Southeast Asian Water Environment 3

Edited by Satoshi Takizawa,
Futoshi Kurisu and Hiroyasu Satoh

IWA Publishing

Water quality biomonitoring using macroinvertebrates in Way Besai, Sumberjaya, West Lampung

Subekti Rahayu[a], Indra Suryadi[a], Bruno Verbist[a], Andy Dedecker[b], Ans Mouton[b] and Meine van Noordwijk[a]

[a]World Agroforestry Centre, Jl. Cifor, Situ Gede, Sindang Barang, Bogor (E-mail: s.rahayu@cgiar.org)
[b]Gent University, Belgium

Abstract Forest conversion to agriculture such as coffee garden and rice field occured in Way Besai watershed, Sumberjaya, Lampung Province, Indonesia, particularly during reformation era, 1998. Land clearing, soil tillage, fertilizing and pesticides application as part of activities during forest conversion to agriculture. Those activities effected to the water quality along the stream and river through sedimentation, nutrient accumulation and pesticide residue.

Water quality is determined by assessing three classes of attributes: physical, chemical and biological. Both of chemichal and physical attributes need higher cost on laboratory analysis that biological assessment using macroinvertebrates. Evaluating biological community of a stream through assessment macroinvertebrates provides a sensitive and cost effective means on determining stream condition.

The objectives of this reaseach are: (1) to know the taxomic diversity of aquatic macroinvertebrates along the streams, (2) to assess water quality condition based on functional feeding group and (3) to assess water quality condition based on Family Biotic Index.

30 plots along Way Besai river with three nested streams (Way Petai, Way Ringkih and Air Hitam) choosed as samples. Aquatic macroinvertebrates collected from the water body in 10 m stream length and moved diagonally across the stream for 5 minutes during April 2005 (rain season) and August 2005 (dry season) using 'kick technique'. Macroinvertebrates were identified up to family level.

Higher family richness and abundance occured in the stream around the forest, followed by stream around coffee garden. Physical and chemical contents in the stream such as substrate of the stream, vegetation around the stream and river bank, chemical organic content effect to the family richness and adundance. Chironomidae is the most common in Way Besai and found in 83% of sampling plot. Cordulegastridae, Hydraenidae and Hydrometridae were only found in forest areas.

More shredders found in the stream with high organic-matter content, more scrapers were found in the streams with an open area; more collectors were found in the stream dominated by sand and loam substrate and more predators were found in the stream dominated by stones substrate. Predators group decreased gradually from upstream to downstream.

Based on the Family Biotic Index (FBI), water quality in Way Besai, Sumberjaya were categorized from excellet to very poor. Stream around forest area and some coffee garden in Air Hitam indicated excellent quality, which means organic pollution were unlikely. The stream which had high shredders also showed a high FBI value, and organic pollution occured in this area.

Keywords Family Biotic Index, macroinvertebrates, rice field, water quality, Way Besai

INTRODUCTION

Forest conversion to agriculture such as coffee garden and rice field occured in Way Besai watershed, Sumberjaya, Lampung Province, Indonesia, particularly during reformation era, 1998. Forest area decreasing from 40% in 1994 to 12% from total area in 2000 (Ekadinata, 2002). During forest conversion, activities such as land clearing, soil tillage, planting, weeding, fertilizing and pesticide applied by farmers. Those activities effected to the water quality along the stream and river through sedimentation, nutrient accumulation and pesticide residue.

Water quality is determined by assessing three classes of attributes: physical, chemical and biological. Both of chemichal and physical attributes need higher cost on laboratory analysis that biological assessment using macroinvertebrates. Evaluating of biological community of a stream through assessment macroinvertebrates provides a sensitive and cost effective means on determining stream condition. Macroinvertebrates are fairly stationary, easy to collect and are responsive to human disturbance (Anonymous, 1999a).

Macroinvertebrates are an essential component of freshwater ecosystems and some of them are sensitive to stressed produced by pollution, habitat modification or severe natural event. Macroinvertebrates population are more sensitive indicators of habitat disturbance on infrequent chemical contamination than standard chemical monitoring. Aquatic macroinvertebrate in streams a biological communities that integrate the effects of many different factors over time.

According to Wallace and Webster (1996), macroinvertebrate assemblage of most streams in highly diverse, and many of the individual species may be redundant in the sense that ecosystem function can proceed if there are absent.

The objectives of this reaseach are: (1) to know the taxomic diversity of aquatic macroinvertebrate along the streams, (2) to assess water quality condition based on functional feeding group and (3) to assess water quality condition based on Family Biotic Index.

 Southeast Asian Water Environment 3. Edited by Satoshi Takizawa, Futoshi Kurisu and Hiroyasu Satoh. ISBN: 9781843392767. Published by IWA Publishing, London, UK.

MATERIALS AND METHODS

30 plots along Way Besai river with three nested streams (Way Petai, Way Ringkih and Air Hitam) choosed as a samples as show in Figure 1. Aquatic macroinvertebrate collected from the water body in 10 m stream length and move diagonally across the stream for 5 minutes during April 2005 (wet season) and August 2005 (dry season) used 'kick technique'. The materials collected put in the plastic bag and transported to field laboratory, washed and sieved. Macroinvertebrates identified up to family level.

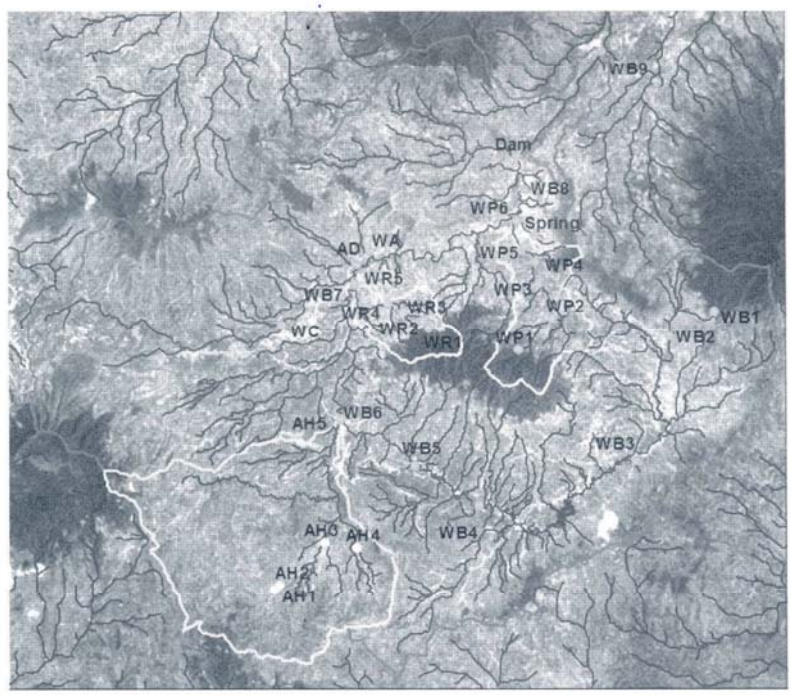

Figure 1. Sampling point of macroinvertebrates along Way Besai river in Sumberjaya.

Data analysis

Shannon-Wiener Index is used to know the macroinvertebrates diversity in each plot along the streams as foollowing formulation:

$$H' = -\sum p_i \ln(p_i)$$

where: H' = Shannon-Wiener Index; p_i = proportion of individual species to total individu in one plot.

Jaccard Similarity Index used to know the similarity percentage of family between plot samples. Otherwise, this index could not distinguish which families are similar among plot samples. Jaccard index can be calculated with:

$$J_{clas} = \frac{A}{A+B+C} \text{ (Chao } et\ al.\text{, 2005)}$$

where: A = family found in both sample 1 and sample 2; B = family found in sample 1 only; C = family found in sample 2 only.

To assess water quality condition based on functional feeding group, all organisms in the sample should be classified according to functional feeding group as: shredders (used course organic particulate materials >1 mm diameter as source of food, feeding directly on living vascular macrophytes or gouge decomposing wood); scrapers (animals which use periphyton, alga and microbiota from mineral and organic substrate); collectors (animals that feed

primarily on fine particulate organic material <1 mm diameter deposited in the stream) and predators (organisms that feed primarily on animal tissue) (Wallace and Webster, 1996). Percentage of each classes calculated.

To assess water quality condition based on Family Biotic Index, used list of tolerance value for macroinvertebrates and calculated with the formula:

$$FBI = \frac{\sum x_i t_i}{n} \text{ (Hilsenhoff's, 1988)}$$

where: x_i = number of individuals within a family; t_i = tolerance value of family; n = total number of organisms in the sample.

FBI value classified by:

0.0–3.75 = Excellent (organic pollution unlikely)
3.76–4.25 = Very good (possible slight organic pollution)
4.26–5.00 = Good (some organic pollution probable)
5.01–5.75 = Fair (fairly substantial pollution likely)
5.76–6.50 = Fairly poor (substantial pollution likely)
6.51–7.25 = Poor (very substantial pollution likely)
7.26–10.00 = Very poor (severe organic pollution likely)

RESULTS AND DISCUSSIONS

Diversity of macroinvertebrates family

Diversity of macroinvertebrates in this analysis refer to family richness and abundance.

Family richness

Generally, family richness increases with increasing water quality, habitat diversity and habitat suitability (Anonymous, 1999b). Macroinvertebrates family richness during dry season more higher than rain season, and indicates significant different in the most of sample plots. In contrast, species richness in Spring, WB7-CR and WR5-R in the rain season more higher than dry season (Figure 2).

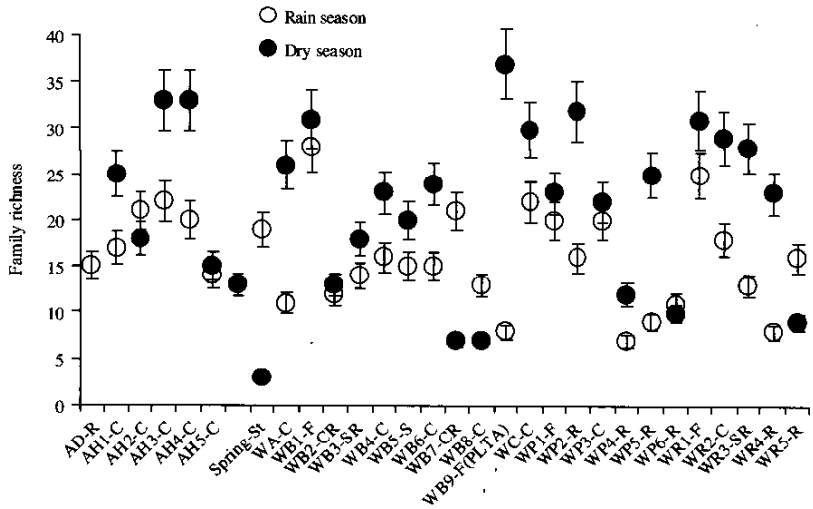

Figure 2. Number of aquatic macroinvertebrates family found along Way Besai river during dry and rain season 2005.

Comparing each sample plots, high family richness in both dry and rain season found in the stream around the forest. Otherwise, in some area around coffee garden such as AH2, AH3, WA, WC, WR2 found high family richness event only in dry season. Most of stream around rice field has low family richness.

Family richness in WB1-F and WR1-F (forest area) is quite similar in both dry and rain season. This result indicates that high richness of macroinvertebrates family found in undisturbed area like forest. In addition, substrate of the stream also has contribution to family richness. Both WB1-F and WR1-F plot are dominated by stones (70%) and gravels (30%) substrate. Some of macroinvertebrates predator prefer live in stoney substrate rather than in the clay.

Lowest family richness found in the spring, WP4-R, WP5-R, WP6-R, WR4-R and WR5-R particularly during dry season. All of sampling area are close to the rice field which have high water fluctuation. Rice field along the stream were managed by semi intensive with fertilizer and pesticide application. Spring is located close to rice field and settlement, and as a public used. Detergent and pesticide may come to the stream. Chemical analysis shown that there was phosphat content (0.5 mg/l) in the spring.

Family diversity

Shannon-Wiener index indicates that diversity of aquatic macroinverebrates family has significant different between dry and rain season for most of samples area (Figure 3). Otherwise, there is no significant different occured in forest area (WB1-F, WP1-F and WR1-F). It is clear indicates that species richness and abundence dynamic between season in undisturbed area such as forest is more stable compared to coffee garden and rice field.

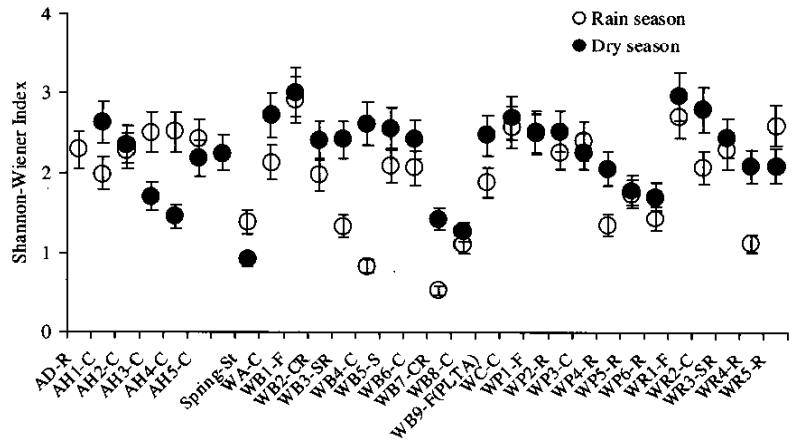

Figure 3. Shannon-Wiener Index of aquatic macroinvertebrates family found along Way Besai river during dry and rain season 2005.

Beside landuse around the stream, position of the stream (upstream and down stream) effect to family diversity. Shannon-Wiener index tend to decrease from upstream to downstream.

Similarity of family

If compared for all plots sample, indicate that in each plot has different composition of macroinvertebrate family. Percent similarity higher than 50 only occured between WR2-WR3 (51%), WB3-WB5 (55%), and WB1-AH3 (63%). Physical condition and landuse systems around the WR2 and WR3 is different, WR2 (coffee garden) and WR3 (shrub and paddy field), but 50% of macroinvertebrates family found in both area are the same. Similarity occured may be because of closer area.

WB3 and WB5 has similar landuse system, which shrub around the plot. Physical condition such as substrate composition, light come to the stream, water color, river bank condition and chemical condition such as phosphat, amonium and nitrate content in both area are similar.

WB1 (forest) and AH3 (coffee garden) are different landuse type. The chemical condition and like phosphat, nitrate and amonium content also different but has similar substrate composition.

Chironomidae is the most common in Way Besai river, it found in 24 plots of 29 (83%), it is categorized a pollutant-tolerant. Beside Chironomidae, there are 4 families (Elmidae, Hydropsychidae, Baetiscidae and Lymnaeidae) found in 50% plot sample. Otherwise, there are 3 families (Cordulegastridae, Hydraenidae and Hydrometridae) only found in forest area (WB1, WP1 and WR1). Stream around the forest indicate no pollutant content.

Macroinvertebrate distribution based on functional feeding group (FFG)

Categorization of any stream macroinvertebrate as a keystone species would be difficult (Mills *et al.*, 1993), but as a group they perform essential function and are critical to the maintenance of stream functional integrity (Angermeier and Karr, 1994). Based on morpho-behavioral mechanism for exploiting food, macroinvertebrate classified by scrapers, shredders, collectors (gatherer) and predators (Wallace and Merritt, 1980).

In Sumberjaya area, changing functional feeding group composition occured between physical condition of stream, stream order and landuse around the stream (Figure 4).

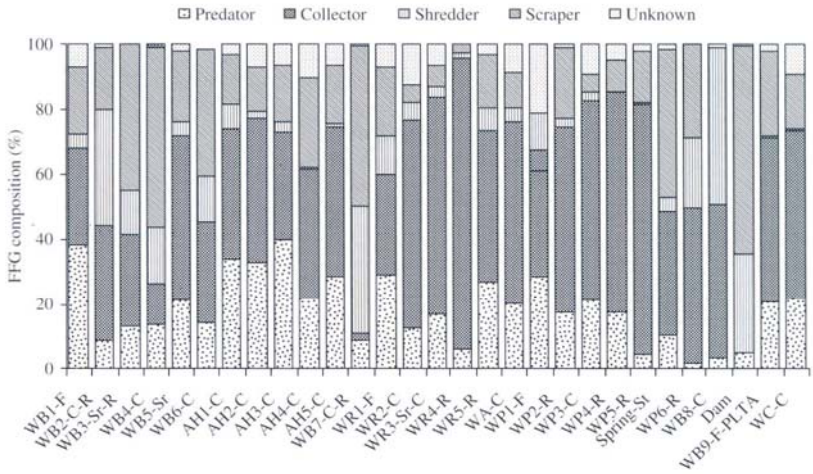

Figure 4. Average of percentage composition of Functional feeding group during dry and rain season 2005 in Way Besai, Sumberjaya.

Shredders

Shredders abundance is naturally low (Anonymous, 1999b), but in Way Besai more shredders group found in certain place such as in WB2 (35%), WB7 (39%) and WB8 (48%). WB2 and WB7 is around the coffee garden and paddy field. WB2 is close to forest area, may be reveice a large portion of coarse particulate organic matter (CPOM) from terrestrial litter as source of shredder food due to forest clearing. WB7 is an outlet of Air Hitam stream, where is a potential of CPOM accumulation. WB8 is an outlet of Way Petai stream where paddy field is dominant in this area. Paddy field is a potential source of organic material pollution like nitrate. Chemical analysis shown that WB8 has very hight nitrat content (7.5 mg/l). Accumulation of nitrate indicated by abundance of water plant such as *Eichornia crassipes* . Litter or *Eichornia crassipes*. leaves as a source of shredders food.

No shredders occured in WP4 (around paddy fields) and dam where located in open area with 70% lightening, rocky riverbank in WP4 and 100% lightening in dam. Shredders are sensitive to riparian zone impacts and are particularly good for indicator of toxic effects when the toxicants involved are readily absorbed to CPOM (Anonymous, 1999).

Scrappers

The relative abundance of scrapers and collectors is an indication of the periphyton community composition, availability of suspended fine particulate organic material (FPOM). Scrapers increase with increasing diatom abundance (Anonymous, 1999). High scrappers composition in Way Besai occured in the dam (63%), WB4 (56%), WB7 (49%), Spring (45%) and WB3 (45%). Hawkins *et al.* (1982), mentioned that high abundance of scrapers associated with increased light levels. High percentage of lightening come to the stream stimulate of periphyton to grow as a source of food of scrapers. WB4, WB7, Spring and WB3 located in the open area with lightening around 70–100% and dominated by sand and loam substrate.

Collectors

High composition of collectors occured in WR4 (90%), WP5 (77%) and WP4 (68%). These plots are located in between paddy field. Collectors uses FPOM as source of food. Filamentous alga and aquatic mosses can provide FPOM

that is utilized by collectors. Organic enrichment often resposible to overabundace of filamentous alga. Collectors are also sensitive to toxicants bound to fine particles and should be first group to decrease when exposed to steady sources of such bound toxicants (Anonymous, 1999). High composition of collectors may be has relationship with organic matter enrichment occured in the stream due to fertilizer in the paddy field.

Predators

In the stream around the forest (WB1, WP1 and WR1) and coffee garden in Air Hitam stream has higher composition of predators. Predators composition seem affected by substrate. Higher percentage of stones has higher predators (Figure 5). Based on the stream order, indicate that predators compostition decrease gradualy from upstream to downstream.

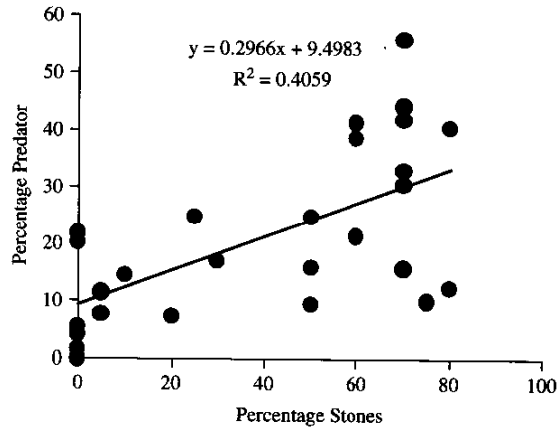

Figure 5. Relationship between percentage stones substrate and predators group in Sumberjaya, Lampung.

Water quality assessment using Family Biotic Index (FBI)

Family Biotic Index (FBI) was developed to detect organic pollution based on the tolerance value of each family, even it is less accurate. Although FBI may be applicable for toxic pollutants, it has only been evaluated for organic pollutants.

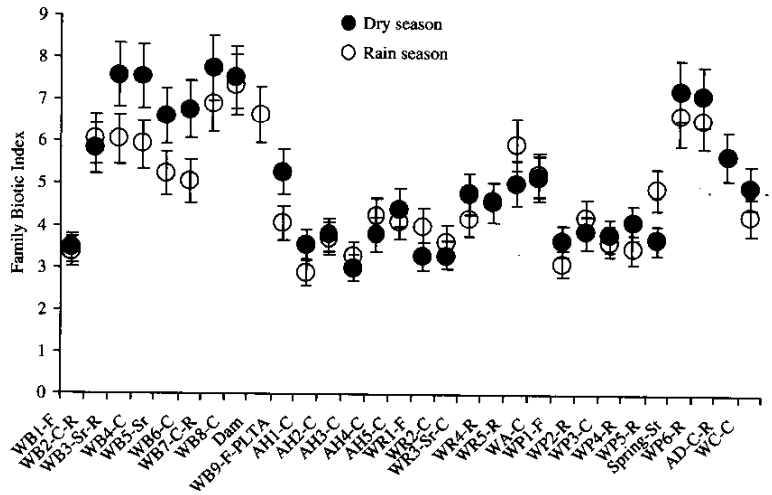

Figure 6. Family Biotic Index in each plot during dry and rain season in Way Besai, Sumberjaya.

In Way Besai, range of FBI value about 2.9 to 7.75 (excellent to very poor categories) as shown in Figure 6. Excellent category occurred in the stream around forest and some of coffee gardens in Air Hitam stream. It is indicate that no organic pollution occurred in the forest. High FBI value occurred in WB7 and WB8 (very poor category).

In both WB7 and WB8 also has higher composition of shredders and indicate there is water plant growing in this area due to organic material accumulation. From two indicators, it is clear that in both areas severe organic pollution have been occurred.

Beside organic pollution occurred in the stream, FBI value also has relationship with substrate of the stream and existence of predators. Higher percentage of stone indicates lower FBI value and it means better water quality (Figure 7). Higher percentage of predator indicates lower FBI value and it means better water quality (Figure 8).

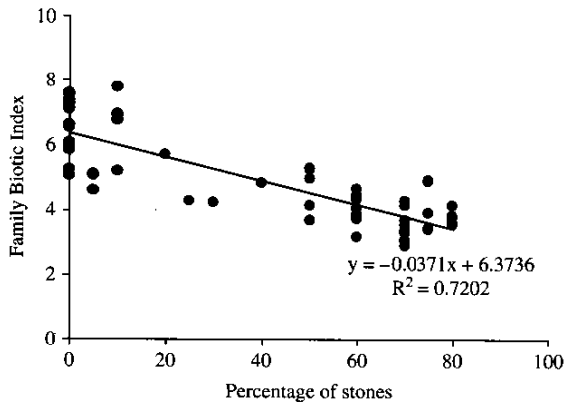

Figure 7. Relationship between percentage of stone in the stream with FBI value in Way Besai Sumberjaya.

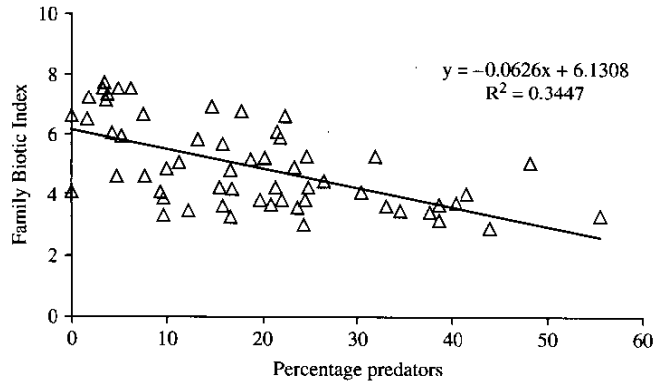

Figure 8. Relationship between percentage of predators group with FBI value in Way Besai, Sumberjaya.

CONCLUSIONS

Stream around the forest has higher number of family and more divers. Similarity analyze indicate that each sampling point along Way Besai is very different composition of family. Chironomidae is the most common in Way Besai and found in 83% of sampling plot. There are 3 families (Cordulegastridae, Hydraenidae and Hydrometridae) only found in forest area.

Functional feeding group composition in Way Besai affected by organic material content in the streams, substrate of stream, vegetation canopy around the stream and stream order. More shredders found in the stream with high organic matter content, more scrapers found in the streams with open area; more collectors found in the stream which dominated by sand and loam substrate and more predators found in the stream which dominated by stones substrate. Predators group decreasing gradually from upstream to downstream.

Based on the Family Biotic Index (FBI), water quality in Way Besai, Sumberjaya categorized from excellet to very poor. Stream around forest area and some coffee garden in Air Hitam stream indicate excellent quality it means organic pollution unlikely. The stream which has high shredders also shown high FBI value, and it in line that organic pollution occured in this area.

REFERENCES

Angermeier, P.L. and Karr, J.R. (1994). Biological integrity versus biological diversity as policy directives. *BioScience*, **44**, 690–697.

Anonymous (1999a). Water Quality Monitoring: Technical Guide Book. The Oregon Plan for Salmon and Watersheds. http://www.oregon.gov/OWEB/docs/pubs/wq_mon_guide.pdf

Anonymous (1999b). Rapid Bioassessment Protocol for Use in Wadable Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Office of Water, US Environmental Protection Agency, Washington DC. http://rpitt.eng.ua.edu/Publications/BooksandReports/Stormwater%20Effects%20Handbook%20by%20%20Burton%20and%20Pitt%20book/appb.pdf

Anonymous (2006). Family Tolerance Value. Soil and Water Conservation Society of Metro Halifax. http://lakes.chebucto.org/Zoobenth/benthos/tolerance.html

Chao, A., Chasdon, R.L., Colwell, R.K. and Shen, T.J. (2005). A new statistical approach for assessing similarity of species composition with incidence and abundace data. *Ecology Letters*, **8**, 148–159.

Ekadinata, A.P. (2002). Deteksi perubahan lahan menggunakan citra satelit multisensor di Sumberjaya, Lampung. Jurusan Managemen Hutan, Fakultas Kehutanan, Institut Pertanian Bogor, Bogor, Indonesia, 56p.

Hawkins, C.P., Murphy, M.L. and Anderson, N.H. (1982). Effects of canopy, substrate composition and gradient on the structure of macroinvertebrates communities in Cascade Range streams in Oregon. *Ecology*, **63**, 1840–1856.

Hilsenhoff, W.L. (1988). Rapid field assessment of organic pollution with a family level biotic Index. *J.M. Am. Benthol. Soc.*, 7(1), 65–68.

Mills, L.S., Soule, M.E. and Doak, D.F. (1993). The keystone-species concept in ecology and conservation. *BioScience*, **43**, 219–224.

Wallace, J.B. and Merritt, R.W. (1980). Filter-feeding ecology of aquatic insects. *Ann. Rev. Entomol.*, **25**, 103–132.

Wallace, J.B and Webster, J.R. (1996). The role of macroinvertebrates in stream ecosystem function. *Annu. Rev. Entomol.*, **41**, 115–139.