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LATERAL DISPERSAL OF ADULT AQUATIC INSECTS FOLLOWING EMERGENCE FROM THE MIDDLE REACHES OF THE CHIKUMA RIVER (HONSHU ISLAND, JAPAN) IN RELATION TO WATERFRONT VEGETATION

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Abstract: To clarify the role of waterfront vegetation of floodplains for adult aquatic insects, Trichoptera and Diptera (Tipulidae and Chironomidae), in the middle reaches of the Chikuma River from May to July, an investigation of the number of these insects was conducted by trapping in each type of vegetation using board traps. A total of 2608.5 adults/m^2 were collected, and we identified a total of 26 species belonging to three taxa, i.e., seven species of Trichoptera, four species of Tipulidae and 15 species of Chironomidae. The most abundant species was *Psychomyia acutipennis* in Trichoptera (95.7%). There was a significant difference between the number of *P. acutipennis* in the all vegetation area (especially, *Salix subfragilis*) and the control area (no vegetation) during the investigation periods ($P < 0.05$, Mann-Whitney U-test). Other taxa did not show a significant difference between the all vegetation area and the control. Moreover, the numbers of adult *P. acutipennis* showed a significant difference in height on each vegetation. In the case of *Vicia villosa varia* and *V. villosa varia* plus dead *Phragmites australis*, the highest number was caught in the traps set in the boundary between one plant and the plant above ($P < 0.05$, Steel-Dwass Test) in May. On the other hand, in the case of almost all vegetation during the investigation periods (except of *S. subfragilis* in May, *Melilotus officinalis* plus dead *P. australis* in June), the highest number was caught in the traps set up within the vegetation ($P < 0.05$, Steel-Dwass Test). As a result, a significant difference was observed in the number of trapped *P. acutipennis* according to the vegetation and its height. It is suggested that the existence of multiple types of vegetation in the floodplain plays an important role for maintaining the diversity of the fauna there.

Key words: Adult aquatic insect; Chikuma River; Flight behavior; Lateral dispersal; Seasonal change; Waterfront vegetation
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Adults of aquatic insects emerge from streams live in the nearby riparian zone where they can select streamside vegetations as preferred sites in order to (a) complete metamorphosis, (b) rest while awaiting proper swarming time, (c) feed in order to produce eggs, or (d) mate to reproduce[1—3].

Most adult aquatic insect dispersal studies have focused on quantifying the degree of upstream movement[4,5]. Some researchers have shown distinct patterns of upstream movement related to post-mating ovipositional behavior[6], while there have been few reports on lateral dispersal patterns in relation to the front vegetation[7,8].

The middle reach of the Chikuma River was characterized by its broad floodplains. And there were many

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types of vegetation in the floodplains. In this study, to clarify the role of waterfront vegetation of floodplain for adult aquatic insects, especially the dominant taxa in the middle of the Chikuma River from spring to summer, Trichoptera and Diptera (Tipulidae and Chironomidae), an investigation of the number of these insects using each type of vegetation was conducted by using board traps.

1 Study sites

The present investigation was perfomed at the floodplain in the middle reaches of the Chikuma River, which is located in the center of Honshu Island. The name of the river was changed from Chikuma River to the Shinano River in Niigata Prefecture. It is Japan's longest river (length, ca. 367km; drainage area, ca. 11,900km^2), running through Nagano and Niigata Prefectures and flowing north into the Japan Sea (Fig. 1). The riverine habitat consists of "unit structures" of a natural river system (i.e., scour pools, riffles, and runs) was generally well preserved. The riverbed was largely covered with cobbles and boulders about 10 to 50cm in diameter. The width of the stream was about 25m, and the average current velocity was 60—80cm s^{-1}. The water was transparent, and the concentration of nutrient elements such as total nitrogen (TN) and total phosphorus (TP) was low (TN, 1.6—2.1mg l^{-1}; TP, 0.079—0.085mg l^{-1}; BOD, 0.8mg l^{-1})[9]. The middle reach of the Chikuma River was characterized by its broad floodplains.

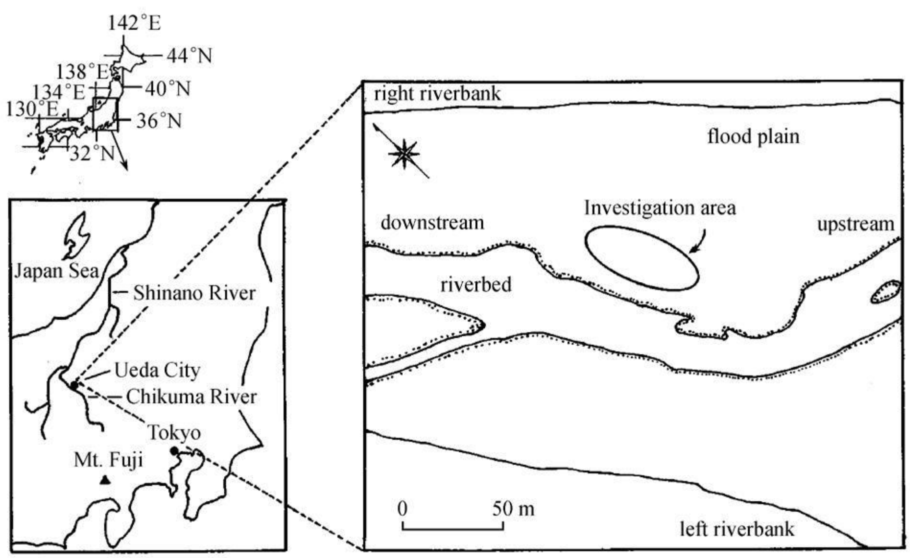

Fig. 1 Map of the Chikuma River, showing location of the investigation area.

2 Materials and methods

Adult aquatic insects were collected every month in May (26—31), June (18—19, 21—22, 23—24 and 25—27) and July (23—28) in 2001 (total of 15 days), by using board traps (a plastic white board; 10.5cm × 29.7cm, sprayed with an adhesive; polyolefin). The board traps were set on a pole 40, 80, 120, 160 and 200cm above 0.5m water level. The distance from the shoreline was about 15m. Each month we selected 3 or 4 vegetational communities along the shoreline of the floodplain for sampling (Tab. 1). The dominant species of vegetation changed with season, i.e., *Vicia villosa varia* (symbol "V", mean vegetation height was about 120cm) and *V. villosa varia* plus dead *Phragmites australis* ("V + dP", about 160cm) in May, *Melilotus officinalis* ("M", about 160cm) and *M. officinalis* plus dead *P. australis* ("M + dM", about 160cm) in June, and *P. australis* plus dead *P. australis* ("P + dP", about 160cm) in July. Moreover, *Salix subfragilis* ("S", about 200 cm) and *Robinia pseudoacacia* ("R", about 160cm) existed during the entire investigation periods. In the case of *V. villosa varia* and *S. subfragilis*, the board trap was set on a pole 40, 60, 80, 120 and 160cm, and 40, 80, 120, 160, 200, 240 and 280 cm above ground level, respectively. During the investigational periods, we also collected adult aquatic insects in the non-vegetation areas (serving as control areas) where the distance from the shoreline was also about 15m but near the experimental area.

A board trap was set up at about 10:00—11:00 AM, and the next day (the same time) it was replaced with a new board trap. At this time, air temperature was measured at the same height of board trap with a thermometer and wind force was measured with a wind gauge. No visible sources of artificial light were noticed in this area during the study periods at night. The adult aquatic insects trapped at each vegetation were identified and counted in the laboratory. They were then mounted on slides in the laboratory and identified according to the keys of Schmid[10] and Wiggins[11] [Trichoptera], Pinder[12] and Sasa &Kikuchi[13] [Diptera, Chironomidae], Alexander &Byers[14] and Torii[15] [Diptera, Tipulidae]. During the investigation periods, to aid identification, adult aquatic insects were also caught qualitatively by sweeping with an insect net around the investigation area.

Tab.1 Plant community of the investigation area from May to July in 2001 in the middle reaches of the Chikuma River

Name of plants (Vegetation type)	(Symbol)	May	June	July
Vicia villosa varia	(V)	○		
Vicia villosa varia + dead *Phragmites australis*	(V + dP)	○		
Melilotus officinalis	(M)		○	
Melilotus officinalis + dead *Phragmites australis*	(M + dP)		○	
Phragmites australis + dead *Phragmites australis*	(P + dP)			○
Salix subfragilis	(S)	○	○	○
Robinia pseudoacacia	(R)	○	○	○
Control (no vegetation area)		○	○	○

The number of adult aquatic insects emerging from the river varied and was affected by weather conditions. To compare each set of daily data, we tried to standardize the daily data by multiply it by a ratio. The ratio was obtained from the mean number of adults in the control area each month divided by the daily number of adults trapped in the control area as 1.0. All collected data were analyzed using a Mann-Whitney U-test (nonparametric test) and a nonparametric multiple comparison test (Steel-Dwass Test).

3 Results

The total numbers of adult aquatic insects caught by board traps each month are presented in Tab.2 A total of 2608.5 adults/m^2 were collected by board traps, 48.8% (1273.4 individual numbers/m^2) of which were trapped in May, 9.0% (233.8) in June and 42.2% (1101.3) in July, respectively. We identified a total of 26 species belonging to three taxa, i.e., 7 species of Trichoptera, 4 species of Tipulidae and 15 species of Chironomidae. The most abundant species was *Psychomyia acutipennis* in Trichoptera (95.7%), *Antocha* (*Antocha*) *bifida* in Tipulidae (87.5%) and *Cricotopus sylvestris* (29.1%) in Chironomidae, which were collected in all months, especially, in May and July. Two species of Chironomid, i.e., *Polypedilum nubeculosom* (110.9 individual numbers/m^2, 20.9% of total chironomidae) and *P. nubifer* (90.3, 17.0%) were also collected, although the overall numbers were very low in May and June.

Tab. 2 Total numbers of adult aquatic insects caught by board traps from May to July

Species of adult aquatic insects (Sample number)	May (135)	June (135)	July (110) (Total No./ m^2)	Total (%) (380)
Trichoptera				
Psychomyia acutipennis	1040.3	169.2	751.9	1961.4(95.7)
Cheumatopsyche infascia	24.9	1.3	11.4	37.6 (1.8)
Cheumatopsyche brevilineata	1.5	0	0	1.5 (0.1)
Hydropsyche orientalis	7.6	3.0	5.1	15.7 (0.8)
Hydropsyche setensis	0	0	1.1	1.1 (0.1)
Hydroptila matsuii	25.3	0.2	7.0	32.5 (1.6)
Rhyacophila yamanakensis	0	0.2	0	0.2 (0.0)
Total Trichoptera	1099.6	173.9	776.5	2050.0 (100)
Diptera				
Tipulidae				
Antocha Antocha bifida	11.2	3.8	8.6	23.6(87.5)
Antocha sp.	3.0	0	0	3.0(10.9)
Erioptera (*Psiloconopa*) sp.	0.2	0	0	0.2 (0.8)
Nephrotoma sp.	0	0.2	0	0.2 (0.8)
Total Tipulidae	14.4	4.0	8.6	27.0 (100)
Chironomidae				
Chironominae				
Chironomus flaviplumus	6.1	3.6	1.5	11.2 (2.1)
Chironomus kiiensis	0.6	1.7	0.2	2.5 (0.5)
Chironomus nipponensis	10.3	8.6	7.8	26.7 (5.0)
Chironomus yosimatsui	0.6	0	0.2	0.8 (0.2)
Polypedilum nubeculosom	29.3	4.0	77.6	110.9(20.9)
Polypedilum nubifer	0	1.3	89.0	90.3(17.0)
Polypedilum parviacumen	16.0	4.4	7.6	56.0 (5.3)
Tanytarsus angulatus	4.9	1.3	38.6	44.8 (8.4)
Tanytarsus unagisextus	6.8	2.5	14.6	23.9 (4.5)
Orthocladiinae				
Cardiocladius fusucus	0	0.6	1.7	2.3 (0.4)
Cricotopus sylvestris	69.6	19.2	66.0	154.8(29.1)
Orthocladius excavatus	2.3	0	0	2.3 (0.4)
Paratrichocladius rufiventris	5.1	1.1	4.0	10.2 (1.9)
Tanypodinae				
Procladius sagittalis	0.2	0	0	0.2 (0.1)
Rheopelopia maculipennis	3.4	0	0.4	3.8 (0.7)
Others (+unknown)	4.2	7.6	7.0	18.8 (3.5)
Total Chironomidae	159.4	55.9	316.2	531.5 (100)
Total insects No.	1273.4	233.8	1101.3	2608.5
(%)	48.8	9.0	42.2	100

Tab. 3 The total adult number of the main three taxa collected by board traps on each vegetation from May to July in 2001

Vegetation type		Trichoptera	Diptera: Chironomidae	Diptera: Tipulidae	Mean air temperature (℃)	Mean wind force (m / s)
		(Individual number of adult aquatic insects / m^2)				
May	Sample No.					
V	25	428.9 ± 97.9d	83.9 ± 28.4	13.7 ± 6.5	24.5 ± 1.7	0.2 ± 0.1
V + dP	25	286.4 ± 130.4c	95.7 ± 36.0	15.4 ± 5.4	24.4 ± 1.0	0.2 ± 0.1
R	25	732.3 ± 296.3b	79.6 ± 14.9	12.1 ± 10.4	25.3 ± 1.8	1.5 ± 0.8
S	35	1689.3 ± 986.4a	96.4 ± 33.1	13.9 ± 15.1	23.9 ± 1.1	0.9 ± 0.2
All vegetation area (mean)	110	784.1 ± 234.7	89.4 ± 17.7	13.7 ± 7.8	24.5 ± 1.4	0.7 ± 0.3
Control (no vegetation) area	25	180.1	119.2	10.3	25.5 ± 1.5	1.8 ± 0.6
June	Sample No.					
M	25	109.8 ± 68.5d	35.8 ± 9.6	4.4 ± 1.7	26.3 ± 4.2	0.1 ± 0.1
M + dP	25	52.9 ± 25.7c	24.9 ± 18.5	7.0 ± 3.5	26.1 ± 4.1	0.1 ± 0.1
R	25	109.1 ± 43.3b	32.8 ± 10.3	5.1 ± 1.7	26.6 ± 4.2	0.2 ± 0.2
S	35	211.1 ± 80.0a	18.1 ± 12.3	6.6 ± 2.5	26.5 ± 4.2	0.2 ± 0.2
All vegetation area (mean)	110	120.7 ± 45.6	29.3 ± 6.1	5.8 ± 1.6	26.4 ± 4.2	0.2 ± 0.2
Control (no vegetation) area	25	44.2	43.6	6.4	26.7 ± 4.2	0.9 ± 0.8
July	Sample No.					
P + dP	25	371.7 ± 119.9	238.8 ± 87.8	8.0 ± 4.6	31.4 ± 2.9	0.3 ± 0.2
R	25	928.5 ± 604.6	210.9 ± 108.5	8.3 ± 4.5	31.6 ± 3.1	0.9 ± 0.7
S	35	1067.1 ± 539.9	175.2 ± 96.9	12.5 ± 6.9	30.3 ± 3.2	1.1 ± 0.8
All vegetation area (mean)	85	784.6 ± 375.7	207.5 ± 93.4	9.5 ± 4.4	31.1 ± 3.1	0.8 ± 0.6
Control (no vegetation) area	25	264.7	419.9	7.7	32.3 ± 3.1	1.7 ± 1.0
During the investigation periods						
All vegetation area (mean)	305	548.5 ± 372.4a	124.9 ± 40.0	9.6 ± 4.8	27.3 ± 2.9	0.6 ± 0.4
Control (no vegetation) area	75	163.1 ± 172.8b	196.0 ± 220.0	8.0 ± 4.2	28.2 ± 2.9	1.5 ± 0.8

a-b, a-c, a-d: $P < 0.05$, V: *Vicia villosa varia*; V + dP: *Vicia villosa varia*; M: *Melilotus officinalis*; M + dP: *Melilotus officinalis*; P + dP: *Phragmites australis* + dead *Phragmites australis*; S: *Salix subfragilis*; R: *Robinia pseudoacacia*

The total adult numbers of the three main taxa, Trichoptera, Chironomidae and Tipulidae, collected by board traps on each vegetation were shown in Tab.3. There was a significant difference in adult Trichoptera between the all vegetation area and the control area during the investigation periods ($P < 0.05$, Mann-Whitney U-test). Especially, there was a significant difference between the trapped number of *S. subfragilis* and other types of vegetation in May and June ($P < 0.05$, Steel-Dwass Test). On the other hand, other taxa did not show a significant difference between the all vegetation area and the control, and other combinations.

Tab. 4 showed the number of adult *P. acutipennis* collected by board traps at different heights on each vegetation from May to July. There was a significant difference in *P. acutipennis* between the all vegetation area and the control area during the investigation periods ($P < 0.05$, Mann-Whitney U-test). Moreover, there was a significant difference between S and other types of vegetations in May, S and M + dP in June, and S and P + dP in July ($P < 0.05$, Steel-Dwass Test). Other combinations did not show a significant difference. The numbers of adult *P. acutipennis* showed significant different heights above the ground level on each vegetation, i.e., in the case of V and V + dP in May, the most individual number was significantly caught at the traps which set up boundary between plant and above plant ($P < 0.05$, Steel-Dwass Test). On the other hand, in the case of almost all vegetation during the investigation periods (except of S in May, M + dP in June), the highest number was caught in the traps set up within the vegetation ($P < 0.05$, Steel-Dwass Test). The number of captured adults in the control area did not show significantly different heights during the investigation periods.

4 Discussion

It is important to know the ecological function and structure of floodplains when flood control is implemented in the watershed[16]. In floodplains, in regions subject to large seasonal changes in rainfall or snowmelt, many rivers cyclically overflow their banks[17]. Associated with this, the vegetation of floodplains also changes each season. The plant communities of floodplains tend to be available only to species with rapid life cycles and good colonization abilities. Plant communities known to live in floodplain included annual herbs, biennial herbs, and climbing plants, such as *Poaceae* (*Gramineae*) *and Fabaceae* (*Leguminosae*)[18]. In this study, there are many types of vegetation in the floodplains and the dominant species of plant changed seasonally from *V. varia* to *M. officinalis* and then, *P. australis* (all annual herbs). Moreover, *S. subfragilis* and *R. pseudoacacia* (woody plant; shrub) existed during the investigation in the middle reaches of the Chikuma River (Tab. 1). Recently, the need to include interactions between adult aquatic insects and the existence of the vegetation of floodplains has been recognized. There have been few studies on the role of the plant community for animals of the floodplain until now[19,20]. In this study, there was a significant difference between the number of adult Trichoptera in the all vegetation area and the control area during the investigation periods (Tab. 3). It suggested that adult Trichoptera used these vegetations in some way. According to Hirabayashi[21], many aquatic insects emerged from the Chikuma River in May and almost all species were mating. In the case of Trichoptera, adults used the plant as a swarming marker[22]. In our data, the highest number of adult *P. acutipennis* was caught between one plant and the plant above in May (Tab.4).

It is suggested that the adult *P. acutipennis* use vegetations (V and V + dP) as a swarm markers in May. The highest number was caught within the vegetation in June and July (Tab. 4). According to Statzner (1977), terrestrial vegetation may influence Trichopteran's swarming behaviour by providing optical stimuli, either directly (treetops etc.) or indirectly (air temperature and light gradients). Further, it provides shelter from the wind, which, when above 3m per sec, suppressed swarming in most of the species. In Tab.3 mean air temperature and mean wind force of the control area always tended to be higher and stronger than the vegetation area, so most adults might escape from these environmental conditions during the daytime. It suggested that adult *P. acutipennis* also used almost all vegetations as a shelter on resting place from several environmental conditions. Adult aquatic insects, even the same species, changed the purpose of utilization of different types of vegetation depending on the season. Thus, many types of vegetations in the floodplain

Tab.4 The number of adult *Psychomyia acutipennis* (Trichoptera) collected by board traps at different heights on each vegetation from May to July in 2001

Name of plants (Symbol)	Height (cm) 40	n	60	n	80	n	120	n	160	n	200	n	240	n	280	n	Total No. (Ind. / m^2)	n
May																		
V	263.3 ± 156.5a	5	261.4 ± 103.9a	5	456.6 ± 129.0	5	696.0 ± 245.6b	5	405.3 ± 258.3	5							416.5 ± 107.4b)	25
V + dP	141.3 ± 58.1a	5			222.3 ± 100.1a	5	296.3 ± 160.9	5	608.5 ± 348.8b	5	137.9 ± 176.3a	5					281.2 ± 140.3c)	25
R	836.4 ± 334.3a	5			978.8 ± 483.1a	5	1049.2 ± 556.7a	5	453.5 ± 216.8	5	172.6 ± 81.7b	5					698.1 ± 324.7d)	25
S	1461.2 ± 833.7	5			2371.6 ± 1904.4	5	1986.8 ± 1252.6	5	1828.4 ± 1208.5	5	1623.2 ± 676.1	5	1005.6 ± 548.4	5	722.7 ± 533.1	5	1570.6 ± 1034.7a)	35
All vegetation area (mean)																	741.6 ± 579.3	110
Control (no vegetation)	141.5 ± 55.0	5			140.9 ± 52.1	5	241.9 ± 84.0	5	193.1 ± 70.3	5	138.4 ± 99.6	5					171.2	25
June																		
M	81.3 ± 38.4a	5			95.8 ± 43.2a	5	282.6 ± 205.1b	5	66.0 ± 76.9a	5	9.4 ± 7.7a	5					107.0 ± 71.0	25
M + dP	51.4 ± 20.4	5			53.0 ± 27.4	5	97.6 ± 102.7	5	30.5 ± 8.8	5	17.8 ± 17.0	5					50.1 ± 24.3a)	25
R	232.0 ± 139.1a	5			136.5 ± 79.1	5	111.6 ± 41.6	5	40.6 ± 35.9b	5	24.4 ± 15.1b	5					109.0 ± 45.9	25
S	343.8 ± 218.7a	5			287.5 ± 176.0	5	316.7 ± 213.6	5	240.2 ± 127.3	5	198.5 ± 126.5	5	67.6 ± 71.3	5	20.0 ± 21.7b	5	210.5 ± 119.6b)	35
All vegetation area (mean)																	119.2 ± 66.8	110
Control (no vegetation)	35.1 ± 18.8	5			59.8 ± 53.9	5	49.6 ± 12.8	5	26.8 ± 16.0	5	43.7 ± 26.5	5					42.9	25
July																		
P + dP	405.4 ± 174.4	5			387.4 ± 53.5	5	606.6 ± 413.5a	5	338.8 ± 133.7	5	53.2 ± 23.8b	5					358.3 ± 116.7a)	25
R	788.9 ± 164.0	5			1817.0 ± 1307.8a	5	1394.1 ± 1016.7	5	506.3 ± 275.0	5	136.2 ± 146.1b	5					897.2 ± 450.0	25
S	1183.7 ± 503.1	5			1008.6 ± 529.0	5	1391.3 ± 774.5	5	2035.9 ± 1189.5a	5	1128.2 ± 587.8	5	490.2 ± 203.9b	5	235.2 ± 105.7b	5	1045.5 ± 414.7b)	35
All vegetation area (mean)																	748.6 ± 245.5	85
Control (no vegetation)	255.8 ± 91.5	5			263.0 ± 24.9	5	227.7 ± 33.1	5	263.2 ± 84.1	5	227.5 ± 89.5	5					247.4	25
During the investigation periods																		
All vegetation area (mean)																	538.0 ± 215.3a)	305
Control (no vegetation area)																	153.8 ± 103.4b)	75

a-b, a)-b), a)-c), a)-d): $P < 0.05$, V: *Vicia villosa varia*; V + dP: *Vicia villosa varia*; M: *Melilotus officinalis*; M + dP: *Melilotus officinalis*; P + dP: *Phragmites australis* + dead *Phragmites australis*; S: *Salix subfragilis*; R: *Robinia pseudoacacia* can be expected to perform an important role for aquatic insects emerging from the river, as a resting place, a mating place and an egg laying place in the Chikuma River.

This is the first report on the role of waterfront vegetation of a floodplain for adult aquatic insects in Japan. However, since the present study was carried out for only one season, further follow-up field investigations are necessary to elucidate the interaction between adult aquatic insects and existing vegetation.

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References:

[1] Nozaki, T., 1996. Terrestrial environment for caddisflies. Aqua-biology 18: 430—433 (in Japanese)

[2] Petersson, E. & A. T. Hasselrot, 1994. Mating and nectar feeding in the psychomyiid caddisfly *Tinodes waeneri*. Aquatic Insects 16: 177—187

[3] Statzner, B., 1977. The effects of flight behaviour on the larval abundance of Trichoptera in the Schierensee brooks (North Germany). Proceedings of the 2nd International Symposium on Trichoptera. Junk, The Hague: 121—134

[4] Winterbourn, M. J. & A. L. M. Crowe, 2001. Flight activity of insects along a mountain stream: is directional flight adaptive. Freshwater Biology 46: 1479—1489

[5] Ehlert, T., T. Timm & H. Schuhmacher, 1999. Spatial and temporal flight behaviour of *Athripsodes bilineatus* (Linne 1758) at a mountain brook (Trichoptera, Leptoceridae). Proceedings of the 9th International Symposium on Trichoptera. Chiang Mai: 93—98

[6] Sode, A. & P. Wiberg-Larsen, 1993. Dispersal of adult Trichoptera at a Danish forest brook. Freshwater Biology 30: 439—446

[7] Griffith, M. B., E. M. Barrows & S. Perry, 1998. Lateral dispersal of adult aquatic insects (Plecoptera, Trichoptera) following emergence from headwater streams in Forested Appalachian Catchments. Annals of the Entomological Society of America 91: 195—201

[8] Petersen, I., J. H. Winterbottom, S. Orton, N. Friberg, A. G. Hildrew, D. C. Spiers & W. S. C. Gurney. 1999. Emergence and lateral dispersal of adult Plecoptera and Trichoptera from Broadstone Stream, U. K.. Freshwater Biology 42: 401—416

[9] Nagano Prefecture, 2003. The water quality monitoring data in 2002. Nagano Prefecture, Nagano: 1—356 (in Japanese).

[10] Schmid, F. 1998. The insects and arachnids of Canada, Part 7, Genera of the Trichoptera of Canada and Adjoining or Adjacent United States. NRC Research Press, Ottawa: 1—319

[11] Wiggins, G. B., 1996. Chapter 17 Trichoptera Families. In. Merritt R. W. and K. W. Cummins. Ed. An Introduction to the Aquatic Insects of North America. 3rd Edition. Kendall/Hunt Publishing Co. Dubuque, Iowa: 309—386

[12] Pinder, L. C. V., 1978. A key to adult males of British Chironomidae (Diptera) the non-biting midges. Freshwater Biological Association Science Publication 37: 1—169

[13] Sasa, M. & M. Kikuchi, 1995. Chironomidae (Diptera) of Japan. University of Tokyo Press, Tokyo: 1—333

[14] Alexander, C. P. & G. W. Byers, 1981. Tipulidae. Manual of Nearctic Diptera, Vol. 1. Research Branch Agriculture Canada (Monograph) 27: 153—190

[15] Torii, T., 1992. Systematic study of the genus *Antocha* recorded from Japan and its adjacent area (Diptera, Tipulidae). Acta Zoologica Cracoviensial 35: 157—192

[16] Benda, L. E., D. J. Miller, T. Dunne, G. H. Reeves & J. K. Agee, 1998. Dynamic landscape systems. In Naiman, R. J. & R. E. Bilby (editors), River Ecology and Management. Springer, New York: 43—68

[17] Ziemer, R. R. & T. E. Lisle, 1998. Hydrology. In Naiman, R. J. & R. E. Bilby (editors), River Ecology and Management. Springer, New York: 43—68

[18] Naiman, R. J., 1998. Biotic stream classification. In Naiman, R. J. & R. E. Bilby (editors), River Ecology and Management. Springer, New York: 97—119

[19] Collier, K. & B. Smith, 1998. Dispersal of adult caddisflies (Trichoptera) into forests alongside three New Zealand streams. Hydrobiologia 361: 53—65

[20] Lynch, R. J., S. E. Bunn & C. P. Catterall, 2002. Adult aquatic insects: potential contributors to riparian food webs in Australia's wet-dry tropics. Austral Ecology 27: 515—526

[21] Hirabayashi, K., 2002. Abundance and seasonal trend of dominant Chironomid midges in the middle reach of the Chikuma River. Japanese Journal of Ecology 52: 281—285 (in Japanese)

[22] Mori, S. & K. Matutani, 1953. Daily swarmings of some caddisfly adults and their habitat segregations. Japanese Journal of Zoology 62: 191—198 (in Japanese)