Mem. Fac. Sci., Shimane Univ.,
18, pp. 59–68 Dec. 20, 1984

Seasonal Changes in Water Quality and Surface Cover of Aquatic Plants in Pond Ojaga-ike, Chiba, 1978–1980

Hidenobu Kunii
Department of Biology, Faculty of Science, Shimane University, Matsue 690, Japan
(Received September 3, 1984)

Abstract

In pond Ojaga-ike, Chiba Pref., the author carried out a limnological study of the pond with special emphasis on the ecology of aquatic plants. The study started in November 1977 and finished in October 1980. This paper contains the result concerning the seasonal changes in water quality (Secchi disc transparency, water temperature, dissolved oxygen content, pH, chlorophyll *a* content, COD of both raw and filtered water and total residue) obtained during the whole investigation period. In addition, the paper describes the result concerning the seasonal and annual changes in surface cover of aquatic plants observed in the present pond.

Introduction

In a continuing comprehensive study on the ecology of aquatic plants, the author investigated the seasonal changes in surface cover of aquatic plants as well as those in water quality in pond Ojaga-ike, one of the typical artificial reservoirs. Till now the author and his colleagues have published two papers concerning this subject and showed marked seasonal variation in both physiognomy of the pond and water quality (Kunii *et al.*, 1980; Kunii and Maeda, 1982). However, the data published were those restricted to only the first half period around 1978. Upon completion of the three year's investigation (November 1977 to October 1980), the author intended to improve the results by supplimenting the new results obtained later. This paper contains the results obtained during the whole three year investigation period and thus compliments the previous results.

Study site

Ojaga-ike is a shallow (maximum depth 3.5 m, mean depth 2.5 m) and small (24.8 ha) pond situated in Tōgane, Chiba. Figure 1 is the bathymetric map of the pond made by the present survey. It is notable here that this contour line differs from the past one drawn in the previous papers as above.

In 1978, there occurred three emergent (*Phragmites australis* (Cav.) Trin. ex Steud., *Leersia japonica* Makino and *Scirpus fluviatilis* (Torr.) A. Gray), three

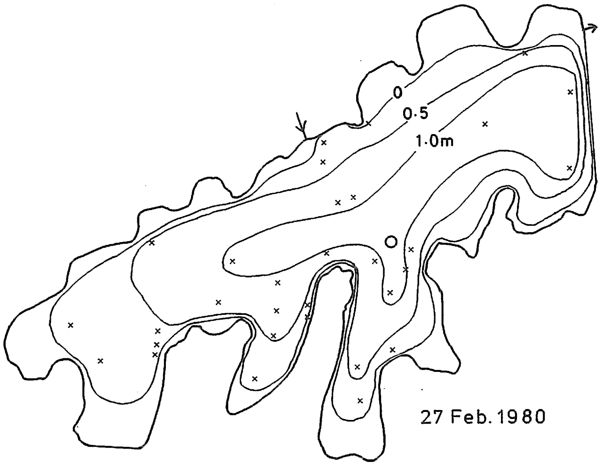

Fig. 1. Bathymetric map of Ojaga-ike observed on 27 February 1980. Circle shows the sampling and measuring point and the crosses in the map show the points where the water depth was measured.

floating-leaved (*Nelumbo nucifera* Gaertn., *Trapa natans* Linn. var. *bispinosa* Makino and *Nymphoides indica* (Linn.) O. Kuntze), two free-floating (*Spirodera polyrhiza* (Linn.) Schleid. and *Ricciocarpus natans* Corda), and seven submerged plants (*Potamogeton crispus* Linn., *Najas minor* All., *Vallisneria denseserrulata* (Makino) Makino, *Hydrilla verticillata* (Linn. fil.) Casp., *Elodea nuttallii* (Planch.) St. John, *Ceratophyllum demersum* Linn. and *Myriophyllum spicatum* Linn.) (cf. Kunii and Maeda, 1982). Of these, however, *Nymphoides indica, Najas minor* and *Ricciocarpus natans* could not be found in 1980.

Methods

More than one visit were made every month over the study period from November 1977 to October 1980. More frequent visits were made since May 1979.

Field measurements of water quality

A single station was set in the center of the pond (Fig. 1). Measurements of the relevant physical and chemical parameters (transparency, water temperature, dissolved oxygen content, pH) were carried out at three different water depths (surface, middle and bottom 10 cm above mud) around noon until April 1979. After May 1979, the measurements were done at 50 cm vertical intervals from the surface to bottom except for pH measurement which was done at three water layers throughout the investigation period.

Water temperature and dissolved oxygen content were determined by a portable oxygen meter. Transparency was measured using a Secchi disc (30 cm in diameter). Measurement of pH was done by colorimetric method.

Laboratory analyses of pond water

Routine analyses of water samples taken from different water depths (surface, middle and bottom) were carried out. For the determination of chlorophyll *a* concentration, one or half liters of pond water was filtered through glass-fiber filters (Millipore AP) and extracted by 90% acetone according to the UNESCO report (1966). Total residue (T-Re) of the water was determined by using 100 ml pond water. The concentration of organic compounds in 100 ml raw pond water (COD) was approximately estimated by alkaline oxidation method using $KMnO_4$ as an oxidizing agent and heating it with a water bath at 100°C for 30 minutes (Saijō, 1957). In addition, the COD of the filtered water was measured. This value represents the COD of the water excluding suspended materials in raw pond water and this is temporally named F–COD in this paper.

In this paper, the results of analyses of middle waters are omitted; because the values obtained were almost fallen between those of surface and bottom water layers.

Phenology and seasonal changes in surface cover of plants

The surface cover of vegetation was observed by traversing the pond with boat and by overlooking from the surrounding high places. The distance between the approximate outer boundary of the plant cover and pond margin was measured by a distance meter from the boat and recorded on the contour map. The seeds, turions, seedlings and grown plants of the underwater stands were sampled randomly by an Ekman-Birge grab and grapnel in order to observe the phenology of the plants in the pond.

Results and discussion

Transparency

Transparency values in the pond were relatively high until December 1979 showing an irregular fluctuation from 1.33 m in November 1977 to over 3.15 m in October 1979 (Fig. 2). From January to October 1980, they ranged between 2.30 m in June and 0.4 m in October.

Figure 3 shows slight correlation between Secchi disc transparency and water depth at the station. It is thought that this slight correlation was caused by the upwelling of the bottom mud which tended to be easily agitated by wind when water depth of the pond decreased.

Water temperature

The surface water temperature ranged between the maximum of 33°C in August

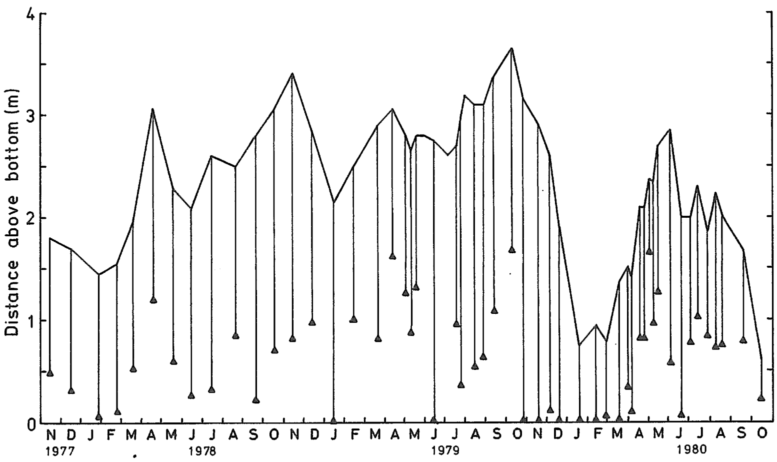

Fig. 2. Temporal changes in Secchi disc transparency.

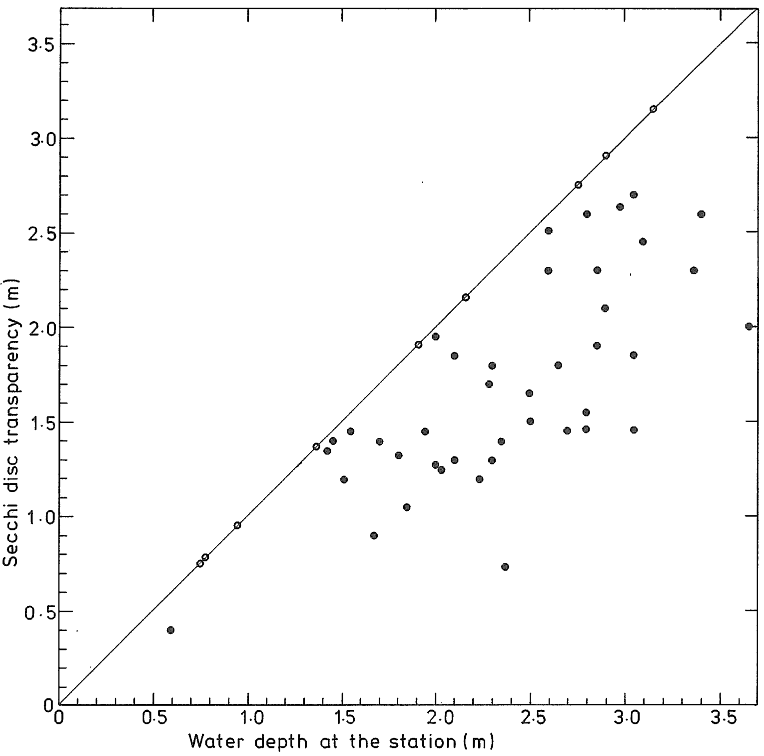

Fig. 3. The relation between Secchi disc transparency and water depth at the station.

1978 and the minimum of 5°C in January 1978 and 1980 (Fig. 4). Weak thermal stratification occurred annually for a short period from late May to early September as

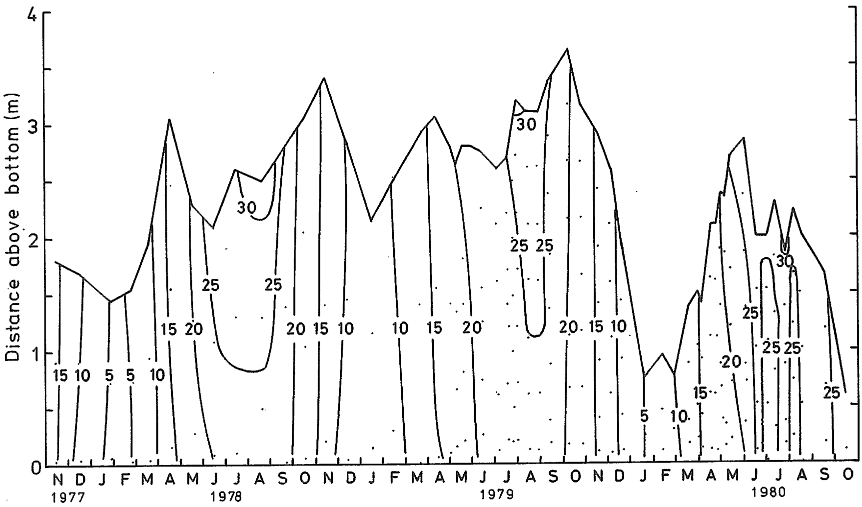

Fig. 4. Temporal changes in the vertical distribution of water temperature. Isotherms in the figure are in °C.

a result of canopy formation of floating-leaved and submerged plants (cf. Kunii, 1983). The maximum difference between surface and bottom water temperature was 8.3°C in August 1978. Ice cover appeared in winter only near shore.

Dissolved oxygen

Vertical distribution in concentration of dissolved oxygen showed conspicuous features especially in summer (Fig. 5). Oxygen saturation of the surface water always

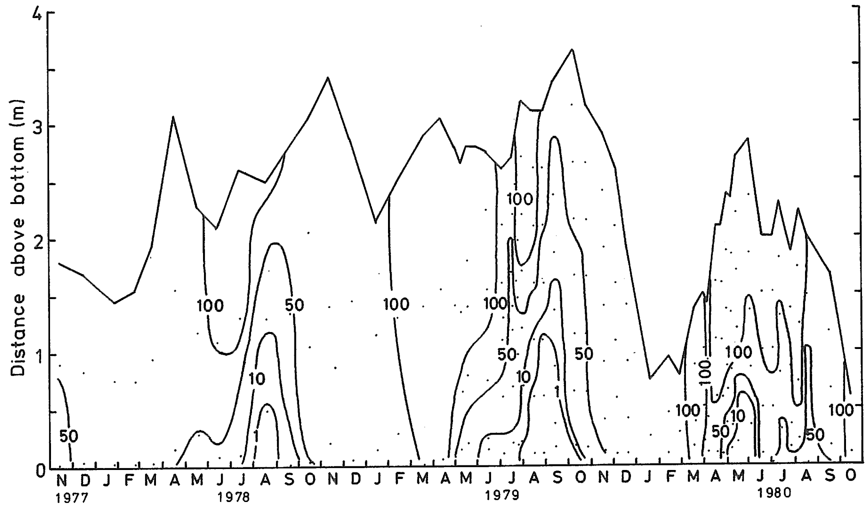

Fig. 5. Temporal changes in the vertical distribution of % saturation of dissolved oxygen.

exceeded over 50% and supersaturation occurred annually around summer period. In August 1978 and 1979 the oxygen saturation exceeded over 200% at surface. In contrast, dissolved oxygen in the bottom water started decreasing usually from April and depleted during summer. The considerable difference in oxygen concentration between the surface and bottom waters appeared for summer periods is due certainly to the dense growth of aquatic plants at that time (cf. Ikusima, 1965; Dale and Gillespie, 1976 and 1977; Kunii, 1983).

pH

Figure 6 shows seasonal changes in pH measured at surface and bottom water layers. Almost all the values in pH of the surface water were found in the alkaline range throughout the study period with only one exception of 6.9 in October 1979. The maximum value was 9.6 in August 1978. The pH values changed drastically at surface with being characterized by the annual summer pulse, while they changed little around 7.0 at bottom (maximum 7.6 in June 1979, minimum 6.4 in September 1979).

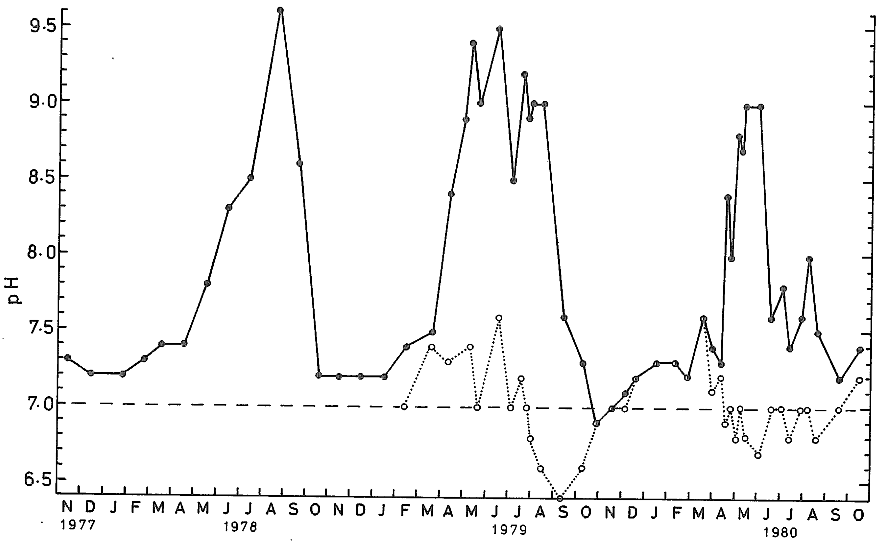

Fig. 6. The seasonal changes in pH of surface (●——●) and bottom (○⋯⋯○) waters.

Chlorophyll a content

The range of chlorophyll *a* content at surface and bottom waters was 3.3 (August 1979) — 82.7 μg/l (October 1980) and 5.9 (November 1978) — 69.7 μg/l (October 1980), respectively (Fig. 7). The annual change in chlorophyll *a* content at surface water was relatively constant in comparison with those of the bottom. This is due perhaps to the accidental contamination of the benthic algae in the bottom water.

Several studies on the relationship between light penetration in water and phyto-

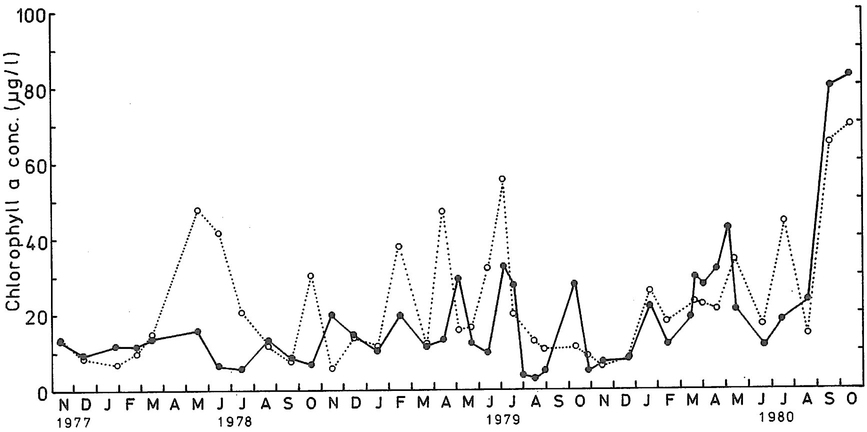

Fig. 7. The seasonal changes in the concentration of chlorophyll *a* of surface (●——●) and bottom (○······○) waters.

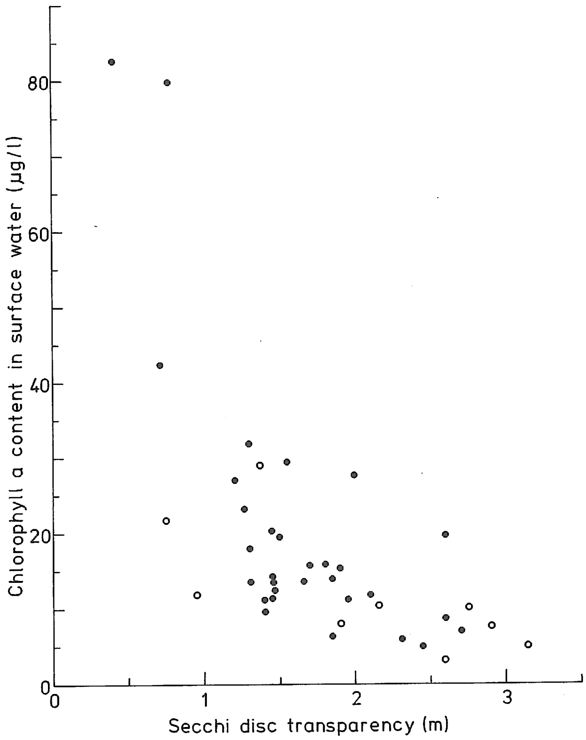

Fig. 8. The inverse relationship between Secchi disc transparency and chlorophyll *a* concentration of the surface water during 3 years from November 1977 to October 1980. When the Secchi disc reached the bottom, the values are shown as open circles.

plankton density (e.g. Ichimura, 1956; Bindloss, 1976; Carlson, 1977; Jewson, 1977; Almazan and Boyd, 1978) have shown an inverse relationship between Secchi disc transparency and chlorophyll *a* content. Such an inverse relationship was also observed in the present pond (Fig. 8).

$KMnO_4$ consumption (COD and F–COD)

COD values of surface and bottom waters ranged between 10.6 (February 1978) — 36.6 mg/l (August 1978) and 10.3 (January 1978) — 23.4 mg/l (October 1980), respectively (Fig. 9). Except for the prominent maximum value observed at surface in August 1978, the mean value of COD at surface and bottom waters fell between 10 and

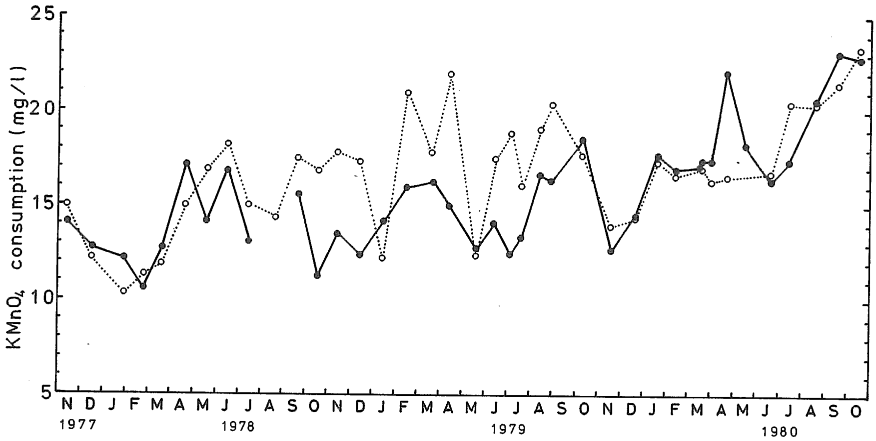

Fig. 9. The seasonal changes in the amount of $KMnO_4$ consumption of surface water (●——●) and bottom water (○······○).

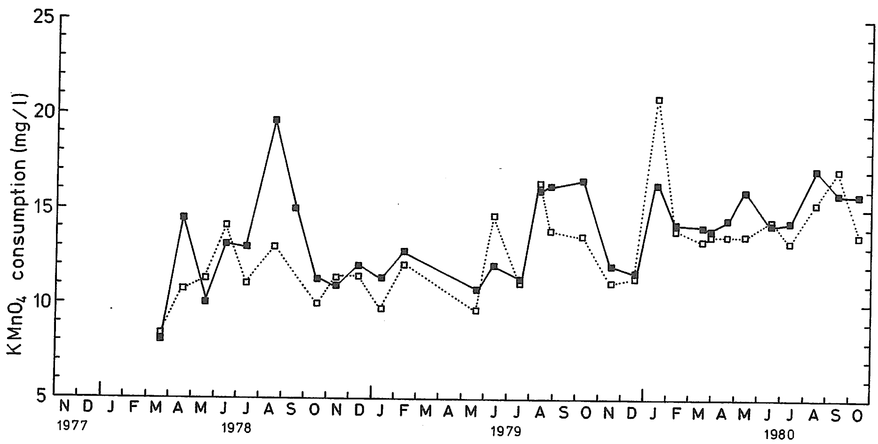

Fig. 10. The seasonal changes in the amount of $KMnO_4$ consumption of filtered surface water (■——■) and filtered bottom water (□······□).

24 mg/l. COD values of the filtered water (F–COD) were always lower than those of raw water for all observations (Fig. 10). The difference of F–COD among surface and bottom waters was smaller than that of COD.

Total residue

Total residue of raw water was measured using 100 ml pond water. Although this volume is not sufficient to analyse the total residue with accuracy, it gives an outline of this value in the pond. Values of surface water varied widely from 10 mg/l (March 1978 and May 1979) to 380 mg/l (January 1979), and those of bottom water from 60 mg/l (January 1978 and June 1979) to 330 mg/l (October 1979). Mean values at surface, middle and bottom of all samples were 137 ($\pm$74SD, n=33), 125 ($\pm$51SD, n=29) and 150 ($\pm$58SD, n=30) mg/l, respectively.

Changes in surface cover

Figure 11 shows the seasonal and annual changes in surface cover of aquatic plants in the pond observed at bimonthly intervals from May to September in each year. From December to early April, no aquatic vegetation was observed at the surface of the pond except for the dead stalks of reed. The considerable reduction of surface cover in 1980 occurred as a result of winter drawdown and unfavorable summer weather occurred at that time and/or the introduction of the grass carps.

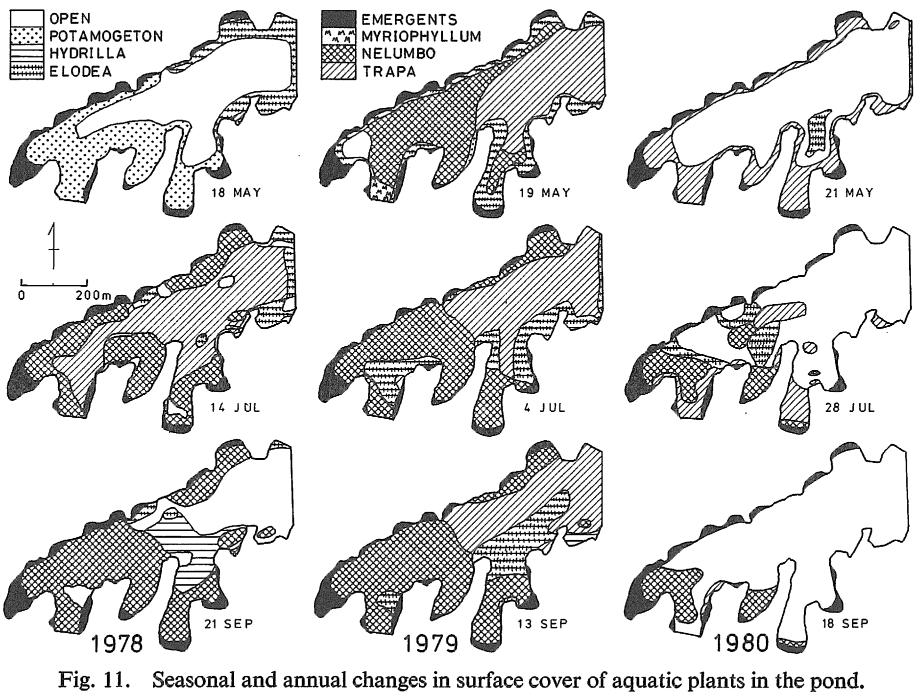

Fig. 11. Seasonal and annual changes in surface cover of aquatic plants in the pond.

References

Almazan, G. and Boyd, C. E. (1978). An evaluation of Secchi disk visibility for estimating plankton density in fish ponds. Hydrobiologia, 61: 205–208.

Bindloss, M. E. (1976). The light-climate of Loch Leven, a shallow Scottish lake, in relation to primary production by phytoplankton. Freshwat. Biol., 6: 501–518.

Carlson, R. E. (1977). A trophic state index for lakes. Limnol. Oceanogr., 22: 361–369.

Dale, H. M. and Gillespie, T. J. (1976). The influence of floating vascular plants on the diurnal fluctuations of temperature near the water surface in early spring. Hydrobiologia, 49: 245–256.

Dale, H. M. and Gillespie, T. J. (1977). The influence of submersed aquatic plants on temperature gradients in shallow water bodies. Can. J. Bot., 55: 2216–2225.

Ichimura, S. (1956). On the ecological meaning of transparency for the production of matter in phytoplankton community of lakes. Bot. Mag. Tokyo, 69: 219–226.

Ikusima, I. (1965). Methods of ecological field survey III. Practical field guide for ecology of aquatic plant communities. I. Measurement of aquatic environments. Bull. Mar. Lab. Chiba Univ., 7: 93–107. (In Japanese).

Jewson, D. H. (1977). Light penetration in relation to phytoplankton content of the euphotic zone of Lough Neagh, N. Ireland. Oikos, 28: 74–83.

Kunii, H. (1983). Diurnal vertical fluctuations in some water variables under the covers of two different aquatic plants, *Elodea nuttallii* and *Trapa* sp. Mem. Fac. Sci. Shimane Univ., 17: 61–69.

Kunii, H., Maeda, K., Sastroutomo, S. S. and Ikusima, I. (1980). Seasonal changes of water quality in Ojaga-ike (Pond) dominated by aquatic macrophytes in summer, in Chiba, Japan. Bull. Mar. Lab. Chiba Univ., 12: 31–40.

Kunii, H. and Maeda, K. (1982). Seasonal and long-term changes in surface cover of aquatic plants in a shallow pond, Ojaga-ike, Chiba, Japan. Hydrobiologia, 87: 45–55.

Saijō, Y. (1957). Manual of limnological studies. Kokon Shoin, Tokyo. 306 pp. (In Japanese).

UNESCO (1966). Determination of photosynthetic pigments in seawater. Report of SCOR-UNESCO Working group 17 (Paris). Monographs on Oceanographic Methodology 1. 69 pp.