THE JOURNAL OF TROPICAL LIFE SCIENCE
VOL. 3, NO. 3, pp.193-201 , Desember, 2013

Application of Water Quality and Ecology Indices of Benthic Macroinvertebrate to Evaluate Water Quality of Tertiary Irrigation in Malang District

Desi Kartikasari[1]*, Catur Retnaningdyah[1], Endang Arisoesilaningsih[1]

[1]Biology Department, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia

ABSTRACT

This research aims to determine the water quality of tertiary irrigation in several subdistricts in Malang, namely Kepanjen, Karangploso, and Tumpang. The water quality depends on the water quality indices (National Sanitation Foundation's-NSF Indices and O'Connor's Indices based on variables TSS, TDS, pH, DO, and Nitrate concentrate) and ecological indices of benthic macroinvertebrate (Diversity Indices Shannon-Wiener, Hilsenhof Biotic Indices-HBI, Average Score per Taxon-ASPT which is calculated by Biological Monitoring Working Party-BMWP, Ephemeroptera Indices, Plecoptera, Trichoptera-EPT). Observation of the physico-chemical water quality and benthic macroinvertebrate on May 2012 to April 2013. The sampling in each subdistrict was done at two selected stations in tertiary irrigation channel with three plot at each station. The data of physico-chemical quality of water were used to calculate the water quality indices, while the benthic macroinvertebrate data were used to calculate the ecological indices. The research findings showed that 27 taxa of benthic macroinvertebrates belong 10 classes were found in the three subdistrict. The pH, DO, Nitrate, TSS and TDS in six tertiary irrigation channels in Malang still met the water quality standards based on Government Regulation No. 82 of 2001 on Management of Water Quality and Water Pollution Control Class III. Based on NSF-WQI indices and O'Connor's Indices, water qualities in these irrigation channels were categorized into medium or moderate (yellow) to good (green) category. However, based on benthic macroinvertebrate communities which was used to determine the HBI, the water quality in the irrigation channels were categorized into the fair category (fairly significant organic pollution) to fairly poor (significant organic pollution), while based on the value of ASPT, the water were categorized into probable moderate pollution to probable severe pollution. The irrigation water which was categorized into good by WQI was consistently included into fair based on HBI and probable moderate pollution based on ASPT.

Keywords: *Ecological index, water quality index, benthic macroinvertebrate, Malang irrigation channel*

INTRODUCTION

Generally, the main source of agricultural irrigation water comes from surface water. The surface water is susceptible to the contamination of many kinds of pollutant from anthropogenic activity. The use of synthetic fertilizer and pesticide by the farmers to increase the food pro ductivity, in fact, causes negative impacts to the environment [1]. The synthetic pesticide residue is one of the toxics in the waters. The impacts of the synthetic pesticide to non-target organism are also highly varied. The application of endosulfan (0,5 kg.ha^{-1}) to the farmland in Indonesia has caused the death of Coleopteran and Tipulidae larva [2, 3].

Irrigation water quality degradation due to pesticide residues will reduce the product efficiency, productivity and carrying capacity of the water resource, which in turn will reduce the natural resource wealth. Estimation of irrigation

*Corresponding author:
Desi Kartikasari
Biology Department, Mathematics and Natural Science Faculty, Brawijaya University, Malang, Indonesia
E-mail: desi.kartikasari88@gmail.com

water quality degradation can be done by looking at the influence of pollutants on aquatic organisms and the living environment. Evaluation of the pollutant can be seen from both physically and biology by approaches of varied water quality indices and ecological indices. Determination of these indices is to simplify the information, so the water quality is enough to present in a single value, and the quality can be compared each other from time to time [4].

Nation Sanitation Foundation Water Quality Index (NSF-WQI) is one of the water quality indices developed since 1970 by Brown, Mc Clelland, Deininger and Tozer. The index has been used by many environmental experts from several countries and proved to be a reliable indices in describing the environment quality. Therefore, NSF-WQI is also referred to as the Environmental Quality Index (EQI) while O'Connor's Index is defined as water quality standards for the utilization of fisheries, aquatic organisms and drinking water [4].

Benthic macroinvertebrates have been used extensively in some countries as a biological indicator to assess the health status and ecological integrity of the waters, because benthic macroinvertebrates system plays an important role in the food chain [5]. Benthic macro-invertebrates are also very sensitive to the environmental changes and characteristics of habitat caused by the presence of human activity, both natural and artificial [6]. Most of the uses of benthic macroinvertebrates as biological indicators are still focused on the deterioration of water quality caused by organic pollution [7]. However, nowadays, this has grown to other pollutions such as heavy metals [8], sedimen-tation [9] and climate change [10]. In several countries, it has been developed many ecological indices for water quality monitoring in addition to the environmental index, such as (Biological Monitoring Working Party-BMWP, Average Score per Taxa-ASPT, Hillsenhof Biotic Index-HBI, Belgian Biotic Index, BBI, Family Biotic Index-FBI, Extended Biotic Index-EBI, EPT% (Ephemeroptera, Plecoptera, Trichoptera) and EPT/Chironomus%. These indices have been used in Turkey to assess the water quality in Cukurca and Isparta River and the results are varied from weak to good [11].

Based on the explanation above, the integration of water quality indices and ecological indices based on the quality of benthic macroinvertebrates community is expected to be more effective as a base for evaluation and reflecting the quality of irrigation water in Malang. Then, the evaluation result is expected to be used as a base for the management of irrigation and providing better water irrigation quality to support the healthy agriculture.

MATERIALS AND METHODS

The research was undertaken by conducting surveys to several tertiary irrigation channels in Kepanjen, Karangploso and Tumpang, located in Malang regency from May 2012 until April 2013 (Figure 1). In those areas, the conditions of the surroundings are different from one another. In Kepanjen irrigation channel, the surrounding is dominated with ricefield and settlements. Karangploso is dominated with lettuce and rice field, while Tumpang is dominated with rice and vegetable field. In those selected subdistricts, sampling was done at two tertiary irrigation channels with three plots repetitions at each observation stations.

Figure 1. Research areas in Malang District, Indonesia

In each plot, benthic macroinvertebrate sampling and measurement of water quality include pH, Dissolved Oxygen (DO), Total Suspended Solid (TSS), Total Dissolved Solid (TDS), and nitrate, were done by using the method by [12]. The benthic macroinvertebrate

sampling was conducted by using Surber Net by putting the frame foot of the net at the opposing directions. The substrate contained in the frame foot was stirred with hand carefully so that benthic organisms attached to rocks or gravel were rinsed, washed away, and collected in Surber Net. Then, the obtained samples were stored, sorted and preserved with formalin 4%. The identification and counting of the benthic macroinvertebrate abundance employed a stereo microscope and identification key by [13, 14, 15, 16].

The obtained data was tabulated by using Microsoft Excel 2007 and analyzed statistically in quantitative descriptive. The data from several variables of water quality was analyzed with Software SPSS 16. The results of measurements of physical-chemical water quality that were used to determine the water quality index are NSF-WQI and O'Connor's Index [4]. The results of identification and counting of the abundance of benthic macroinvertebrate was used to determine several ecological indices, namely Hilsenhof-Biotic Index-HBI, Average Score per taxon-ASPT which was calculated from the Biological Monitoring Working Party-BMWP, Ephemeroptera index, Plecoptera, Trichoptera-EPT [17].

RESULTS AND DISCUSSION

Profile of the Physical-chemical Quality of Water in the Tertiary Irrigation Channels in Malang

The monitoring result of physical-chemical quality of water in six tertiary irrigation channels in Malang regency can be seen in Table 1. All observed variables still met the water quality standards based on Government Regulation No. 82 of 2001 on Management of Water Quality and Water Pollution Control class III (water allocation can be used for bream preservation, livestock, water for irrigating crops, and or other uses that require the same water quality) namely pH 6-9, DO more than 3 mg.L^{-1}, nitrate less than 20 mg.L^{-1}, TSS less than 400 mg.L^{-1}, and TDS less than 1000 mg.L-1. Thus, in general, it can be showed that the quality of the water in those irrigation channels was still good to be used for farmland irrigation

Total Dissolved Solid (TDS) value can reflect the existence of salinity problem or dissolved salt content that will affect structure of the soil and agricultural crops [18]. TDS value 175 mg.L-1 shows very good quality of irrigation water and between 175-525 mg.L-1 indicates good quality that is acceptable for farmland irrigation water [19].

The results of the research conducted by [20] showed that the water conductivity levels in irrigation channels in Malang ranged between 110-279 μS.cm^{-1} or 0.11-0.28 dS.m^{-1}. Hence, it can be concluded that there was no salinity water in irrigation water in Malang. TDS value between 450-2000 mg.L-1 indicates that there was low to moderate salinity problem so that it was recommended to avoid planting plant that was sensitive to salt.

The highest nitrate level was in Karangploso 1 (nitrate 6.70+0.61 mg.L-1) and Tumpang 1 (nitrate 6.64+0.19 mg.L-1). Levels of NO3--N more than 5-30 mg.L-1 indicates slight to moderate degree of restriction on use, while the nitrate concentration less than 5 mg.L-1 has a good quality which may be used for any plant [21]. Thus, it is necessary to do the preparation process, such as remediation of irrigation water. Based on the research by [22], it was shown that planting riparian vegetation along 275 m in the irrigation channel for at least 40 days could improve the water quality from lightly polluted becomes unpolluted and from significantly polluted with organic material into lightly polluted. According to [23], the presence of riparian vegetation plays an important role in aquatic ecosystems: (1) as a trapper sediment particles (usually clay)-biofiltration, (2) for stability of the channel to reducing the risk of erosion, (3) habitat and corridor, (4) balancing the water flow, availability of light, and reducing the extreme temperature in the surrounding environment.

Result of the determination of water quality index (WQI) of the six areas of research through NSF-WQI index measurement and O'Connor's Index (Figure 2) showed that the irrigation channels in Malang can be categorized into medium or moderate (yellow) to good (green). Thus, irrigation channels in Malang can still be

used for the purposes of fisheries, aquatic organisms and even for the drinking water.

Profile of the Benthic Macroinvertebrate in Tertiary Irrigation Channels in Malang

In six tertiary irrigation channels there were 27 taxa of benthic macroinvertebrates belonging to ten classes, namely Dipteran (6 taxa), gastropods (6 taxa), Oligochaeta (4 taxa), Ephemeroptera (3 taxa), Trichoptera (2 taxa), crustaceans (2 taxa), Coleopteran (1 taxa), Odonata (1 taxa), Bivalve (1 taxa) and Hirudinea (1 taxa). This was in line with the research findings of Semwal & Akolkar [18], who reported that the benthic macroinverte-brates found along the irrigation channel in Delhi NCR were

Table 1. Average of Water Quality in Tertiary Irrigation Channels in Malang

Regions	pH	DO (mg.L^{-1})	Nitrat (mg.L^{-1})	TSS (mg.L^{-1})	TDS (mg.L^{-1})
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Kepanjen 1	8.09 ± 0.18^{c}	3.53 ± 0.05^{b}	0.81 ± 0.69^{a}	48.53 ± 8.63^{a}	214.33 ± 8.39^{a}
Kepanjen 2	8.31 ± 0.09^{cd}	4.02 ± 0.21^{c}	0.32 ± 0.12^{a}	78.67 ± 21.49^{a}	185.67 ± 24.85^{ab}
Karangploso 1	8.40 ± 0.06^{de}	3.46 ± 0.07^{ab}	6.70 ± 0.61^{c}	15.11 ± 3.42^{a}	253.33 ± 14.22^{ab}
Karangploso 2	8.60 ± 0.05^{e}	3.16 ± 0.15^{a}	3.35 ± 1.17^{abc}	84.22 ± 41.38^{a}	253.00 ± 39.69^{ab}
Tumpang 1	7.33 ± 0.01^{a}	3.76 ± 0.12^{bc}	6.64 ± 0.19^{c}	20.00 ± 11.62^{a}	274.67 ± 16.92^{ab}
Tumpang 2	7.80 ± 0.03^{b}	5.32 ± 0.10^{d}	4.31 ± 0.54^{b}	136.8 ± 91.96^{a}	283.33 ± 4.04^{b}

Description: The same notation on each variable shows no real difference based on Anova test that followed by Tukey HSD (DO parameter, pH) and Brown Forsythe test, and followed by Games Howell (nitrate concentration, TDS, TSS) at α 0.05

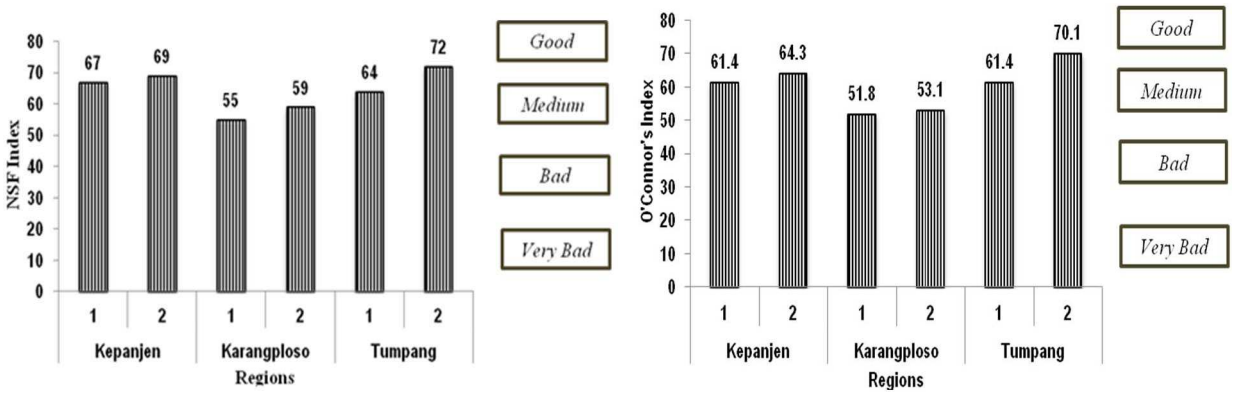

Figure 2. The measurement result of National Sanitation Foundation's (NSF) Index (a) and O'Connor's Index (b) in several tertiary irrigation channels in Malang. Description: 1-2 = stations

the member of the class Mollusca, Oligochaeta, Hirudinea, Ephemeroptera, Trichoptera, Odonata and Crustaceans.

Based on abundance of benthic macroinverte-brates that dominate each station is highly variation (Figure 3). The water in irrigation channel in Kepanjen 1, Karangploso 2, and Tum-pang 1 were dominated by *Melanoides tuberculata*. [24] said that *M. tuberculata* are animals whose presence is abundant, reproduction is by par-thenogenesis, active at night and prefers tempera-tures between 18°-32°C. Snail *M. tuberculata* has operculum that can protect it from drying out so it can survive for days on dry land and at high salinity. [25] also said that operculum on *M. tuberculata* is not only used to protect themselves from dryness but also can increase tolerance to toxic chemicals in the environment. Thus, *M. tuberculata* can be used as bioindicators of an contaminated ecosystem.

The calculation of HBI (table 2) show that the water of irrigation channels in Kepanjen 1, Karangploso 2, and Tumpang 1 (which was dominated by *M. tuberculata*) were categorized in Fairly poor (significant organic pollution). These

three areas also had relatively low value of Shannon -Wiener diversity index (0.7-1.8). High pollution in the waters was due to the impacts of anthropogenic activity, especially application of synthetic fertilizers and pesticides in agriculture. Benthic macroinvertebrate in irrigation channel in Kepanjen 2 was dominated by Hydropschydae, Karangploso 1 by Baetidae and Tumpang 2 was dominated by *M. tuberculata* and Hydropschydae (Figure 3). The result of HBI calculation also showed that all three waters were categorizedinto fair (fairly significant organic pollution) with diversity Shannon-Wiener index values relatively high (2.4-2.8).

Aquatic benthic macroinvertebrate domina-ted by Hydropschydae and Baetidae indicates good water quality. Based on research by [26], who stated that the existence of Hydropschydae can be used as an indicator of good water quality. This was proven by the high survival and distribution of larval Hydropschydae in Rhine River which had better water quality than in Meuse River which had low concentrations of dissolved oxygen (1.7 mg.L^{-1}), high ammonium concentrations (4.1 mg.L-1), and fluoride (1.3 mg.L^{-1}).

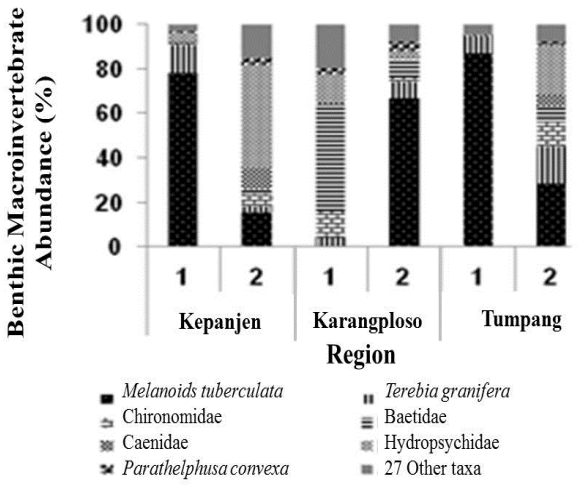

Figure 3. Abundance of macroinvertebrate bethic found in tertiary irrigation channels in Malang
Description: 1-2 = stations

Larval Hydropsychidae were reported very sensitive to heavy metals pollution indicated by disturbance of the respiratory system by morphological changes in the larval gill. The gill to be was blackening and reducted, when exposed to heavy metals such as cadmium and aluminum [27]. Baetidae is a family of the order Ephemeroptera. Order Ephemeroptera, Plecoptera and Trichoptera (EPT) are sensitive taxa to contaminants such as metals and insecticides. The EPT taxa usually in clean water with high DO [28].

Water quality criteria can be determined by benthic macroinvertebrate diversity index. The result of Shannon-Wiener diversity index calculation in six stations ranged from 0.7-2.8 (Figure 4). Based on index diversity criteria from Shannon-Wiener, water in Kepanjen irrigation channel 2 (H'=2.6), Karangploso 1 (H'=2.4), and Tumpang 2 (H'= 2.8) were categorized into uncontaminated. While water in Karangploso 2 irrigation channel (H'=1.8) was categorized into light polluted, water in Kepanjen 1 irrigation channel (H'=1.2) was included into moderate contaminated, while water in Tumpang 1 irrigation channel (H'=0.7) was categorized into heavily polluted.

The highest value of Shannon-Wiener diversity Index was found in irrigation channel in Tumpang 2 (H'= 2.8). Flow of the Water in this agricultural irrigation channel is 0.7 m.detik^{-1} (swift) and abundant riparian vegetation along this irrigation channel. According [29] riparian vegetation food provided supply for largely macroinvertebrate benthic organic eater and a safe place to receive a lot of input of organic matter (allochtonous). Riparian vegetation also has several significant benefits, such as provider of energy sources, provider of debris wood supply, provider of shade, provider of habitat for various fauna, ground protector from erosion, and as filter of sediment, phosphorus and nitrogen, so that the water quality is protected [30].

Order Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa are very sensitive against pollutants [17]. Highly EPT index values indicate the increasing water quality. Based on the EPT index calculations in three research areas (Figure 5), it was found that water in Karangploso 2 and Tumpang 2 irrigation channel showed the best quality, while the quality of irrigation water in Kepanjen 1 was low. Moreover, the other regions were in the moderate category. The presence of EPT taxa groups which are not tolerant of poor

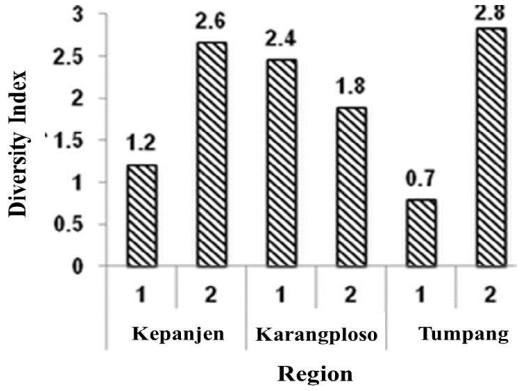

Figure 4. Shannon-Wiener diversity index macro-invertebrate bethic tertiary irrigation channels in Malang.
Description: 1-2 = stations

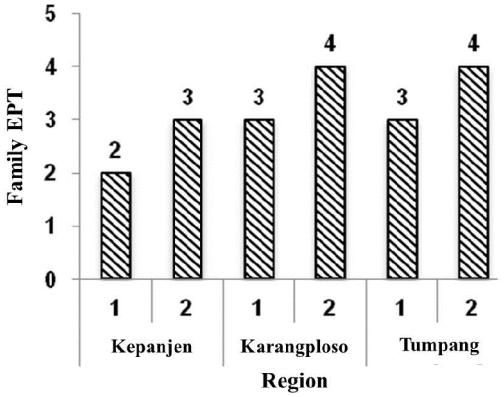

Figure 5. Index Ephemeroptera, Plecoptera, Trichoptera EPT) macroinvertebrate bethic found in tertiary irrigation channels in Malang
Description: 1-2 = stations

Table 2. Water Pollution of Tertiary Irrigation Channels in Malang based on the Value of Biotic Index (HBI and ASPT) Macroinvertebrate Benthic

Regions	Stations	HBI	Values Categories	ASPT	Values Categories
Kepanjen	1	6.87	Fairly poor	3.60	Probable severe pollution
	2	5.65	Fair	3.33	Probable severe pollution
Karangploso	1	5.59	Fair	3.80	Probable severe pollution
	2	6.66	Fairly poor	4.50	Probable moderate pollution
Tumpang	1	6.93	Fairly poor	4.40	Probable moderate pollution
	2	6.35	Fair	4.43	Probable moderate pollution

water quality is an indication that the physical condition of the waters is still good [31].

Besides can be seen from the diversity index and EPT index, the water quality which is based on the benthic macroinvertebrate community structure can also be seen from the Hilsenhof Biotic Index (HBI) and Average Score per taxon (ASPT) calculation which is calculated from the Biological Monitoring Working Party (BMWP).

The results of HBI and ASPT index of the six waters in Malang irrigation channels (Table 2). Based on HBI value, the water quality in tertiary irrigation channels in Malang were categorized in fair (fairly significant organic pollution) to fairly poor (significant organic pollution). Based on ASPT value, the channels were included in the category of probable moderate pollution to probable severe pollution. Therefore, though, based on NSF and O'Connor's Index, the water quality in all irrigation channels were medium to good, however based on HBI and ASPT Index, only water in Tumpang 2 irrigation channel that were categorized to good and consistently categorized into fair or probable moderate pollution. The water quality measurement by point sampling might not really represent water quality fluctuation. Therefore, the ecological index which determined by benthic macro-invertebrate. Community that living in water is more suitable. Some reports indicated that ecology indices such as BMWP, ASPT, FBI and SI for assessment of water quality of rivers based on benthic macroinvertebrate could reflect the condition of the waters [32, 33, 34].

Based on Kalyoncu & Zeybek [11] diversity measures were useful method for describing community structure, but it was not for determing the pollution level of water bodies. The same author maintains that ecological indices must be limited to environments polluted by easily degradable organic matter (sewage) and not by other types of pollutants. Benthic macro-invertebrate species are differentially sensitive to many biotic and abiotic factors in their

environment. Consequently, macro invertebrate community structure has commonly been used as an indicator of the condition of an aquatic system [35, 36].

[37] reported that diversity indices are good for indicating physical and toxic pollution which stress most species in a community without encouraging replacement species. He warns that high diversity does indicate good quality water but low diversity may not necessarily indicate low quality. According to our results, low diversity expresses low quality and high diversity expresses good quality. The ecological index and score systems are better for assessing organic pollution and eutrophication but inappropriate for assessing toxic and physical pollution. Therefore, to obtain a fair overall assessment of the quality water, both methods is important and need to be combined with other alternative methods to evaluating biota response [38].

CONCLUSIONS

The pH, DO, Nitrate, TSS and TDS in six waters of tertiary irrigation channels in Malang still met the water quality standards based on Indonesian Government Regulation No. 82 of 2001 on Management of Water Quality and Water Pollution Control Class III. More one based on NSF-WQI index and O'Connor's Index, water of irrigation channels were categoryzed medium or moderate (yellow) to good (green). Based on the benthic macroinvertebrate communities, the water quality water in irrigation channels were categorized in the fair (fairly significant organic pollution) to fairly poor (significant organic pollution). While based on the value of ASPT, the channels were included into probable moderate pollution to probable severe pollution category. Based on all indices, the water quality of Tumpang 2 irrigation channel was consistently categorized into good, fair, and probable moderate pollution.

ACKNOWLEDGMENT

Deepest gratitude is addressed to Dr. Catur Retnaningdyah M.Si and Dr. Endang Arisoesilaningsih for funding this research from PHBI competitive research fund (Penelitian Hibah Bersaing Institusi) Batch 1 Brawijaya University. Thanks are also to Purnomo S.Si, the Staff of Ecology and Animal Diversity Laboratory for helping sampling and providing tools, and other research teams, especially Budiman M.Si, Chatarina Gradict Semiun M.Si, Hamdani Dwi Prasetyo, Khairunnas Ivansyah, Leni Agustina and Zidny Furaidah.

REFERENCES

1. Daam MA, Rink PVJ (2010) Implications of differences between temperate and tropical freshwater ecosystems for the ecological risk assessment of pesticides. Ecotoxicology. 19: 24-37.
2. Gorbach S, Haaring R, Knauf W, Werner HJ (1971) Residue analyses and biotests in ricefields of East Java treated with thiodan. Bulletin of Environmental Contamination and Toxicology. 6: 163-199.
3. Simpson IC, Roger PA (2002) The Impact of Pesticides on Nontarget Aquatic Invertebrates In Wetland Ricefields. Enviromental Toxicology and Chemistry. Rev 9: 1147-1154.
4. Ott WR (1978) Environmental Indices Theory and Practice. Ann Arbor Scin. Publ. Inc. Ann Arbor. Mich. Washington, DC.
5. Arimoro FO & Ikomi RB (2008) Ecological integrity of upper Warri River, Niger Delta using aquatic insects as bioindicators. Ecological Indicators. 9(3): 455-461.
6. Kratzer EB, Jackson JK, Arscott DB, Aufdenkampe AK, Dow CL, Kaplan LA, Newbold JD, Sweeney BW (2006) Macroinvertebrate distribution in relation to land use and water chemistry in New York City drinking water supply watersheds. Journal of the North American Benthological Society. 25(4): 954-976.
7. Chakona A, Phiri C, Day JA (2009) Potensial for Trichoptera communities as biological indicators of morphological degradation in riverine system. Hydrobiologia. 621: 155-167.
8. Kiffney PM & Clements WH (1994) Effects of heavy metals on a macroinvertebrate assemblage from a Rocky Mountain stream in experimental microcosms. Journal of the North American Benthological Society. 13(4): 511-523.
9. Kaller MD & Hartman KJ (2004) Evidence of a threshold level of fine sediment accumulation for altering benthic macroinvertebrate. Hydrobiologia. 518: 95-104.
10. Hering D, Schmidt-Kloiber A, Murphy J, Lucke S, Zamora-Munoz C, Lopez-Rodriguez MJ, Huber T, Graf W (2009) Potential impact of climate change on aquatic insects: A sensitivity analysis for European caddisflies (Trichoptera) based on distribution patterns and ecological

preferences. Aquatic Sciences Research across Boundaries. 71(1): 3-14.
11. Kalyoncu H & Zeybek M (2011) An application of different biotic and diversity indices for assessing water quality: A case study in Rivers Cukurca and Isparta (Turkey). African Journal of Agricultural Research. 6(1): 19-27.
12. Clesceri LS, Greenberg AE, Eaton AD (1998) Standart Methods for the Examination of Water and Waste Water. 20th Ed, Washington.
13. Jutting WSS (1956) Critical Revision of the Javanese Freshwater Gastropods. Treubia. 23: 259-47.
14. Edmondson WT (1959) Freshwater Biology. Second Ed. John Wiley and Sons Inc. New York.
15. Quigley M (1977) Invertebrates of Streams and Rivers. A Key to Identification. Edward Arnold Publ. Ltd. London.
16. Ristiyanti M, Marwoto, Isnaningsih NR, Mujiono N, Heryanto, Alfiah, Riena (2011) Keong Air Tawar Pulau Jawa (Moluska, Gatropoda). Pusat Penelitian Biologi-LIPI. Jakarta.
17. Mandaville SM (2002) Benthic Macroinvertebrates in Freshwaters Taxa Tolerance Values, Metrics, and Protocols. (Project H-1) Soil & Water Conservation Society of Metro Halifax. New York.
18. Semwal N & Alkolkar P (2011) Suitability of Irrigation Water Quality of Canals In NCR Delhi. International Journal of Basic and Applied Chemical Sciences. 1(1): 60-69.
19. Sakthivel R (2007) TDS levels for traditional crops and TDS resistant crops India. International Journal of Environmental Sciences. 2(2): 572-580.
20. Retnaningdyah C & Arisoesilaningsih E (2012) Laporan Hasil Penelitian: Analisis kesesuaian indeks ekologis untuk kelayakan kualitas air irigasi di daerah Malang Raya. Universitas Brawijaya. Malang.
21. Ayers RS & Westcot DW (1994) Water Quality for Agriculture. FAO Irrigation And Drainage Paper 29 Rev. 1 Rome. The Scientific World Journal. 22(1): 1-10.
22. Retnaningdyah C & Arisoesilaningsih E (2013) Ecological Significance of Irrigation Channel Riparian to Improve Benthic Macroinvertebrates Diversity. ORAL presentation in 4th International Conference on Global Resource Conservation (ICGRC) and 10th Congress of Indonesian Society for Plant Taxonomy (ISPT) 7-8 February, 2013 at Widyaloka Convention Hall, Brawijaya University.
23. Oates J & Oswald H (2000) The values of the riparian zone. Water and Rivers Commission Restoration Report No. RR7. Perth.
24. Othman MS, Amalina R, Nadzifah Y (2012) Toxicity of Metals to a Freshwaters Snail, Melanoides tuberculata. The Scientific World Journal. 22(1): 1-10.
25. Mitchell AJ, Hobbs MS, Brandt TM (2007) The effect of chemical treatments on red-rim Melanoides tuberculata, an exotic aquatic snail that serves as a vector of trematodes to fish and other species in the USA. North American Journal of Fisheries Management. 27(4): 1287-1293.
26. Stuijfzand SC, Engels S, Ammelrooy EV, Jonker M (1999) Caddisflies (Trichoptera: Hydropsychidae) used for evaluating water quality of large european rivers. Archieves Environmental Contamination Toxicology. 36: 186-192.
27. Sudarso Y (2009) Potensi Larva Trichoptera Sebagai Bioindikator Akuatik. Oseanologi dan Limnologi di Indonesia. 35(2): 201-215.
28. Cavallaro KOR, Spies MR, Siegloch AE (2010) Ephemeroptera, Plecoptera, Trichoptera assemblages in Miranda River basin, Mato Grosso do Sul State, Brazil. Biota Neotropica. 10(2): 253-260.
29. Mahajoeno E, Efendi M, Ardiansyah (2001) Keanekaragaman Larva Insekta pada Sungai-sungai Kecil di Hutan Jobolarangan. Biodiversitas. 2(2): 133-139.
30. Richardson D, Holmes PM, Esler KJ, Galatowitsch SM, Stromberg JC, Kirkman SP, Pysek P, Hobbs PJ (2007) Riparian vegetation: degradation, alien plant invasions, and restoration prospects. Diversity and Distributions. 13: 126-139.
31. Dudgeon D (1994) Endangered ecosystem: a review of threats to tropical Asian running water. Hydrobiologia. 248: 167-191.
32. Duran M (2006) Monitoring water quality using benthic macroinvertebrates and physicochemical parameters of the Behzat Stream (Tokat, Turkey). Polish Journal Environment Studies. 15(5): 709-717.
33. Kazancı N, Dugel M, Girgin S (2008) Determination of indicator genera of benthic macroinvertebrate communities in running waters in western Turkey. Hydrobiologia. 1(1): 1-16.
34. Kalyoncu H, Akyildirim GH, Yorulmaz B (2009) The Comparison of the Diversity and Biotic Indices with Physical-Chemical Analyses Applied to Macroinvertebrate Community to Determine the Water Quality. International Conference On Lakes and Nutrient Loads-Pocrades, 24-26 April 2009 at Agricultural University of Tirana, Albania.
35. Friberg N, Sandin L, Furse MT, Larsen ES, Clarke RT (2006) Comparison of macroinvertebrate sampling methods in Europe Hydrobiologia. 566: 365-378.

36. Ortiz JD & Puig MA (2007) Poind source effects on density, biomass and diversity of bentic macroinvertebrates in a mediterrian stream. River Research Applications. 23: 155-170.
37. Hawkes HA (1978) Invertebrate indicators of river water quality. Proceeding of Symposium on Biological Indicators of Water Quality, University of Newcastle upon Tyne. 1(2): 12-45.
38. Hewitt G (1991) River quality investications, Part 1: Some Diversity and Biotic indices. Journal Biology Education. 25(1): 44-49.