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Diurnal Vertical Fluctuations in Some Water Variables under the Covers of Two Different Aquatic Plants, *Elodea nuttallii* and *Trapa* sp.

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Abstract

The diel fluctuations in water temperature, percentage oxygen saturation, pH and chlorophyll *a* content in water under the covers of two aquatic plants, *Elodea nuttallii* (Planch.) St. John and *Trapa* sp., were observed at once through one clear summer day in a shallow pond, Ojaga-ike, Chiba Pref. Marked stratifications in both water temperature and percentage oxygen saturation were established during a day under these two plant covers. There distinctly occurred trophogenic zone that resulted in oxygen supersaturation (from surface to ca. 0.5 m deep) and tropholytic zone that resulted in oxygen depletion (from ca. 1.5 m deep to bottom). The difference of the magnitude in diel fluctuation of percentage oxygen saturation near water surface between these two plant covers is finally discussed in terms of structure and function of the aquatic plant covers.

Introduction

Many observations of diurnal changes in water conditions under the covers of aquatic plants have been done in various waters (e.g. Miki, 1929; Yoshimura, 1937; Buscemi, 1958; Ikusima, 1970a; Wetzel, 1975; Dale and Gillespie, 1976, 1977; Šmíd and Přibáň, 1978; Aizaki *et al.*, 1979; Reddy, 1981). It is well known that diurnal changes in the physical and chemical parameters in the vertical water column are strongly affected by local environmental factors or geomorphological features of the water body. In a shallow eutrophic pond where aquatic plants grow well, plants influence considerably on water conditions during summer period, as observed in conspicuous differences between littoral and pelagic zones, and surface and bottom waters (cf. Ikusima, 1972; Wetzel, 1975).

In Pond Ojaga-ike, situated in Chiba Prefecture (35°33′N, 140°20′E), there flourished many aquatic plants including three floating-leaved and seven submerged plants, and more than 90% of the pond surface was covered by the plants during the summer of 1978 (Kunii and Maeda, 1982). Seasonal changes of water conditions in this pond had already been observed and strong influence of the plants on water conditions was reported (Kunii *et al.*, 1980). However, the data presented were restricted to those that obtained at hours near noon at the center of the pond. Hence, the observation on the diurnal changes in the environmental parameters under the covers of aquatic plants was required for the purpose of getting better information about the limnology of this pond.

In this paper, diurnal vertical changes of some water parameters under two dominant plant covers are comparatively described; one is submerged plant, *Elodea nuttallii* (Planch.) St. John, and the other the floating-leaved plant, *Trapa* sp. (mainly composed of *T. natans* L. var. *bispinosa* Makino). In addition, general explanation of the effect of aquatic plants on the establishment of stratification in both water temperature and dissolved oxygen concentration is presented, and the difference of the intensity of influence between *Elodea* and *Trapa* stands on diurnal changes in water conditions is discussed in relation to structure and function of the two stands.

Observation methods

Two observation points were set up in the pond. One point was set in a larger pure stand of *Elodea*, which had grown up to the water surface, situated near the northeast end of the pond where water depth was 2.3 m. The other was set in a larger stand of *Trapa*, 2.75 m in depth, in the vicinity of the *Elodea* stand. At each point, following measurements were done for vertical layers of 0.5 m from pond surface to bottom at about three hours intervals over one clear and calm day from 0935 on 26 July 1978 to 1145 on 27 July 1978. Water temperature and percentage oxygen saturation were measured by a portable oxygen meter, and pH by glass electrode. For the estimation of chlorophyll *a* content, more than half liter of pond water was sampled from each point at about six hours intervals and taken back to the laboratory. The water for the analysis was sampled from surface, 1.0 and 1.5 m deeps in *Elodea* stand and from 0.5, 1.5 and 2.5 m deeps in *Trapa* stand. Determination of chlorophyll *a* content was done by the method of UNESCO report (1966) using an AP Millipore filter.

Results

Water temperature

Fig. 1 shows diurnal changes of air and water temperatures at each water depth in each stand. The air temperature measured at about 50 cm above surface cover of *Elodea* reached its maximum (32.0°C) at near noon and minimum 23.0°C just before dawn. Surface water temperature in *Elodea* and *Trapa* changed from 31.8°C and 32.2°C before dusk to 27.7°C and 27.7°C before dawn, respectively. It is evident that the deeper the water depth the smaller the daily fluctuation in water temperature in both stands. Below the depth of 1.0 m, temperatures at each water layer fluctuated only within the range of 1°C during a day. The average value of eight-time measurements at 1 m depth in *Elodea* and *Trapa* stands was 27.2°C and 27.3°C, respectively.

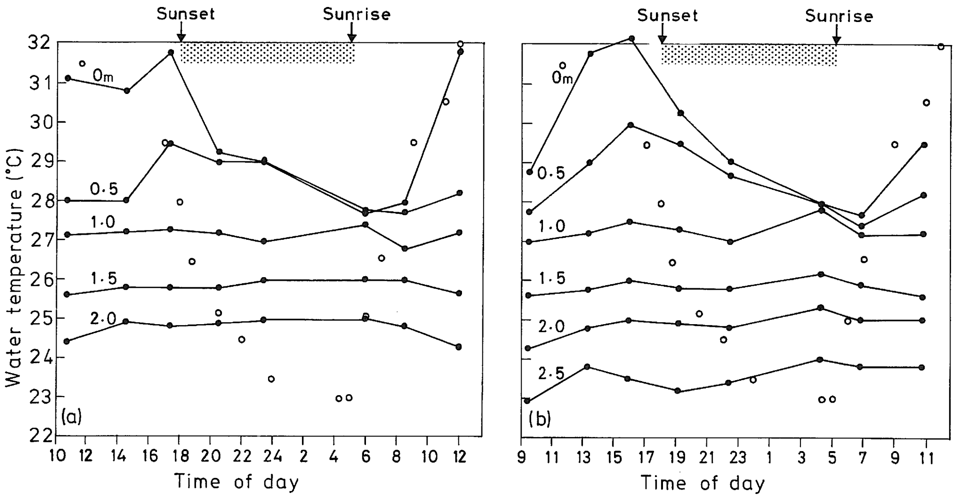

Fig. 1. Diurnal fluctuations of water temperature at each water depth within (a) *Elodea* stand and (b) *Trapa* stand. Open circles in the figure denote air temperature.

Dissolved oxygen

Occurrence of stratification was apparent not only in water temperature but also in percentage oxygen saturation (Fig. 2). At the surface of *Elodea* stand, a maximum value of 180% was recorded just before sunset and the value fell down to the minimum of 74% just after sunrise. At the surface of *Trapa* stand, a maximum value of 124%

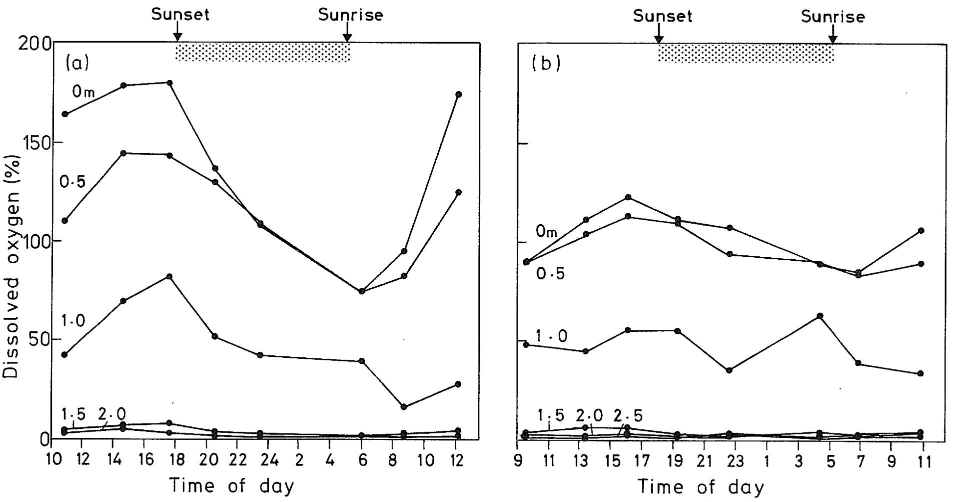

Fig. 2. Diurnal fluctuations of % saturation of dissolved oxygen at each water depth within (a) *Elodea* stand and (b) *Trapa* stand.

was recorded just before sunset and the value gradually decreased to reach a minimum of 85% just after sunrise. The range of fluctuation at 1 m depth in *Elodea* and *Trapa* stands was from 16% to 82% and from 34% to 63%, respectively. These ranges were smaller than those found in the water layers at the surface and 0.5 m deep. In both stands, percentage saturation became lower towards the bottom, showing less than 10% (usually between 1 and 5%) below 1.5 m deep.

Vertical profile in dissolved oxygen concentration is clearly shown in Figs. 3 and 4,

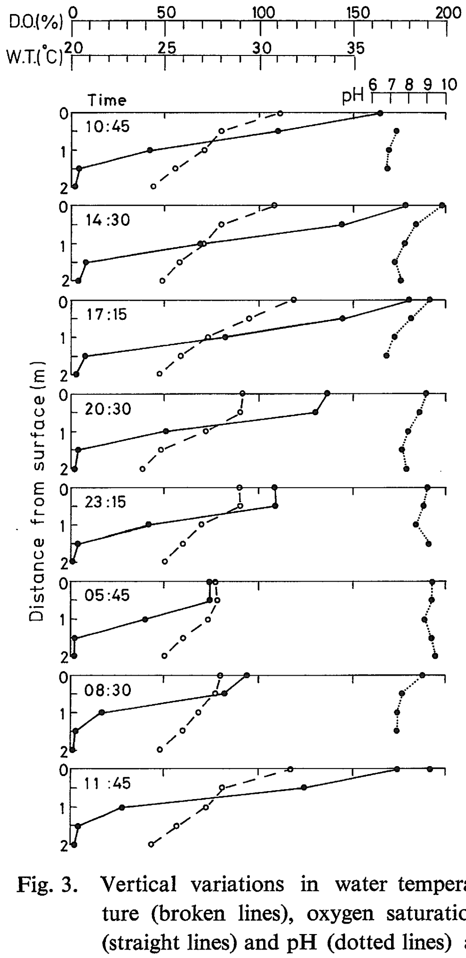

Fig. 3. Vertical variations in water temperature (broken lines), oxygen saturation (straight lines) and pH (dotted lines) at different times of day in *Elodea* stand.

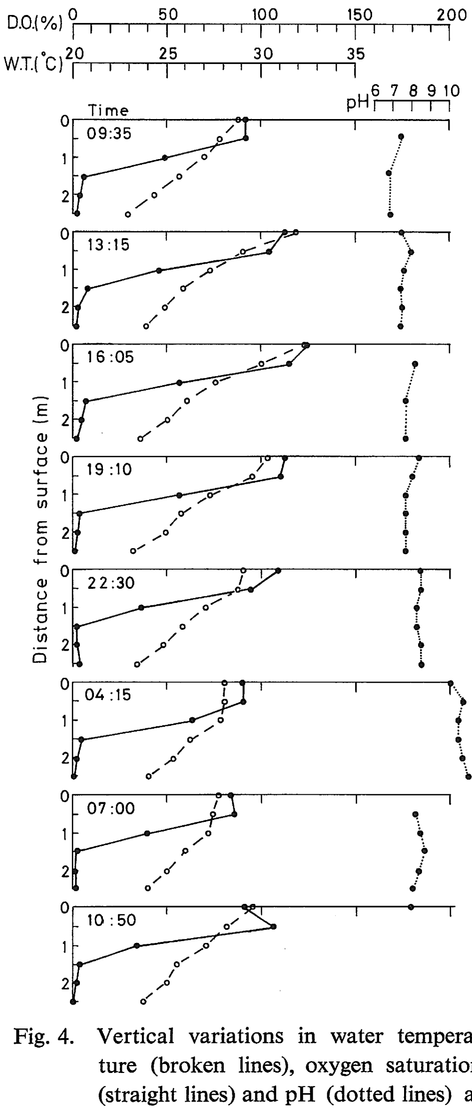

Fig. 4. Vertical variations in water temperature (broken lines), oxygen saturation (straight lines) and pH (dotted lines) at different times of day in *Trapa* stand.

for *Elodea* and *Trapa* stands, respectively. The curves show sharp decrease in oxygen concentration with increasing depth at any time of day in both stands. It seems reasonable to conclude that in both stands there occurred production layer down to about 0.5 m deep and decomposition layer or tropholytic zone from the depth of about 1.5 m to bottom. It is no doubt that oxygen depletion occurred throughout a day below the depth of 1.5 m in both stands.

pH value

The vertical variation in pH is shown in Fig. 3 for *Elodea* stand and in Fig. 4 for *Trapa* stand. In *Elodea* stand, a maximum value of 9.8 was recorded at the surface at 1430. Except for a minimum value of 6.8 which was observed only occasionally at 1.5 m deep, all of the recorded values were found in the alkaline range. In *Trapa* stand, a maximum value was 10.2 at the surface at 0415 and a minimum 6.8 at the deeper region below 1.5 m.

It should be noted that the result obtained for pH is thought to be rather dubious because the author did not make any adjustment of the meter after it had been done at the beginning of the observation.

Chlorophyll a concentration

Chlorophyll *a* concentration at different water depths in *Elodea* and *Trapa* stands is summarized in Table 1. The relatively high values observed at the depth of 2.5 m in *Trapa* stand might be due probably to the contamination of the benthic algae. Diurnal fluctuation was obscure at both stands.

Table 1. Chlorophyll *a* concentration (μg/l) at different water depths under *Elodea* and *Trapa* covers.

Stand name	Depth	Sampling time in hours			
	(m)	1050–1120	1715–1800	2330–2355	0830–0900
Elodea	0	20.7	9.2	9.2	21.5
	1.0	11.5	8.8	9.1	10.8
	1.5	10.6	10.0	11.8	9.8
		1015–1035	1650–1700	2210–2235	0610–0640
Trapa	0.5	19.2	5.5	7.5	6.3
	1.5	28.1	9.7	10.2	17.8
	2.5	12.4	41.0	54.9	38.6

Discussion

Fig. 5 shows the vertical distribution of water temperature, percentage saturation of dissolved oxygen and pH measured on several months of 1978 at both *Elodea* stand

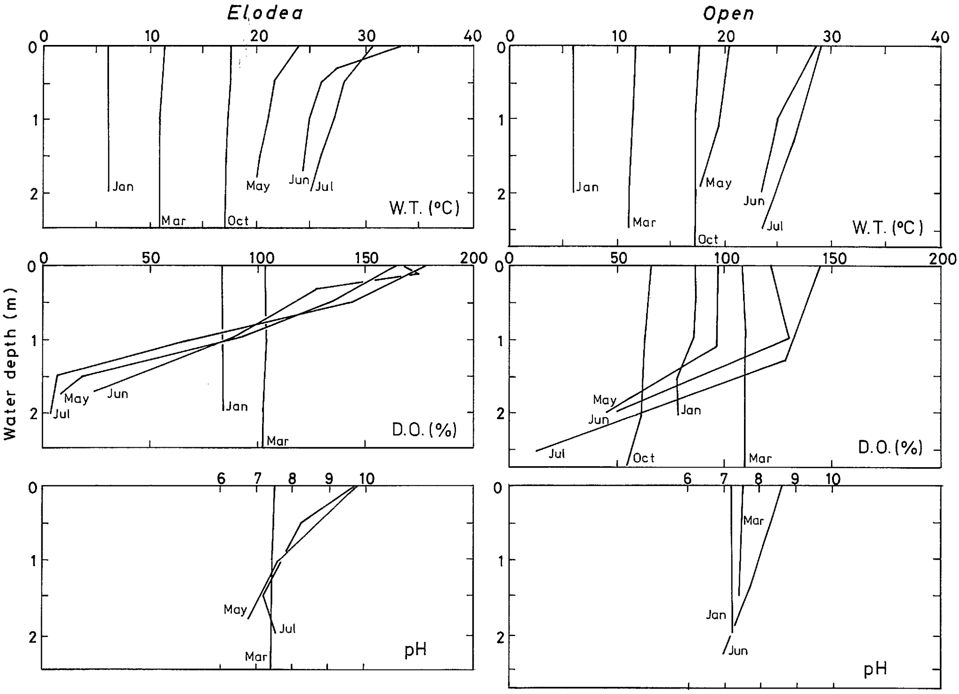

Fig. 5. The vertical distributions of water temperature, % saturation of dissolved oxygen and pH measured on several months in 1978 at both *Elodea* stand and open site (center of the pond).

and an open site (center of the pond). The difference of the vertical distribution of these parameters between these two points is remarkable only in summer period, especially at near water surface. It is reasonable to think that the difference was caused by the dense canopy of shoots existed at that time.

With respect to the effect of aquatic plants on the temperature gradient in water, Dale and Gillespie (1977) showed in Lake Opinicon that steep temperature gradients developed during clear weather when there were large standing crops of submerged macrophytes (or algae) and little of the light energy penetrated to the substrata, whereas, with sparse vegetation, little shadow was produced and the energy was more evenly distributed throughout the profile and only small temperature differences developed between surface and bottom. Buscemi (1958) showed that a massive biomass of *Elodea canadensis* Rich. inhibited vertical water circulation, and the shading effect greatly reduced photosynthetic activity of the lowermost stems and leaves. He concluded that two physiological zones, in consequence, developed within the vegetation area during the early period of summer growth: (1) an upper photosynthetic zone, and (2) a lower respiratory zone.

In addition to those fact mentioned above, there exists the exponential relationship between plant biomass and extinction of light intensity (cf. Owens *et al.*, 1967; Ikusima, 1970b). Therefore, general explanation of the effect of aquatic plants on establishment of stratification in water temperature and dissolved oxygen concentration can be illustrated in the simplified schema as Fig. 6.

Light intensity under different aquatic plant communities in the present pond is shown in Table 2. It can be seen from these figures that there is little difference in light penetration inhibition between *Elodea* and *Trapa* covers. The depth at which relative light intensity decreased to 1% is 1 m and 1.5 m under *Elodea* and *Trapa*, respectively. These depths are nearly coincided with the boundaries of trophogenic and tropholytic zones as exhibited by the percentage saturation of dissolved oxygen (Fig. 2). Here the consideration about the difference of structure and function between these two plant communities is needed to explain the cause of the difference in diurnal changes in

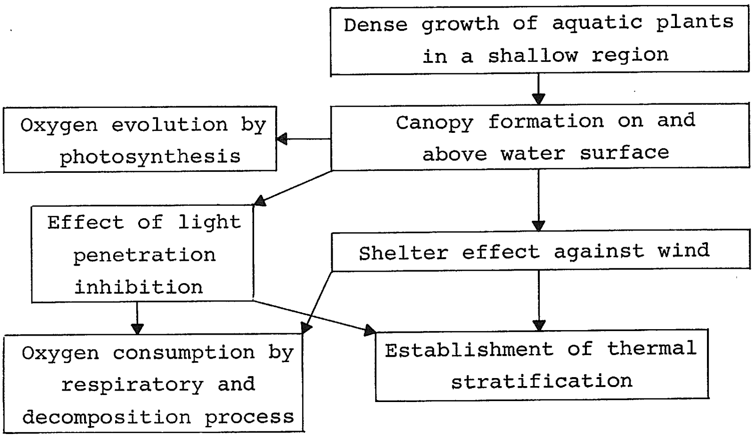

Fig. 6. Schema explaining the effect of aquatic plant cover on the stratification of both water temperature and dissolved oxygen.

Table 2. Relationship between RLI (%) and water depth (cm) under the cover of different aquatic plants dominated in each month of 1978 in Pond Ojaga-ike.

Stand name		RLI (%)			
		50	10	5	1
Open		60	200	240	300
Elodea nuttallii	(May)	2	10	30	100
Trapa natans	(Jul)	5	15	50	150
Nelumbo nucifera	(Sep)	—	20	40	250
Potamogeton crispus	(May)	10	50	65	100

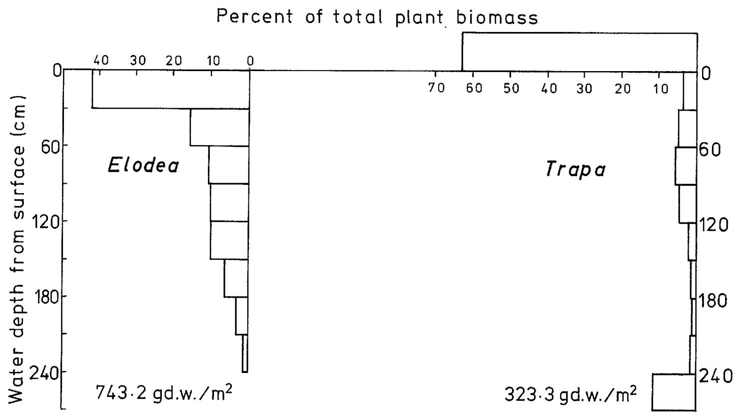

Fig. 7. Vertical profile of the plant biomass shown in relative percentage in both *Elodea* community observed on 31 July 1979 and *Trapa* community on 24 July 1979.

dissolved oxygen concentration. In Fig. 7 the vertical profiles of the plant biomass collected at the same month in 1979 at Pond Ojaga-ike are shown. *Trapa* is one of the floating-leaved plants and it expands its leaves just on the water surface (cf. Ambasht and Ram, 1976). Therefore the canopy of this plant can hardly contribute to increase dissolved oxygen concentration in water beneath it. In contrast, the submerged plant, *Elodea*, has a greater part of the photosynthetic biomass in the uppermost portion of the water column. The high biomass value in the topmost layer of the plant community is due to repeated branching near the apex (cf. Kunii, 1984). So the dissolved oxygen concentration can be increased by photosynthesis and decreased by respiration by the canopy itself.

It can be concluded that the difference of diurnal changes in dissolved oxygen concentration in uppermost layer between *Elodea* and *Trapa* communities is resulted mainly from the difference in the function of the canopy as well as the structure of vertical profile of plant biomass.

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