Changes in the Ecosystem of Lake Suwa Attendant upon Human Activities*

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1. Introduction

Today I am going to talk about the changes in the ecosystem of Lake Suwa from the beginning of the 20th century. The ecosystem of Lake Suwa has been suffering from the various human activities for a long time. At the beginning of the 20th century this lake used to be classified as a mesotrophic lake. Since 1960's, however, Japanese economy has grown remarkably year by year and accordingly the human activities in the watershed area of Lake Suwa, such as the intensive agriculture, the precision and food industries and tourism, have become considerably augmented. These intensified human activities have brought more and more nutrients into the lake and consequently this lake has changed into a hypertrophic lake. By "hypertrophic" I mean "highly eutrophicated". Nowadays, the thick layer of the vivid green *Microcystis* covers the lake surface from late June to October every year.

In order to cope with this situation, the local government and the inhabitants around the lake started to inquire into the possible ways to clean the lake in 1966, and worked out a plan of a large-scale waste water treatment plant, which deals with the domestic, industrial and other waste water, and human feces and urine from the cities around the lake. In October 1979, a part of the sewage plant began to operate.

The purpose of this presentation is to show you the changes in some chemical and biological parameters of the ecosystem of Lake Suwa from the beginning of this century, and to pre-estimate the effect of the partial operation of the sewage plant on the lake ecosystem.

2. Location and morphometric feature of Lake Suwa

Lake Suwa is located in the central part of Japan proper. Figure 1 shows the morphometric feature of Lake Suwa. This lake is morphometrically characterized as shallow. Its surface area covers 13.3 km². However, its maximum depth is only 6.5m and the mean depth is 4.1m. The lake lies in a relatively high land of 759m above sea level. This is in the tectonic belt crossing the Japanese Islands, and Lake Suwa is one of the tectonic lakes on this belt. More than 20 rivers and streams flow into the lake from the catchment area, but the River Tenryu is the only outlet.

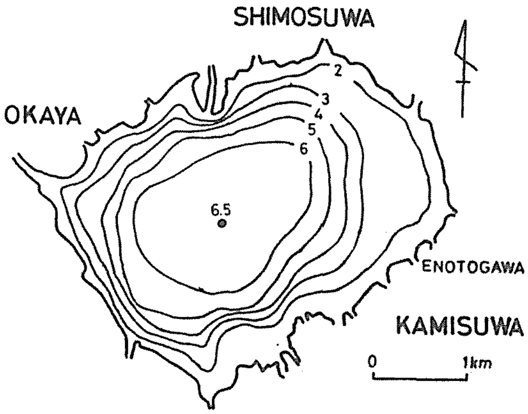

Fig. 1. The contour map of the water depth of Lake Suwa and the location of the cities around the lake.

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3. Lake Suwa and human activities

Now, we are going to explain how Lake Suwa has suffered from human activities. About 200,000 people live within the catchment area of the lake. Figure 2 shows the land use of the catchment area of Lake Suwa. The urban areas are located close to the shore line (Fig. 2). These urban areas contain quite a number of factories of precision and food industries. Moreover, there are lots of hotels and restrants around the lake, for this area attracts many tourists on account of its hot springs.

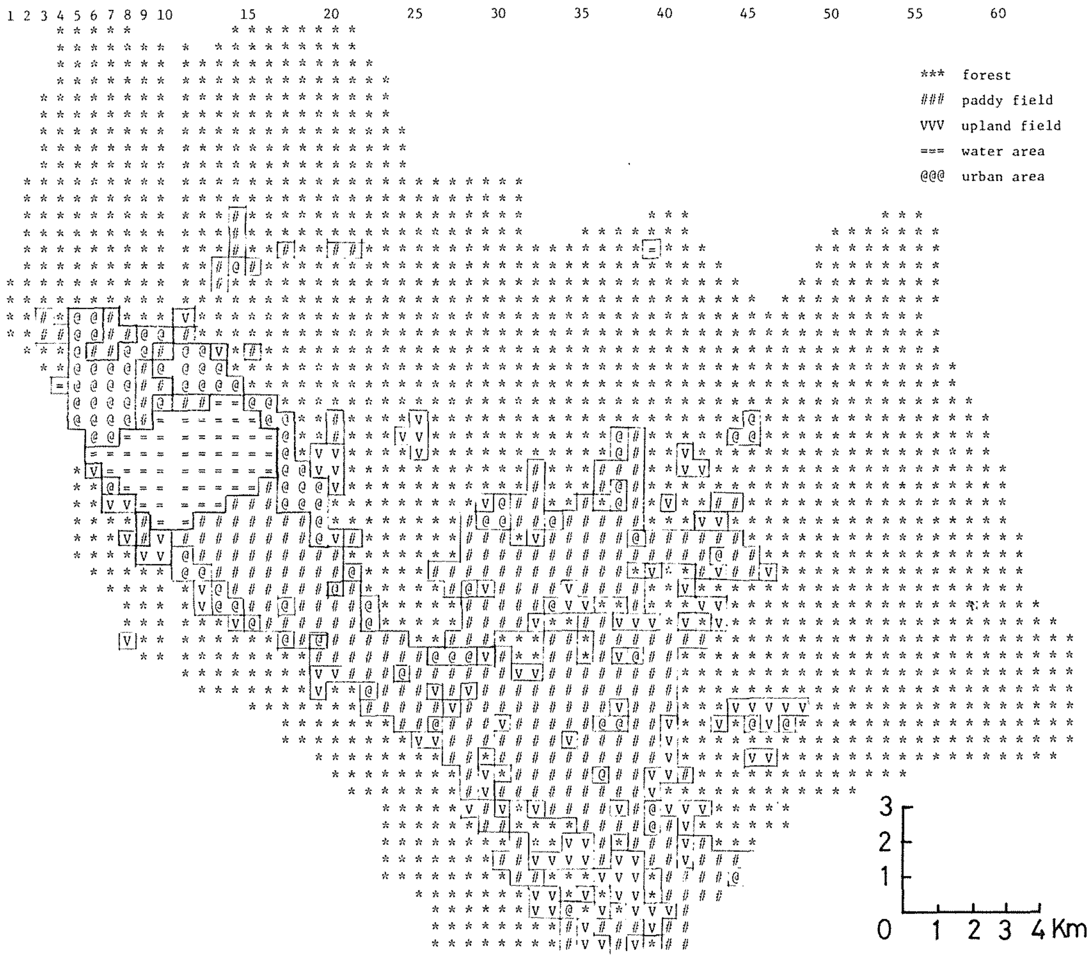

Fig. 2. The map of the urban utilization of the watershed area of Lake Suwa drawn by 0.25 km² mesh (Quated from Matsuda, M., Okino, T. 1982).

Before 1971, no regulation was adopted for the quality of the waste water which flowed into Lake Suwa from factories, hotels, domesticities and so on. Nutrients contained in the waste water from factories and hotels as well as domesticities, all of which flowed into the lake finally, had been accelerating the eutrophication. In 1971, the local governments established the regulation for the quality of the waste water from facteries, hotels and others. However, nutients such as ammonium, nitrate and phosphate were out of the regulation. Therefore, the regulation for waste water has scarcely improved the hypertrophic condition of Lake

Suwa.

About 65% of the cultivated land is the paddy fields and the rest is the upland vegetable fields (Fig. 2). Especially for the vegetable fields, they use a lot of fertilizers, and consequently the nitrogen compounds from these areas have been another factor which accelerates the eutrophication of the lake.

The bait for cultured carps in the floating net cages in the lake is the last artificial source supplying nutients to the lake ecosystem. They feed carps with the artificial bait rich in nitrogen and phosphorus. In 1978, as will be shown in the Fig. 5 later, the landing amount of the cultured carps increased 13 times as great as that in 1964.

Furthermore, Lake Suwa suffers from the civil engineering activities, such as dredging, reclaiming, and embanking of the lake shore all of which have changed the lake morphometrically. Nowadays, more than 90% of the lake shore has been embanked artificially and the surface area has decreased by 8.3% by the reclamation. Thus, the lake has been suffering from the various human activities.

4. Influx of the nutrients into the lake

Now, we are going to show a rough estimation about the nutrients influx to Lake Suwa from the various sources (Table 1). Although the data are not the latest ones, it can be seen in this table that the main source of the influx of nutients is the waste from the domestic life, that is, the domesticities and the human feces treatment plant. These suorces account for some 38% for nitrogen and 57% for phosphorus. The bait for cultured carps is the least artificial source of nutrients (Table 1). The nutrients from the factories and the cultivated fields are some 10 to 20%.

In total, about 3 metric tons of nitrogen and 0.3 metric ton of phosphorus flowed into the lake in a day in 1975. And the nitrogen and the phosphorus originated from various human activities amount to 75% and 87% of the total, respectively.

Next, we will show you how Lake Suwa has undergone drastic changes in the past 80 years.

Table 1. Influx of nitrogen and phosphorus flowing into Lake Suwa from various sources in 1975

Source	Influx of N		Influx of P	
	$kg \cdot day^{-1}$	%	$kg \cdot day^{-1}$	%
Domesticities	420	12.6	116	35.7
Human feces treatment plant	856	25.7	68	21.0
Factories	364	10.9	53	16.3
Cultivated fields	754	22.7	37	11.4
Forests	247	7.4	4.2	1.3
Bait for carps	100	3.0	8.5	2.6
Miscellaneous	586	17.7	38	11.7
Total	3,327	100	324.7	100

(Modified from the office report of Nagano Prefecture 1975)

5. Transparency

Since the 1910's during which the first scientific research of Lake Suwa was conducted by Dr. Tanaka, a considerable number of scientists have carried out the investigations. Figure 3, which is based upon their studies, shows the change in the transparency of the lake water. The upper line indicates the maximum numerical value of each year while the lower line indicates the minimum numerical value of each year.

As you can see from this figure, the maximum transparency was about 2.7m and the minimum was about 1 m in the 1910's, but about 1960 they began to decrease drastically and in the summers of the 1970's they often reached about 0 m.

The 1960's was the period when Japan adopted the high economic growth policy and our economic activities were rapidly accelerated as Fig. 4 shows.

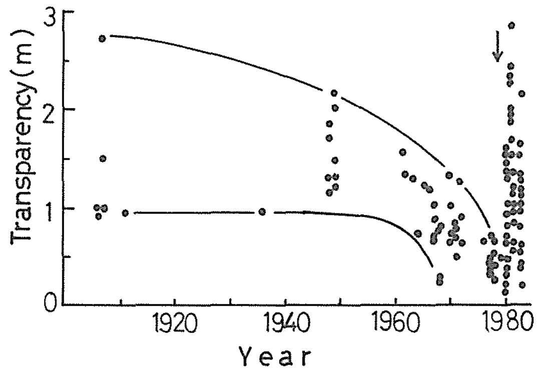

Fig. 3. The process of the change of the transparency in Lake Suwa since the 1900's. The mark of an arrow in this figure shows the opening year of the sewerage system in Lake Suwa area (Modified from Hayashi,H., Okino, T. 1981).

6. Economic growth and Lake Suwa

Figure 4 shows the changes in GNP (Gross National Product) and the production of synthetic detergent for domestic use. The high economic growth policy adopted in the 1960's brought about the exponential increase in Japanese GNP. The similar increase can be seen in the production of the synthetic detergent for domestic use which was selected as an example of the accelerated industrial productions. The reason why we selected the synthetic detergent for domestic use is that it contains the phosphorus compounds as a builder. The synthetic detergent for domestic use contains 2 to 5% of phosphorus on a weight basis.

As I told you, the largest source of phosphorus flowing into Lake Suwa was the waste water from domesticities. It comprises about 36% of the total influx. A part of this phosphorus comes from the synthetic detergent. This figure suggests the rapid increase in the phosphorus load from the synthetic detergent in the hydrosphere including Lake Suwa.

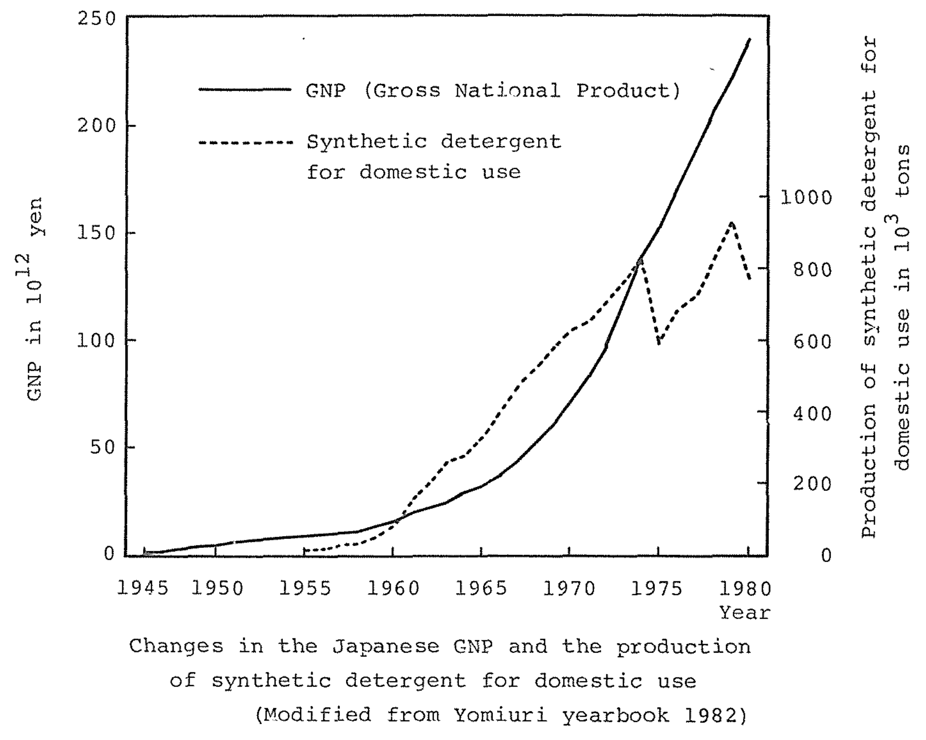

Fig. 4. Changes in the Japanese GNP and the annual production of synthetic detergent for domestic use in Japan (Modified from Yomiuri yearbook 1982).

It is worthy to note that the increase in the GNP and the production of the synthetic detergent coincided the decrease in the transparency of the water of Lake Suwa. Generally speaking, the decrease in the transparency of the lake water indicates the acceleration of the eutrophication of lakes. The corelation between the GNP or the production of the synthetic detergent and the transparency of the lake water suggests that the eutrophication which has been proceeding in Lake Suwa since the 1960's is an artificial one.

7. Changes in the concentration of N and P in Lake Suwa

You will understand from Table 2 that Lake Suwa has undergone a remarkable change in the standing stock of nitrogen and phosphorus. The total amount of nitrogen has increased by about 6 times and the total amount of phosphorus about 15 times as much as 50 years ago. Lake Suwa has been changed into an extraordinary productive lake, now.

Table 2. Changes in the concentration of nitrogen and phosphorus in the water of Lake Suwa in μg/l

Date	TN	TIN	TP	RP
1931 Aug.	260	—	20	—
1949 Sept.	490	220	80	14
1958 May.	1160	—	80	14
1966 July.	—	193	30	3
1969 June.	1350	325	—	—
1977 Aug.	1630—2020	2—60	260—340	80—100
1981 Aug.	1220—1500	190—630	160—290	24—40

TN: Total nitrogen TIN: Total inorganic nitrogen
TP: Total phosphorus RP: Reactive phosphorus

(Modified from Sakamoto 1974)

8. Changes in fish catch

Well, I will show you the change in fish catch from Lake Suwa (Fig. 5). Lake Suwa is noted for the greatest fish catch for the unit area in Japan. This figure is based upon the statistics concerning the yields of aquatic macro-organisms from the lake since 1895.

The yields of aquatic organisms to man from the lake have changed by many factors including the change in the commercial demand, the changes in the composition and standing stock of organisms, the change in the number of fishermen, the technological improvement of fisheries, and the influence of the Second World War. Roughly speaking, the total fish catch has been stable at about 400 metric tons a year after the Second World War (Fig. 5).

When it comes to the component of the fish catch, however, there has been a notable change in recent years. Especially, among benthic fishes and shells, Corbicula and shrimps have remarkably decreased (Fig. 5), As a result, 70% of the total fish catch is pond smelt now, and if we add carps and crucian carps to it, more than 90% goes to these three kinds of fishes. Pond smelt is one of the few species that can take good advantage of the eutrophication of the lake, because there are plenty of rotifers in the water, which make a good food for the fry of pond smelt and enable them to grow in large quantities. In addition to that, there are few fishes that eat pond smelt in this lake. In order to promote the landing of pond smelt and enable them to grow in large quantities. In addition to that, there are few fishes that eat pond smelt in this lake. In order to promote the landing of pond smelt, the collection of fish eggs, fertilization and stock are all artificially done here.

Figure 5 also indicates the remarkable increase in the yield of carps by aquaculture. The total landing of the cultured carps exceeded four times as much as that by fisheries in 1978.

We know that the change in the composition of aquatic organisms caught by fishers does not always reflect the *in situ* change. However, these are the only data about the aquatic macro-organisms in Lake Suwa which cover nearly 90 years. Thanks to these data, we can know the outline of the change in the composition of aquatic macro-organisms from the times before the scientific researches began.

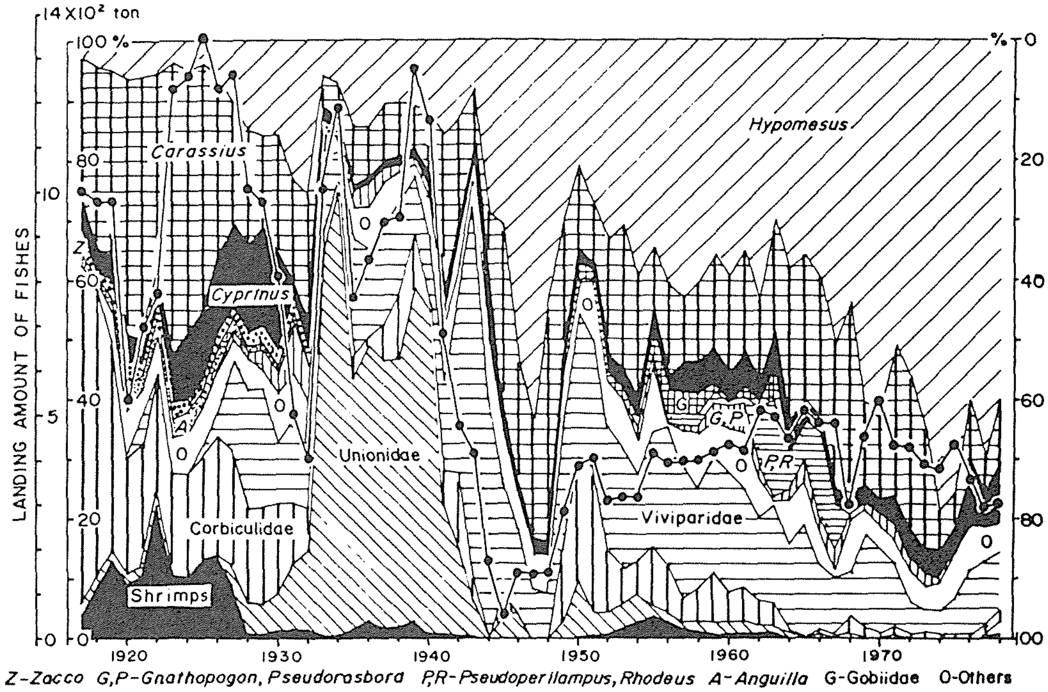

Fig. 5. Transitions in percent abundance of annual landing amounts of commercial fishes, molluscs and shrimps in Lake Suwa. A solid line in this figure shows the total landing amounts of fishery products in Lake Suwa (Quoted from Kurasawa, H. and others, 1983). ●——● Total amount

9. Changes in the rooted aquatic plants

Figure 6 is showing the changes in the standing crops of the rooted aquatic plants and the changes in the percentages of three different groups of life form of the aquatic plants in Lake Suwa.

The total standing crop of the rooted aquatic plants in the whole lake reached the maximum in 1966. The standing crop at that time was about 1960 metric tons. It decreased by 24% in 1976. This decrease is attributable mainly to the decrease in their habitats. The habitat of the emerged plants has been destroyed by the reclamation and that of the submerged plants by the dredging.

As was mentioned previously, the surface area of Lake Suwa in 1978 decreased by 8.3% as compared with that in the 1910's by the reclamation. They reclaimed by using the sediments dredged from the lake. These human activities brought about not only the changes in the standing stock of the plants but also the changes in the percentage of the three different groups of life from of the aquatic plants as can be seen in this figure. The submerged plants were dominant in 1949. But, in 1976 the floating leaf plants became dominant in their place. The floating leaf plants have suffered least from these engineering works.

On the other hand, the standing crop per unit area for the distribution zone of the aquatic plants continued to increase until 1972 but after that it decreased (Fig. 6). This increase is due to the eutrophication of the lake, in other words the eutrophication brought about the high production of the plants. And the standing crop per unit area decreased in 1972 because the hypertrophic condition of the lake took the light out from the submerged plants.

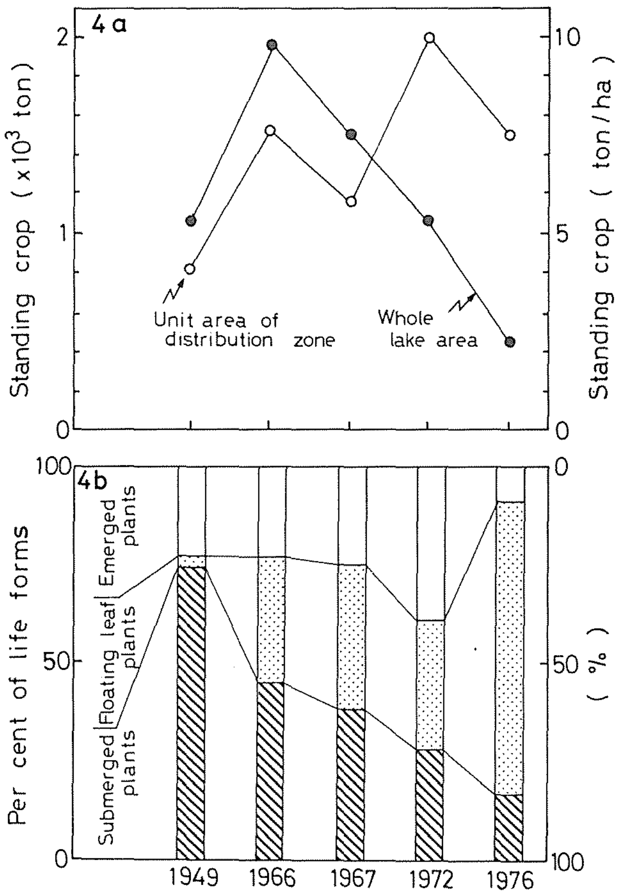

Fig. 6. Upper fig.; Standing crop of rooted aquatic plants in the whole lake area and the unit area of distribution zone of Lake Suwa. Lower fig.; Changes in the percentage of three life forms of aquatic plants (submerged, floating leaf and emerged plants) (Quoted from Kurasawa, H. and others, 1979).

10. Seasonal change in chlorophll a

As was mentioned previously, the surface of Lake Suwa is covered by the thick green layer of bloomed *Microcystis* in summer. Figure 7 shows the seasonal change in chlorophyll *a* in 1977. The summer peak indicates the bloom of *Microcystis* and the vernal peak the bloom of diatoms.

According to the remote sensing sent from an American Resource Satellite, the lake looks very like a grass land when *Microcystis* blooms. The tourists who visit there, sometimes mistake it for the green paint thrown in by accident. In order to improve this condition a large-scale waste water treatment plant is being constructed now.

11. Waste water treatment plant

The project area is shown in Figure 8. This plant deals with the domestic, industrial and other waste water and human feces and urine conveyed from the surrounding areas by the main pipe lines. In October 1979, a part of this plant started to operate. The mouth of the drain pipe from this plant opens into the Tenryu River, the only outlet of the lake. The nutrients coming from the catchment area of the lake decreased by 30% by the partial operation of this plant.

In order to study the effect of the construction of this plant on the hypertrophic condition of Lake Suwa, a project team, to which we belong, has been carrying out a routine survey since 1977. More than 30 par-

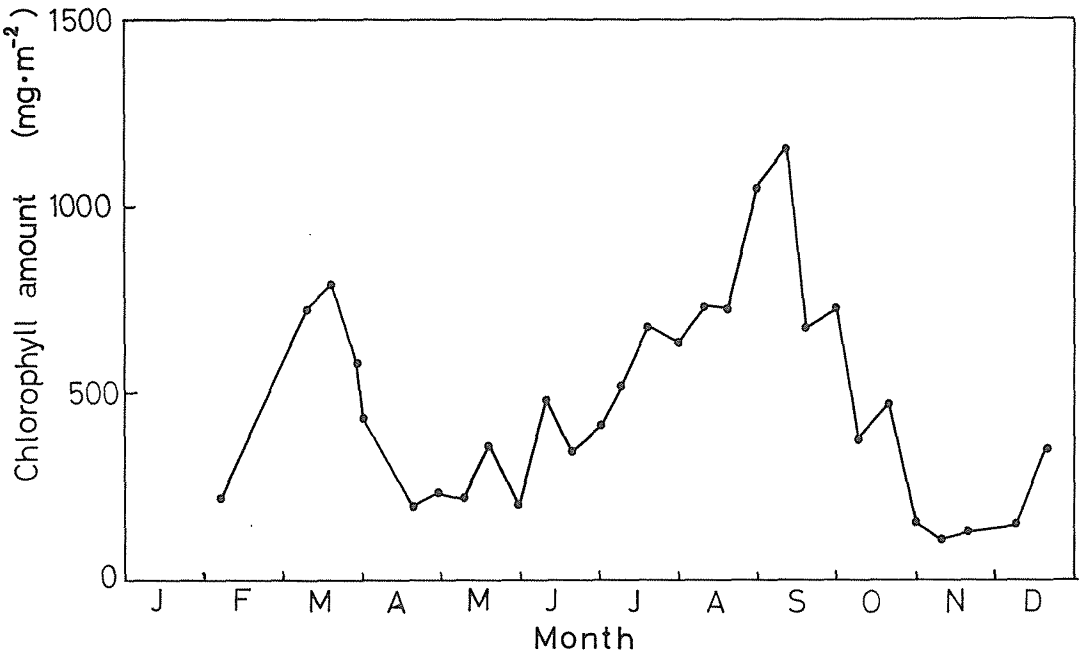

Fig. 7. Seasonal change of chlorophyll-a amounts of Lake Suwa in 1977 (after Okino, T. and M. Yamamoto, 1978).

ameters including the biological, chemical and physical ones have been surveyed at the water column of the lake center every ten days in 1977, 1981 and 1982 and once a month in 1978 and 1979. Out of these vast data, I will show you a brief summary.

12. N and P in Lake Suwa before and after the sewage plant operation

As you can see in Table 2, the concentrations of all parameters in 1981 are smaller than those in 1977 except the total inorganic nitrogen. A part of the sewage plant began to operate in October 1979. Therefore, these data show the concentration of the nitrogen and phosphorus compounds in the lake water before and after the partial operation of the sewage plant.

13. Gross production in Lake Suwa befoe and after the sewage plant operation

Table 3 shows the changes in gross production and other items. The gross production in the lake was 260g^{C}/m^2/y in 1949. It became double in 1969. And then just before the sewage plant began to operate, it tripled. It seems that the gross production after the partial operation of the sewage plant decreased to the level of 1969.

14. Conclusion

Do these decreases in nitrogen and phosphorus (Table 2), and gross production (Table 3) indicate that the lake has become cleaner because of the partial operation of the sewage plant ? This problem caused a great controversy among the members of our project, and it is yet to be solved. Someone argues that the fluctuation in the weather conditions, especially the amount of precipitation in among the main factors which caused these decreases. It will take a long time to evaluate the effect of the construction of the sewage plant on the lake ecosystem.

Anyway, Lake Suwa has suffered from various human activities for a long time and the construction of the sewage plant in the latest human activity significant for the lake. Lake Suwa is under a big experiment now.

Aknowledgment

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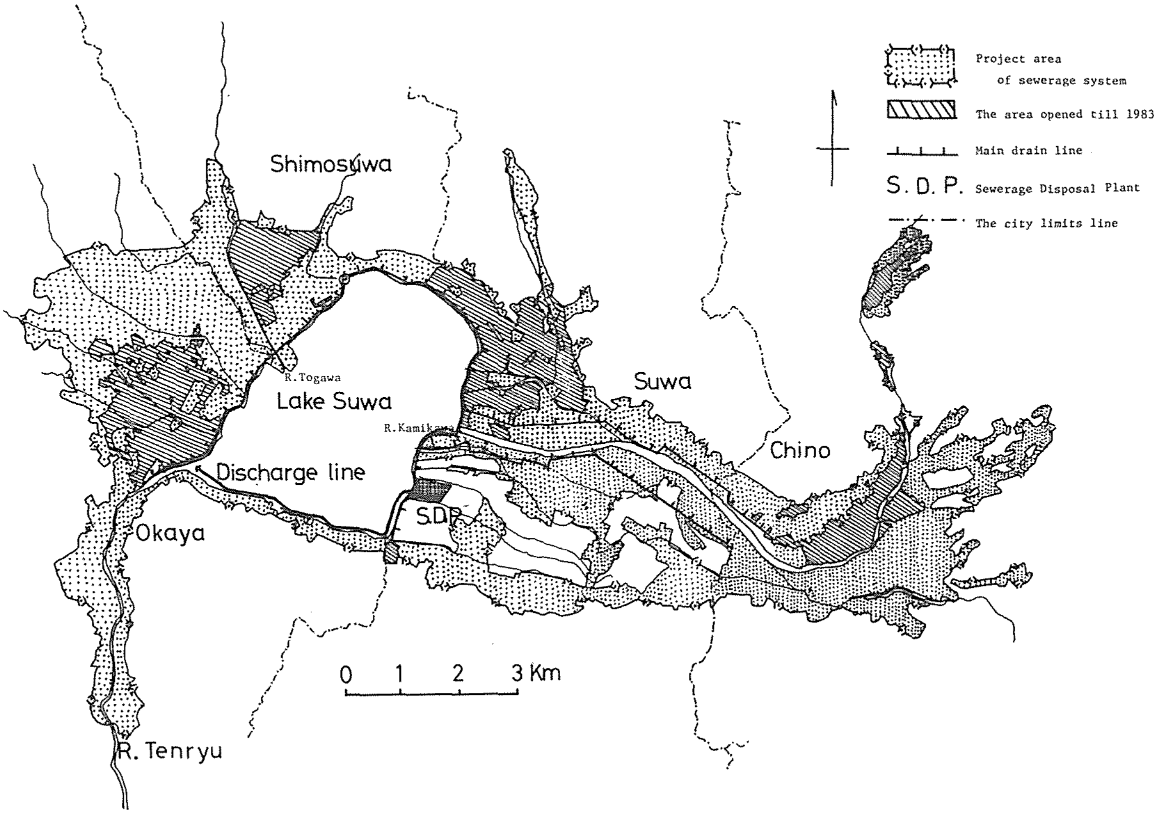

Fig. 8. The project area of sewerage system and the opened area among this system till 1983 (by panphlet of the office of local government, Nagano Prefecture, 1983).

Table 3. Changes in the annual gross production, annual mineralization, annual solar radiation and energy transfer efficiency by phytoplankton in Lake Suwa.

Year	Annual gross production $gCm^{-2} \cdot y^{-1}$	Annual mineralization $gCm^{-2} \cdot y^{-1}$	Annual solar radiation $Kcal\ cm^{-2} \cdot y^{-1}$	Energy transfer efficiency %
1949*	260	211	—	0.24
1969	557	615	—	—
1977	756	642	—	—
1978	699	708	114	0.61
1979	777	625	106	0.73
1980	—	—	110	—
1981	576	559	121	0.48
1982	629	541	115	0.55

* from Hogetsu et al. (1952)

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