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Diel Periodicity in the Drift of the Fourth Instar *Micrasema quadriloba* (Trichoptera: Brachycentridae) Larvae in Relation to Body Size

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We investigated the diel periodicity in the drift in relation to body size by field survey using the fourth instar grazing larvae of *Micrasema quadriloba* Martynov (Trichoptera, Brachycentridae) as a material. Although the larvae showed nocturnal drift periodicity, drift density in the nighttime was only twice that in the daytime. In both time periods, smaller individuals drifted significantly more, and the drift individuals in the daytime was the smallest in size ($P<0.05$ in Sheffe's F). We discussed whether the drift of the fourth instar larvae drift behaviorally or accidentally considering larval size and food depletion.

Key words : drift, diel periodicity, *Micrasema quadriloba*, Trichoptera, grazer

INTRODUCTION

It has been well known that benthic invertebrates drift with distinct diel periodicities, and that the drift induces dispersal in stream ecosystems (Waters, 1972). Since notable drift organisms are ephemeropteran species, especially genus *Baetis*, which are grazers with high moving abilities, most drift studies have been performed in *Baetis* species. Waters (1965) classified drift patterns into three schemes, i.e., catastrophic, constant (i.e. accidental), and behavioral drifts. Firstly, benthic invertebrates perform the behavioral drift to avoid pradation risks (cf. Allan, 1995; Miyasaka and Nakano, 1999, 2001). Thus, larger size classes of *Baetis* species drifted in the nighttime when predation risks decreased (Allan, 1978; Skinner, 1985). They also perform the behavioral drift owing to depletion of periphyton as food resources (Kohler, 1985; Hinterleitner-Anderson *et al*., 1992).

The major components of drift are not only ephemeropteran species but also trichopteran species. In trichopteran species, however, causes of drift have not been studied in detail while the diel periodicity of drift has been examined frequently (cf. Elliott 1965, 1967; Statzner *et al*., 1987). Since the trichopteran species, especially case-bearing species, are the one of powerful grazers with poor moving abilities (Lamberti *et al*., 1987; Steinman, 1996), starvation by the resource depletion may induce them to drift.

Micrasema quadriloba is a small case-bearing trichopteran species, and they graze periphyton on substrata (Katano *et al*., 2002) dispersing downstream as they grow (Isobe, 2000). They have low moving ability (Katano, unpublished data), and they are very abundant and predominant in the Shigogawa Stream, a second-order mountain stream in the Kii peninsula in central -southern Japan.

As a pilot study on the drift of case-bearing caddisflies due to food depletion, we conducted a field survey on the diel periodicity in the drift of the forth instar *Micrasema quadriloba* Martynov

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(Trichoptera, Brachycentridae). We compared body sizes and the extent of starvation between the drifting larvae and the benthic larvae to demonstrate the characteristics of drifting individuals. In the Shigogawa Stream, predator fishes such as minnow (*Phoxinus oxycephalus*) and dace (*Leuciscus hakonensis*) occur throughout a year. Since Mizuno and Gose (1993) reported that the minnow provided the larvae with the predation risks, it might be possible to see the effect of predation risks on the drift.

MATERIALS AND METHODS

Field survey to investigate the diel periodicity of *M. quadriloba* larvae was conducted from 2 to 3 December, 2000, at the center of a riffle of the Shigogawa stream (lat. 34° 22′N, long. 136° 1′E). At the investigation dates, most of *M. quadriloba* are fourth instar larvae. Drifting insects were collected using a 225 µm mesh server net (25 × 25 cm mouth opening, 0.6 m net length) that was placed on the streambed by pegs. The server net was set on the streambed at 0900 hours in 2 December, and was salvaged after every 3 h (1200, 1500, 1800, 2100, 2400, 0300, 0600, 0900, and next 1200 hours) over a 27 h period. At the above sampling times, everything in the server−net, which was filtered through the server−net throughout 3 h, was collected as a sample. Then, the server−net was replaced for the next sampling. Water temperature, current velocity at the net opening and light intensity above water surface were measured using a thermometer, a portable current meter (Tanida *et al.*, 1985), and a portable digital LUX meter (DX−100, Takemura Electric Works Ltd.), respectively. In laboratory, individual number of *M. quadriloba* larvae in the sample (i.e. drift larvae) was counted, and then drift density was calculated. The drift density was expressed as number of insects drifting per 100 m^3 water, following Smock (1996). Then, the drift densities of 3 h samples were compared each other.

About 30 benthic individuals of the larvae were collected haphazardly at each sampling time to compare drift and benthic individuals of *M. quadriloba* larvae. In addition, to measure the benthic density of the larvae and to examine the species composition of benthos, four benthos samples were collected using a server−net sampler from the same riffle where the drift sampling was performed. The drift and benthic individuals and benthos samples were immediately preserved in 5% buffered formalin solution.

To identify periphyton abundance at the sampling station, the amounts of chlorophyll *a* were measured on four cobbles selected haphazardly. Periphyton on the cobble was wiped with acrylic fiber clothes in a circle (ø3 cm) according to the simple acrylic fiber sampler method (Tanida *et al.*, 1999). These samples were placed into vials containing 10 mL of 99.5% ethanol. After preservation in dark in a refrigerator at 4°C for 24 h, the amount of extracted pigment was measured using a spectrophotometer (Model MPS−2000, Shimadzu). The data were then used for chlorophyll *a* determination following UNESCO (1966).

Two parameters were established for the comparison between drift and benthic *M. quadriloba* larvae. One is body size represented by abdominal length, and another is a repletion index of the larval gut, which is established to show starvation level. In the repletion index, four ranks were established, zero, one, two, and three, showing the completely empty, from a little to a half filled, from a half to completely filled, and completely filled gut, respectively. Both all the drift and all the benthic individuals were examined with a binocular stereoscopic microscope to measure the abdominal length and the repletion index. These characteristics were compared between the benthic and drift individuals and among three time periods, i.e., the daytime (1200, 1500 and next 1200 hours), the nighttime (2100, 2400, 0300 and 0600 hours), and the dusk & dawn (1800 and 0900 hours), since the sunset and sunrise were at 1646 hours and 0645 hours on the survey date. The abdominal length was compared using one−way ANOVA and a multiple comparison test, Scheffe's *F*, and the repletion index was compared using Kruskal−Wallis test and Scheffe's *F*.

RESULTS

The benthic density of *M. quadriloba* larvae and the periphyton abundance was 1.18 ± 0.43 individuals cm^{-2} and 1.7 ± 0.2 µg chlorophyll *a* cm^{-2}, respectively. The larvae occupied higher than 80% of the total number of benthic invertebrates. Water temperature and current velocity at the net opening was 7.6±0.49°C and 22.2 ±1.28 cm s^{-1}, respectively, and did not change much during the survey period. Weather was cloudy in both dates. At each sampling time, it was verified visually that neither backwater nor clogging were observed in the server−net.

The larvae showed a tendency of nocturnal habits in drift density (Fig. 1). Drift density increased dramatically between 1800 hours and 2100 hours (just after sunset), remaining relatively high until 0300 hours, and decreased drastically after 0300 hours (before sunrise).

The abdominal lengths of benthic and drift individuals among time periods were significantly different ($F_{5,\,857}$ = 24.6, P < 0.00001 in one−way ANOVA) (Table 1 and Fig. 2A). Scheffe's *F* showed that the drift individuals were significantly smaller than benthic individuals in both daytime and nighttime, and that the drift individuals in the daytime was the smallest among all groups. At dusk & dawn, however, the difference between benthic and drift individuals was not significant.

The repletion indices of benthic and drift individuals among time periods were also significantly different (H = 54.1, P < 0.01, Kruskal−Wallis test). Scheffe's *F* showed that the repletion index of drift individuals was also significantly less than that of benthic individuals in both daytime and nighttime (Fig. 2B). At dusk &

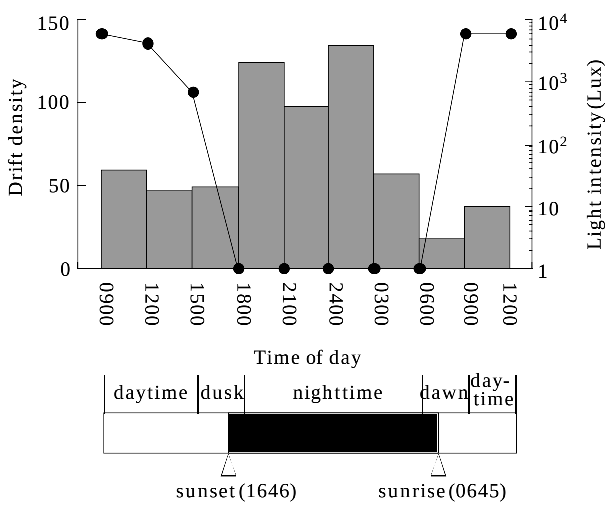

Fig. 1. Diel periodicity in the drift of *M. quadriloba* at the riffle of the Shigogawa Stream. Bars show drift density, which was expressed as number of the larvae drifting per 100 m^3 water, following Smock (1996). The solid line shows the light intensity. A nocturnal drift pattern was exhibited in diel periodicity.

Table 1. The result of one−way ANOVA in the abdominal length between benthic and drift individuals among each time period.

Source	*MS*	*d.f.*	*SS*	*F*	*P*
S_A	6.62	5	1.324	24.570	< 0.00001
Residual	46.17	857	0.054		
S_T	52.79	862			

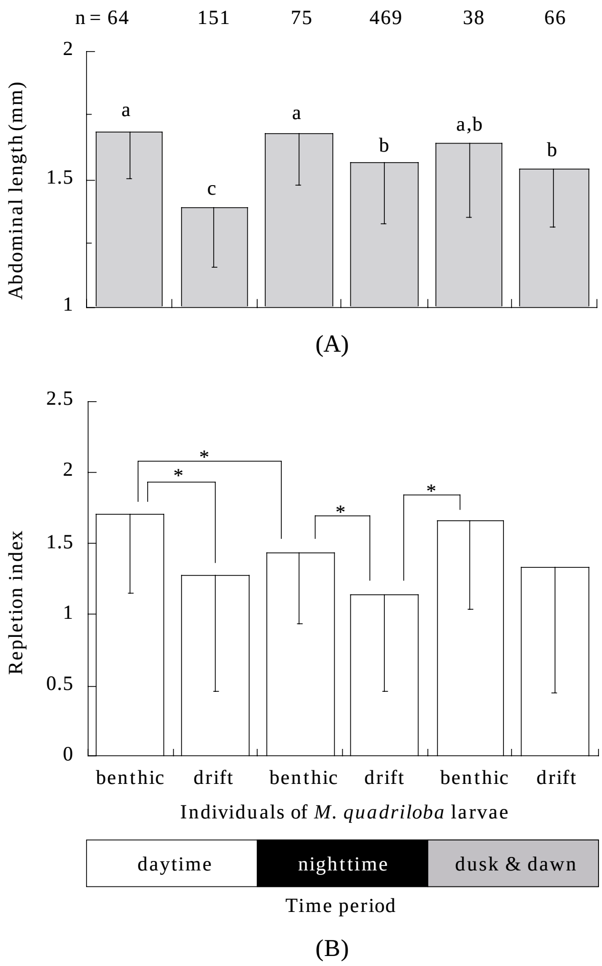

Fig. 2. Comparison of characteristics between benthic and drift *M. quadriloba* larvae among three time periods. Numbers of individuals were shown on the chart. (A) abdominal length of benthic and drift larvae during each time period. Within chart, columns with similar labels do not differ significantly (P > 0.05, a multiple comparison test, Scheffe's *F*). (B) the repletion indeices of benthic and drift larvae during each time period. *significant difference at P = 0.05 by Scheffe's *F*.

dawn, however, the difference between benthic and drift individuals was not significant. In addition, the repletion index of benthic individuals in the daytime was significantly higher than that of benthic individuals in the nighttime.

DISCUSSION

Nocturnal drift has been shown in several trichopteran species (Elliott, 1965, 1967; Statzner *et al*., 1987). The nocturnal drift was shown in *M. quadriloba* larvae as well in the present study. The magnitude of diel periodicity, however, was smaller than that of *Baetis* nymphs, the drift of which in the nighttime is logistically two or three times higher than that in the daytime (Müller, 1965; Elliott, 1969). Thus, it could be mentioned that the numbers of drift individuals among time periods in *M. quadriloba* larvae did not vary so much, although they had nocturnal drift periodicity. Similarly, in small *Limnephilidae* larvae, the number of drift individuals in the nighttime was only twice that in the daytime (Elliott, 1967).

Predators, i.e., drift−feeding fishes, rely on vision for prey capture with great size−selectivity on prey. Therefore, in *Baetis* (Allan, 1978; Skinner, 1985) and *Gammarus* (Anderson *et al*., 1986; Newman and Waters, 1984) species, the individuals of larger size classes drifted in the nighttime to avoid predation risks, because they were exposed to high predation risks during daytime. In contrast, the present study revealed that smaller individuals of *M. quadriloba* drifted in both daytime and nighttime. The larvae might be well below the size with the predation risk similar to the results of water mites (Elliott and Minshall, 1968; Allan, 1981) and Chironomid larvae (Cowell and Carew, 1976). Thus, the drift of small individuals might reflect not to avoid predation risks behaviorally but the possibility that they mainly drifted accidentally.

With a few exceptions, the diel activity patterns were not so much recognized in case−bearing caddisfly species. Their activity patterns were different (i.e., nocturnal or diurnal periodicity) depending on species (Elliott, 1970). Although the activity pattern of *M. quadriloba* is not known, the significant difference in the repletion index of benthic individuals between daytime and nighttime would suggest that they are more active in the daytime than in the nighttime. This construction is consistent with the observation that the drift individuals in the daytime were the smallest in size, and would support the above possibility that smaller larvae drift accidentally.

The repletion index was significantly low in drift individuals in both the daytime and nighttime. At a first glance, starved individuals in benthic population might drift more. However, a bias by sampling method of every three hours might have advanced the digestion of the trapped drift individuals. Although digestive speed of *M. quadriloba* is unknown, a caddisfly, *Uenoa tokunagai* (Uenoidae), digested 70% of the gut contents in three hours (H. Hosokawa, unpublished data). Since the method of the present study was not good to argue the starvation drift hypothesis, a new method with shorter trap periods will be required in future studies.

In our recent study, the fifth (final) instar *M. quadriloba* larvae increased their drift with a decrease of food resource (i.e. periphyton), while the fourth instar larvae did not respond to decrease of periphyton (Katano, unpublished data). In addition, *Baetis* species, which is larger body size than the final instar *M. quadriloba* larvae, also increased their drifts when periphyton abundance decreased (Kohler, 1985; Hinterleitner−Anderson *et al*., 1992). The present study was performed when *M. quadriloba* larvae were in the fourth instar, whose demand for food resource must be less than that of the fifth instar larvae. Thus, it is difficult to interpret that fourth instar larvae drift to response to food depletion. Therefore, it is more probable that the fourth instar larvae drifted not behaviorally (i.e. to avoid predation risks and to response to food depletion) but accidentally.

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