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Distribution Pattern of Aquatic Insects in the Upper and Middle Reaches of the Chikuma River in Central Japan

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The species composition and abundance of aquatic insects were investigated by light trap in summer, 2002 at three stations in the Chikuma River, Japan's longest river. A total of 3278 adults/day were collected, the great majority (57.5%) of which were Diptera, followed by Trichoptera (35.4%) and then Ephemeroptera (7.1%). The number of collected aquatic insects and their biomass gradually increased towards downstream, whereas the number of species and species diversity index (H′) decreased. 36 species (H′ = 4.30) of aquatic insects were collected at St. 1, versus 31 species (H′ = 2.81) at St. 3. Moreover, the relative abundance of functional feeding groups changed from St. 1 to St. 3, i.e., "collectors" increased and "shredders" decreased.

Key words : aquatic insect, Chikuma River, distribution pattern, functional feeding group, species diversity index (H′)

INTRODUCTION

The structure and function of the benthic invertebrate community from headwater to river mouth are strictly regulated by the gradient of allochthonous and autochthonous organic matter (the river continuum concept; Vannote *et al*., 1980). Most of the major functional invertebrate groups, shredders, grazers, collectors, and predators gradually change downstream with the food supply (Vannote *et al*., 1980). Considerable effort has gone into determining the applicability of the river continuum concept to stream-river systems in general as reviewed by Horne and Goldman (1994). They reported that most works have been done in small streams (orders 1 to 4), and there is evidence that the concept applies in general terms to numerous streams and rivers in temperate climates (Minshall *et al*., 1983; Townsend and Hildrew, 1988).

In Japan, only a very few reports have verified this hypothesis, and most of the research has focused on the upper reaches of rivers. In the present study, the focus is on the middle reaches of Japan's longest river, the Chikuma. A survey was conducted in the summer and winter of 2002, to elucidate the species composition, abundance, diversity, and changes in functional feeding groups of aquatic insects from upstream to downstream.

MATERIALS AND METHODS

Study site

The present investigation was performed at three stations in the upper and middle reaches of the Chikuma River, which is located in the center of Honshu Island. It is Japan's longest river (length, ca. 367 km; drainage area, ca. 11,900 km^2), running through Nagano and Niigata Prefectures and flowing north into the Japan Sea (Fig. 1). At each station, a riverine habitat consisting of "unit structures" of the natural river system, i.e., scour

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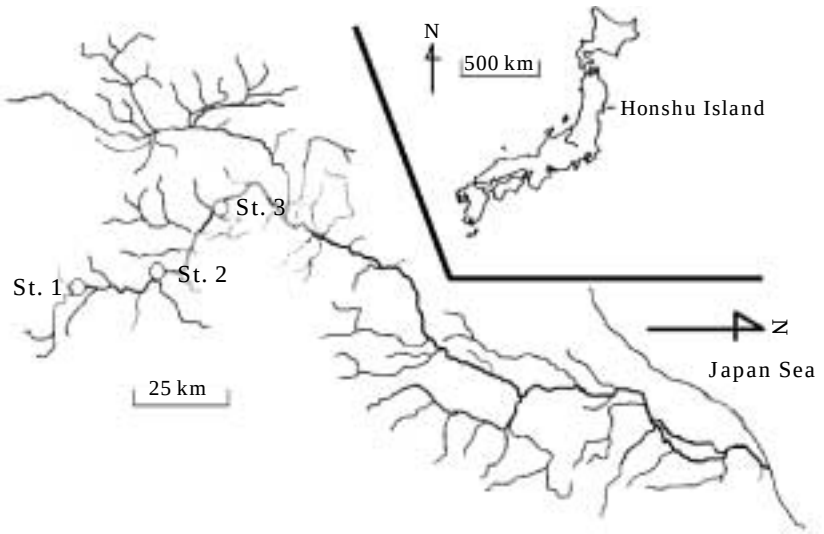

Fig. 1. Map of the Chikuma River, showing the locations of the sampling sites.

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. The width of the river was about 31 m at Station 1 (Hizawa area, Kawakami–Village; 320 km from the mouth; stream order 3, mountain area; plateau vegetable cultivation area), and the average current velocity was 100 cm s^{-1}. Station 2 (Usuda area, Usuda–Town; 295 km; stream order 4, small town and rice field) and 3 (Nezumi area, Sakaki–Town; 250 km; stream order 5, middle reaches; city area) were located about 25 and 70 km downstream from Station 1. The width of the river at Station 2 and 3 was about 23 m and 56 m, respectively. The average current velocity was about 80 cm s^{-1} at Station 2 and 50 cm s^{-1} at Station 3 (Fig. 1).

Collection of aquatic insects

Most of the aquatic insects were collected from August 9 to 10 in 2002 using light traps equipped with a 6–W black fluorescent lamp (Nozawa NH–5) set up in the floodplain at each of the three stations, i.e., St. 1 (distance from the water (D): 35 m, height above ground (H): 1.8 m), St. 2 (D: 40 m, H: 1.0 m), and St. 3 (D: 12 m, H: 1.8 m). Insects that had entered the cage were killed with insecticide spray in the morning at about 10 a.m. After being sorted out from the terrestrial insects, the males and females were counted separately in each species, and their wet weight was measured in the laboratory. No visible sources of artificial light were noticed at each station during the nocturnal study period. In order to compare the aquatic insect fauna among the three stations, we calculated the index of diversity, i.e., Shannon–Wiener diversity index $H' = -\Sigma p_i \cdot \log_2 p_i$ ($p_i = n_i/N$). On the other hand, the classification of aquatic insect species into the functional feeding groups was according to the key of Merritt and Cummins (1978). When a given species belongs to more than one functional feeding group, it is counted in both groups.

From August 9 to 10 and December 20 to 21 in 2002, we measured some environmental factors, i.e., water temperature, pH, EC (electric conductivity) and DO (dissolved oxygen concentration) intervals of 2 hours. At a depth of 50%, water temperature, pH, and EC were measured with a EC/pH meter (WM–22EP, DKK TOA Co.). DO was determined by Winkler's method with azide modification.

Benthic macroinvertebrates on the riverbed were collected using a Surber sampler over an area of about 0.09 m^2, taking three replicate samples in the riffles at each station on August 10 and December 21. They were dislodged by manual disturbances in the square and were trapped in an extended downstream net (opening mesh size: 450 μ). In the laboratory, the individual numbers in each sample were counted using a

binocular microscope.

RESULTS AND DISCUSSION

Physical environmental conditions at three stations in August and December

Table 1 shows the mean values of the water temperatures, pH, EC, and DO at the three sampling stations in August and December. In all of the environmental factors in summer, there was a significant difference among the three stations ($p < 0.05$, ANOVA). In winter, there was a significant difference between St. 1 and other stations in water temperature, between St. 1 and St. 3, and St. 2 and St. 3 in pH, and among all three stations in EC and DO, respectively ($p < 0.05$, ANOVA). Compared to December, the water temperature in August showed large changes at all stations, while pH stayed almost the same. EC showed a different pattern at each station.

Abundance of aquatic insects collected with a light trap in August

A total of 3278 individual aquatic insects were collected by light trap at three stations. We identified 8 orders (Diptera, Trichoptera, Ephemeroptera, Lepidoptera, Neuroptera, Hemiptera, Coleoptera and Hymenoptera). Aquatic insects belonged to only three orders, Diptera, Trichoptera and Ephemeroptera. The most abundant taxa was Diptera (1886 individuals; 57.5%, Chironomidae 23.9%, Tipulidae 32.7%, and other Diptera 0.9%), followed by Trichoptera at 35.4%, and Ephemeroptera at 7.1%. The number of captured insects increased from St. 1 toward St. 3. Diptera dominated at every station; its percentage decreased towards downstream. On the other hand, the total biomass (wet weight, mg per day) was 2898.8 mg per day, with Trichoptera at 61.7%, followed by Diptera at 30.0%, and Ephemeroptera at 8.3%. The biomass also increased towards downstream, and the percentage of Trichoptera also increased.

Density of aquatic insect larvae at three stations

Table 1 shows that the larval density of aquatic insects at three stations in August and December. In August, a total of 16452 individual larval aquatic insects per m^2 (mean density: 5487 individuals per m^2) were collected at three stations (excluding mollusks and oligochaetes). The most abundant taxa was Diptera (9266 individuals; 56.3%, Chironomidae 54.4% in Diptera), followed by Ephemeroptera at 29.3% and Trichoptera at 13.8%. There was a difference in species composition between larval and adult percentages. The results of the larval survey were estimated on the basis of a very restricted sampling range, namely riffle sites. In the adult investigation, on the other hand, riffles and pools in the survey area provided many winged and flying insects to be caught in the light traps. Also, the ratio of Ephemeroptera caught was around one fourth that of larvae. Presumably, they were more difficult to catch because of their peculiar behavior. The highest density of larvae was at St. 2, i.e., more than 8000 individuals per m^2, and about 3000 individuals per m^2 at the other stations.

On the other hand, in December, a total of 27800 individuals per m^2 (mean density: 9267 individuals per m^2) of larvae were collected at three stations. The most abundant taxa were Chironomidae (16044 individuals; 57.7%), followed by Ephemeroptera at 19.4% and Trichoptera at 13.3%. Aquatic insect larvae collected in December were about 1.7 times more than that in August, and the percentage of Tipulidae increased while the percentage of Ephemeroptera decreased. The highest density of larvae was at St. 2, i.e., more than 15000 individuals per m^2, followed by about 10000 individuals per m^2 at St. 1. The density at St. 2 was about 5.7 times that at St. 3. From comparison of the levels in both seasons at each station, there was no significant difference at St. 1, while the percentage of Tipulidae was significantly higher at St. 2 in winter. At St. 3, the high percentage of Ephemeroptera in August decreased by winter, but the percentage of Chironomidae was increased.

Longitudinal changes of fauna of aquatic insects

Focusing on the main taxa of aquatic insects (Chironomidae, Tipulidae and Trichoptera), we calculated the index of diversity (H′) and the percentage of the functional feeding group along the river flows (Table 1). We identified 9 families 37 genera 59 species in all three taxa at all stations in August. The species number of aquatic

Table 1. List of aquatic insect catches by light traps at the three stations.

		Station 1				Station 2				Station 3				Total			
		August		December		August		December		August		December		August		December	
Water temperature (°C)		16.5±1.6		6.7±0.9		19.3±1.1		5.4±0.6		23.4±1.2		5.2±0.6					
pH		7.8±0.4		7.0±0.1		7.2±0.3		7.1±0.3		7.5±0.4		8.0±0.4					
EC (μS cm^{-1})		88.1±2.5		113.2±5.3		113.1±1.9		67.4±1.4		186.1±5.5		194.8±5.5					
DO (mg L^{-1})				10.0±1.8		9.9±0.8		15.3±0.6				10.1±0.2					
		Adult (No. day^{-1})	Biomass (mg day^{-1})	Larvae (Aug.) (No. m^{-2})	Larvae (Dec.) (No. m^{-2})	Adult (No. day^{-1})	Biomass (mg day^{-1})	Larvae (Aug.) (No. m^{-2})	Larvae (Dec.) (No. m^{-2})	Adult (No. day^{-1})	Biomass (mg day^{-1})	Larvae (Aug.) (No. m^{-2})	Larvae (Dec.) (No. m^{-2})	Adult (No. day^{-1})	Biomass (mg day^{-1})	Larvae (Aug.) (No. m^{-2})	Larvae (Dec.) (No. m^{-2})
Diptera	Chironomidae	114	27.3	2722	5933	370	106.6	5196	8411	301	46.5	1037	1700	785	180.4	8956	16044
	Tipulidae	55	78.2	85	156	272	247.5	163	1811	745	349.7	11	56	1072	675.4	259	2022
	other Diptera	10	4.7	48	333	8	5.1	0	22	11	5.5	3	33	29	15.3	51	389
Trichoptera		14	69.9	233	556	149	616.5	1581	2667	996	1101.6	452	467	1159	1787.9	2267	3689
Ephemeroptera		1	0.6	1370	2967	10	27.5	2052	2022	222	211.7	1393	400	233	239.8	4815	5389
others				22	78			52	189			30	0			104	267
Total		194	180.7	4481	10022	809	1003.2	9044	15122	2275	1714.9	2926	2656	3278	2898.8	16452	27800
Feeding group (%)	Shuredders	8.2				1.6				0.1				1.0			
	Collectors	83.6				90.5				97.5				94.8			
	Grazers	0.5				0.0				0.5				0.4			
	Predators	2.6				7.6				1.3				3.0			
	unknow	5.1				0.2				0.6				0.8			
No. of Species		36				36				31				59			
Species diversity (H′)		4.30				3.68				2.81							

insects and the index of diversity decreased from St. 1 toward St. 3: St. 1 (species number: 36, H′ = 4.3) > St. 2 (36, 3.7) > St. 3 (31, 2.8). On the other hand, the relative frequency of the functional feeding group of macroinvertebrates (aquatic insect larvae) changed from upstream to downstream. The percentage of shredders (such as *Goerodes* and *Limonia*, which tear leaves into smaller fragments) decreased, while the percentage of collectors, including almost all chironomid larvae that filter out small particles including shredder feces, increased along the river flow (Vannote *et al*., 1980).

In conclusion, from St. 1 toward St. 3, changes in the fauna of aquatic insects and the number of individuals collected were found to increase, whereas the number of species and the index of diversity decreased. In the relative frequency of the functional feeding group, the percentage of shredders decreased, while that of collectors increased.

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＜**국문적요**＞

Chikuma 강 상–중류 수역 수서곤충의 분포 양상 (Central Japan)

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일본에서 가장 긴 Chikuma 강의 세 지점에서 2002년 여름 동안 수서곤충의 종조성과 밀도를 light trap에 의해 조사하였다. 하루 동안 총 3,278 성체가 채집되었으며, 그 중 가장 주요한 분류군은 파리목(57.5%)로 나타났고, 그 다음으로 날도래목(35.4%), 하루살이목(7.1%) 순으로 나타났다. 채집된 수서곤충의 밀도와 생체량은 하류로 갈수록 증가하였던 반면, 종수와 다양도지수(H′)는 감소하였다. 제1, 제3 조사 지점에서 종 수는 각각 36종(H′ = 4.30), 31종(H′ = 2.81)으로 나타났다. 또한, 제1 지점에서 제3 지점으로 갈수록 기능적 섭식군(functional feeding group)의 상대밀도는 제1 지점에서 “collectors”가 증가하고 제3 지점에서 “shredders”가 감소하는 것으로 나타났다.