「森林総合研究所研究報告」(Bulletin of FFPRI), Vol.3, No.3 (No.392), 213 - 219, Sep. 2004

論　文（Original Article）

Comparison of sampling methods for aquatic insect indicators of forest condition in terms of collection efficiency

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Abstract

Aquatic insects (Ephemeroptera, Plecoptera, Trichoptera) are highly dependent on forest environments. In order to research for aquatic insect indicators that respond to alteration in the forest environment, useful and simple sampling methods are required. In this study, quantitative and qualitative sampling surveys and light trap surveys were compared with regard to the number of families and individuals which were collected. For Trichoptera, light trap survey of adults was the most effective method. For Plecoptera and Ephemeroptera, qualitative sampling survey of larvae from the beds of shallow streams was the most effective method.

Key words : Plecoptera, Ephemeroptera, Trichoptera, quantitative sampling survey, qualitative sampling survey, light trap survey, stream invertebrates

Introduction

The aquatic insects of Ephemeroptera, Plecoptera, and Trichoptera (EPT) spend their larval stage in the freshwater streams. Leaves fallen from riparian trees or transferred from the forest floor into the stream are consumed by some aquatic insects such as stoneflies (Plecoptera). Particles of litter are used as larval cases of aquatic insects such as caddisflies (Trichoptera) (Giller & Malmqvist, 1998; Flory & Milner, 1999). Larval growth is affected by the quality of nutrients in the stream derived from the riparian forests (Fiance, 1978; Malley, 1980; Rodgers, 1984). When the riparian forest consists of deciduous trees, the density and production of aquatic insects are higher than when it consists of conifers, because of the higher dietary quality of deciduous leaves (Eggert & Burton, 1994). Larval growth is also affected by the temperature and incident radiation. Riparian forests can also provide shade, though their effectiveness changes depending on the season and stream widths (Gregory et al., 1991). When there is no riparian forest, for example, algal biomass increases and the abundance of aquatic insects also increases with considerable changes in species composition (Hawkins et al., 1982). Aquatic insects are thus strongly influenced by forest conditions, and therefore can be expected to be sensitive indicators of changes in the forest environment.

If aquatic insects are to be used as indicators of change in the forest environment, useful and simple sampling methods are required. Hewlett (2000) reports only fifty percentage of total aquatic invertebrate could be discriminated by the species level identification, whereas ninety-eight percentage of total aquatic invertebrate could be discriminated by the family level identification. He also indicates that aquatic invertebrate assemblage is similar between using genus and family level identification. So, species level identification is not necessary and family level identification is enough to monitor aquatic invertebrate assemblage in a broad scale, not in a single habitat scale. Commonly used methods for characterizing populations of aquatic insects are quantitative and qualitative sampling surveys for larval collection, and light trap surveys for adult collection. In this study, aquatic insects are collected by these three methods and identified at the family level. Then, aquatic insect assemblages are compared and tried to determine which method is the most effective to assess and monitor aquatic insect indicators and diversity.

Materials and Methods

Larvae of Ephemeroptera, Plecoptera and Trichoptera (EPT) were collected on December 14, 2000 and March 2, 2001 from one of the upper reaches of Kuroson Stream (33°10' N, 132°38' E, ca. 620 m a.s.l.), Kochi prefecture, by quantitative sampling survey and qualitative sampling survey. There were no ponds and wetlands around here, but some tributary flow into the Kuroson stream (fig. 1).

原稿受付：平成 16 年 3 月 24 日 Received Mar. 24, 2004　　原稿受理：平成 16 年 5 月 31 日 Accepted May 31, 2004
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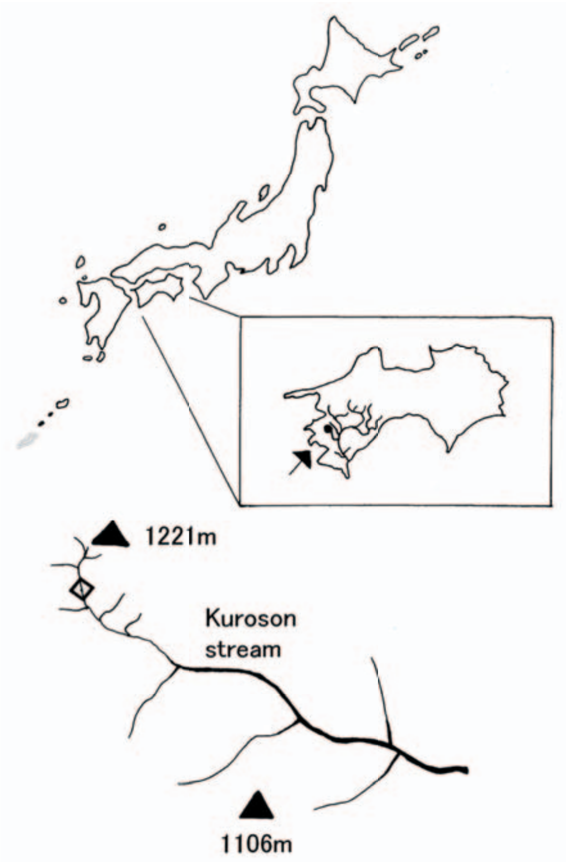

Fig. 1. Study site of Kuroson stream

Collection points were arranged within 5.5-m (stream width) × 25-m along old-growth riparian forests of broad-leaved species. Air temperatures were 7.2 ºC on December 14 and 7.6 ºC on March 2 at 15:00. Water temperatures were 6.0 ºC on December 14 and 7.1 ºC on March 2 at 15:00. All collected insects, regardless of methods, were preserved in 80% ethanol, identified to family level and counted.

The quantitative sampling survey was accomplished at five points in the shallows at depths of 20 to 25 cm with 0.15 to 0.2 m / s flow. At each point, a 30 × 30 cm quadrat was placed on the substrate and a D-frame net with 1 mm mesh size was set on the downstream side of the quadrat across the flow. Then, large stones inside the quadrat were quickly removed and put into a white container. The surface of the substrate inside the quadrat was then disturbed to make insects drift into the D-frame net. All the larvae of EPT on the stones in the container and in the D-frame net were retrieved.

The qualitative sampling survey was accomplished at two points on a pebble substrate in the shallows at 20 to 25 cm depth and 0.15 to 0.2 m / s flow, at two points on a pebble or sand substrate at 10 to 20 cm depth without flow such as near the bank, and at one point in a litter pool without flow regardless to the depth. At each point, a D-frame net was set across the flow and surfaces of the substrate were disturbed for 1 minute to make insects drift into the D-frame net (the area of disturbed substrate was not fixed). Then all the EPT larvae in the D-frame net were retrieved.

Adults of EPT were collected by light trap survey on May 16, June 7, June 25 and July 26 2001, at the same place as larval collection (Fig. 1). Air temperatures were 15.5 ºC on May 16, 19 ºC on June 7, 21 ºC on June 25 and 21.9 ºC on July 26 at 20:00. A sheet of white cloth (1.5 × 3 m) was set up facing the stream 5 m from the bank. It was steep slope behind the sheet. One 20-watt black and one 20-watt white fluorescent lamp were hung near the cloth. At 19:00, lights were turned on. Forty-five minutes later, adults of EPT attracted to the lights were collected from one side of the cloth for 15 minutes and this was repeated by the hour until 23:00. Aquatic insects were defined according to Kawai (1985) and Merritt & Cummins (1996).

Results

Nineteen families and 1257 individuals of EPT larvae were collected by quantitative sampling surveys of 5

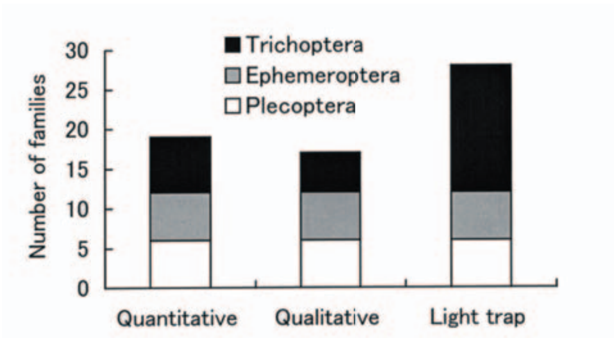

Fig. 2. Number of families collected in three different sampling methods. Quantitative: quantitative sampling survey of larvae; Qualitative: qualitative sampling survey of larvae; Light trap: light trap survey of adults

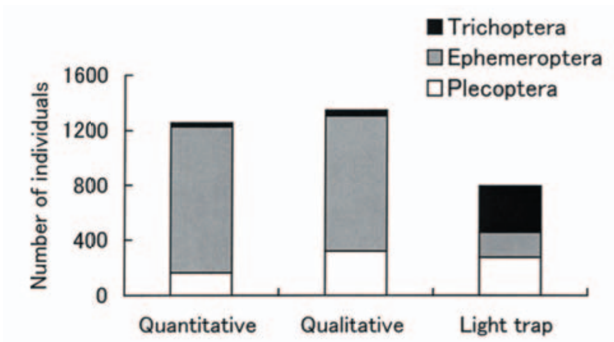

Fig. 3. Number of individuals collected in three different sampling methods. Quantitative: quantitative sampling survey of larvae; Qualitative: qualitative sampling survey of larvae; Light trap: light trap survey of adults.

points on December 14 and March 2 together (Figs. 2, 3). Two persons required 170 minutes on December 14 and 150 minutes on March 2 to collect larvae at 5 points. Seventeen families and 1349 individuals of EPT larvae were collected by qualitative sampling surveys of 5 points on December 14 and March 2 together (Figs. 2, 3). Two persons required 110 minutes on December 14 and 130 minutes on March 2 to complete this task. Twenty-eight families and 793 individuals of EPT were collected by light trap surveys on May 16, June 7, June 25 and July 26 (Figs. 2, 3). We spent 4 hours on each of these days to collect the insects.

Many trichopteran families collected by light trap survey were not collected by the quantitative and qualitative sampling surveys (Fig. 2, Table 1). The numbers of plecopteran and ephemeropteran families were the same for all three methods. However, ephemeropteran abundance was much lower for light trap surveys as compared with the larval sampling methods (Fig. 3). Taeniopterygidae and Peltoperlidae of Plecoptera were collected only by larval sampling surveys and light trap surveys, respectively (Table 1).

Table 1. Number of individuals and number of families collected by three different sampling survary.

Order	Family	Quantitative sampling survey	Qualitative sampling survey	Light trap sampling survey
Plecoptera	Perlidae	●	●	●
	Perlodidae	○	×	○
	Leuctridae	○	○	○
	Capniidae	×	○	×
	Nemouridae	●	●	●
	Taeniopterygidae	●	●	×
	Chloroperlidae	○	●	●
	Peltoperlidae	×	×	○
	Number of individuals	166	318	273
	Number of families	6	6	6
Ephemeroptera	Siphlonuridae	●	●	●
	Heptageniidae	●	●	●
	Ephemeridae	○	○	○
	Ephemerellidae	●	○	●
	Bartiidae	●	●	●
	Leptophlebiidae	●	●	●
	Number of individuals	1062	988	182
	Number of families	6	6	5
Trichoptera	Stenopsychidae	×	×	●
	Rhyacophilidae	○	○	●
	Goeridae	×	×	○
	Uenoidae	○	×	×
	Hydropsychidae	○	○	●
	Lepidostomatidae	○	●	●
	Leptoceridae	×	×	○
	Philopotamidae	○	○	●
	Phryganopsychidae	○	●	×
	Brachycentridae	×	×	○
	Psychomyiidae	×	×	●
	Xiphocentronidae	×	×	○
	Polycentropodidae	○	×	●
	Glossosomatidae	×	×	●
	Odontoceridae	×	×	○
	Beraeidae	×	×	○
	Phryganeidae	×	×	○
	Calamoceratidae	×	×	○
	Number of individuals	29	43	338
	Number of families	7	5	16
	Total number of individuals	1257	1349	793
	Total number of families	19	17	28

Number of individuals ●:10～、○:1～9、×:None

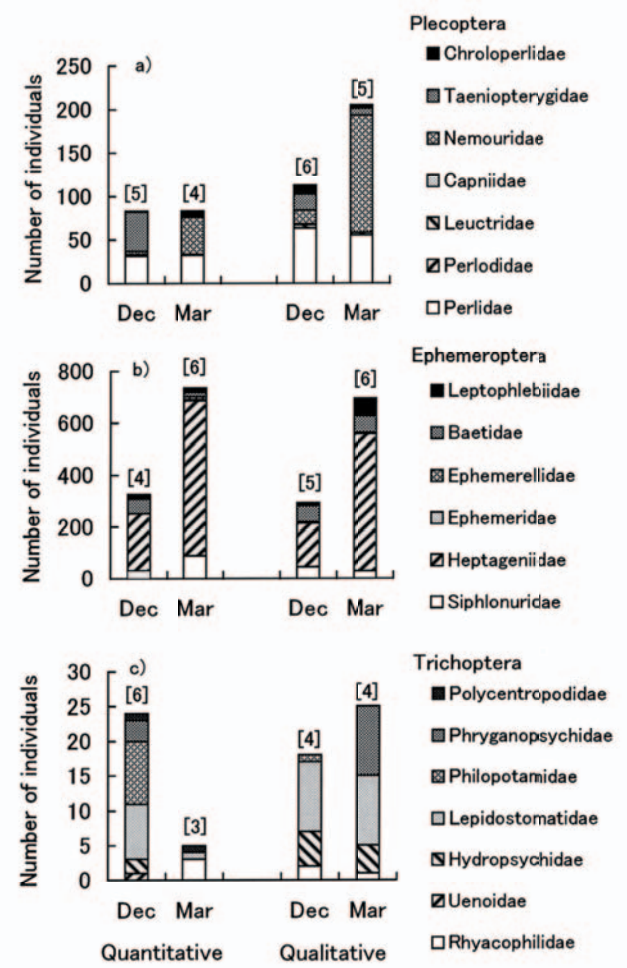

Fig. 4. Number of individuals collected by quantitative sampling survey and qualitative sampling survey on December 14 and March 2. [Number] indicates the number of families collected by each method. a) Plecoptera, b) Ephemeroptera, c) Trichoptera

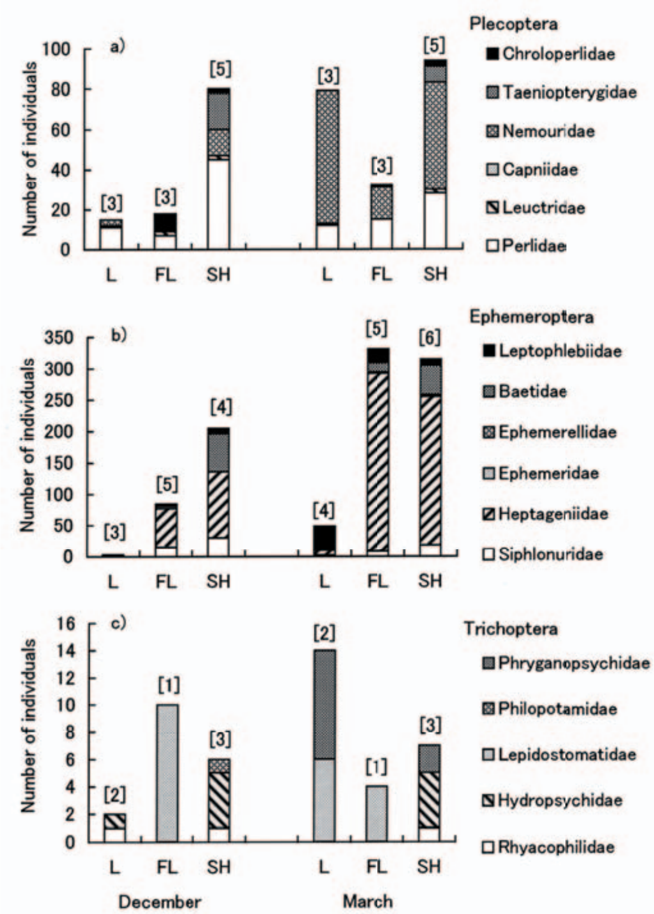

Fig. 5. Number of individuals collected by qualitative sampling survey accomplished on the pebble substrate in the shallows (SH), on the pebble to sand substrate without flow (FL) and in the area of litter pool (L) on December 14th and March 2nd. [Number] indicates the number of families collected on each substrate. a) Plecoptera, b) Ephemeroptera, c) Trichoptera

Many plecopteran families and individuals were collected by qualitative sampling surveys (Fig. 4a), chiefly in the shallows (SH) (Fig. 5a). Family composition was different between sampling dates. Some families, for example Taeniopterygidae and Nemouridae of Plecoptera (Fig. 4a) were difficult to collect in one season, but collected in another season. Catches of ephemeropteran families were similar for the two larval sampling methods (Fig. 4b). However, many families tended to be collected more frequently when the qualitative sampling surveys were carried out in the shallows (Fig. 5b). More families and individuals were collected on March 2 than on December 14 by both methods (Fig. 4b). Family composition of Trichoptera varied depending on the larval sampling method and collection date (Figs. 4c, 5c). The numbers of collected families and individuals were both largest when the quantitative sampling survey was carried out on December 14 (Fig. 4c).

Discussion

Various methods, such as kicknet and, D-frame samplers, the Surber, and Ekman techniques as well as collection by hand, are used for collecting and processing benthic macroinvertebrate samples from streams. Quantitative sampling survey using the Surber employs fixed-quadrat collection and is considered to be useful because absolute abundance of benthic macroinvertebrates can be determined and compared. However, beds of shallow streams are the only places where the fixed-quadrats can be set up. Kicknet or D-frame samplers for the qualitative sampling survey are easily transported and have the advantage of being used in various habitats. They are also useful for habitat-specific species, though precise abundance of benthic macroinvertebrates cannot be measured. There are many sampling methods for collecting adults of benthic macroinvertebrates such as light trap, sweeping, emergence trap and Malaise trap. The Malaise trap is easily set up, but it gathers not only aquatic insects but also a lot of other unwanted insects. Emergence trap is only useful when we collect specific species. Light traps are easy to use and can collect many aquatic insects, but collection takes several hours and those insects not reacting to light cannot be collected.

The comparison of the three sampling methods has shown that many families of Trichoptera and the Peltoperlidae of Plecoptera were collected only by light trap surveys. Trichopteran larvae can occupy various habitats and they tend to be gregarious (Campbell & Meadows, 1972; Lamberti & Resh, 1979). Then, in order to collect most of the families of this order, collection from various substrates is needed i.e. not only in the shallows but also streamsides, on the wetted surfaces of large stones, and in isolated pools. Larvae of the Peltoperlidae prefer streamside habitats so it is difficult to collect them by the general larval sampling methods. Light trap surveys are considered to be useful for these families. This method need many hours per day and is best carried out in the longer summer days. However, efficient selection of the emergence period of these families helps to shorten the collection period by light trap.

If Plecoptera and Ephemeroptera are selected as indicators of forest environmental change, then larval sampling surveys are more useful than light trap surveys. Ephemeropteran family composition did not vary significantly between the two larval sampling methods, though many families of Plecoptera and Ephemeroptera tended to be gathered by qualitative sampling surveys of shallow streams. Larger numbers of plecopteran larvae were obtained by means of qualitative sampling survey in the shallows in this study. Qualitative sampling surveys are currently the most commonly used methods of rapid bioassessments, although, in the USA, quantitative sampling surveys were often used in earlier years (Carter & Resh, 2001). As shown in our study, qualitative sampling surveys of the beds of shallow streams also have the advantage of collecting more taxa than quantitative sampling surveys (Stark, 1993), and are appropriate where monitoring indicator abundance is not the aim. If Plecoptera and Ephemeroptera are selected as indicators, then qualitative sampling survey of the shallows would be preferred, because it is the fastest and easiest method at the lowest cost of the three. Collection should be done through the winter and spring months for Plecoptera, because some families such as the Taeniopterygidae and Nemouridae can be collected only in one of these seasons. For Ephemeroptera in this study, on the other hands, collection might be confined to the spring season rather than winter season when most families and individuals were collected.

Acknowledgements

We wish to thank Dr Ken Old, forest health team leader of CSIRO Forestry and Forest Products for English correction and his critical comments. This work was partly funded by the Research grant #200004 of the Forestry and Forest Products Research Institute.

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水生昆虫の指標種モニタリングのための効率的な採集方法

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要 旨

カゲロウ、カワゲラ、トビケラ等の水生昆虫の生息には、水温・日射・落葉等の森林の環境状態が大きく左右する。森林環境の変化を反映する水生昆虫の指標種を調査するためには、効果的で簡便な方法が求められる。そのため、川の瀬に枠を設置しその内部に生息する幼虫すべてを採集する定量採集と、様々な底質に生息する幼虫を採集する定性採集、成虫の採集方法としてライトトラップを行い、採集した個体数と科数を比較した。定量採集ではカワゲラ 6 科・カゲロウ 6 科・トビケラ 7 科、定性採集ではカワゲラ 6 科・カゲロウ 6 科・トビケラ 5 科、ライトトラップではカワゲラ 6 科・カゲロウ 5 科・トビケラ 16 科の水生昆虫が採集できた。トビケラの場合、成虫のライトトラップ調査がもっとも効率的な方法であることがわかった。カワゲラやカゲロウの場合、瀬における定性採集が最も効果的な方法であることがわかった。

キーワード : カワゲラ、カゲロウ、トビケラ、定量採集、定性採集、ライトトラップ

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