



Flight density of the aquatic insect fauna over the water surface in the middle reaches of the Shinano River, Japan, mainly among caddisflies (Trichoptera)

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Abstract

We focused on the relative number of flying adult caddisflies on the river surface captured by sticky board traps with the aim of elucidating differences in the distribution pattern of caddisfly larvae along the slope in the middle reaches of the Shinano River. The individual number of adult caddisflies caught increased from April and decreased from October. Even in the same middle reaches of a river, there was a large difference geographically in the species captured. *Hydroptila* sp. was caught mainly downstream of the Taishyobashi Bridge, *Psychomyia acutipennis* (Ulmer 1908) in the vicinity of the Taishyobashi Bridge, and *Stenopsyche marmorata* Navás 1920 upstream of the Awasabashi Bridge. It is known that the slope of the Shinano River bed suddenly becomes less and the flow rate slower in the area from the Taishyobashi Bridge to the Awasabashi Bridge, and it was shown that the species composition and number of aquatic insects caught changes with the change in the slope of the river bed.

Key words: flight behavior, geographical distribution, seasonal change, river bed slope, species composition, sticky board trap

Introduction

Aquatic insects are the major component of freshwater benthic macroinvertebrates and include many taxonomic groups (Merritt *et al.* 2008). Some kinds of aquatic insect larvae, especially Trichoptera, Ephemeroptera, Diptera-Chironomidae and so on, are sensitive to water pollution, and their density and species composition can be monitored over a period of time as a good indicator of water quality (reviewed by Hellawell 1986; Watanabe 1995; Tanida 2010). Recently, these aquatic insect larvae have been used as indicators of water conditions in environmental assessment in Japan (Nozaki 2012; Tanida 2010). On the other hand, these larvae are often classified into functional feeding groups (FFGs) depending on the type of food and the way of feeding (Merritt *et al.* 2008). Among FFGs, there are many filterers and collectors; *e.g.*, some caddisfly larvae (Trichoptera) feed themselves by spinning silk into filtering nets and retreats to collect particulate organic matter (POM) derived from organic debris and wastes. Thus, these aquatic insect larvae play an important role in the material flows in aquatic ecosystems, especially in the detritus food chain (reviewed by Wallace & Merritt 1980; Ward 1992).

When we investigate the fauna of benthic macroinvertebrates in rivers with the methods generally used in surveys (*e.g.*, surveys that focus on larvae of species of aquatic insects), there are various problems of taxonomy, study site selection, collection tools and methods, processing of caught specimens, and the amount of work involved (*e.g.*, Nozaki & Yamasaki 1995). It is very difficult to understand the characteristics of inhabiting aquatic species in a short time during the same period over a wide area. Therefore, new and simpler methods are needed. Our laboratory has conducted studies using various methods with the aim of understanding the characteristics of aquatic insects in the middle reaches of a river in the same period, and in

a short time over a wide area. In this study, we focused on the adult aquatic insect fauna over the river water surface. It is known that adult aquatic insects move upstream, triggered by light reflections from the water surface, as part of their oviposition behavior. There are also reported to be differences in flying ability and differences in flight distance and height depending on the species.

In the present study, we focused on the relative number of flying adult caddisflies on the river surface captured by sticky board traps with the aim of elucidating differences in the distribution pattern of caddisfly larvae along the slope in the middle reaches of the Shinano River.

Materials and methods

Study site. The Shinano is Japan's longest river (length *ca.* 367 km; drainage area *ca.* 11,900 km²), running through Nagano and Niigata Prefectures and flowing north into the Japan Sea (Fig. 1). The present investigation was performed at ten stations in the middle reaches of the Shinano River, which is located in the center of Honshu Island. These stations cover a range of about 88 to 125.5 km from the head of the Shinano River. At each station, a riverine habitat consisting of "unit structures" of a natural river system (*i.e.*, scour pools, riffles, and runs) was generally well preserved, although a few artificial structures, such as concrete banks and small dams were also present. The riverbed in these stations was generally covered with cobbles and boulders. Table 1 shows the characteristics of ten sampling stations in the Shinano River. From St. 1 to St. 10, there are some large cities and towns, an area with typical middle reaches of the Shinano River (stream order 5, discharge 41.8–46.5 t/s, river width 320–520 m). The slope of the riverbed becomes far less, with slower flow rate, in the area from the Taishyobashi Bridge (St. 5) to the Awasabashi Bridge (St. 7) (Chikumagawa River Office, Hokuriku Regional Development Bureau, Ministry of Land Infrastructure, Transport and Tourism 2012). The water was transparent (with low turbidity), the total nitrogen (*ca.* 1.8 mg/L) and total phosphorus (0.074–0.080 mg/L) were low, and the BOD was 0.9–1.6 mg/L at each station (Nagano Prefecture 2012).

Collection of flying aquatic insects. Flying aquatic insects were collected every month from November in 2009 to December in 2010 with sticky board traps (a white plastic board 30 × 10 cm², sprayed with the adhesive material polyolefin, applied to both sides) at each station. For each collection, the traps were suspended with fishing line from a bridge at a height of 10 m above the river water surface during 48 hours. The traps were set with three plates at each station (three replicates). The adult aquatic insects trapped at each station were identified (Trichoptera, Ephemeroptera, Chironomidae, and others) and counted in the laboratory. Adult caddisflies were identified according to the keys of Schmid (1998) and Kawai & Tanida (2005). Among the samples from April to August 2010, we identified all caddisfly adults, but from September to November 2010 we identified mainly the following dominant caddisflies: *Psychomyia acutipennis* (Ulmer 1908), *Hydroptila* sp. and *Stenopsyche marmorata* Navás 1920. At the time that the traps were recovered, we also measured some environmental factors, such as water temperature, pH, and EC (electric conductivity) at each station every month. Water temperature, pH, and EC were measured with an EC/pH meter (WM-22EP, DKK Toa Co.). In addition, weather data (daily mean air temperature in each month) from the Ueda Meteorological Observatory Station were used during the investigation.

Collection of benthic macroinvertebrates on the riverbed. Benthic macroinvertebrates on the riverbed were collected using a Surber sampler over an area of about 0.09 m² (30 × 30 cm²), taking three replicate samples in the riffles at St. 1, St. 5, and St. 8 on 20 March 2010 (before periods of adult caddisfly emergence) and 6 December 2010 (after the emergence period), 2010. [At stations other than Sts. 1, 5, and 8, we could not collect benthic macroinvertebrates from the riverbed because the water flow was very fast (80–100 m/sec.) and the water depth was very deep (>1 m).] They were dislodged by manual disturbances in the Surber sampler square and were trapped in an extended downstream net (opening mesh size: 450 μ). In the laboratory, one net sample at each station was examined on a white tray, and all animals were collected and stored in 70% ethanol. The caddisfly larvae were counted using a binocular microscope, separately for each taxa at the species or genus level by using the keys provided by Kawai & Tanida (2005). In the field, we also measured some environmental factors, such as water temperature, pH, EC, and DO (dissolved oxygen concentration) at each station. Water temperature, pH, and EC were measured with an EC/pH meter at the mid-depth of the station. DO was measured with DO meter (HQ30d, HACH). In December 2010, we measured the surface area of cobbles and the composition of coarse particles on the riverbed surface in each

sampling station. We examined all the cobbles more than 3 cm in diameter in a 30×30 cm² sample area, measured their major and minor axes and estimated their surface area. After studying cobbles in the 30×30 cm² sample area, we collected coarse particles on the river bed surface (upper 5 cm) and then used 3 kinds of mesh sieves, *i.e.*, mesh size 4.76 mm, 2.00 mm, and 0.71 mm, to estimate composition of particles in 4 classes on the riverbed surface.

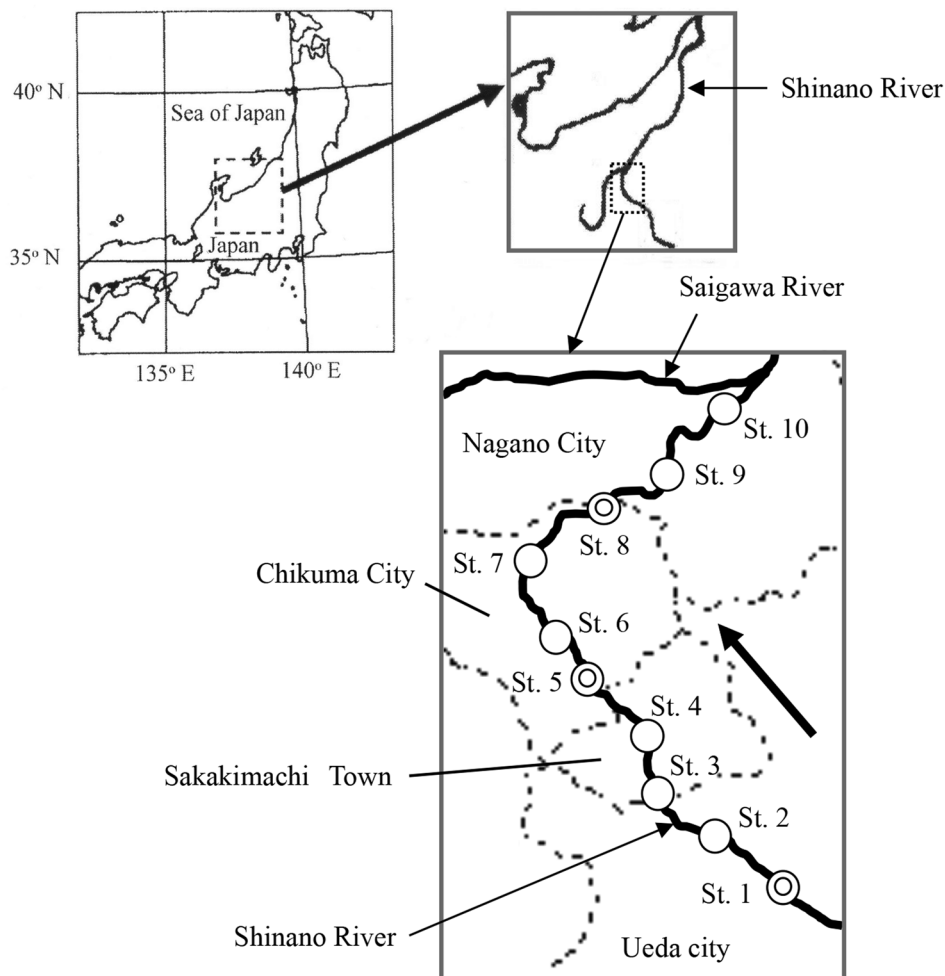


FIGURE 1. Map of the Shinano River, showing the locations of the ten sampling stations. ○ = sticky board traps, ⊙ = sticky board traps + collection of benthic macroinvertebrates. The large arrow shows the water flow direction.

Results

Figure 2 shows the mean water temperature, pH, and EC at the ten sampling stations from November 2009 to December 2010. The EC increased slightly from upstream (St. 1) to downstream (St. 10), while pH decreased slightly from St. 1 to St. 10. However, there were no significant differences among the ten stations in the measured environmental factors.

Using the sticky board traps, a total of 330,900±45,252 individuals/m²/day aquatic insect adults were captured during the investigation period. The dominant taxa were Trichoptera, Ephemeroptera, Chironomidae, among others, with annual flying density in the order of Trichoptera (130,375±15,541 individuals/m²/day, 39.4% of total aquatic insects), Chironomidae (86,642±6,425 individuals/m²/day, 26.2%), and Ephemeroptera (8,733±892 individuals/m²/day, 2.6%). Figure 3(a) shows changes in the monthly capture of total number of adult caddisflies (all stations) by sticky board traps. Trichoptera began to be collected in April (daily mean air temperature was 8.6°C, 58±8 individuals/m²/day), reaching maximum in June (21.0°C, 47,533±7,689 individuals/m²/day, 36.5% of the total number of Trichoptera during the investigation periods). In July a smaller number was collected (21.4°C, 1,467±181 individuals/m²/day, 1.1%) and by September

(21.4°C, 40,733±8,312 individuals/m²/day, 31.2%) the individual number of Trichoptera increased. In October 2010 only a few were collected (14.9°C, 9,333±965 individuals/m²/day, 7.2%). We could not capture adult caddisflies from November 2009 to March 2010 and November to December 2010 because air temperatures were too cold, ranging 0.1–7.7°C. Figure 3(b) shows the changes in the total number of adult caddisflies captured at each station during the investigation periods (all seasons). At St. 5, the maximum number (70,033±18,532 individuals/m²/day, 53.7% of the total number of adult caddisflies) was collected, followed by St. 6 (20,233±5,292 individuals/m²/day, 15.5%), St. 10 (10,233±2,595 individuals/m²/day, 7.8%), and St. 7 (8,933±2,367 individuals/m²/day, 6.9%). From St. 1 to St. 4, St. 8 and St. 9, the number collected ranged from 2,000 to 5,000 individuals/m²/day.

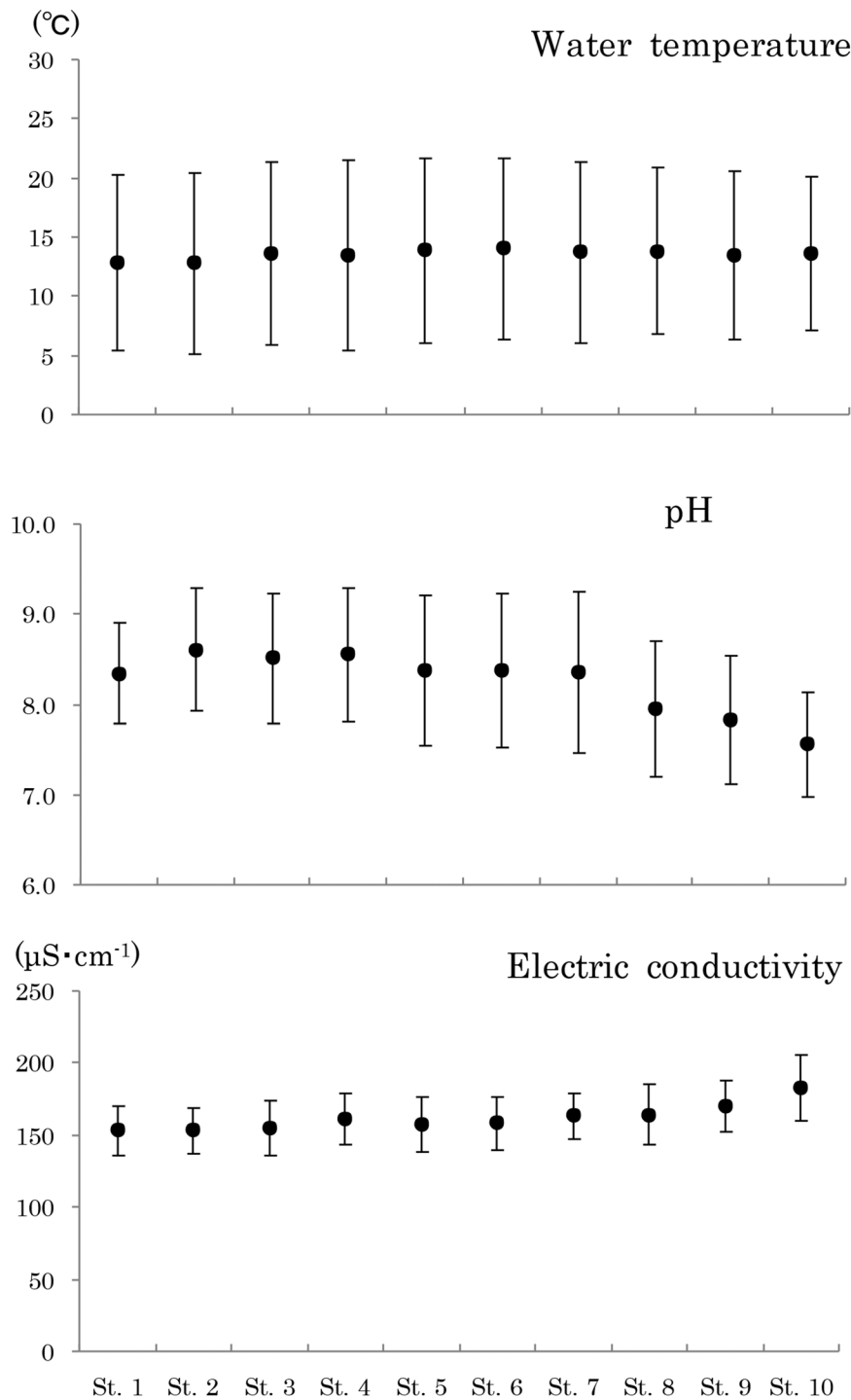


FIGURE 2. Mean values (±SD) of water temperature, pH and electric conductivity in the river water at ten stations from November 2009 to December, 2010.

TABLE 1. Channel and streambed characteristics at ten stations in the middle reaches of the Shinano River. Data from Chikumagawa River Office, Hokuriku Regional Development Bureau, Ministry of Land Infrastructure, Transport and Tourism (2012) and Nagano Prefecture (2012)

Station No.	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	Station 10
Bridge name	Tokidashin Bashi	Uedaoh hashi	Nezumi bashi	Sakakioh hashi	Taishyo bashi	Kamuriki bashi	Awasa bashi	Iwano bashi	Mastushirooh hashi	Sekizaki bashi
City name	Ueda City	Ueda City	Sakakimachi Town	Sakakimachi Town	Chikuma City	Chikuma City	Chikuma City	Chikuma City	Nagano City	Nagano City
Distance from headwater (km)	88	93	95.5	99.5	104	106.5	111.5	116.5	121	125.5
Stream order	5	5	5	5	5	5	5	5	5	5
River-bed gradient ($\times 10^{-3}$)	5.6	4.5	4.5	4.5	2.9	2.9	0.98	0.98	1.0	0.98
Discharge (m ³ /s)	41.8				42.7		46.5			
River width (m)	400	450	360	420	320	450	420	480	520	510
BOD (mg/l)	0.9		1.4			1.6	1.4			
Total phosphorus (µg/l)	0.074		0.077			0.080				
Total nitrogen (mg/l)	1.80		1.88			1.79				

Table 2 shows the list of adult caddisflies caught by sticky board traps from April to August 2010. A total of 15,501 individuals/m²/day adult caddisflies were captured. We identified a total of 8 species. The dominant species was *Psychomyia acutipennis*, with 7,355 individuals/m²/day (47.4%), followed by *Hydroptila* sp. (3,697 individuals/m²/day, 23.9%), *Hydropsyche setensis* Iwata 1927 (10.0%) and *H. orientalis* Martynov 1934 (7.3%). *Psychomyia acutipennis* and *Hydroptila* sp. were dominant, accounting for 71.3% of total adult caddisflies.

TABLE 2. List of adult caddisfly species caught with sticky board traps at ten stations from April to August 2010.

	individuals/m ² /day	Percent (%)
<i>Psychomyia acutipennis</i> Ulmer	7,355	47.4
<i>Hydroptila</i> sp.	3,697	23.9
<i>Hydropsyche setensis</i> Iwata	1,545	10.0
<i>Hydropsyche orientalis</i> Martynov	1,133	7.3
<i>Stenopsyche marmorata</i> Navás	704	4.5
<i>Cheumatopsyche infascia</i> Martynov	381	2.5
<i>Goera japonica</i> Banks	24	0.2
<i>Rhyacophila yamanakensis</i> Iwata	17	0.1
Other	644	4.2
Total	15,501	100.0

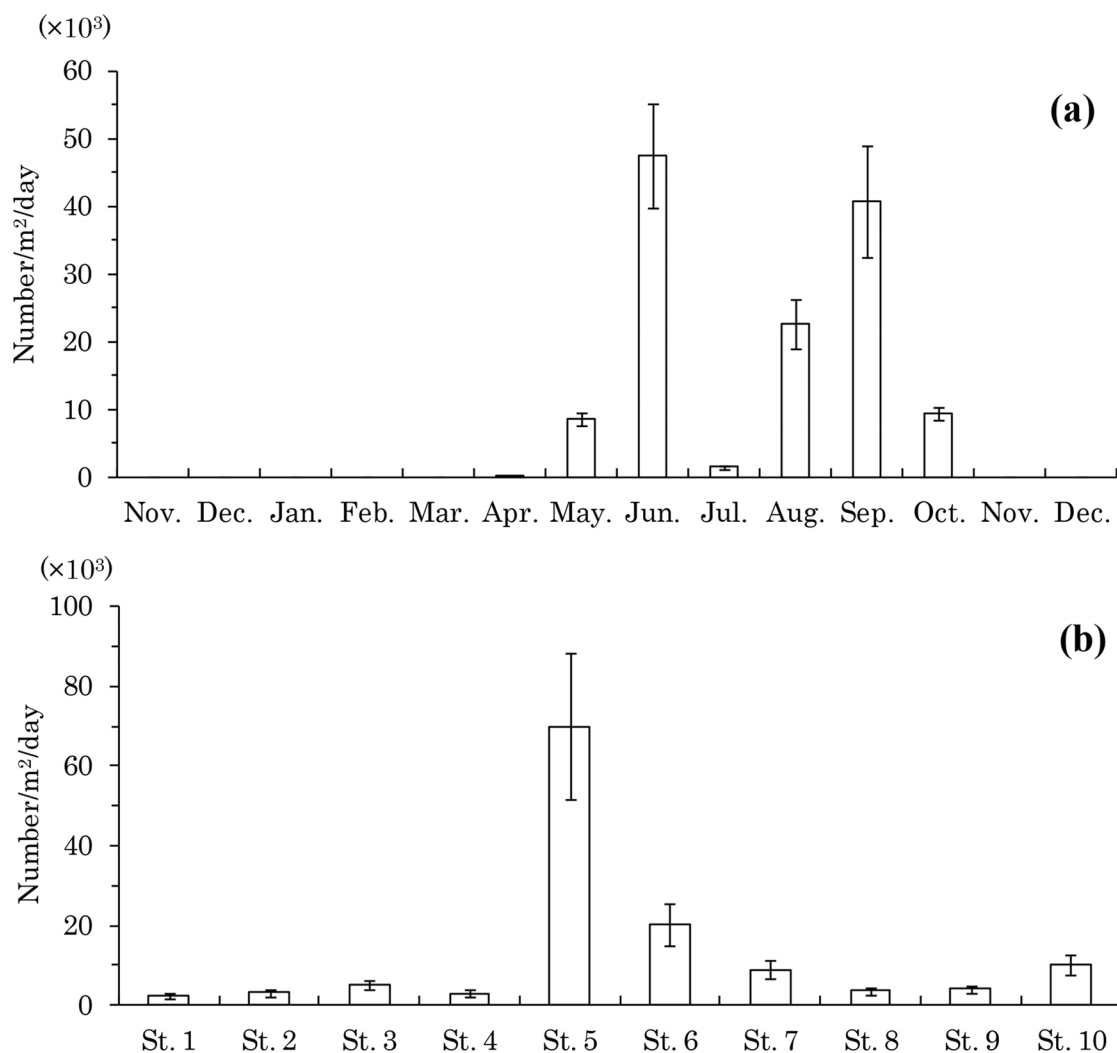


FIGURE 3. Total numbers of adult caddisflies trapped by sticky board traps at ten stations from November 2009 to December 2010. (a): seasonal change: each month, (b): distribution: each station.

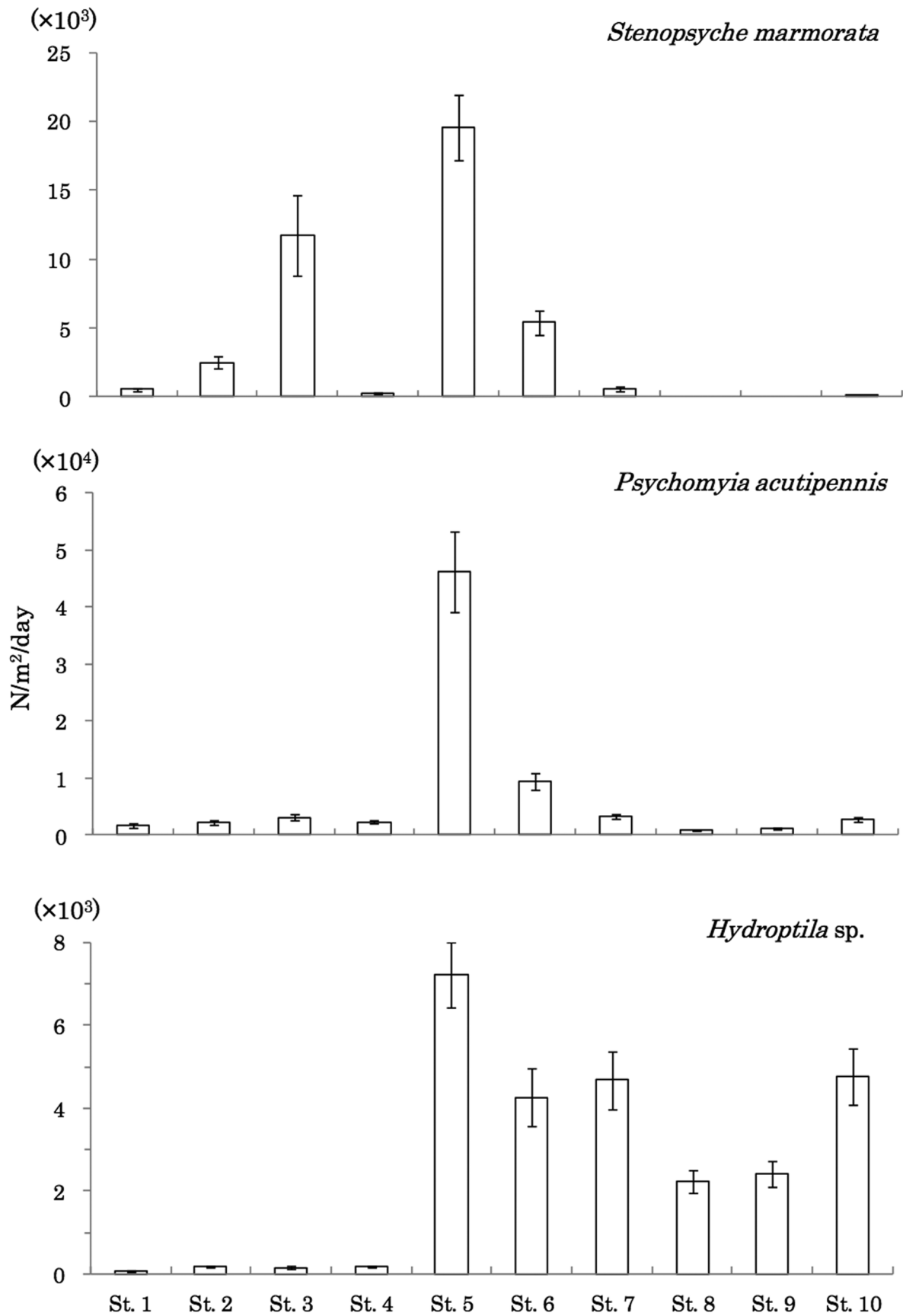


FIGURE 4. Distribution of the capture of total number of *P. acutipennis*, *Hydroptila sp.* and *Stenopsyche marmorata* in the middle of the Shinano River during the investigation periods.

TABLE 3. Physical environmental conditions and abundances (individuals/m²) of species of benthic caddisfly larvae at three stations (Stations 1, 5, and 8) in the Shinano River, Japan.

	20 March 2010			16 December 2010			March & December 2010		
	St. 1	St. 5	St. 8	St. 1	St. 5	St. 8	St. 1	St. 5	St. 8
Environmental factors									
W.T. (°C)	11.4	11.0	9.8	7.6	8.5	7.6	622±450	741±259	37±44
pH	7.8	7.7	7.7	8.7	9.0	7.5	991±1299	1330±682	50±76
EC (µS/cm)	134.0	138.4	154.6	161.9	167.3	184.2	46±33	2030±1279	309±426
DO (mg/l)	6.9	9.5	5.8	12.3	14.2	13.4	324±426	1369±1034	302±420
Benthic Trichoptera larvae									
<i>Stenopsyche marmorata</i> Navás	315±17	859±315	33±58	930±472	622±161	41±39	622±450	741±259	37±44
<i>Cheumatopsyche infascia</i> Martynov	156±51	1211±203	26±28	1826±1457	1448±1039	74±110	991±1299	1330±682	50±76
<i>Hydropsyche setensis</i> Iwata	56±33	1259±525	48±28	37±36	2800±1426	570±498	46±33	2030±1279	309±426
<i>Hydropsyche orientalis</i> Martynov	30±17	496±192	48±42	619±441	2241±597	556±496	324±426	1369±1034	302±420
<i>Psychomyia acutipennis</i> Ulmer	233±59	1704±932	4±6	885±1090	1319±456	52±17	559±777	1511±689	28±29
<i>Hydroptila</i> sp.	0	0	0	0	7±6	48±42	0	4±6	24±37
Others	126±46	448±207	7±13	85±74	285±132	48±50	106±60	367±179	28±40
Total density	915±162	5978±1146	167±125	4381±3362	8722±2015	1389±1175	2648±2853	7350±2100	778±1003

Figure 4 shows the distribution of the total number of *P. acutipennis*, *Hydroptila* sp. and *Stenopsyche marmorata* captured at each station during the investigation periods. The species of caddisflies caught differed geographically even in the same middle reaches of the Shinano River. Namely, *Hydroptila* sp. was caught mainly downstream of St. 5 (ranged from 2,225 to 7,217 individuals/m²/day), while few were caught from St. 1 to St. 4 (ranged from 67 to 183 individuals/m²/day). *Psychomyia acutipennis* was caught in the vicinity of St. 5 (maximum number was 46,225±7,177 individuals/m²/day). *Stenopsyche marmorata* was caught upstream of St. 7, with the maximum at St. 5 (1,958±238 individuals/m²/day), decreasing slightly upstream.

Table 3 shows some environmental factors and the list of caddisfly larval densities at Stations 1, 5, and 8 in March and December 2010. In addition, Fig. 5 presents the distribution patterns of the surface area of cobbles and the composition of coarse particles on the riverbed surface (4-class demarcation) at each sampling station. The surface area of cobbles and the composition of coarse particles on the riverbed surface changed with the change in the slope of the riverbed, i.e., the large cobbles and coarse-grained particles were distributed at upstream St. 1, and gradually changed to small-size cobbles and fine-grained particles at downstream St. 8.

The highest density of total caddisfly larvae was observed at St. 5, followed by St. 1 in March and December. The maximum number of *P. acutipennis* larvae was collected at St. 5 (1704 individuals/m² in March 2010) followed by St. 1. More than 500 individuals/m² of *S. marmorata* larvae were collected at St. 1 and St. 5, while there were few larvae at St. 8. *Hydroptila* sp. was caught at St. 5 and St. 8, but not at St. 1.

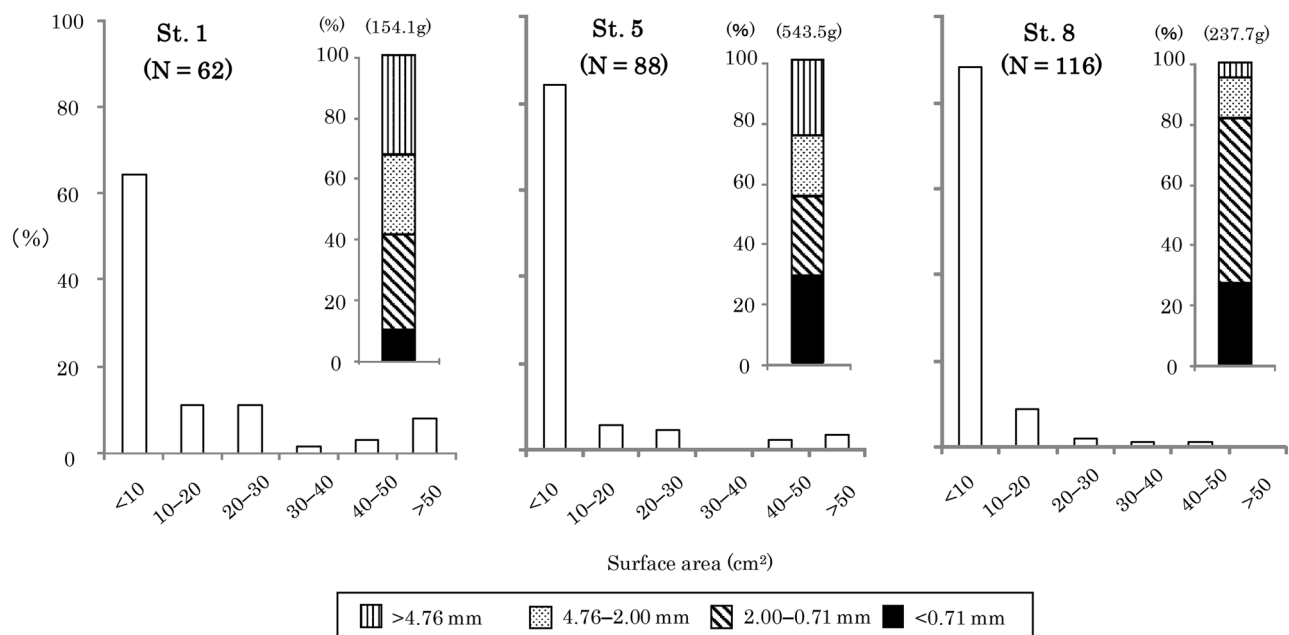


FIGURE 5. The distribution patterns of the surface area of cobbles and the composition of coarse particles on streambed surface (4-class demarcation) at Stations 1, 5, and 8.

Discussion

Sticky board traps are frequently used to estimate presence and densities of pests (*e.g.*, flies, mosquitoes, chironomid midges, etc.) in buildings/factories/houses. Hirabayashi & Watanabe (1996) monitored the massive flights of chironomid midges on the shoreline of a natural lake by using a sticky board trap, reporting their species composition and abundance. In the present study, many caddisfly adults were trapped by sticky board traps 10 m above the water surface (Figs. 3(a) and (b)). Adult movement of aquatic insects has attracted considerable interest with regard to Müller's colonization cycle hypothesis that describes the sequence of downstream drift of larvae and supposed upstream flight for oviposition by females (Müller 1954, 1982). Therefore, the specimens caught in the sticky board traps are hypothesized to be the sum of (1) insects

migrating from upstream to downstream, (2) insects going upstream from downstream, and (3) insects emerging at that trap location. Therefore, more-detailed surveys with the use of emergence traps will be necessary in the future. In this study, we also collected benthic caddisfly larvae at Stations 1, 5, and 8. There was a good correspondence between the density of caddisfly larvae and the caddisfly adults caught by the sticky board traps. Thus, in this study, almost all the adult caddisflies trapped by sticky board traps might have emerged at the station where they were caught as adults.

It is known that the slope of the Shinano River bed suddenly becomes less and the flow rate is slower in the area from the Taishyobashi Bridge (St. 5) to the Awasabashi Bridge (St. 7) (Table 1), and it was shown that the species composition and number of caddisflies caught changes with the change in the slope of the river bed (Fig. 4). That is, *Hydroptila* sp. was caught mainly downstream of the St. 5, *P. acutipennis* in the vicinity of the St. 5, and *S. marmorata* upstream of the St. 7. *Stenopsyche marmorata* larvae are net-spinning caddisflies which are commonly part of the biomass in the middle reaches of the river (Hirabayashi *et al.* 2007); larvae of this species spin silk and form filtering nets or silken retreats between stones in the water to collect particulate organic matter for food. Thus, the smaller sizes of stones or cobbles are not preferred for *S. marmorata* larvae. Kimura *et al.* (2008) reported that a few *H. phenianica* Botosaneanu 1970 (= *Hydroptila matsuii* Kobayashi 1974) adults (just 49 individuals) were collected by light from April to November (249 nights) in 2006 near the Tokidashinbashi Bridge (St. 1) and other species of *Hydroptila* were not recorded in the middle reaches of the Shinano River. Thus, almost all *Hydroptila* sp. larvae/adults might be *H. phenianica* in this study. According to Ito *et al.* (2011), *H. phenianica* specimens have been collected from the middle and lower reaches of streams in Japan. Moreover, *Hydroptila* larvae make their cases with sand and/or fine particle organic matter and attached algae (Wiggins 2004). Smaller stones, cobbles and sand are preferred by *Hydroptila* larvae (Wiggins 1998), which explains why we collected them mainly downstream from St. 5 to St. 10. *Psychomyia acutipennis* is widely distributed in Japan (Kawai & Tanida 2005), and *P. acutipennis* has been known to be dominant in the Kamo River, Kyoto (Tsuda 1942) and Shinano River, Nagano (Kimura *et al.* 2009), but there has been little ecological and biological information published about this larva. *Psychomyia* larvae are small in size (Kawai & Tanida 2005) and are typically abundant in riffles that have relatively low current velocities (Yamagishi 1977). In addition, Hirabayashi *et al.* (2005) reported that *Psychomyia* larvae dominated the slow sand filter beds used for filtration of drinking water where low velocity conditions prevailed. Moreover, Kimura *et al.* (2009) also have observed that low current velocity has likely contributed to rapid colonization by *P. acutipennis*. According to Wiggins (2004), *Psychomyia* larvae feed on fine organic particles and periphyton from the upper surfaces of rocks. In this study, we cannot explain why the maximum numbers of adult *P. acutipennis* were collected by board traps at St. 5. We need to increase ecological knowledge about this species in the field and from laboratory examinations.

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