ranges of variation during the first year were relatively large compared with those in the second year. In general, the ignition loss was higher during the dry season copared with that in the rainy season throughout the year.

Figure 5 shows the seasonal changes of the particulate organic matter calculated from the

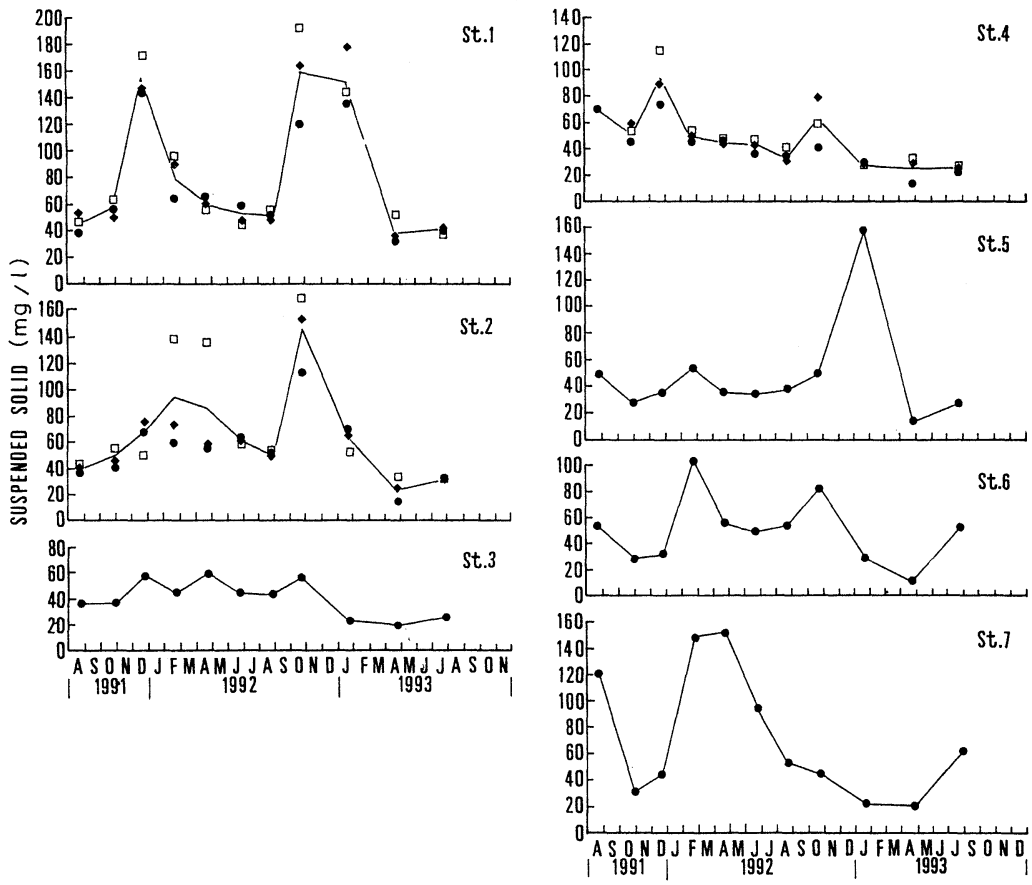

Fig. 3. Seasonal changes of the suspende solid at Stns. 1–7 in Thale Sap Songkhla. Lines are average values in the surface (●), middle (◆) and bottom (□) layers at Stns. 1, 2 and 4, and values in the surface layer at other stations.

ignition loss and the amounts of suspended solid at Stns. 1–7. Amounts of the particulate organic matter varied with stations and with seasons ranging from 1.9 to 29.4 mg/l. The level of particulate organic matter were slightly higher at the stations located in the southern part of the lake (Stns. 1, 2 and 7; 11.41–13.29 mg/l in average values) than those at other stations (7.30–9.66mg/l in average values). The seasonal patterns were similar at Stns. 1 and 2 but different from each other among the stations situated in the inner part of the lake (Stns. 3–7). Seasonal patterns of the particulate organic matter were not always similar to those of the suspended solid in the lake water.

Figure 6 illustrates seasonal changes of chlorophyll *a* concetrations in the lake water at Stns. 1–7. Trends of seasonal change were quite similar at every stations even though a little difference was observed at Stn. 5, where might be influenced by a considerable amount of municipal sewage flowing in from the Hat Yai area through the U-tapao channel. A rapid increase in chlorophyll *a* concetrations was occurred at most stations in December 1991, and the values exceeded up to 30 μg/l. In the succeeding seasons, however, the consentrations of chlorophyll *a* were less than 10 μg/l, and no remarkable increase occurred. The level of chlorophyll *a* concentrations was relatively higher in the first year than in the second year even if the highest values due to an extreme bloom were excluded.

Figure 7 indicates seasonal variations of the percentage of chlorophyll *a* in suspended solid in

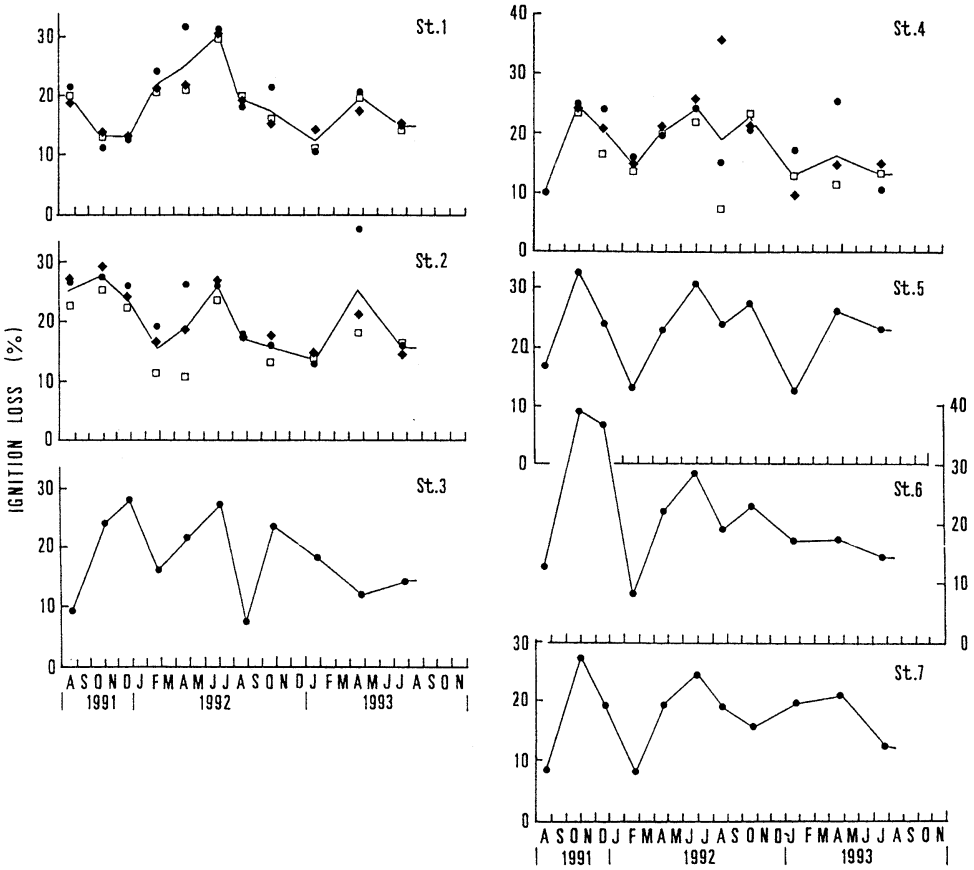

Fig. 4. Seasonal changes of the ignition loss at Stns. 1–7 in Thale Sap Songkhla. Symbols are the same as in Fig. 3.

water at Stns. 1–7. The seasonal patterns at Stns. 1 and 2 were different from those at otherstations. The percentage of chlorophyll *a*, however, was quite low irrespective of the stations and seasons (0.002–0.064 %). Higher proportions of chlorophyll *a* were obtained in December 1991 when considerable amounts of chlorophyll *a* were detected at every stations.

Relationships were investigated between the chlorophyll *a* concetration and the suspended solid and the particulate organic matter in water (Fig. 8). Positive correlations with considerably scattered data points were detected between the concetration of chlorophyll *a* and suspended solid, and the particulate organic matter in December 1991 when an extreme bloom of phytoplankton was observed at all stations. In other seasons, however, data points were scattered disorderly and no clear relationships were detected between the chlorophyll *a* and the two parameters.

4. Discussion

Routine observations of seasonal variations in the standing stock of phytoplankton as well as the related biologically important parameters are essential when one wishes to estimate the primary production of phytoplankton in combination with the data of photosynthetic activity of phytoplankton and solar radiation by the chlorophyll method (ICHIMURA *et al.*, 1962). The aim of the present paper is to show the standing stock and the seasonal variation of phytoplankton chlorophyll *a* in relation to the changes of suspended solid as the first attempt to describe the results of the routine

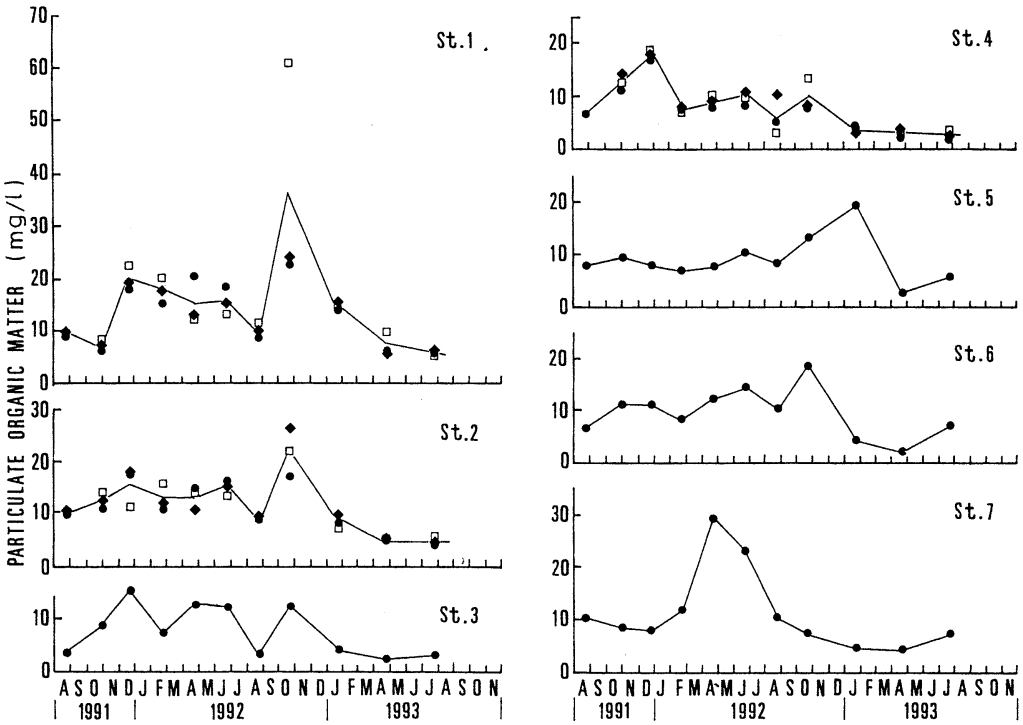

Fig. 5. Seasonal changes of the particulate organic matter at Stns. 1–7 in Thale Sap Songkhla. Symbols are the same as in Fig. 3.

observations which have been carried out in Thale Sap Songkhla from August 1991 through November 1993.

The lake water was yellow-brown in color due to high concentrations of suspended materials throughout the year suggesting that this lake should belong to the lake type of so-called "whitewaters" (SIOLI, 1984).

The seasonal patterns of the Secchi disk depth were similar among the seven stations (Fig. 2) with higher values during the dry season and with lower values during the rainy season. The difference in the Secchi disk depth was big in the dry season compared with that in the rainy season indicating that the Secchi disk depth at the shallow inner part of the lake might be affected strongly by wind mixing.

The levels of suspended solid in the lake were generally high during the rainy season at most stations. The patterns of seasonal change in the amount of suspended solid, however, were not always the same among the stations. This indicates that the movement of suspended solid might be different from station to station in such shallw waters well mixed by strong wind disturbance, especially in the inner part of the lake.

The ignition loss of suspended solid was less than 40 % at all stations throughout the yaer. These low levels in the ignition loss could be due to the relatively high proportion of the inorganic materials contained in the suspended solid in this lake. High proportion of inorganic matter in the total suspended solid should be proved by low percentages of chlorophyll *a* in the total suspended solid (Fig. 4). The variations in the ignition loss of suspended solid were big and showed no clear seasonal trend in their distributions. This suggests that there had been big variations in the proportion of inorganic material to the total suspended solid or to particulate organic matter in samples collected at different stations and in different seasons.

The amount of chlorophyll *a* in water has been measured as an index of standing stock and their primary productivity of phytoplankton in

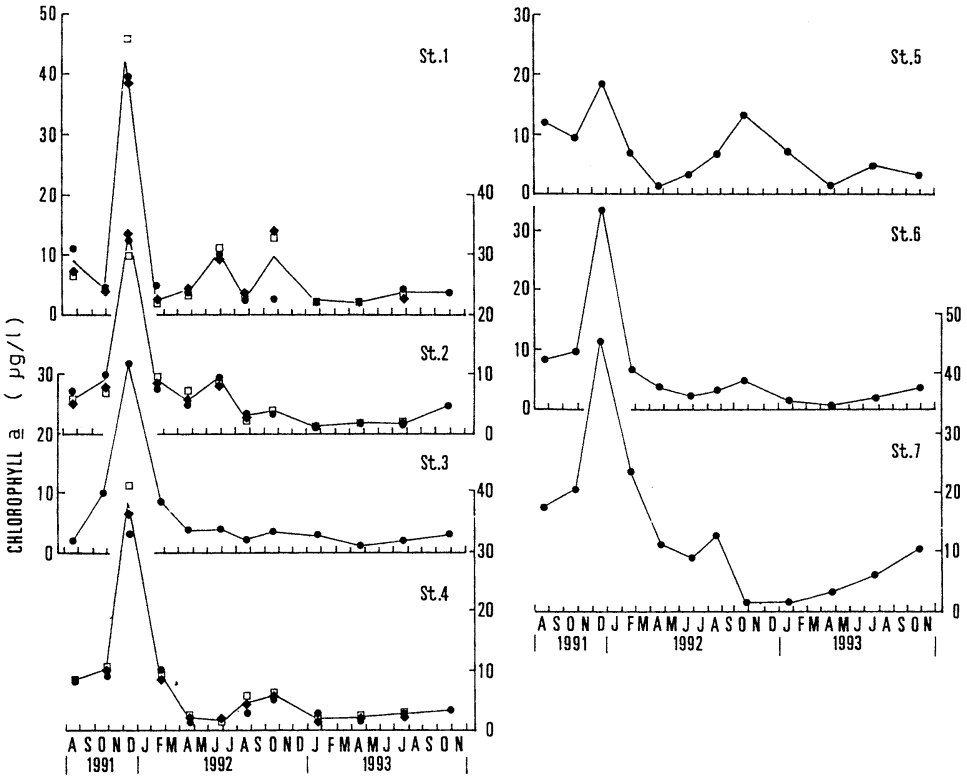

Fig. 6. Seasonal changes of the chlorophyll *a* at Stns. 1–7 in Thale Sap Songkhla. Symbols are the same as in Fig. 3.

freshwater lake as well as in marine waters (GESSNER, 1944; ARUGA and MONSI, 1963). Because of its shallowness, the vertical difference of the amount of chlorophyll *a* in water was small. The levels of the mean value and/or the chlorophyll *a* concentrations of each station were higher in 1991–1992 than in 1993. Extremely high concentrations of chlorophyll *a* were measured in December 1991 although the cause for this bloom had not been elucidated. Except this rare bloom of phytoplankton, the amounts of chlorophyll *a* observed in this lake seemed to be in the range from 1 to 10 μg/l, which corresponded to those observed in inner lake, Thale Luan (NACHIANGMAI, 1979; LUORSINSUP *et al.*, 1986), and in the outer lake, Thale Sap Songkhla (LUORSINSUP *et al.*, 1986). The level of chlorophyll *a* concentrations in Thale Sap Songkhla corresponds to those of mesotrophic and/or of moderatoly eutrophic waters (ARUGA and MONSI, 1963; SAKAMOTO, 1966).

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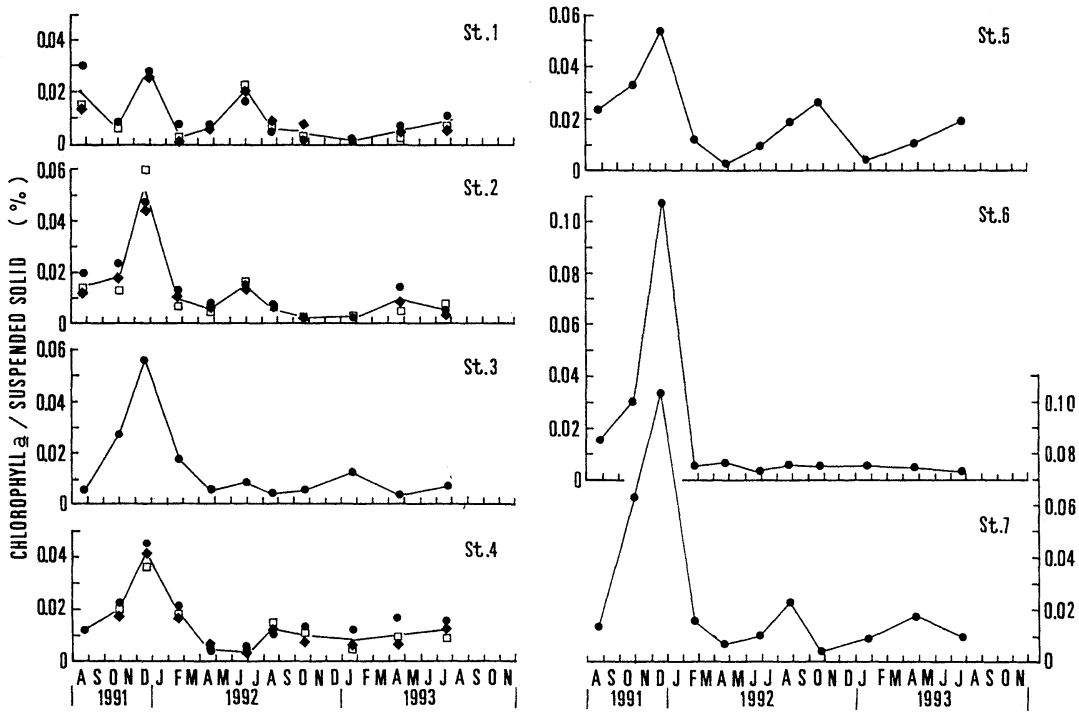

Fig. 7. Seasonal changes of the ratio ofchlorophyll *a* suspende solid at Stns. 1–7 in Thale Sap Songkhla. Symbols are the same as in Fig. 3.

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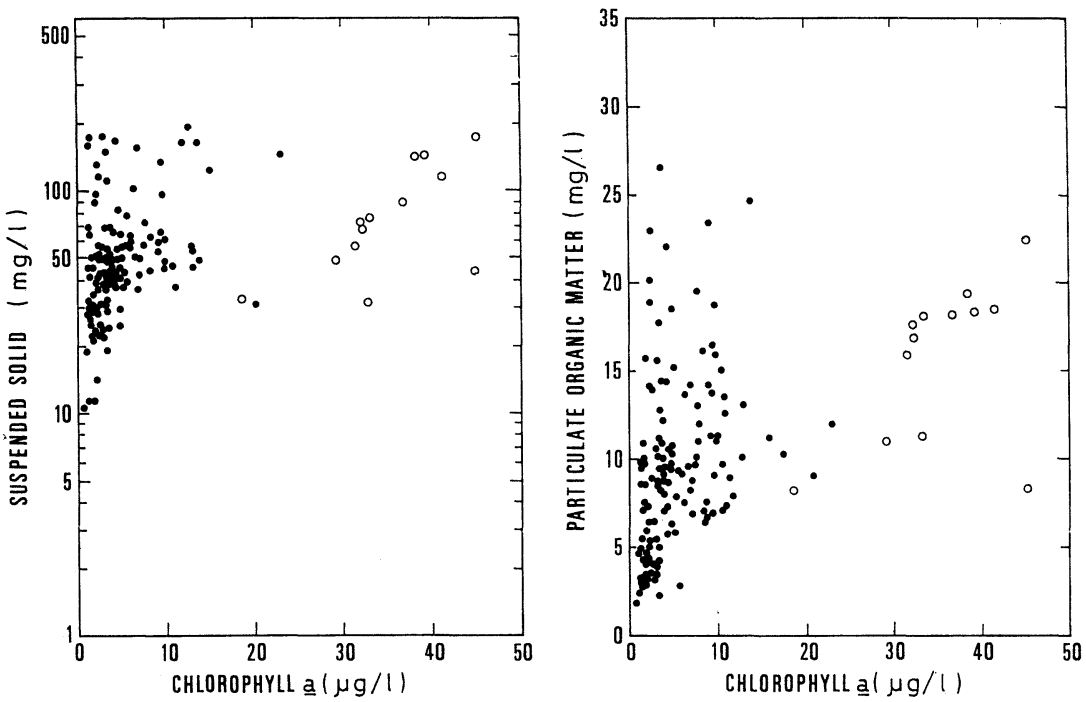

Fig. 8. Relationships between the chlorophyll *a* and the suspende solid (A) and between the chlorophyll *a* and the particulate organic matter (B) at Stns. 1–7 in Thale Sap Songkhla. ○, Dec. 27, 1991; ●, other seasons.

ソンクラ湖における植物プランクトンクロロフィル *a* および懸濁物質の季節変化

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要旨：タイ国ソンクラ湖（南湖: Thale Sap Songkhla）の7観測点で，1991年8月から1993年11月まで，透明度，懸濁物質，クロロフィル *a*，強熱減量および懸濁態有機物を調査した。平均水深が浅いため，試水は表層（0.5m）から採取し分析した。本湖は年間を通して黄褐色を呈し，透明度は雨期に特に低くなる。水中の懸濁物質濃度は，一般に雨期に高く乾期に低いが，年変化の傾向は測点間で必ずしも一致せず，測点の水深と風による攪乱のために様々な値を示した。懸濁物質の強熱減量は，年間を通して40%以下であり，懸濁物質中の有機物含量は必ずしも多くなかった。また，懸濁物質中のクロロフィル *a* 含量も著しく低く，0.1 %以下にすぎなかった。この事は，本湖の懸濁物質の大半が無機の粘土成分である事を示唆している。植物プランクトンの現存量の指標としてのクロロフィル *a* 量は，1991年12月に著しく高く，30–40 μg/l を記録したが，それ以後はこのような著しい値は測定されず，年間を通しておおむね1–10 μg/l の範囲を変動し，顕著な季節変化は認められなかった。クロロフィル *a* 量から判断して，本湖は現在中栄養段階にあると考えられる。