

Vertical Migration and Horizontal Distribution of *Chaoborus* Larvae in Lake Fukami-ike, Japan

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Diel vertical migration (DVM) and horizontal distribution of *Chaoborus flavicans* larvae were studied in Lake Fukami-ike (maximum depth 7.75 m, Central Japan). The larvae showed a clear migration in the 4~7 m layer during the day and throughout the water column at night. It should be noted that, while old instar distributed throughout the column during the night. Young instar was found only in the 1~4 m layer. An examination of horizontal distribution revealed that larval stage was clearly related with the depth. It suggests that *Chaoborus* appear to exist in the deeper area during the larval stage.

Key words : *Chaoborus*, DVM, horizontal distribution

INTRODUCTION

The major ecological features of *Chaoborus* larva are well studied (e.g., Hanazato and Yasuno, 1989; Iwakuma *et al.*, 1989; Fukuhara, 2000). *Chaoborus* performs extensive diel vertical migrations (Northcote, 1964; Malueg and Hasler, 1966; LaRow, 1968; Goldspink and Scott, 1971). Several studies have shown that *Chaoborus* larvae stay in deep water or hypolimnion during the day and return to the surface waters or epilimnion at night (e.g., Teraguchi and Northcote, 1966). Fourth-instar larvae usually overwinter in the sediment or deep water until pupation starts in early summer of the following year. Third- and fourth-instar larvae have been reported to migrate vertically, although younger larvae usually do not migrate as to the same extent (e.g., McGowan, 1974). Horizontal and vertical distribution may also be size-specific and vary seasonally (Voss and Mumm, 1999).

Chaoborus in Lake Fukami-ike have been studied by Uéno (1952), Sakurai and Watanabe (1974) and Tanaka (1992), and the population

density of planktonic or benthic larvae has been revealed. The lake shows unique characteristics and the limnological value is high. The only *Chaoborus* species collected in this lake was *C. flavicans* (Meigen). Larvae undergo four stages before molting, and the four instars were determined by measuring the head length (HL: base of antenna ~ eye ~ posterior tentorial pit or in other words 'head capsule'). For over many years, *Chaoborus* larvae have been extensively studied, and their population density was found to be the highest among all other Diptera species. Although *Chaoborus* larva are thus a major benthos and zooplankton in this lake, population dynamics remains to be elucidated. This study examined the diel vertical migration (DVM) and horizontal distributions of *Chaoborus* larvae in Lake Fukami-ike.

MATERIALS AND METHODS

Study site

Lake Fukami-ike (35° 19'N, 137° 49'E) is a eutrophic lake in central Japan with the surface

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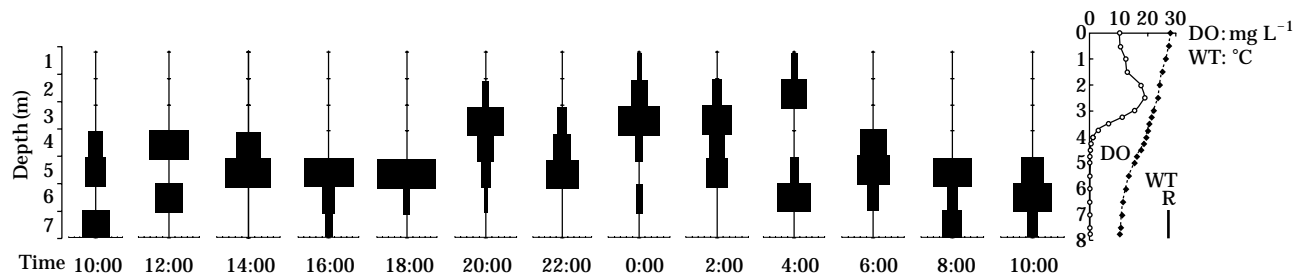


Fig. 1. Diel changes in the vertical migration of *Chaoborus* larvae shown by the population rate ($R = 5\%$ of the population), average of water temperature and dissolved oxygen (Lake Fukami-ike, 23~24 August 2003).

area of 0.022 km^2 and the maximum depth of 7.75 m. It is a small monomictic lake that stratifies from March to October, where anoxic conditions prevail below 4 or 5 m.

Sampling

DVMs of *Chaoborus* were examined on 23~24 August, 2003. Samples were taken with a Van Dorn water sampler (about 2.5 L) every 1-m depths throughout the water column. *Chaoborus* were sampled from 10:00 on 23 August to 10:00 on 24 August at two-hour intervals at the maximum depth of the sampling site. Horizontal distribution of larvae was examined on 19 October 2003. Selecting 28 sites covering the whole area of the lake, vertical hauls were conducted with a plankton net (NXX 7,200 μm) along the bottom at each site, and the numbers of collected larva were counted. At the same time, water temperature (WT), dissolved oxygen (DO) and hydrogen sulphide (by indicator tube) were measured every 1 m or more.

All the collected samples were divided into four instar groups by measuring HL.

RESULTS AND DISCUSSION

Diel vertical migration

DVM of *Chaoborus* larvae in Lake Fukami-ike is shown in Fig. 1. All larvae distributed in anoxic layer from 4 m to 7 m during the day (10:00~18:00). The distribution during the night (20:00~4:00), ranged to all layers, but once again in the morning (6:00~10:00), all larvae distributed between 4 and 7 m. WT and DO showed no change during this observation; the thermocline developed between 3 m and 4 m, and dissolved

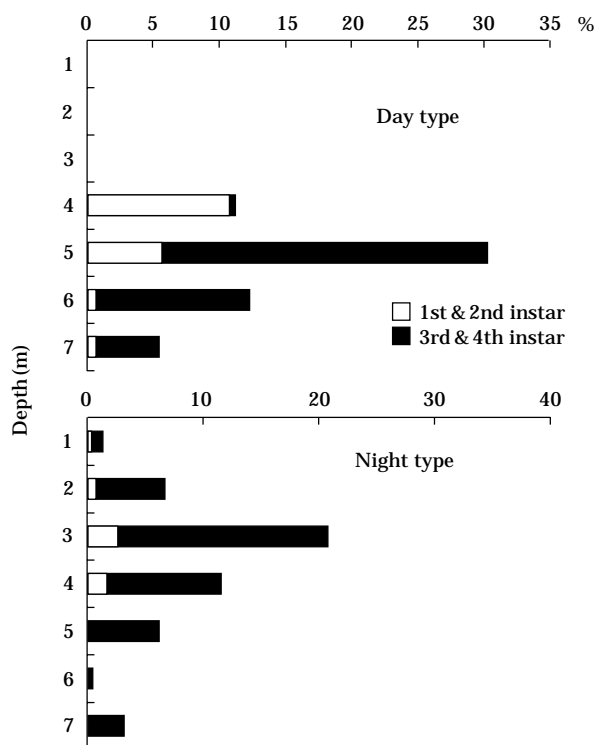


Fig. 2. Vertical changes in the number of *Chaoborus* larvae.

oxygen was 0.47 mg L^{-1} at 5 m. Hydrogen sulphide increased with depth, and the bottom sediment was black in color, suggesting that younger instar larvae probably have a low tolerance to H_2S . Such migratory behavior observed in this lake has also been reported in many other lakes. The migratory pattern seen in the present study was similar to those reported by Sugiyama (1994), although our study revealed more complex DVMs. Collected larvae were categorized into day type (10:00~18:00, 6:00~10:00) and night type

(20 : 00~4 : 00) based on the time of sunset (8 : 23) and sunrise (5 : 11), and also into younger (1st and 2nd) and older (3rd and 4th) instar based on the HL (Fig. 2). Day type larvae were most frequently found at 5 m depth (54.8%), and Night

type larvae at 3 m depth (42.3%). night type young instar larvae distributed only between 1 and 4 m, but older instar in all layers. The density of old instar larvae was higher than the young.

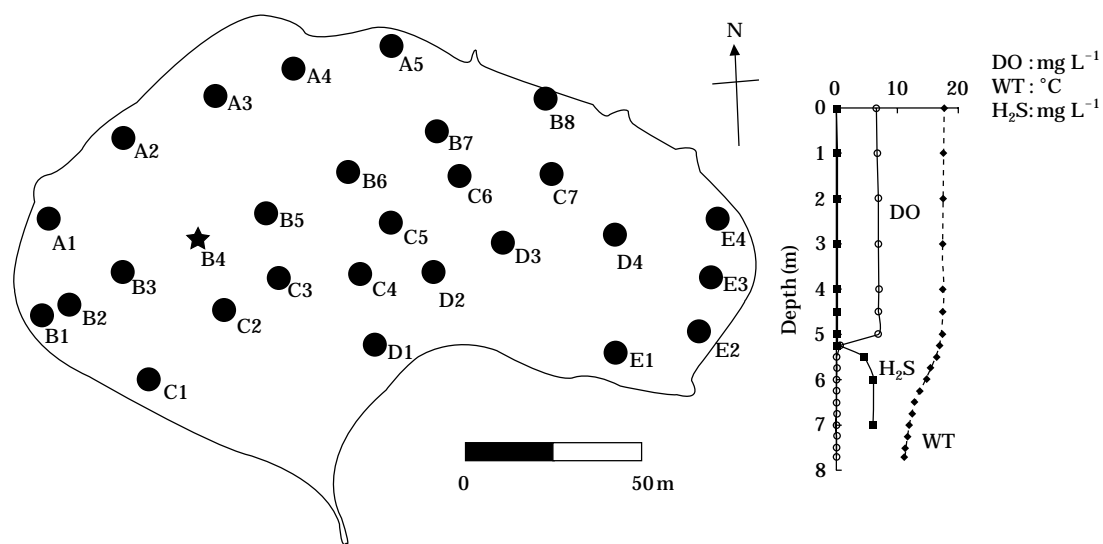


Fig. 3. Sampling sites for examining horizontal distribution of *Chaoborus* larvae in Lake Fukami-ike on 19 October 2003 (★: the site for regular observation).

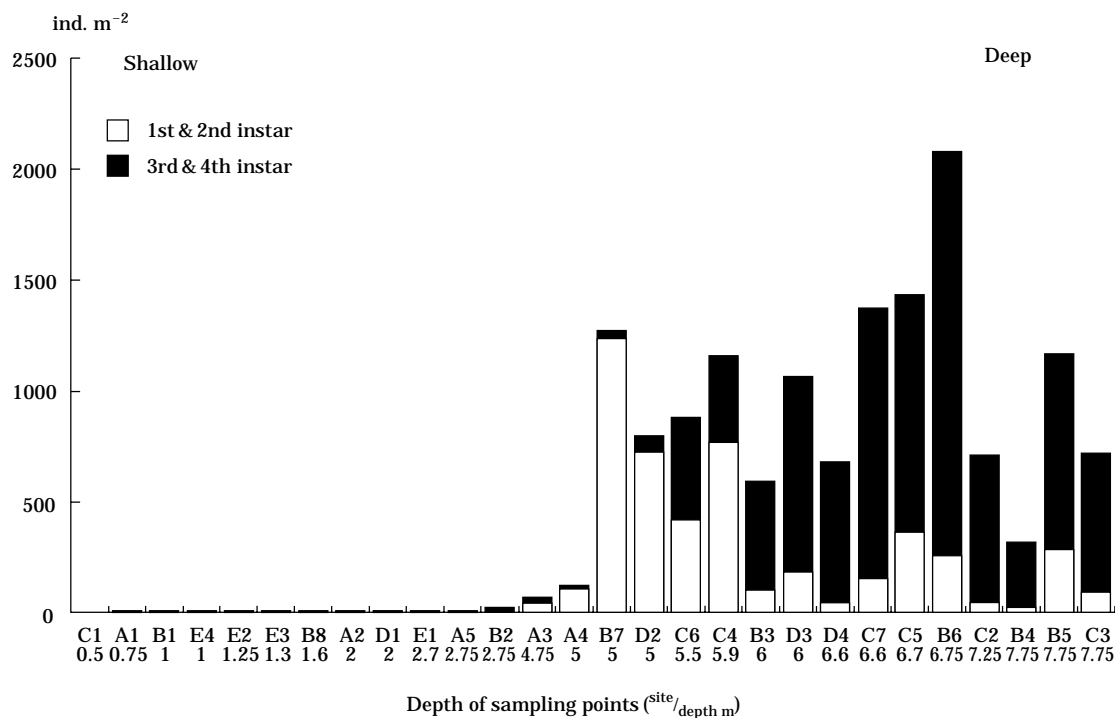


Fig. 4. Densities of *Chaoborus* larvae at each sampling site. The site are aligned by depth.

Horizontal distribution

Sampling sites are shown in Fig. 3. WT and DO were measured at all sampling sites, vertical distribution of WT, DO and H₂S where sampled at maximum depth site were shown in Fig. 3. In Fig. 4, all the sampling sites are aligned by depth. No larvae were found in the littoral zone (11 sites). The density of larva at site B6 (6.75 m) (2075 ind. m⁻²) was higher than that at the site for regular observation (B4) (315 ind. m⁻²). The rate of old instar increased with depth, especially at sites deeper than 6 m. It suggests that larvae move to hypolimnion (5.5 ~ 7 m) as they grow.

By investigating the DVM, it was revealed that younger larvae formed smaller population than the older. The results of horizontal study suggest that *Chaoborus* larvae move toward the deeper area (about 6.5 m) during the larval stage. The number of young instar in larvae at the regular sampling site was therefore low.

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