Diel Vertical Movement of *Neomysis intermedia* Czerniawsky (Crustacea, Mysidacea) Population in a Shallow Eutrophic Lake

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Abstract

Diel vertical movement of *Neomysis intermedia* population in Lake Kasumigaura, a shallow hyper-eutrophic lake, was investigated. *N. intermedia* tended to concentrate more near the lake bottom during the daytime and to disperse throughout the whole water column at night. This behavior was observed at all growth stages, and the timing of this movement closely corresponded with sunset and sunrise. Diel vertical movement of *N. intermedia* may be initiated by a critical light intensity encountered at certain times of sunset and sunrise.

1. Introduction

Diel vertical movement of mysid shrimps has been reported for some mysid species; *Mysis relicta* (BEETON, 1960), *Neomysis americana* (HERMAN, 1963), and *Neomysis awatschensis* (HEUBACH, 1969). These investigators indicated that mysids concentrated near the bottom in a shallow water body or in the lower stratum in a deep water body during the daytime. They were found to disperse throughout the water column in a shallow water body or to migrate into the upper stratum in a deep water body at night. This movement of mysids corresponded closely with the change in solar radiation.

The ecological significance of vertical migratory behavior of mysids has also been evaluated. LASENBY and LANGFORD (1973) showed that *M. relicta* was a voracious predator on cladocerans during migration to the shallow zone at night in a temperate eutrophic lake. MURTAUGH (1981) further studied the selective predation of *Neomysis mercedis* on other zooplankton species in relation to the vertical migration in Lake Washington. On the other hand, the nocturnal migratory behavior of *M. relicta* was related to effective grazing on phytoplankton at the subsurface chlorophyll maximum layer in Lake Michigan (BOWERS

and GROSSNICKLE, 1978; GROSSNICKLE, 1979).

Neomysis intermedia is extremely abundant in Lake Kasumigaura, a shallow hypereutrophic lake (TODA *et al.*, 1981). The maximum density exceeds 10,000 individuals per m² or 2,500 individuals per m³, and the species predominates among zooplankton of the lake throughout the year except for summer (TODA *et al.*, 1982). Such being the case, these mysids may well play an important role in the matter cycles of this lake. It is essential to account for the diel vertical movement for a full understanding of their predatory dynamics in the food web.

2. Materials and Methods

Field surveys were made at three stations in Takahama-iri Bay, the north arm of Lake Kasumigaura (Fig. 1). Samplings were conducted twice at St. 2 (depth 2 m) in June and July 1979, twice at St. 6' (depth 2-3 m) in February and May 1980 and once at St. 3 (depth 4 m) in October 1980. Mysids were collected with an ordinary plankton net (mouth area 0.102 m², mesh size 297 μ m) or a square net (mouth area 0.3 $\times$ 0.5 m, mesh size 630 μ m). The net was towed horizontally at different depths at a speed of about 0.5 m $\cdot$ sec⁻¹ over a distance of 20-40 m. Mysids near the lake bottom were

Fig. 1. Takahama-iri Bay of Lake Kasumigaura and sampling station (x). Depth contour interval is 2.5 m (dotted line).

collected with a net attached to a sled. Mysids collected were either preserved immediately in 5-10% formalin or frozen in refrigerator and brought back to the laboratory. All individuals of mysids in whole samples or subsamples were counted, and their wet weight was determined with a balance after the removal of water by absorption paper. Wet weight was converted to dry weight by using a conversion factor of 0.176 (TODA unpubl.). The mysids were separated into 3 or 4 groups according to growth stage and sex (TODA *et al.*, 1982). Stomach contents of preserved mysids were examined under 100-256 $\times$ magnification. Small zooplankton were sampled with a 6-l Van Dorn water sampler at depths of 0.5, 2, and 3.5 m, collected by filtration with a net (mesh size 94 μ m), and preserved in 5-10% formalin. Chlorophyll *a* concentration as phytoplankton biomass was measured by fluorometry (STRICKLAND and PARSONS, 1972).

Water temperature and light intensity were measured with a thermistor thermometer and a quantum meter, respectively. Values for surface light intensity during the night were referred to BEETON (1960). Water temperature and light intensity in summer were quoted from AIZAKI *et al.* (1981).

3. Results and Discussion

Diel vertical movement of mysid population showed almost the same pattern in Lake Kasumigaura throughout the year. Representative patterns of diel vertical movement are shown in Figs. 2 and 3. In both cases, mysids concentrated near the lake bottom during the daytime and they began to disperse upward in the evening just after sunset, distributing throughout the whole water column during the night. Early next morning, mysids shifted down to the deeper layer and again formed a dense population near the bottom. Although some differences have been reported in the distribution pattern at different growth stages (BEETON, 1960; HERMAN, 1963), in the present study, the diel vertical movement of *N. intermedia* was fairly similar at all stages in both sexes, except for large mature mysids, some of which settled close to the lake bottom even during the night (Fig. 3). Vertical homogeneity in the

Fig. 2. Diel changes in the vertical distribution of *N. intermedia* and the surface light intensity (dotted line) on 2-3 May 1980 at St. 6'. Black circle indicates the center position of net mouth.

Fig. 3. Diel changes in the vertical distribution of *N. intermedia* and the surface light intensity (dotted line) on 18-19 October 1980 at St. 3. Black circle indicates the center position of net mouth.

distribution of mysids at night may be a great advantage for quantitative sampling, and night vertical tow may assure a reliable estimation of mysid abundance (c.f. TODA *et al.*, 1982).

In some cases, however, a little different pattern was observed. On a dark rainy day in July, a considerable amount of mysids was collected in the water column about one hour before sunset, and in February many mysids were distributed at the intermediate depth of water in the morning. Another exception in the diel vertical movement of mysid population was observed in a shallow nearshore region, where the mysids formed a dense swarm in winter. They appeared near the surface even during the daytime (TODA unpubl.).

Light has been known to control the distribution of mysids. HEUBACH (1969) stated that the distribution of *N. awatschensis* population in the daytime was clearly defined in the water column by a certain critical light intensity (10^{-5} lux = 1.9×10^{-7} $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{sec}^{-1}$). The light intensity at the surface of Lake Kasumigaura was 10^2 – 10^3 $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{sec}^{-1}$ during the daytime and 10^{-5} – 10^{-3} $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{sec}^{-1}$ during the night (Figs. 2 and 3). Figure 4 shows the vertical profiles of light

and temperature in Lake Kasumigaura. Light reduced rapidly with depth, and the calculated extinction coefficients ranged from a minimum of 2.4 (m^{-1}) in February with lower algal biomass to a maximum

Fig. 4. Vertical profiles of water temperature (solid line) and relative light intensity (dotted line): a, 4 June 1979; b, 25 July 1979; c, 9 February 1980; d, 2 May 1980; e, 19 October 1980.

Fig. 5. Diel changes in the biomass of *N. intermedia* in the surface layer (0-0.5 m) (solid line) and the surface light intensity (dotted line) at St. 6'. a, 9-10 February 1980; b, 2-3 May 1980.

of $4.2 \text{ (m}^{-1}\text{)}$ in July when blue-green algae grew densely. Consequently the relative light intensity near the lake bottom was estimated to be 0.003-0.9% of surface light intensity, which corresponded to 3×10^{-3} - $0.9 \times 10^1 \mu\text{E} \cdot \text{m}^{-2} \cdot \text{sec}^{-1}$ during the daytime.

In order to show the close relationship between light and mysid movement, the timing of diel movement was further examined by surface sampling made at short time intervals of 30-60 minutes. Two examples obtained under short and long day conditions are shown in Fig. 5. Under a short day condition in February (Fig. 5a), the biomass of mysids in the surface layer began to increase rapidly just after sunset when surface light intensity decreased from 10^0 to $10^{-5} \mu\text{E} \cdot \text{m}^{-2} \cdot \text{sec}^{-1}$. Three noticeable peaks were observed at 18:30, midnight, and 05:00. They almost completely disap-

peared from the surface layer before sunrise when surface light intensity sharply increased from 10^{-5} to $10^0 \mu\text{E} \cdot \text{m}^{-2} \cdot \text{sec}^{-1}$. Under a long day condition (Fig. 5b), the mysid biomass in the surface layer also began to increase just after sunset when surface light intensity greatly reduced. The biomass reached a peak at 19:30, decreased at midnight, and again increased at 03:00-04:00. An abrupt reduction in mysid biomass occurred after 04:00, when surface light intensity sharply increased; a very small amount of mysids remained in the surface layer just before sunrise. Mysids appeared in the surface layer by 18:00 in February and by 19:00 in May, and disappeared by 06:30 in the former and by 04:30 in the latter. In both waters mysids appeared about one hour later and disappeared two hours earlier during a long

day as opposed to a short day. This suggests that diel vertical movement of *N. intermedia* population was regulated by a certain threshold light intensity encountered at certain times of sunset and sunrise, probably between 10^0 and $10^{-5} \mu\text{E}\cdot\text{m}^{-2}\cdot\text{sec}^{-1}$. When the light intensity is less than the threshold, mysids may be released from the light pressure and they disperse into the whole water column. While under the light intensity higher than the threshold, mysids are affected negatively by the light and move toward the deeper layer. Thus, they concentrate near the lake bottom in a shallow water body.

Bright moonlight has been considered to affect the vertical movements of mysids (BEETON, 1960; HERMAN, 1963). During the present study, bright moonlight ($2.6 \times 10^{-3} \mu\text{E}\cdot\text{m}^{-2}\cdot\text{sec}^{-1}$) was observed in May (Fig. 2). However, the disturbance in the distribution pattern of *N. intermedia* population was negligibly small. A sharp temperature gradient or warm water has also been known to prevent the vertical movement of mysids (BEETON, 1960; HERMAN, 1963). In the shallow Lake

Kasumigaura, however, thermal stratification is naturally slight (Fig. 4), and *N. intermedia* appeared in the surface layer even in summer. It seems, therefore, unlikely that the temperature gradient or warm water restricts the diel movement of mysids in Lake Kasumigaura.

Under microscopic examination, fragments of copepods as well as phytoplankton were often noticed in the stomach of mysids collected at night. The dispersion of mysids into the water column at night may increase the chances of encountering living prey which is evenly distributed in the column (Fig. 6). Conversely, zoo- and phytoplankton might suffer predation pressure by mysids at night.

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摘 要

霞ヶ浦においてイサザアミ (*Neomysis intermedia*) 個体群の日周行動について通年にわたり調査した。イサザアミ個体群は日中は湖底近くに集まり、夜間は湖水の全層に分散していた。この日周行動は、各季節を通して、すべての发育段階の個体において観察され、その時刻は日没と日出とに密接に関連していた。イサザアミ個体群の日周行動は日没および日出時のある光照度によって引き起こされていると考えられる。

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Fig. 6. Vertical distribution of zoo- and phytoplankton at midnight on 18-19 October 1980 at St. 3.

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