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論　文（Original article）

Comparison of aquatic invertebrates among four small forest streams in Takatori Mountain, Shikoku, Japan

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Abstract

We compared the aquatic invertebrate assemblages among four small streams, two of which were covered with planted forests comprised of Japanese cypress and cedar, and the other two of which were covered with natural forests comprised mainly of Japanese cypress, fir, and hemlock. Genus richness and composition of aquatic invertebrates were different among four sites. The difference could not be explained only by the difference of forest vegetation. It was suggested that stream width and basin area have to be taken into consideration when the assemblage of aquatic invertebrates is compared among small streams.

Key words : aquatic invertebrates, stream width, basin area, functional feeding groups, forest type

Introduction

Japanese forest consists of various kinds of deciduous trees, evergreen broad-leaved trees and/or coniferous trees. Leaves in the forest streams are transferred from the forest floors and/or directly fall from the riparian trees. These coarse particle organic materials (CPOM) of the litter are enriched by microorganisms in the stream. Aquatic invertebrates such as Ephemeroptera, Plecoptera, and Trichoptera spend their larval stage in the freshwater streams. Shredders of these invertebrates fragment the enriched CPOM to fine particle organic materials (FPOM). FPOM is used as food for collectors, grazers and filterers and used as materials of larval cases by some caddisflies.

Riparian forests have a great influence on the in-stream habitat of aquatic invertebrate assemblage. Leaf litter fallen into the stream could play several roles for aquatic invertebrate assemblage (Cummins et al., 1989) and larval growth is affected by the quality of nutrients in the stream derived from the riparian forests (Fiance, 1978; Malley, 1980; Rodgers, 1984). Deciduous broad-leaved vegetation provides more and higher quality food for shredders than coniferous vegetation (Eggert & Burton, 1994). More plecopteran shredders are in the maple litters than in the pine litters (Whiles & Wallace, 1997). Rriparian red alder forest can provide nutrient–rich stream ecosystem (Volk et al., 2003) and support more aquatic invertebrate biomass than riparian conifer forest (Piccolo & Wipfli, 2002). Composition of basin forests is also indispensable factor for considering the habitat in the stream. In-stream chemistry is affected by the quality and quantity of changing vegetation in the basin and it might be indirectly related with the growth of aquatic invertebrates (Krueger & Waters, 1983; Johnson et al., 1997). In northeastern Pennsylvania, hemlock basin forests support more aquatic invertebrate taxa than mixed hardwood basin forests (Snyder et al., 2002). However, studies that examined aquatic invertebrate assemblage in relation to the basin vegetation are not so much.

Composition of basin and riparian forests would be one of the most important variables affecting the aquatic invertebrate assemblage. Recently, Yoshimura and Maeto (2006,) found that aquatic invertebrate assemblages were differed between the two large basins, one of which had an old-growth natural broadleaved forest, and the other a planted coniferous forest. In Japan, 40 % of land is covered by planted, monoculture, conifer forests. However, the differences in aquatic invertebrate assemblages resulting from different coniferous forest types have not been investigated. In this study, aquatic invertebrate assemblages among four small coniferous basins, two of which were natural coniferous forest and the others were planted coniferous forests, were compared as a preliminary study in order to know the effect of coniferous forest vegetation on aquatic invertebrate assemblages.

Materials and methods

The four small streams in our study area flow into the Kita River, a tributary of the Shimanto River, in Takatori Mountain, Shikoku, Japan (33º 20´ N, 132º 57´ E). Two of the streams

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flow through natural forest basins. These basins are 19.5 ha (A) and 21 ha (B), and stream widths are 1 m and 2 m, respectively. Conifers (more than 175 years old; mainly comprised of *Cryptomeria japonica*, *Abies firma* and *Tsuga sieboldii*) mixed with some native broadleaved trees cover these basins. The other two streams flow through planted forest basins. These basins are 45 ha (C) and 6.5 ha (D), and stream widths are 2.3 m and 0.5 m, respectively. Conifers (20 to 30 years old; *Chamaecyparis obtuse* and *Cryptomeria japonica*) mixed with some planted broadleaved trees cover these basins. The four basins are located side by side on Takatori Mountain (Fig. 1). The highest point of three basins (A, B, C) is the same (ca. 740 m a.s.l.) and that of basin D is ca. 550 m a.s.l. The nature of the surface soil of these basins is categorized as Shimanto Terrane and consists of alternating beds of sandstone and mudstone.

The collection sites were located on the 50 m upper reaches (ca. 280 m a.s.l.) of each basin, from the Kita River. Aquatic invertebrates were collected every 2 months from August 2002 to June 2003 at each site. The collection was done within a 2-m length and 20 cm width along the stream in the main flow whose depth was within 10 to 15 cm in each basin. Collection was accomplished using a 0.5-mm mesh net (20 × 15 cm) placed downstream across the flow. The surface of stream bed substrate was disturbed to cause aquatic invertebrates to drift into the net. All invertebrates in the net were collected and preserved in 80% ethanol. All the aquatic invertebrates preserved were identified to genus except Chronomidae and Tipulidae that were to subfamily using a 10-70× microscope (SMZ-U, Nikon).

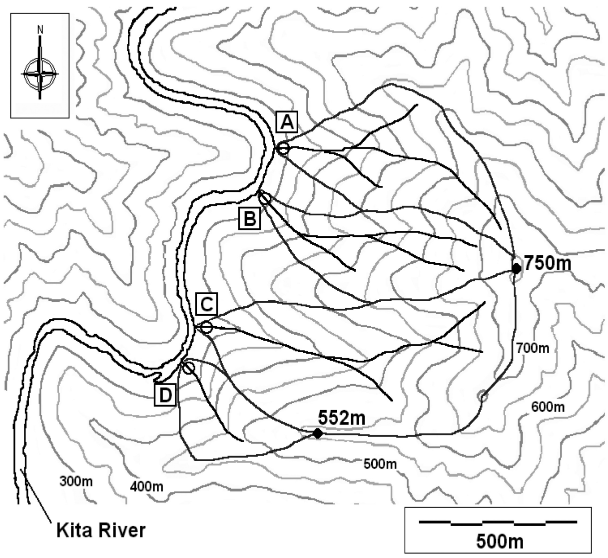

Fig. 1. Location of basin A, B, C and D. "○" indicates each collection site of four basins

At each site, water temperature, electrical conductivity (EC) and pH were measured when the collection was done using a portable thermometer (5473, TANITA), a portable Compact Twin Conductivity meter (B-173, HORIBA) and a portable Compact Twin pH meter (B-212, HORIBA), respectively. Dissolved oxygen (DO) was measured using a portable DO meter (DO-5509, Lutron). Water temperature, DO, pH and EC (Table 1) were tested among the four sites and six collection times using the Friedman two-way analysis of variance by ranks.

Abundance, Shannon-Wiener genus diversity index and genus richness were determined for each site at each collection time. Subfamily was treated as genus in Chronomidae and Tipulidae that were identified to subfamily. These variables were tested using the Friedman two-way analysis of variance by ranks among four sites and six collection times. Similarity of genus composition was assessed with abundance data collected at four sites through the year. The Ward method using Euclidean distance was used to cluster them. All the collected individuals were categorized into five functional feeding groups (FFGs) according to Merritt & Cummins (1996) and Thorp & Covich (2001), and the abundance of five FFGs (predators, shredders, grazers, filterers and collectors) at each site through the year was calculated. The percentage of individuals for these groups in each site was calculated and analyzed using chi-square test among four sites. These statistical analyses were done using SYSTAT 10 (SPSS Inc., 2000).

Results

Water temperature ranged from 4.1 to 21.4°C, DO ranged

Table 1. Basin area, stream width, forest age and averaged value of four factors at each site

	Site				Friedman-test
	A	B	C	D	*Fr* (*d.f.* = 3)
Area (ha)	19.5	21	45	6.5	-
Stream width (m)	1	2	2.3	0.5	-
Forest age (year)	More than 175	More than 175	20 - 30	20 - 30	-
WT (℃) *	12.6 ± 6.53	12.8 ± 6.43	13.2 ± 5.82	13.8 ± 3.73	0.66
DO (mg L^{-1}) *	11.1 ± 2.18	11.1 ± 2.14	11.0 ± 2.17	11.2 ± 1.90	5.17
pH *	7.9 ± 0.85	8.1 ± 1.01	8.0 ± 0.85	8.1 ± 0.64	0.38
EC (μs cm^{-1}) *	97.8 ±29.52	124.7±31.96	99.0 ±14.89	84.3 ±14.85	14.00*

*: Average ± SD, *: $P < 0.05$

from 7.8 to 13.8 mg L^{-1}, pH ranged from 6.9 to 9.2, and EC ranged from 13 to 178 μs cm^{-1}, depending on collection time and site. Average values of these factors at each site throughout the year are shown in Table 1. There were no significant differences among the four sites except for EC. The significant difference in EC among sites was explained by the difference between site A and B ($|R_A - R_B| = 12.0$, $P < 0.05$, Friedman test) band between sites B and D ($|R_D - R_B| = 16.0$, $P < 0.05$, Friedman test).

The averaged abundance, genus diversity and genus richness at each site are shown in Table 2. Seven to 192 individuals were collected and diversity ranged from 0.96 to 2.75 depending on the collection time and site. There was no difference of abundance and diversity index among four sites. Genus richness ranged from 3-23 depending on the collection time and site. There were significant difference in genus richness among four sites, and it could be explained by the differences between sites B and D ($|R_D - R_B| = 13.0$, $P < 0.05$, Friedman test).

Similarity of genus composition between sites throughout the year showed that aquatic invertebrate assemblage in site A and B was most similar and that in site C was most dissimilar to other sites (Fig. 2). The composition of five FFGs throughout the year was significantly different among four sites ($\chi^2_{cal} = 82.3$, $d.f. = 12$, $P < 0.001$) (Fig. 3). The percentage of shredders was the highest in site D and filterers was the highest in site C.

Discussion

Aquatic invertebrate composition of functional feeding groups (FFGs) was different among the sites. Besides, genus composition in site A and B was the most similar and their forest vegetation was the same. Different type of forest provides different water quality for the stream (Friberg, 1997; Friberg et al., 1997), and different aquatic invertebrate assemblage (Cummins et al., 1989; Eggert & Burton, 1994; Whiles & Wallace, 1997; Piccolo & Wipfli, 2002). So, the difference of composition of FFGs in this study might be largely related with the difference of forest vegetation.

Genus composition in site C and D was not similar, though forest type of these two sites was the same. Genus richness was also differed by site and averaged genus richness and abundance was the lowest at site D in this study, although stream chemistry was not different between site C and D. Major difference between site C and D was stream width and basin area. They were the smallest in site D and largest in site C. Jenkins et al. (1984) showed that taxon richness is correlated with river width, pH, water hardness, and the number of habitat types. Brönmark et al. (1984) found that taxon richness increases with stream size. The effect of stream width and basin area on the composition of genus and FFGs might be greater than the effect of forest type.

The difference of FFG composition and genus richness among sites does not result solely from the differences in forest vegetation in this study. Forest vegetation, forest age, amount and types of leaf litter, the size of stream and basin area, water temperature, and stream chemistry, all of which might alter the structure and quality of stream habitat, might change aquatic invertebrate assemblages. Although pH and EC are important chemical factors and relate to aquatic invertebrate assemblages (Friberg et al., 1997), stream width and basin area would affect

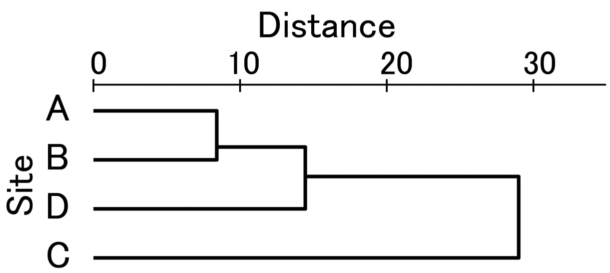

Fig. 2. Cluster analysis of aquatic invertebrate assemblages among four sites by the Ward method and Euclidean distance

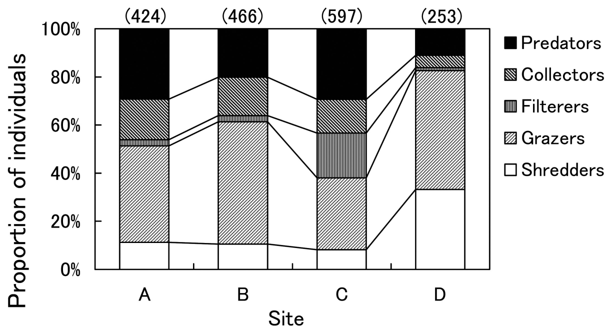

Fig. 3. The individuals proportion of five FFGs in each site through the year. "(number)" indicates the number of individuals in each site through the year.

Table 2. Abundance, Shannon-Wiener diversity index and genus richness at each site

	Site				Friedman-test
	A	B	C	D	Fr ($d.f.$ = 3)
Abundance	70.67 ±28.367	77.67 ±47.999	99.50 ±68.240	42.17 ±34.874	7.40
Diversity	2.06 ± 0.228	2.16 ± 0.339	2.12 ± 0.284	1.37 ± 0.347	6.8
Genus richness	13.67 ± 3.011	15.67 ± 5.086	14.33 ± 4.457	7.50 ± 3.507	10.05*

Average ± SD, *: $P < 0.05$

aquatic invertebrate assemblages more strongly, especially in small streams.

References

Brönmark, C., Herrmann, J., Malmqvist, B., Otto, C. and Sjöström, P. (1984) Animal community structure as a function of stream size, Hydrobiologia, **112**, 73-79.

Cummins, K.W., Wilzbach, M.A., Gates, D.M., Perry, J.B. and Taliaferro, W.B. (1989) Shredders and riparian vegetation, BioScience, **39**, 24-30.

Eggert, S.L. and Burton, T.M. (1994) A comparison of *Acroneuria lycorias* (Plecoptera) production and growth in northern Michigan hard-soft-water streams, Freshwater Biol., **32**, 21-31.

Friberg, N. (1997) Benthic invertebrate communities in six Danish forest streams: Impact of forest type on structure and function, Ecography, **20**, 19-28.

Friberg, N., Winterbourn, M.J., Shearer, K.A. and Larsen, S.E. (1997) Benthic communities of forest streams in the South Island, New Zealand: Effects of forest type and location, Arch. Hydrobiol., **138**, 289-306.

Jenkins, R.A., Wade, K.R. and Pugh, E. (1984) Macroinvertebrate-habitat relationships in the river Teifi catchment and the significance to conservation, Freshwater Boil., **14**, 23-42.

Johnson, L.B., Richards, C., Host, G.E. and Arthur, J.W. (1997) Landscape influences on water chemistry in Midwestern stream ecosystems, Freshwater Biol., **37**, 193-208.

Krueger, C.C. and Waters, T.F. (1983) Annual production of macroinvertebrates in three streams of different water quality, Ecology, **64**, 840-850.

Merritt, R.W. and Cummins, K.W. (1996) An introduction to the aquatic insects of North America, 3rd ed., Kendall/Hunt, USA, 862p.

Piccolo, J.J. and Wipfli, M.S. (2002) Does red alder (*Alnus rubra*) in upland riparian forests elevate macroinvertebrate and detritus export from headwater streams to downstream habitats in southeastern Alaska? Can. J. Fish. Aquat. Sci., **59**, 503-513.

Snyder, C.D., Young, J.A., Lemarié, D.P. and Smith, D.R. (2002) Influence of eastern hemlock (*Tsuga canadensis*) forests on aquatic invertebrate assemblages in headwater streams, Can. J. Fish. Aquat. Sci., **59**, 262-275.

SPSS Inc. (2000) SYSTAT 10, Chicago.

Thorp, J.H. and Covich, A.P. (2001) Ecology and Classification of North American Freshwater Invertebrates, 2nd ed., Academic press, USA, 1056p.

Volk, C.J., Kiffney, P.M. and Edmonds, R.L. (2003) Role of riparian red alder (*Alnus rubra*) in the nutrient dynamics of coastal streams of the Olympic Peninsula, WA. U.S.A., In Stockner, J.G. (ed.) *"Nutrient in salmon ecosystems: sustaining production and biodiversity"*, American Fisheries Society, Bethesda MD., 213-225.

Whiles, M.R. and Wallace, J.B. (1997) Leaf litter decomposition and macroinvertebrate communities in headwater streams draining pine and hardwood catchments, Hydrobiologia, **353**, 107-119.

Yoshimura, M. and Maeto, K. (2006) Comparison of an aquatic invertebrate assemblage between an old-growth natural forest and planted coniferous forest basins in a Japanese temperate region: the Kuroson stream in the Shimanto River basin, Landscape Ecol. Eng., **2,** 81-89.

鷹取山（高知県梼原町）の４小渓流における水生生物群集の比較

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要 旨

スギ・ヒノキの植林地内を流れる 2 小渓流と主にヒノキ・モミ・ツガからなる天然林内を流れる 2 小渓流における水生生物群集の比較を行った。4 渓流間で水生生物の属数や群集構成に違いがあった。この違いは各渓流の流域内の森林構成の違いのみでは説明できなかった。小渓流における水生生物群集を比較する際には川幅や流域面積を考慮する必要があると考えられた。

キーワード：水生生物、川幅、流域面積、摂食機能群、森林タイプ

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