Note

Net Primary Production of *Nymphoides peltata* (Gmel.) O. Kuntze Growing on Sandy Sediment at Edosaki-iri Bay in Lake Kasumigaura, Japan

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Abstract

The seasonal maximum biomass of *Nymphoides peltata* growing on sandy sediment at the littoral zone of Edosaki-iri Bay in Lake Kasumigaura was only 47.6 g dry weight $\cdot$ m⁻² in late September. Leaf life span was 28 days and thus biomass turnover rate was estimated as 3.4 for 200 days, comparable with those reported for floating-leaved plants and much higher than other herbaceous plants. The yearly net production per unit ground area was estimated at 182 g dry weight $\cdot$ m⁻². This value is smaller than that reported for phytoplankton at the same site and for floating-leaved plants growing at other regions of this lake.

Key words : biomass, leaf life span, *Nymphoides peltata*, net production

1. Introduction

Lake Kasumigaura, located 60 km northeast of Tokyo, is a eutrophic lake in Japan. The water area is 168 km², while average water depth is only 4 m. Environmental conditions and littoral vegetation vary among sites in this lake. Takahama-iri Bay, located northwest in the lake, is the most eutrophicated area of this lake and the sediment consists of mud. In this bay an annual floating-leaved plant, *Trapa natans* L., showed high productivity in spite of its small biomass (TSUCHIYA and IWAKI, 1983, 1984). The *T. natans* stand can support a large amount of fishes by providing shelter, food and breeding sites (SAKAI *et al.*, 1984) and the heavy algal blooms are frequently observed in summer (TAKAMURA *et al.*, 1987).

In contrast in a southern bay of the lake, Edosaki-iri Bay, water is less eutrophicated than at Takahama-iri Bay. Wind and wave exposure are relatively high and the sediment consists of sand or fine sand. A perennial floating-leaved plant, *Nymphoides peltata*

(Gmel.) O. Kuntze, has dominated the floating-leaved plant zone at Edosaki-iri Bay, where few plants of *T. natans* were found. Because of different environmental conditions and species composition, the relative importance of the macrophyte vegetation for the carbon and nutrient dynamics at Edosaki-iri Bay may be different from those at Takahama-iri Bay.

In the present study we attempted to estimate net production of *N. peltata* growing on sandy sediments at Edosaki-iri Bay. For floating-leaved plants annual net production is not equivalent to seasonal peak biomass because of high rates of biomass turnover (BROCK *et al.*, 1983; TSUCHIYA and IWAKI, 1983; 1984; TSUCHIYA, 1989). Therefore, we measured seasonal biomass and longevity of leaves to estimate net production. Furthermore, the productivity of *N. peltata* was compared with that of phytoplankton in this area and that of *T. natans* growing at Takahama-iri Bay.

2. Study site

The study site is located at the inlet of Edosa-

ki-iri Bay in the southern region of Lake Kasumigaura (Fig. 1). The sediment is sand or fine sand. The wind exposure and velocity of coastal water current are relatively high compared with other regions in this lake. The sampling station was established just outside of the mouth of the River Ono-gawa. The yearly fluctuation range of the water level of Lake Kasumigaura was 40 cm in 1984 (Fig. 2). Water level was highest in July just after the rainy season, and low in spring and fall.

Zonal distribution of macrophytes was observed at the study site (NOHARA *et al.*, 1986). The emergent vegetation dominated by *Phragmites australis* (Cav.) Trin. ex Steud., *Zizania*

latifolia Turcz. and *Typha angustifolia* L., distributed on the shelf with a gentle slope extending to about 80 cm of water depth. *N. peltata* occurred almost exclusively the steeper slope, 60–200 cm deep, beyond the shelf. At the *N. peltata* zone, only a little coverage of *Trapa natans* and several submerged species, *Potamogeton malaianus* Miq., *Potamogeton crispus* L., *Potamogeton pectinatus* L., *Potamogeton maackianus* A. Benn., and *Valisneria asiatica* Miki, were found. Beyond the *N. peltata* zone, *i.e.*, deeper than 200 cm, no submerged vegetation was found.

3. Materials and methods

3-1. Determination of biomass

Once or twice a month from May to November 1984, the aboveground parts of macrophytes were collected from 5–8 quadrats, with an area of 1 m², at the various water depths.

The plants harvested were brought to laboratory in polyethylene bags and divided into species. *N. peltata* was further divided into its various parts (leaf lamina, petiole and reproductive parts). Biomass of belowground parts (root in the sediment and stem running on the bottom surface) was estimated from the ratio of above- and belowground biomass, which was obtained by harvesting plants in one quadrat, several thousand cm² in area, at the center of the stand. Epiphytic algae and detritus were cleaned off the samples. After the planimetric measurement of leaf area using a tablet digitizer (Graphtech Mitablen) and a personal computer (NEC PC9801F2), subsamples of the component parts were dried at 85°C for two days to determine dry weight.

3-2. Determination of leaf life span

N. peltata has a roundish floating lamina which is connected with the thin long petiole to the stem at the sediment surface. Leaves of *N. peltata* can be marked easily with colored vinyl tape tied loosely around the petiole. From 20 to 40 leaves of *N. peltata* were marked every two or three weeks from August to November. In this period living leaf number per unit ground area and mean dry weight of a single leaf were approximately constant. Thus, biomass turn-

Fig. 1. Study site at Edosaki-iri Bay in Lake Kasumigaura.

Fig. 2. Seasonal change in deviation from annual mean water level in Lake Kasumigaura in 1984 reported by Erosion and Dam Control Division, Ibaraki Prefecture.

over rate of leaf lamina (k , day^{-1}) was estimated using the following equation :

$$k = \frac{n_0 - n_1}{n_0 (t_1 - t_0)},$$

where n_0 is the number of leaves marked on a date t_0 and n_1 is the number of the leaves remaining on the next census date t_1 . The life span of leaf lamina (day) is defined as the reciprocal of k .

Mean life span of petiole was not measured because the leaf marks were easily lost from the laminaless petiole. BROCK *et al.* (1983) reported that the life span of the *N. peltata* petiole in the Netherlands is 25% longer than that of the lamina. We observed that about 15% of the living petioles were laminaless in October. Therefore, the petiole life span was arbitrarily decided to be 20% longer than that of leaf lamina.

4. Results

Seasonal change in leaf area index of *N. peltata* is shown in Fig. 3. Leaf area index at the sites shallower than 80 cm was consistently about $0.32 \text{ m}^2 \cdot \text{m}^{-2}$ from July to November, while that at the sites deeper than 80 cm decreased in July and increased again to reach the maximum, $0.77 \text{ m}^2 \cdot \text{m}^{-2}$, in September. This seasonal variation in LAI at the deeper sites was probably caused by seasonal fluctuation in water level (Fig. 2).

Seasonal change in biomass of *N. peltata* averaged for all the depths measured is shown in Fig. 4. Leaf biomass, nearly equivalent to aboveground biomass, was much larger than the other parts throughout the growing period. Few reproductive parts (flower and seed) were produced this year.

N. peltata overwinters as a form of tuberous rhizome. In April it began to produce leaves with long petiole and lamina reaching water surface. Stoloniferous rhizome creeping on the sediment was produced during the growing period. Leaves continuously rose from the lateral bud of rhizome. Maximum aboveground biomass was 37.0 ± 15.6 (SD, $n=8$) g dry weight $\cdot \text{m}^{-2}$ in late September. Belowground biomass began to increase after the peak of

Fig. 3. Seasonal change in leaf area index of *Nymphaoides peltata* at the various water depths in the floating-leaved plant zone ; $\circ$, less than 80 cm ; and $\bullet$, over 80 cm in water depth. Water depth at each site is expressed as the yearly mean value. Vertical bars indicate 95 % LSD.

Fig. 4. Seasonal change in above- and below-ground biomass of *Nymphaoides peltata*.

aboveground biomass. Consequently, the total biomass of above- and belowground parts reached its maximum, $47.6 \text{ g dry weight} \cdot \text{m}^{-2}$, in November.

Biomass of other floating-leaved and submerged plants under the canopy of *N. peltata* was less than $3 \text{ g dry weight} \cdot \text{m}^{-2}$.

Turnover rate of lamina biomass of *N. peltata* was $0.037 \pm 0.007 \text{ day}^{-1}$ (SD, $n=4$), corresponding to the life span of 28.1 days. Daily net production for lamina and petiole was determined as the biomass multiplied by biomass turnover rate (Table 1). Daily aboveground net production was about $1 \text{ g dry weight} \cdot \text{m}^{-2} \cdot$

Table 1. Daily aboveground (lamina+petiole) net production of *Nymphoides peltata* determined as the biomass multiplied by the turnover rate.

Duration	Daily net production (g dry weight·m ⁻² ·day ⁻¹)		
	Lamina	Petiole	Aboveground
May 16 - May 30	0.13	0.09	0.22
May 30 - June 7	0.21	0.15	0.36
June 7 - June 20	0.37	0.22	0.59
June 20 - July 12	0.49	0.34	0.82
July 12 - July 25	0.46	0.38	0.84
July 25 - Aug. 15	0.47	0.37	0.84
Aug. 15 - Sept. 6	0.52	0.43	0.94
Sept. 6 - Sept. 19	0.64	0.53	1.18
Sept. 19 - Oct. 11	0.65	0.56	1.21
Oct. 11 - Nov. 1	0.51	0.53	1.04
Nov. 1 - Dec. 4	0.19	0.33	0.52
Total (g·m ⁻²)	85.45	75.80	161.25

day⁻¹ after July. Thus aboveground net production for 200 days of the growing period amounted to only 161 g dry weight·m⁻², but was 3.4 times as large as maximum biomass. This indicates that a large amount of leaf biomass was continuously lost over the growing periods. In contrast, few belowground parts formed in the current year were lost and they disappeared before the middle of the next growing season. Therefore, yearly belowground net production was approximated to the maximum belowground biomass, 17 g dry weight·m⁻². Yearly total net production of *N. peltata* was estimated at 178 g dry weight·m⁻².

5. Discussion

N. peltata occurs widely in alkaline waters (SMITS *et al.*, 1988). Though Lake Kasumigaura is an alkaline eutrophic lake, peak biomass of the *N. peltata* stand at Edosaki-iri Bay was only 47.6 g dry weight·m⁻² with leaf area index of 0.6 m²·m⁻². These values are smaller than those reported for *N. peltata* growing in other regions (IKUSIMA, 1970 ; KVĚT and HUSÁK, 1978 ; VAN DER VELDE *et al.*, 1979 ; SAKURAI, 1981 ; BROCK *et al.*, 1983). The small biomass at Edosaki-iri Bay may be partly because of seasonal fluctuation in water level. Coinciding with a rise in water level, the

biomass of *N. peltata* stopped increasing in late June and further decreased at the deep sites (Figs. 2 and 3). Decrease in biomass after a sudden rise in water level causing leaf submergence was also reported for *N. peltata* in the Netherlands (BROCK *et al.*, 1983) and for *Nelumbo nucifera* Gaertn. in Lake Kasumigaura (NOHARA and TSUCHIYA, 1990).

However, one good reason for the small biomass at Edosaki-iri Bay may be the sediment characteristics and exposure to wind and wave action. The highest biomass of *N. peltata*, 425 g dry weight m⁻², was reported for plants growing on the muddy sediment at a sheltered oxbow lake in The Netherlands (BROCK *et al.*, 1983). Another floating-leaved plant, *Trapa natans* L., growing on the muddy sediment at Takahama-iri Bay of Lake Kasumigaura, had a peak biomass over 300 g dry weight·m⁻² (SAKURAI, 1981 ; TSUCHIYA *et al.*, 1987), while few individuals of *T. natans* were found in the present study site. *T. natans* grows vegetatively by branching in the water column and producing rosette leaves on water surface. Since apical bud is located near the water surface, its damage and loss by heavy wave and wind action seriously affect the following regrowth. In contrast, *N. peltata* has stems usually running on the water bottom. If

aboveground parts, composed chiefly of leaves, are lost by wave action, the plant can soon recover vegetative growth by producing leaves from the runner. In addition, overwintering shoot bearing roots of *N. peltata* is likely to be less worn down by wave action than seed of *T. natans*. Thus *N. peltata* is supposed to tolerate the high exposure to wave action in spite of small biomass.

Environmental stress may prolong leaf life span (CHABOT and HICKS, 1982) and thus lower the rate of biomass turnover. Leaf life span of *N. peltata* in the present study, 28.1 days, was relatively long compared with those previously reported for the floating-leaved plants (e.g., *Euryale ferox* Salisb., *Hydrocharis dubia* Bacher, *Nuphar lutea* (L.) Sm., *Nymphoides peltata*, *T. natans*) ranging from 11 to 35 days (TSUCHIYA, 1988). This long life span is possibly related with the sandy sediment because *Nymphoides peltata* is likely to obtain nutrients primarily from the sediment. The similar value, 27.9 days, was estimated for *N. peltata* grown in an experimental pond with the sandy sediment (TSUCHIYA, 1988), while BROCK *et al.* (1983) reported a smaller estimate, 23.1 days, for *N. peltata* attaining large peak biomass supported by the muddy sediment.

The biomass turnover rate of *N. peltata* shown in the present study was similar to or somewhat lower than those reported previously for floating-leaved plants (BROCK *et al.*, 1983; TSUCHIYA and IWAKI, 1983; TWILLEY *et al.*, 1985; TSUCHIYA, 1989), but was much higher than those of other macrophytes.

The yearly net production of *N. peltata* at Edosaki-iri Bay was 178 g dry weight $\cdot$ m $^{-2}$, corresponding to 82 g C $\cdot$ m $^{-2}$ based on the carbon content of 45% reported by NOHARA *et al.* (1988). This value is much smaller than yearly production of the phytoplankton at the *N. peltata* stand (370 g C $\cdot$ m $^{-2}$, TAKAMURA *et al.*, 1990). Thus, *N. peltata* is not a predominant primary producer at Edosaki-iri Bay.

Acknowledgements

We thank Drs. M. AIZAKI, T. KAWAI, T. HANAZATO, N. TAKAMURA and Mr. R. UENO

(National Institute for Environmental Studies) for their assistance in the field measurements and helpful discussion. Thanks are due to the Erosion and Dam Control Division, Ibaraki Prefecture for providing the data of water level.

摘 要

霞ヶ浦・江戸崎入りの砂質地に生育する 浮葉植物アサザの純生産量

霞ヶ浦・江戸崎入りの砂質地に生育する浮葉植物のアサザの成長を調べ、純生産量を推定した。葉の寿命が28日と比較的短いために、最大現存量は47.6 g 乾重 m $^{-2}$ と非常に小さく、現存量の生育期間(200日)の回転率は3.4と大きな値であった。そして、アサザの年間の純生産量は182 g 乾重 m $^{-2}$ と推定された。この純生産量推定値は、同じ地点での植物プランクトンや霞ヶ浦の他の地域の浮葉植物における値よりも小さかった。

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Received : 23 March 1990

Accepted : 14 June 1990