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BIOLOGICAL OBSERVATION ON THE POND SMELT, *HYPOMESUS OLIDUS* (PALLAS), IN LAKE KOGAWARA, AOMORI PREFECTURE, JAPAN. III. ANNUAL CYCLE OF ECOLOGICAL ELEMENTS IN RELATION TO PRODUCTION OF FOOD ORGANISMS OF THE FISH*

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Introduction

In Lake Kogawara in southeast Aomori Prefecture the pond smelt, *Hypomesus olidus* (Pallas), whose annual production amounts to nearly 350 tons a year, consumes mainly the zooplankton (Sato, 1950). Such feeding habits have been also recognized in Lakes Kasumiga-ura and Abashiri by Miyauchi (1934) and Ishida (1949), respectively. Therefore, the supply of zooplankton is indispensable for the production of the pond smelt. The annual fluctuation of the production of zooplankton is considered to have great influence on the production of the fry of the pond smelt and its growth. In the analysis of smelt population in Kogawara, therefore, the fluctuation in the production of zooplankton in relation to annual cycle of ecological elements and its range should be studied.

The writer observed the seasonal changes of physical and chemical characters of the lake water in relation to the annual cycle of plankton and pond smelt production from March 9, 1949 to May 16, 1950. As a result, he could illustrate the quantitative relation among the annual cycle of nutrient salts and productions of producers, phytoplankton, primary consumers, zooplankton, and secondary consumers, pond smelt.

Methods

Station No. 26. off Iwagasaki in the deepest place near the center of the lake was selected for sampling. At each water sampling, the temperature was

* Contribution from the Onagawa Fisheries Laboratory

recorded at 0, 5, 10, 20 and 23 meters depth. The chlorinity was determined by titration with silver nitrate. pH value was colorimetrically measured with brom thymol blue, cresol red and thymol blue, as indicators. Dissolved oxygen was measured by the Winkler method and percentage oxygen saturation was calculated from Fox's table. Among nutrient salts, inorganic phosphate, silicate and inorgainc nitrogen compounds such as ammonia, nitrite and nitrate were determined by the methods described in "Methods of Oceanogaphical Observations" ("Kaiyo-Kansoku-ho" Kaiyo-Kishodai, 1940). Transparency of water was measured by means of Secchi disc. For the plankton collection, a net of silk bolting-cloth of 129 mesh and with a diameter of 30 cm. at the mouth was used. The hauling was made vertically from the bottom, to the surface. For the collection of *Neomysis intermedia*, a net of silk mosquito-net cloth of 25 mesh and with one meter in diameter at the mouth was used. Hauling was made horizontally in the shallow water, less than 10 m in depth, along shore of the lake. Pond smelts of various growth stages were collected near the station once every month to examine their stomach contents.

Results

1. *Limnological condition.*

Vertical monthly differences of limnological elements in the lake is shown in Fig. 1 and 2. The water of the upper stratum, from surface to 20 m depth, for most of the time, was mixed well even during the thermal stratification period of both summer and winter seasons. This seems to be due to intermittent mixing of water by the stirring action of the wind and probably of currents. However, the water of the bottom stratum, or of depths exceeding 20 m was stagnant during the summer and winter seasons and nutrient salts such as inorganic phosphate and ammonium which was derived from deposited organic matter were in reserve there. Monthly change of physical and chemical conditions of the water in the surface and bottom of the lake is shown in Figs. 1, 2 and 3.

Temperature.

The temperature of the surface water fell to 0°C in January and the whole lake was caked with thick ice. In the beginning of March, as the temperature rose, the ice began to melt. The temperature of surface water exceeded 4°C in early April, and reached 10°C in May and 20°C by the end of July. The maximum temperature of the surface water was 27°C in the middle of August. Thereafter the water temperature began to fall and it was 20°C in early October, 10°C in November and finally it fell to 0°C in January. Although a thermocline was faintly noticed at the 5–10 m depth in the upper water stratum during the

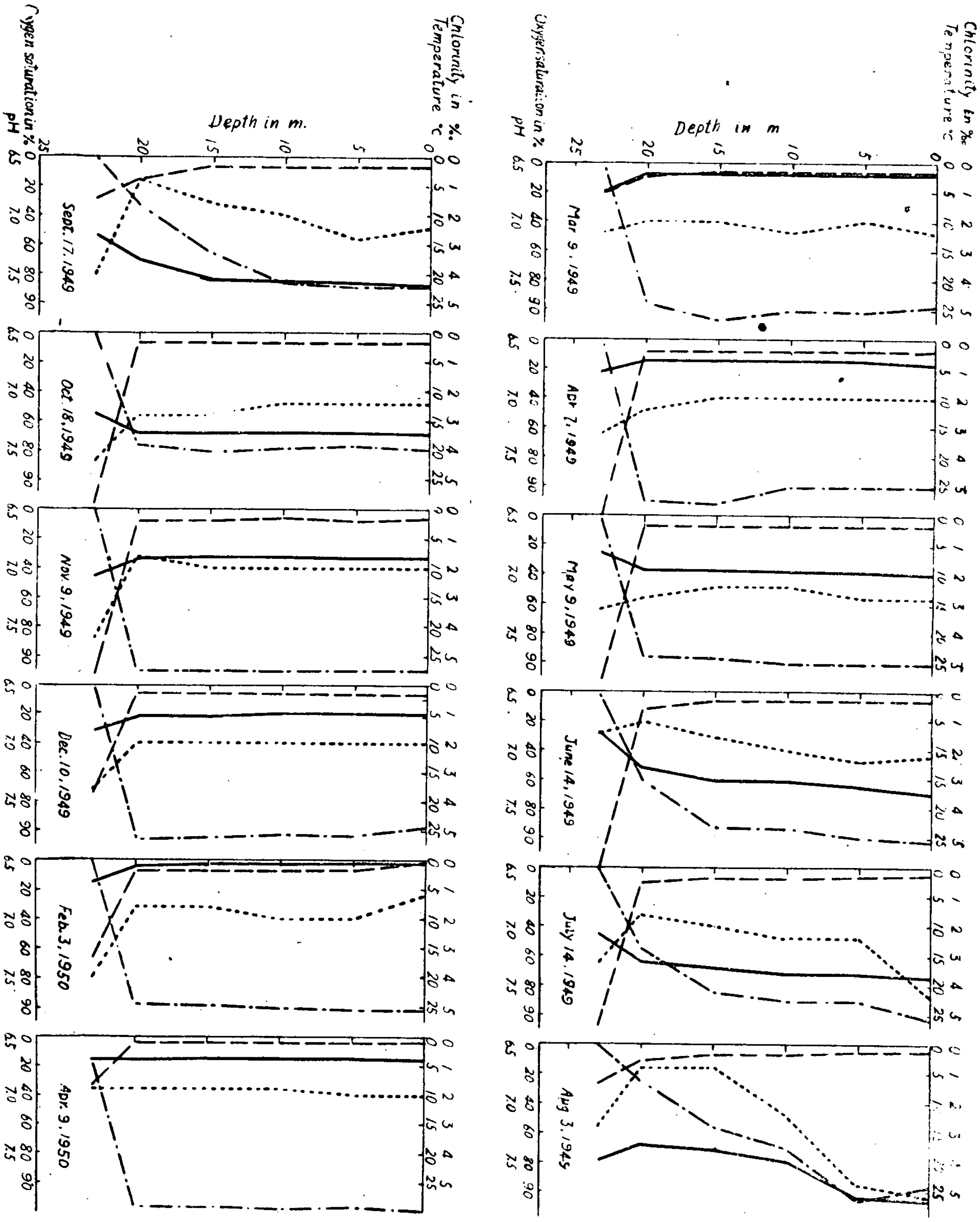

Fig. 1. Vertical distribution of physical and chemical elements observed monthly from March 9, 1949 to April 9, 1950.

——————— water temperature, — — — — chlorinity,
— - — - — - — oxygen saturation, ---------- pH value.

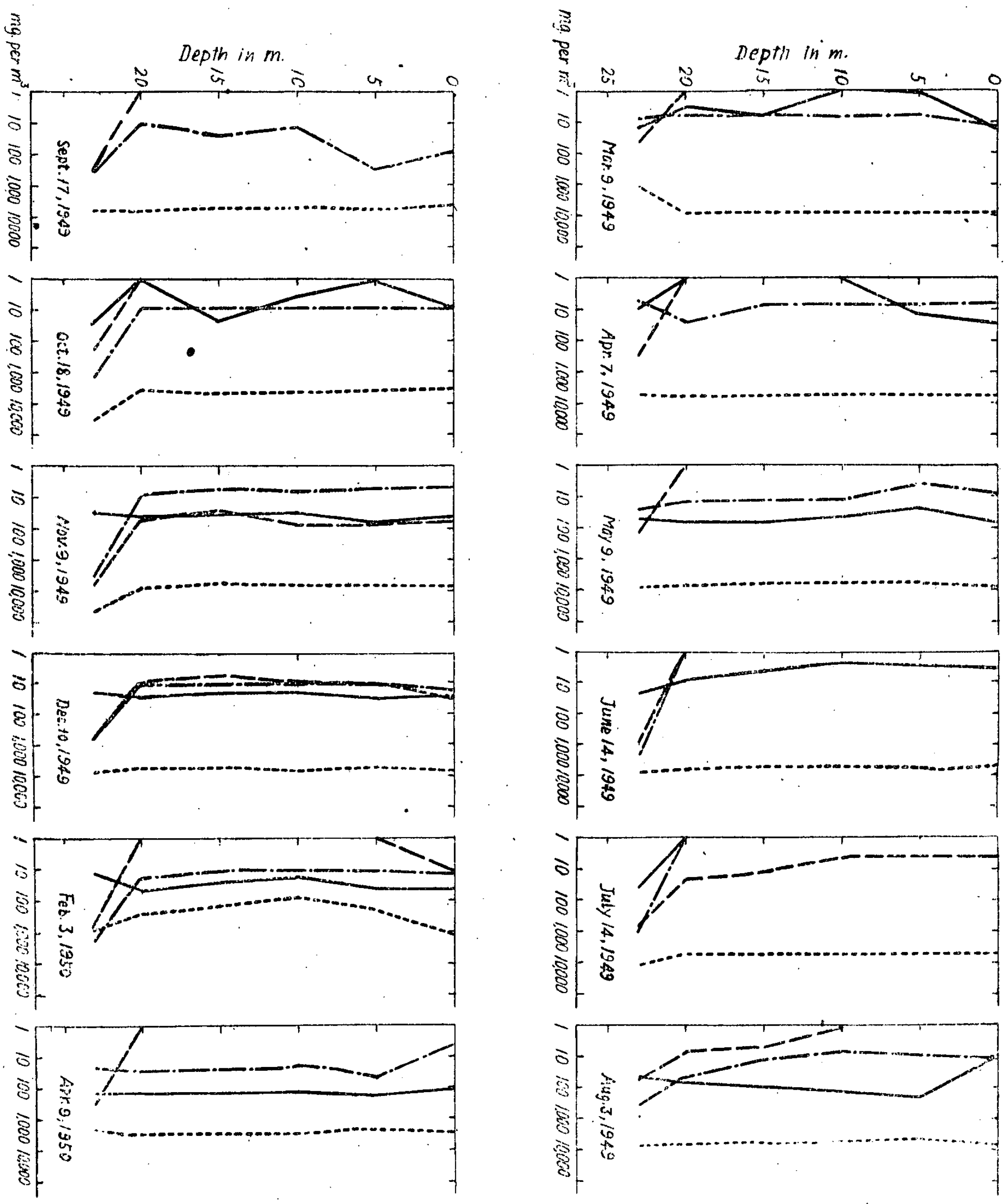

Fig. 2. Vertical distribution of nutrient salts content observed monthly from March 9, 1949 to April 9, 1950.
———— NO_3-N, — — — — NH_4-N,
— - — - — P_2O_5-P, - - - - - - - SiO_2-Si.

summer stratification period as is seen in Fig. 2, it was never well marked throughout the year. It seemed to be due to mixing of the upper water. In the bottom water stratum, from 20 m to the bottom, the temperature range of fluctuation lessened, and the maximum was 19.9°C in summer and the minimum was 3.7°C in winter.

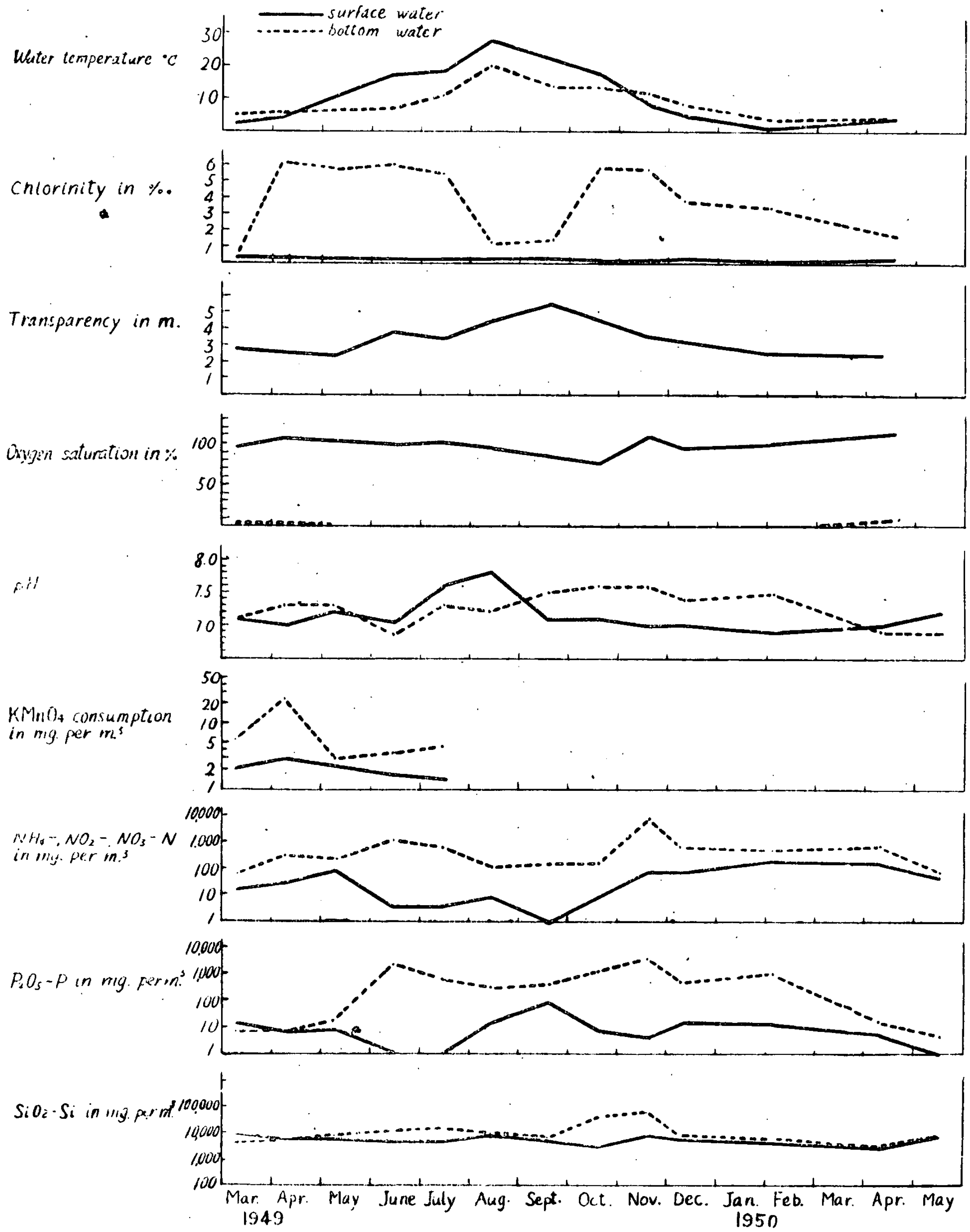

Fig. 3 Monthly change of physical and chemical conditions in surface and bottom water.

Chlorinity.

Chlorinity of the upper water stratum, from the surface to 20 m depth, was less than 0.5 per mill throughout the year. However, the bottom water, was 1.0 per mill or more and the peaks were 6.0 and 5.9 per mill in spring and

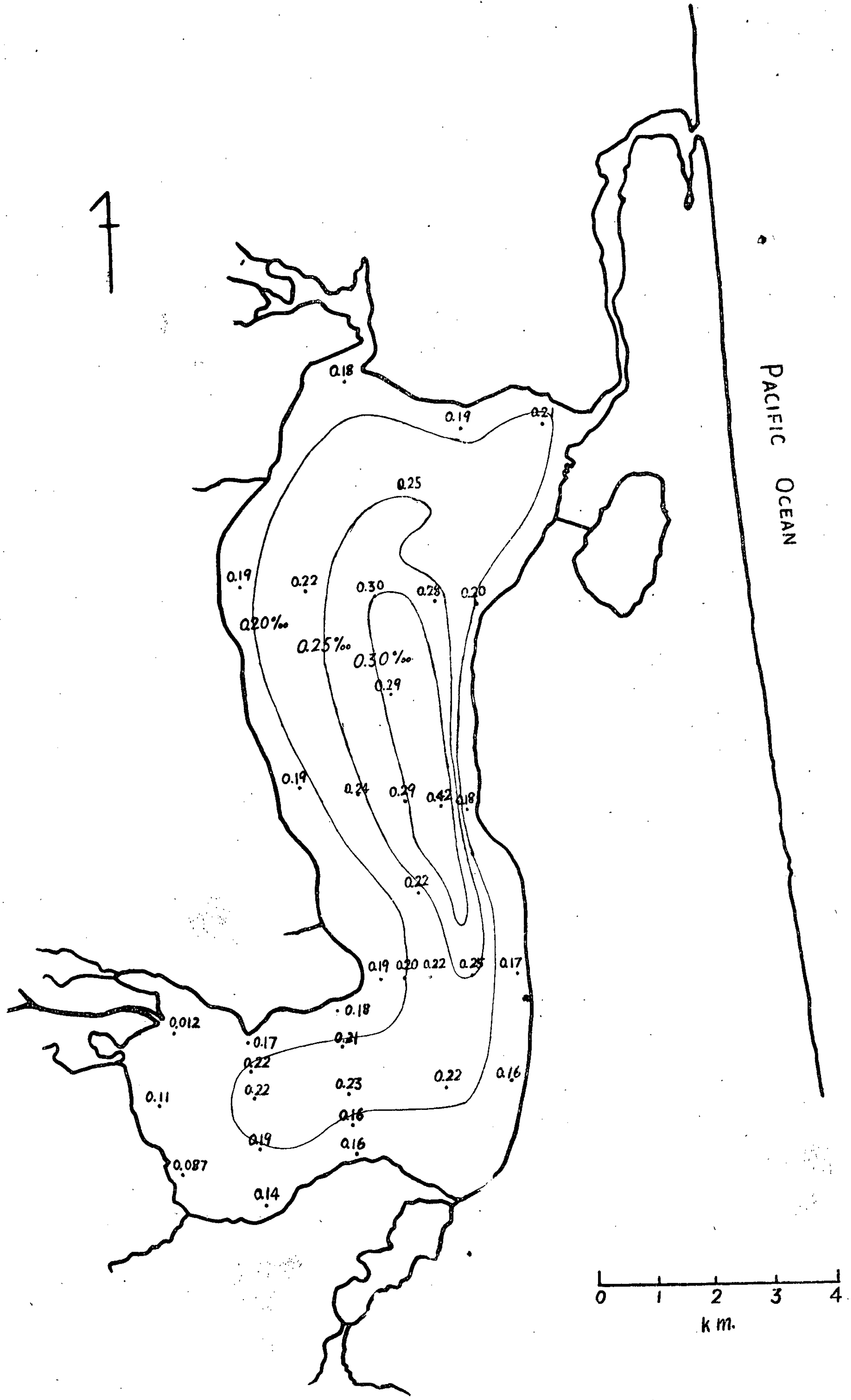

Fig. 4 Distribution of chlorinity in the bottom water in the summer of 1950.

autumn. This was due to the inflowing of sea water from the Pacific Ocean at the time of high tide in spring and also to the lowering of water level of the lake in autumn. Distribution of chlorinity in the bottom water of the lake during the summer stagnation period is shown in Fig. 4.

Transparency of water

Transparency of water varied from 2.5 to 5.5 m at Station 26. The change of transparency of the water was generally reversible to the amount of phytoplankton as is seen in Fig. 5. From February to May, it was less than 2.5 m while in October, it was 5.5 m.

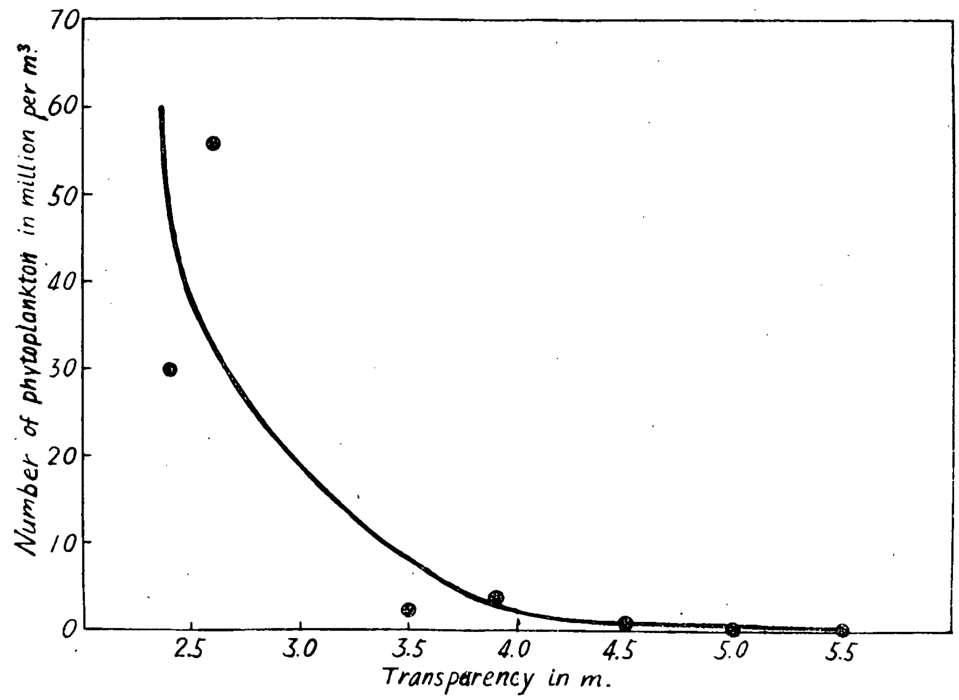

Fig. 5 Relation between the density of phytoplankton and the transparency of water.

Percentage oxygen saturation.

The dissolved oxygen in surface water was supersaturated in the spring season. It decreased to 75 per cent during the summer season, and then increased again to supersaturation in autumn. The increase of oxygen saturation accompanied the fall of transparency of water as a result of phytoplankton growth. The dissolved oxygen of the bottom water was zero or nearly so throughont the year. Distribution of percentage oxygen saturation in the bottom water of the lake during the summer stagnation period is shown in Fig. 6.

Hydrogen ion concentration

The range of pH values of the upper water stratum, surface to 20 m depth,

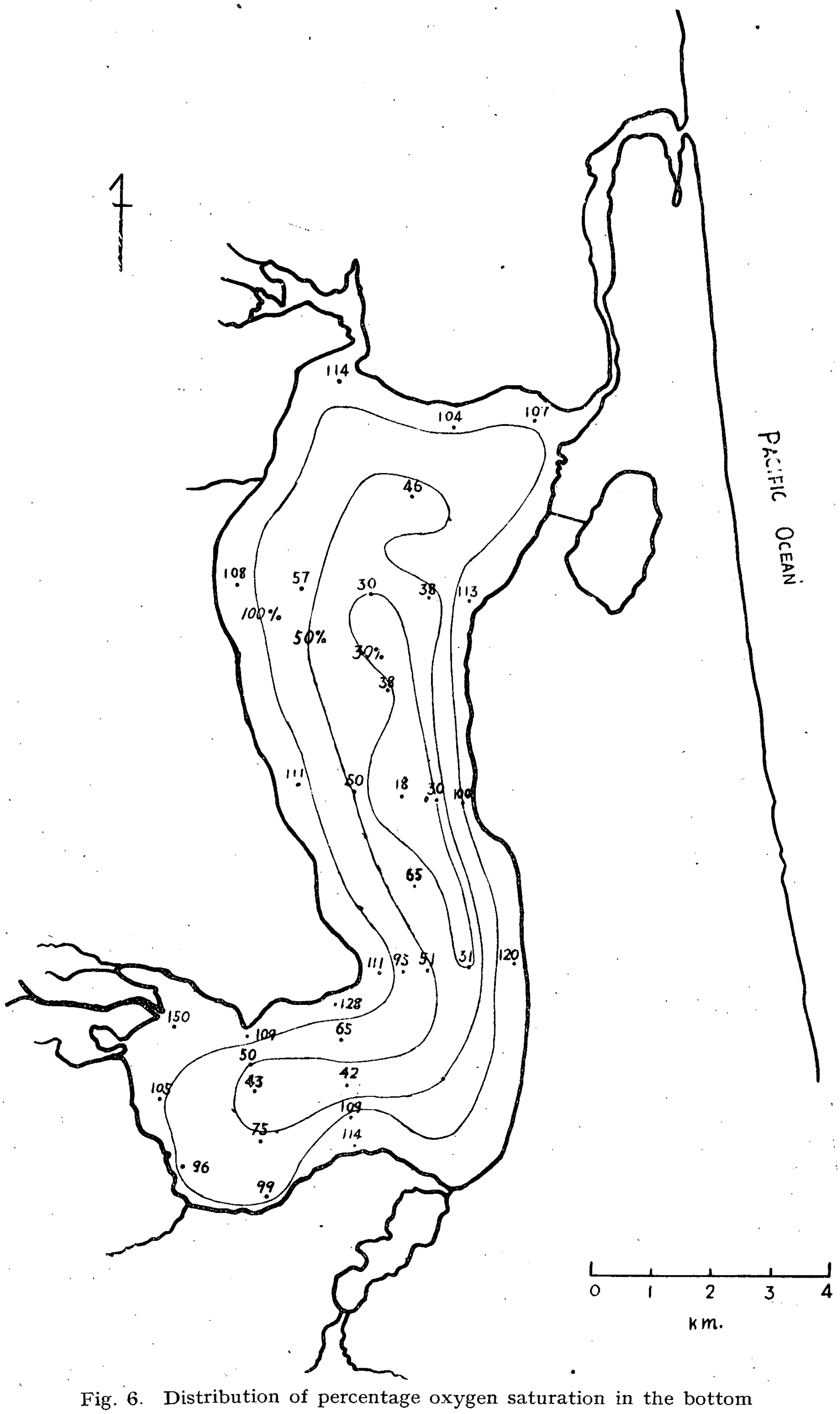

Fig. 6. Distribution of percentage oxygen saturation in the bottom water in the summer of 1950.

was 6.7 to 7.8. While pH values of bottom water stratum, from 20 m down to the bottom, were 6.85 to 7.6 with a narrower range of fluctuation, seemingly due to the buffer action of added sea water.

2. *Nutrient salts.*

The amount of inorganic phosphate phosphorus of the upper water stratum (down to 20 m depth), fell to zero in June and July after the spring outburst of phytoplankton. However, it reached to 255 mg/m^3 in September immediately after the disappearance of phytoplankton as is seen in Figs. 1 and 2. In the bottom water stratum (below 20 m depth) the highest contents of 2,199 and, 3,663 mg/m^3 of phosphate phosphorus was found during the stagnation period of the late spring and outumn seasons. Its content exceeds 17–750 mg/m^3 of phosphate phosphorus in the bottom water of 15 Wisconsin lakes in late spring and summer (Juday, Birdge et al., 1928).

Among inorganic nitrogenus compounds, ammonium was rich in the anaerobic bottom water stratum though it was also detected in the upper water stratum at the stagnation period of both summer and winter. The maximum amounts of ammonium nitrogen was 6,675 mg/m^3 in the bottom water stratum in autumn.

Nitrate and nitrite were generally present in the aerobic upper water stratum. The amount of nitrite nitrogen was generally low and it was less than 64 mg/m^3 even in the anaerobic bottom water stratum. The maximum content of nitrate nitrogen was 194 and 183 mg/m^3 in the aerobic upper water stratum in the early autum and spring season. The content gradually fell to zero in July as a result of the spring outburst of phytoplankton as a case of phosphate phosphorus

The silicate silica was rich in both upper and bottom water strata and fluctuated from 4,638 mg/m^3 to 47, 329 mg/m^3.

The average contents of nutrient salts in the upper water stratum were 15 mg/m^3 for phosphate phosphorus and 64 mg/m^3 for total inorganic nitrogen. Therefore the lake should be classified as the oligotrophic type according to the classification of Thieneman (1921) modified by Yoshimura (1937).

3. *Plankton population.*

In the lake, 45 species of phytoplankton organisms and 39 of zooplankton organisms had been recorded by Kokubo (1949), Tamura (1951) and Sato (1952).

The horizontal distribution of the main species by net collection at nine stations (Fig. 6) on July 21, 1948 is shown in Table 1.

The distribution was not homogeneous particularly in the case of zooplankton. In the north-eastern part of the lake, *Sinocalanus tenelus* was abundant. While in the south-western part, rotifers, *Polyarthra platyptera* and *Keratella aculeata*,

Table 1. Average number of plankton per m^3, collected by net hauling from bottom to surface at nine stations in the lake, on July 21, 1948.

Station	St. 6	St.14	St.17	St.23	St.23	St.32	St.33	St.35	St.37
Forel's scale (No.)	11	10	9~10	8	8	8	—	8	—
Transparency (m)	2.2	3.0	4.0	3.8	3.8	4.5	3.8	3.8	—
Zooplankton									
Sinocalanus tenelus	46	126	127	42	147	132	1,294	258	168
Copepod nuauplii	133	272	208	124	48	40	813	48	56
Bosmina coregoni	0	584	127	1,052	123	45	495	0	0
Chydorus sphaericus	0	0	0	0	0	0	0	0	7
Polyarthra platyptera	995	627	892	122	44	174	566	12	0
Keratella aculeata	265	358	297	220	91	47	1,096	12	21
Total	1,853	1,967	1,651	1,560	453	438	4,264	330	252
Phytoplankton									
Asterionella formosa	c	none	c	cc	none	r	cc	c	none
Rhizosolenia sp.	rr	rr	none	none	none	none	none	none	none
Coscinodiscus sp.	rr	none	none	none	none	none	none	none	none
Total									

were abundant. *Neomythis intermedia* was distributed widely in the lake.

At St. 26, the deepest place in the lake, plankton groups of both the north-eastern and south-western parts were collected in moderate abundance. The seasonal fluctuation of the amount of net plankton had been studied for station 26 and the results had been reported by Sato (1952).

Among phytoplankton organisms, *Asterionella formosa*, the main constituent of diatoms, was the most abundant in spring, and it again appeared in less quantity in the fall. Other phytoplanktons, *Synedra sp.*, *Fragilaria spp.* and *Melosira sp.* and other microdiatoms showed a similar mode of fluctuation though their quantity less than that of *Asterionella formosa*.

A blue green algae, *Anabaena sp.*, however, showed a peak in the summer season. The abundance of net phytoplankton was inversely proportional to the degree of transparency as is shown in Fig. 4.

Among zooplanktonic organisms, *Keratella aculeata*, *Tryarthra longiseta* and *Brachionus sp.* of Rotifers were abundant only in spring, *Keratella cochlearis* and *Polyarthra platyptera* were abundant both in spring and autumn and *Asplanchna sp.* was very abundant in the summer season. As for crustacea, *Bosmina coregoni* and *Diaphanosoma brachiurum* of cladocerans and *Pseudodiaptomus inopius* and *Cyclops strenus* of copepods were abundantly found in the summer season. *Sinocalanus tenelus* and its nauplii and *Neomysis intermedia* were found throughont the year, though the former was abundant in summer and the later in spring.

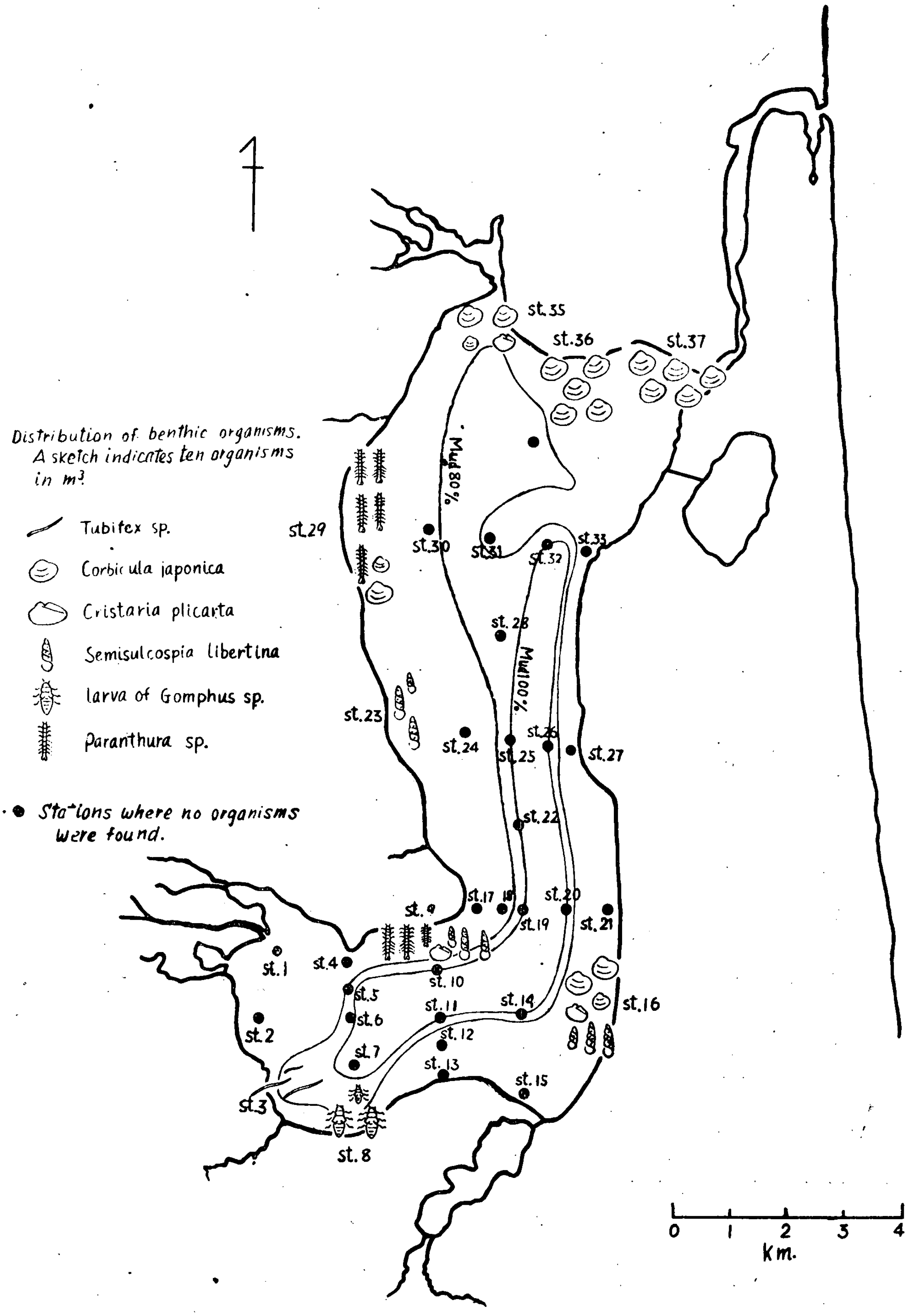

Fig. 7. Distribution of benthic organisms in the bottom in summer of 1950. 80 percent and 100 percent mud line are shown in the map.

4. *Benthic population.*

Population of benthic organisms were generally poor owing to the anaerobic condition of the bottom water for half to three quarters of the bottom in the mid portion of the lake. Therefore a few benthic organisms such as the annelid, *Tubifex sp.* the crustacean, *Paranthura sp.* and the larva of *Gomphus sp.* and *Chironomus sp.* were found in the shallow waters of the south-western part of the lake. Molluscs as *Corbicula japonica, Cristaria plicata* and *Semisulcospira libertina,* were found in the shallow waters of the north-eastern part of the lake (Fig. 7). Among benthic organisms, *Chironomus* larvae were consumed by the adult pond smelts in the early spring. However the amount of *Chironomus* larvae consumed by the pond smelts were far less than that of zoolpankton as already been reported by Sato (1952).

Tabie 2. Fishes collected in Lake Kogawara

	English name.	Japanese name
Oncorhynchus keta (Walbaum)*	Dog salmon, Chum salmon	Sake
Oncorhynchus masou (Brevoort)*		Masu
Hucho Perryi (Brevoort)*	Hucho trout	Ito
Salanx microdon Bleeker **	Whiting, Ice fish	Shirauwo
Hypomesus olidus (Pallas)**	Pond smelt	Wakasagi
Parasilurus asotus (Linné)	Fresh-water catfish	Namazu
Leuciscus hakuensis Günther *	Japanese dace	Ugui
Cyprinus carpio Linné	Carp	Koi
Carassius auratus (Linné)	Crucian carp	Funa
Archeilognathus moriokae Jordan & Thompson	Minnow, Shiner	Tanago
Misgurnus anguillicaudatus (Cantor)	Loach	Dojo
Oryzias latipes (Temminck & Schlegel)	Killifish	Medaka
Anguilla japonica Temminck & Schlegel *	Eel	Unagi
Gasterosteus cataphractus (Pallas)*	Stickleback	Itouwo
Pygosteus brevispinosus Otaki	Stickleback	Kita-no-tomiyo
Hemirhamphus kurumeus Jordan & Starks *	Halfbeak	Kurume-sayori

Mugil cephalus Linné *	Mullet	Bora
Liza hematocheila (Temminck & Schlegel) *	Japanese mullet	Menada
Latcolabrax japonicus (Cuvier & Valenciennes)*	Common sea bass	Suzuki
Cottus pollux Günther	River sculpin	Kazika
Platycephalus indicus Linné *	Flat head	Kochi
Acanthogobius flavimanus (Temminck & Schlegel)*	Spiny goby	Ma-haze
Chloea castanea (O'Shaughnessy)		Biringo
Tridentiger obscurus (Temminck & Schlegel)		Chichibu
Chaenogobius macrognathus (Bleeker)*		Ukigori
Platichthys stellatus (Pallas)*	Starry flounder	Numa-garei

* indicates anadromous fishes and ** indicates landlocked ones.

5. *Fish population.*

26 species of fish as were caught in Lake Kogawara (Table 2), and of them, 13 are anadromous fishes and 13 are landlocked and aboriginal fish. Landlocked pond smelt, the plankton feeder, was the most abundant and 375,000 kg of them were caught in 1949; they occupied 82 per cent of the total catch (456,000 kg) of the year.

6. *Relation of the ecological cycle to the pond smelt production.*

Seasonal fluctuation of phytoplankton population in relation to the amount of nutrient salts.

The nutrient salts such as inorganic phosphate and ammonium accumulated in the bottom water stratum during autumn to winter as is shown in Fig. 3. However, a large part of them were delivered to the upper water stratum as a result of turnover during winter to spring, and then they were utilized in the spring outburst of phytoplankton. The dead phytoplankton sank down to the bottom water stratum, and the nutrient salts derived from them accumulated there again during spring to summer. Another turnover of the lake water during summer to autumn, drove the nutrient salts to the upper layers and this became available for the autumnal outburst of phytoplankton. Such cyclic change of nutrient salts can be clearly seen in the content of inorganic phosphate.

The volume of the stagnant bottom water, from 20 m down to the bottom, is estimated to be 14 millions cubic meters, while that of the upper stratum is 523 millions cubic meters. Thus the maximum amount of phosphate phosphorus in the bottom water during summer and winter stratification was estimated to be roughly 40,000 kg.

From the cyclic change of the nutrient salts in the lake, it was suggested that the phytoplankton growth in the upper water stratum was governed by one of the nutrient salts. Therefore the relation of nutrient salts to the growth of phytoplankton population in the surface water of the lake was examined. A green algae, *Scenedesmus obliquus*, was cultured in 200 cc of the surface lake water of August 13, 1949, and the effect of the addition of two drops of 5 per cent solutions of 9 kinds of inorganic substances upon the algal growth was studied. As a result, it was proved that only the addition of inorganic nitrogen compounds, $(NH_4)_2SO_4$ and $NaNO_3$, was effective upon the growth of the algae. No growth promoting effect was observed in cultures into which Na_3PO_4, K_2SO_4, $CaCl_2$, NaCl, Na_2SO_4, $MgSO_4$ and $Fe_3(SO_4)_2$ were added as is shown in Table 3. It was evident from the experiment that the minimum substance for the growth of the algae was inorganic nitrogen.

While it was also ascertained that the growth of algae was promoted by adding phosphate under the presence of the nitrogen. Thus it was clear that either inorganic nitrogen or phosphor is the limiting factor for the algal growth in the

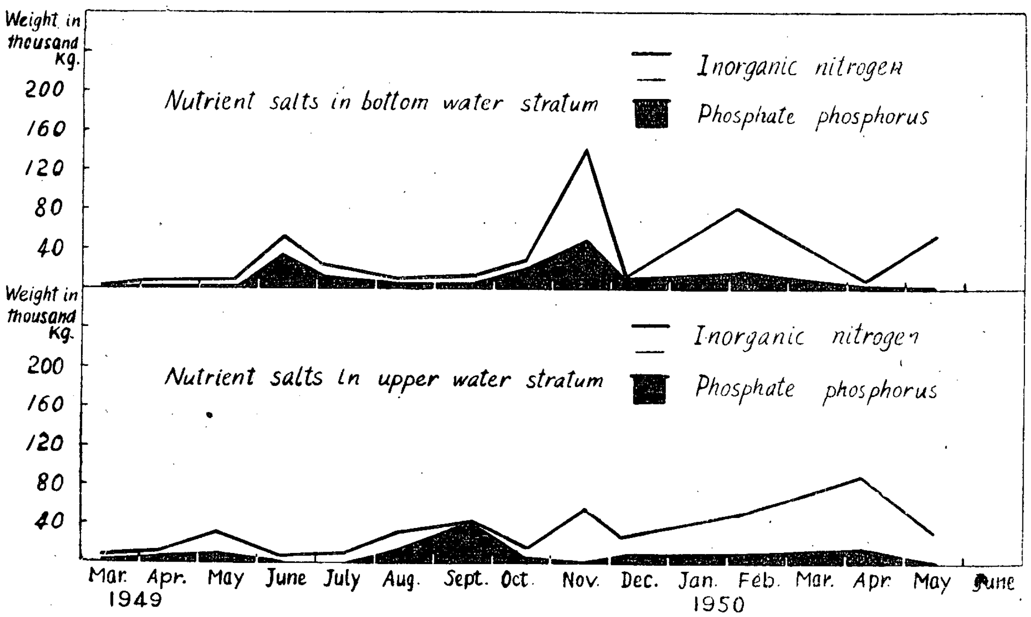

Fig. 8. Seasonal variation of total amount of phosphate phosphorus and inorganic nitrogen in the bottom and upper water stratum.

Table 3. Effect of the addition of various inorganic salts in *Scenedesmus obliquus* culture. Water for the culture was collected from the surface of the lake on August 13, 1949. The water contained 0.0089 mg/L of inorganic nitrogen and 0.0118 mg/L of phosphate phosphorus.

No.	Inorganic salts added	Number of individuals per cc on 10th day of culture
1	$(NH_4)_2SO_4$	545×10^3
2	$NaNO_3$	755×10^3
3	Na_3PO_4	155×10^3
4	K_2SO_4	98×10^3
5	$CaCl_2$	53×10^3
6	NaCl	113×10^3
7	Na_2SO_4	45×10^3
8	$MgSO_4$	60×10^3
9	$Fe_3(SO_4)_2$	0
10	Control	68×10^3

surface water of the lake. According to Kurashige (1933), 6.8 parts of nitrogen against 1 part of phosphor by weight was required for the growth of the fresh water *Synedra sp.* The ratio is close to that of N : P=7.0 : 1 for the marine phytoplanktons which was suggested by Fleming (1940). If we apply the ratio N : P = 6.8 ; 1 to the case of the phytoplankton growth in the surface water of the lake, it will be shown that the minimum substance among nutrient salts for phytoplankton growth in the surface water is inorganic nitrogen in summer while it is phosphorus in other parts of the year as is seen in Table 4. Such assumption seems to illustrate well the fluctuation of phytoplankton abundancy in the lake as is shown in Fig. 9.

Table 4. Seasonal change of the inorganic nitrogenus and phosphorus compounds, and its available amounts for the chlorophyl bearing plankton growth.

Date	NH_4-, NO_2-, NO_3-N (mg/m^3)	P_2O_5-P (mg/m^3)	Availabe P_2O_5-P (mg/m^3) on the bases of N:P=6.8:1	Minimum substance on the bases of N:P=6.8:1
Mar. 9, 1949	17.0	13.7	2.5	N
Apr. 9, 〃	25.6	6:4	3.8	N
May 9, 〃	65.7	8.4	8.4	P
June 14, 〃	3.4	0	0	P
July 14, 〃	4.1	0	0	P
Aug. 13, 〃	8.9	11.8	1.3	N
Sep. 9, 〃	0	77.4	0	N
Oct. 18, 〃	9.4	18.0	1.4	N
Nov. 19, 〃	101.0	4.9	4.9	P
Dec. 8, 〃	65.8	17.7	9.7	N
Feb. 4, 1950	244.2	12.8	12.8	P
Apr. 9, 〃	105.0	4.9	4.9	P
May. 16, 〃	64.8	0	0	P

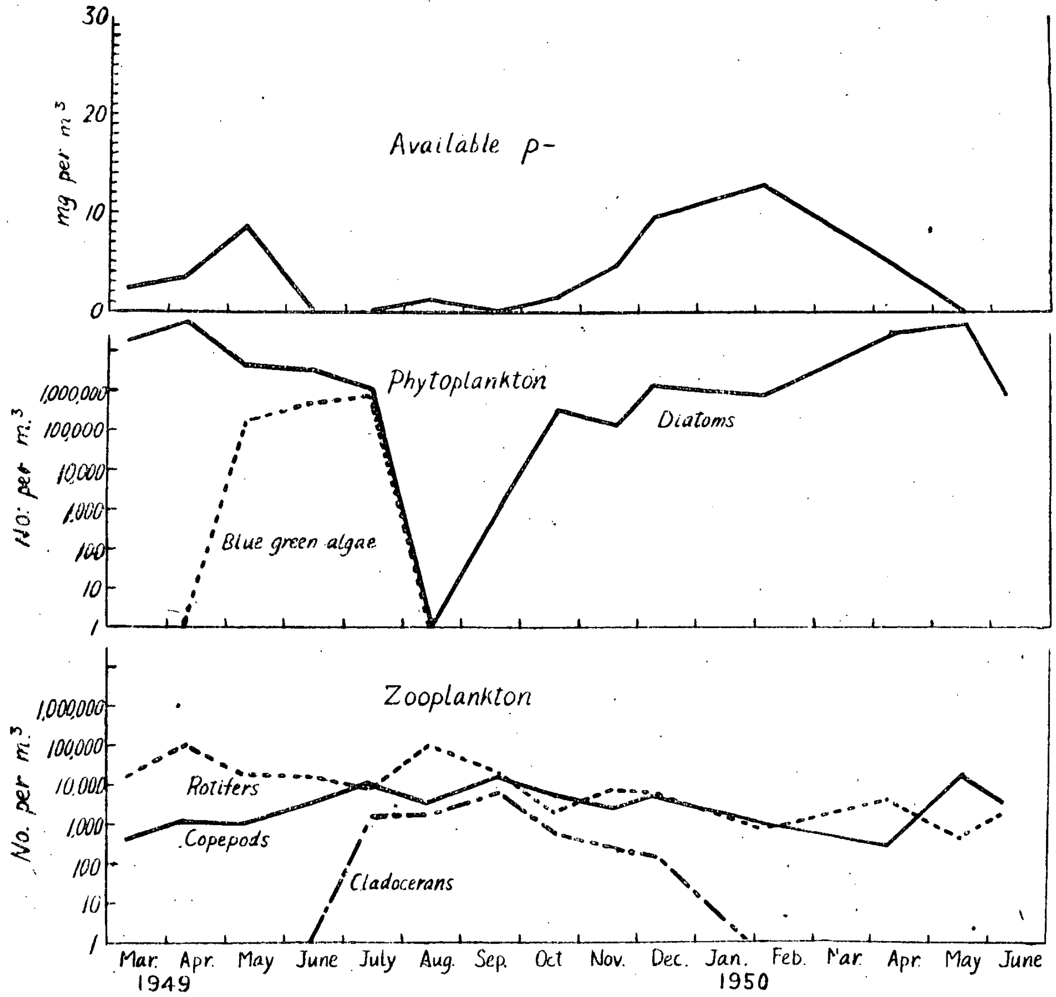

Fig. 9. Relation between available amount of phosphate phosphorus calculated from N:P=6.8:1 and the amount of phytoplankton and zooplankton.

Seasonal fluctuation of zooplankton population in relation to that of phytoplankton population.

Nauman (1921), Klugh (1927) and others have proved that zooplankton takes nannoplankton algae and finely divided debris derived from algae as food. Imai and Sato (1949) have also reported that the zooplanktonic organism, *Moina macrocopa*, takes bacteria and minute protozoa which were produced by the decomposition of organic substances as food together with chlorophyll bearing algae. Judging from these results, it can be expected in the lake that some zooplankton are strictly phytoplankton eaters and others prefer bacteria and minute protozoa or a mixed diet of plants and animals. Increase of rotifers such as *Keratella aculeata*, *Tryarthra longiseta* and *Brachionus sp.* seemed to depend on the spring outburst of phytoplankton (Fig. 9). While the increase of *Asplanchna sp.* of a rotifer and *Bosmina coregoni*, *Diaphanosoma brachiurum*, *Sinocalanus tenelus*, *Pseudodiaptomus inopius* and *Cyclops strenus* seemed to depend mostly on the debris, as food, which was produced as a result of decomposition of organic substances of phytoplankton in summer. Such disintegration of organic substances during summer could be recognized by the presence of ammonia in the surface and mid layer water.

The volume of each planktonic organism was calculated by microscopic measurement, and then its wet weight in grams was obtained by giving the specific gravity equal to 1 (Table 5). Thus the standing crop of each zooplankton could be estimated in wet weight. Average standing crop of all zooplankton was 47,700 kg and the range of variation was from 9,900 kg to 135,000 kg for the period from March of 1949 to June of 1950. The maximum occured in September when the decomposition of dead phytoplankton was in progress (Fig. 10).

Table 5. Average individual weight of various zooplanktonic organisms found in Lake Kogawara.

Species of Zooplankton	Average individual weight in gram.
Mysis	
Neomysis intermedia	$8,000,000,000 \times 10^{-12}$
Copepods	
Sinocalanus tenelus	$21,000,000 \times 10^{-12}$
Cyclops strenus	$1,666,000 \times 10^{-12}$
Pseudodiaptomus inopius	$1,666,000 \times 10^{-12}$
copepod nauplii	$400,000 \times 10^{-12}$
Cladocerans	
Bosmina coregoni	$6,845,000 \times 10^{-12}$
Diaphanosoma brachiurum	$1,119,888 \times 10^{-12}$
Rotifers	
Keratella aculeata	$996,874 \times 10^{-12}$
Tryarthra longiseta	$1,072,494 \times 10^{-12}$
Brachionus sp.	$210,000 \times 10^{-12}$
Keratella cochlearis	$160,000 \times 10^{-12}$
Polyarthra platyptera	$380,000 \times 10^{-12}$
Asplanchna sp.	$170,000 \times 10^{-12}$

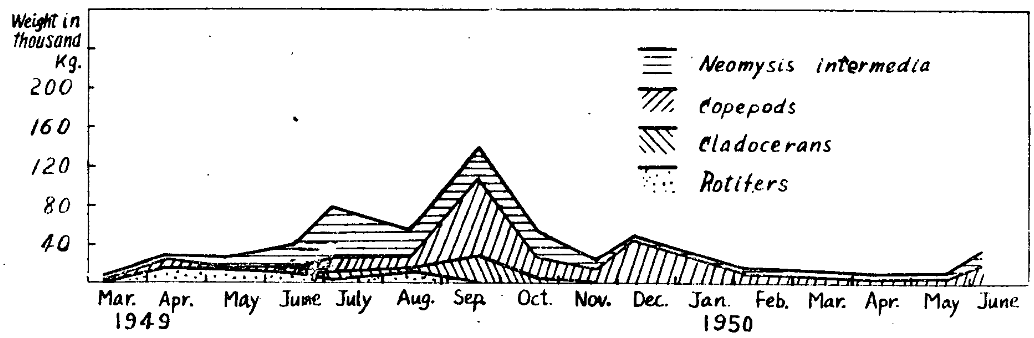

Fig. 10. Seasonal fluctuation of standing crop of zooplankton.

Production of the pond smelt in relation to that of zooplankton.

In Lake Kogawara, the early larvae of the pond smelt appear usually at the beginning of May. The post-larvae, less than 7 mm in length, fed on certain species of rotifers and subsequently on copepod naupli besides rotifers as was already reported by Sato (1952). As the post-larvae grew to young, other food organisms such as *Bosmina coregoni*, *Sinocalanus tenelus* and *Neomysis intermedia* were taken successively. Among these food organisms, *Sinocalanus tenelus* and *Neomysis intermedia* were found predominantly in the stomach of the young and adult pond smelt as is shown in Fig. 11.

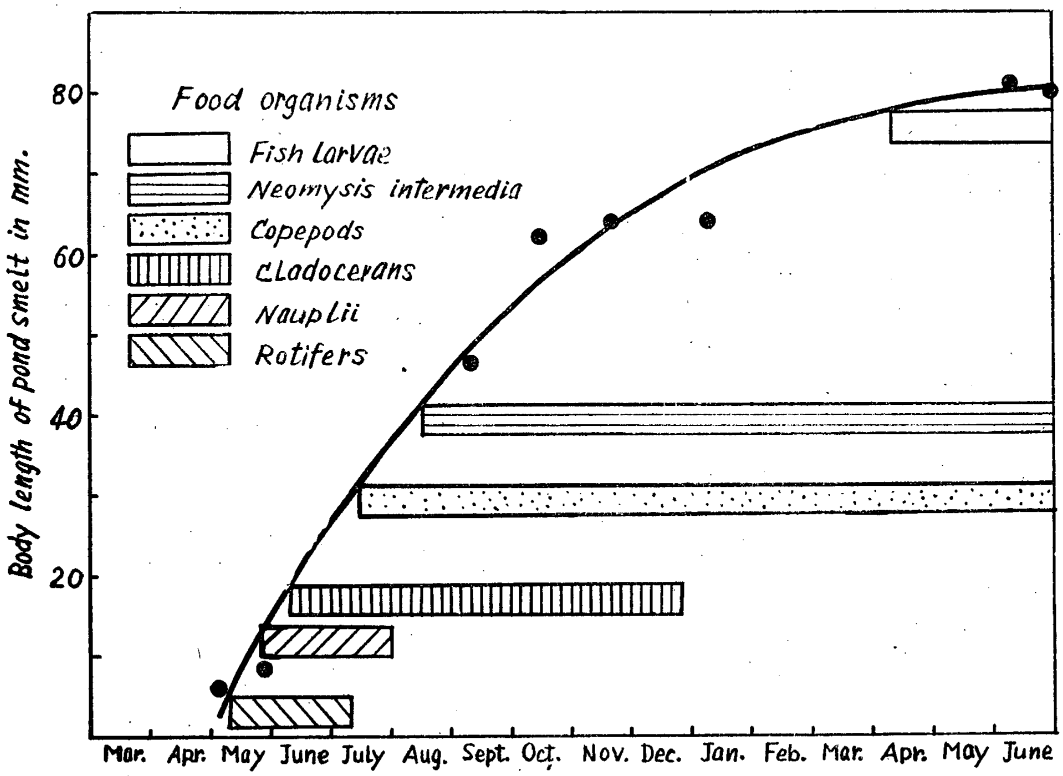

Fig. 11 Succession of food organisms in relation to the size of o-aged pond smelt.

The estimation of the stock of pond smelt at the beginning of the fishing season was made by applying De Lury's (1949) formula on estimating the fish population from the change in catch per unit effort as time passed. As a result, standing crops of 0, I and II age groups of the pond smelt at the beginning of the fishing season, September 1, 1949, were estimated to be 55,000,000, 72,000,000, and 8,000,000 respectively. By weight it was 61,000 kg of 0 age group, 194,000 kg for I age group and 51,000 kg for II age group, with a total of 306,000 kg. Its ratio to 135,000 kg of the standing crop of zooplankton of the time was 2.3 : 1.

Total catch in the lake during 1949 was 375,000 kg. While the annual production of zooplankton will be estimated as 1,239,000 kg if we assume that the turnovers of zooplankton take place every two weeks during the year as was suggested by Juday (1940). Then the ratio of the pond smelt production to the zooplankton production will be 0.30 : 1.

Conclusion and discussion

High content of nutrient salts was seen in the bottom water stratum immediately after the spring and autumn outburst of phytoplankton. This may be due to the accumulation of nutrient salts mixed in the stagnant bottom water. The accumulation of nutrient salts could be seen most clearly in the case of inorganic phosphor, and the total amount of it was estimated to be 40,000 kg in both periods of stagnation. The accumulative nutrient salts in the bottom were delivered to the upper water stratum during autumnal and spring overturn. As a result, two peaks of the phytoplankton growth were observed in the upper water stratum. Among zooplankton, rotifers increased in spring and autumn while crustaceans increased in summer. The former seems to feed on the phytoplankton while the latter on microorganisms produced by the decomposition of dead phytoplankton. The maximum standing crop of zooplankton was 22 kg/ hectare in the summer season. It was less than in the cases of the oligotrophic Lakes Weber and Nebish where the maximum of 74 kg/ hectare and 42.kg /hectare were reported (Juday, 1942). Pond smelts are zooplankton eaters and the standing crop was estimated as 57 kg/ hectare at the beginning of the fishing season, September 1, 1949. The value was more than 23kg and 35kg of fish per hectare in Lakes Weber and Nebish in the summer season (Juday, 1942). The production of the pond smelt estimated from the yield in the lake was 62 kg per hectare per year and it was far less than 800 kg in the eutrophic Lake Mendota (Juday, 1942) or 320~1,490 kg of Georges Bank (Clark, 1946). The production of zooplankton was estimated to be 183 kg/ hectare / year. Therefore the ratio of the pond smelt production to zooplankton production was 0.30 : 1. It was close to the ratio 0.21 : 1 in Ceder Bog Lake but it differed significantly from 0.05 : 1 in Lake Mendota (Lindeman 1942) though the secondary consumers in these lakes are different from Lake Kogawara.

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