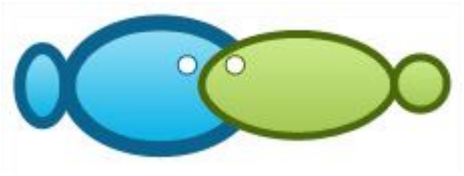

A comparative study on macroinvertebrates community in three rivers of Jawa Island, Indonesia

[1]Majariana Krisanti, [2]Luk Luk I. Maknuun, [3]Yunita M. Anzani, [4,5]Arief S. Yuwono, [6]Rahayu Widyastuti, [1,7,8]Yusli Wardiatno, [9]Dewi Wulandari

[1] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia; [2] Master Program in Aquatic Resources Management, Graduate School, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia; [3] Department of Aquatic Resources Management, Faculty of Agriculture, University of Tanjungpura, Pontianak, West Kalimantan, Indonesia; [4] Department of Civil and Environmental Engineering, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia; [5] SEAMEO BIOTROP, Jalan Raya Tajur, Bogor Selatan, Kota Bogor 16134, Indonesia; [6] Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia; [7] Environmental Research Center, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia; [8] Center for Coastal and Marine Resources Studies, IPB University, Kampus IPB Baranangsiang, Bogor 16143, Indonesia; [9] Department of Environmental Engineering, Indonesian Islamic University, Yogyakarta, Indonesia. Corresponding author: Y. Wardiatno, yusli@ipb.ac.id

Abstract. Macroinvertebrates are often used for monitoring water quality of rivers. The presence of macroinvertebrates in river ecosystems is influenced by physical, chemical and natural conditions. The aim of this study was to compare the macroinvertebrates community in three rivers of Jawa Island, Indonesia. The abundance, composition and taxa richness of macroinvertebrates community in Brantas River (the largest river in East Java) and Opak-Progo Rivers (two large rivers in Special Region of Yogyakarta) were described for comparison. The macroinvertebrate communities were sampled using surber at ten stations in Brantas River, six stations in Opak River and four stations in Progo River. One-way ANOVA tests revealed significant differences in temperature, pH, dissolved oxygen (DO) and current velocity ($p < 0.05$) among rivers but, it was not in case of chemical oxygen demand (COD). Based on Post Hoc test using LSD, Brantas River had significantly different environmental parameters compared to the other two rivers. Brantas River showed a rich and diverse macroinvertebrate fauna comprising 45 genera of 29 families and 11 orders. While in Opak River 39 genera of 21 families and 7 orders were found, and in Progo River 55 genera of 29 families and 10 orders were obtained. Of the three rivers, Brantas River showed the highest abundance of macroinvertebrates. The number of taxa richness among three rivers was not significantly different. The differences in environmental parameters seemed to be the factors causing the difference in composition, abundance and taxa richness of macroinvertebrates of these three rivers.

Key Words: benthos, Brantas River, environmental parameter, stream ecosystem, Yogyakarta.

Introduction. Macroinvertebrates are invertebrates that have size more than 0.5 mm and enough to be seen with eyes directly (Jacobsen et al 2008). Macroinvertebrates are one of the best biological indicators for stream health (Sudarso & Wardiatno 2015; Agouridis et al 2015) in addition to chemical analysis use (Effendi et al 2015). In some countries their presence has been widely used to monitor the ecological status of rivers (Li et al 2010), man-made lakes (Sudarso et al 2008) or coastal waters (Sahidin et al 2014; Wardiatno et al 2017). It is often used in river monitoring system since their most life cycles settled in the bottom substrates such as sediment, rocks, snags and aquatic

plants in the ecosystem (Sengupta & Dalwani 2008). They have relatively long life span (Uherek & Gouveia 2014), i.e. a few months to a year or more (Selvanayagam & Abril 2016). Furthermore, macroinvertebrates also have many species at different trophic levels (Cook 1976) and are relatively sensitive to various kinds of pollutants and pressures such as organic pollutants, heavy metals, hydromorphological degradation, enrichment of nutrients, acidification and other general pressures (Purwati 2015; Sudarso & Wardiatno 2015). They can be found in almost every water body, even rivers and ponds that dry from time to time (Chessman 2003). Macroinvertebrates are difficult to be found only in the most extreme and harsh conditions such as when stream system losses current velocity due to long drought period (Hauer & Resh 2017).

Macroinvertebrates are very sensitive with changes of water quality (Rahayu et al 2009) and generally have limited mobility, so they are hardly to escape from pollution events (Varnosfaderany et al 2010). They will show a high diversity in good water quality and in optimum conditions. In contrast, the diversity is low when the water quality is bad. This common phenomenon is caused by the ability of few species only to tolerate low water quality. In that case, the tolerant species will have large number of individuals in the community (Lyons 2006). The other advantage of using macroinvertebrates for monitoring stream health is that macroinvertebrates are relatively easy to collect and to identify (Tjokrokusumo 2006; Sudarso & Wardiatno 2015).

The presence of macroinvertebrates in rivers is affected by physicochemical factors such as temperature (Li et al 2012; Eady et al 2013), substrate composition (Duan et al 2008; Yunitawati et al 2012; Nakin et al 2017), current velocity (Schoen et al 2013; Everaert et al 2014), pH (Shimabukuro & Henry 2011; Linares et al 2013), dissolved oxygen (Connolly et al 2004; Vandra et al 2016) and organic matter (Musthofa et al 2014; Putri et al 2016). Whereas their taxonomic composition is influenced by substrate type, riparian zone (such as canopy cover) and catchment land use around river banks (Collier 1995; Jonsson et al 2017). Some studies also showed different composition of macroinvertebrates in different elevation and stream size (Jacobsen 2003; Jiang et al 2010).

Brantas River is the longest river in East Java which has catchment area about 14,103 km^2 and length about 320 km. The area of the Brantas River covers 25% of the area of East Java Province through the volcano and mountains resulting a variety of topographical conditions starting from mountain, hilly, valley, and flat. Whilst Opak and Progo Rivers are two large rivers in Special Region of Yogyakarta which has catchment area about 1,376.34 km^2 and 2,421 km^2 with length about 171.75 km and 138 km, respectively. The topographic conditions in Opak and Progo Rivers generally consist of mountains, hills and lowlands. The milieu difference between these two river systems will affect to the composition of the macroinvertebrates community. Accordingly, this study was aimed to describe the macroinvertebrates community in these three river systems that located in two different provinces in Jawa Island, Indonesia. The composition, abundance and taxa richness of macroinvertebrate communities are compared.

Material and Method

Description of the study site. Samples were collected at 10 sampling sites in Brantas River, 6 sampling sites in Opak River, and 4 sampling sites in Progo River (Figure 1). Determination of sampling stations was based on altitude, canopy coverage and land use. Sample collection in the Brantas River was carried out starting from the upstream of the river with altitude of 1,268 to 430 m, meanwhile in the Opak River was carried out starting from the upstream of the river with altitude of 873 to 95 m, and in Progo River from upstream with altitude of 444 to 126 m. Sample collection in Brantas River was conducted on 23 and 24 April 2018, while in Opak-Progo Rivers on 14, 15 and 16 May 2018.

Sampling methods. The physicochemical parameters, i.e. temperature, pH, dissolved oxygen (DO), and chemical oxygen demand (COD) were measured. Measurements of temperature, pH and DO were recorded *in situ*, while the COD was carried out *ex situ*

following American Public Health Association protocols (APHA 2012) in Laboratory of Aquatic Productivity and Environment, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University. Macroinvertebrates were collected by surber net (30 cm × 30 cm, 1 mm mesh) that placed in front of the direction of flow. The substrate in the frame was disturbed in five minutes to wash macroinvertebrate away from substrate and enter into the net. The collected macroinvertebrates were removed from the net and put into sample container, and were then preserved using alcohol (70%) and rose Bengal. In laboratory the samples were sorted and identified to genus level following McCafferty (1983), Merritt & Cummins (1996), Pescador et al (2000), Richardson (2003), and Pescador & Richard (2004).

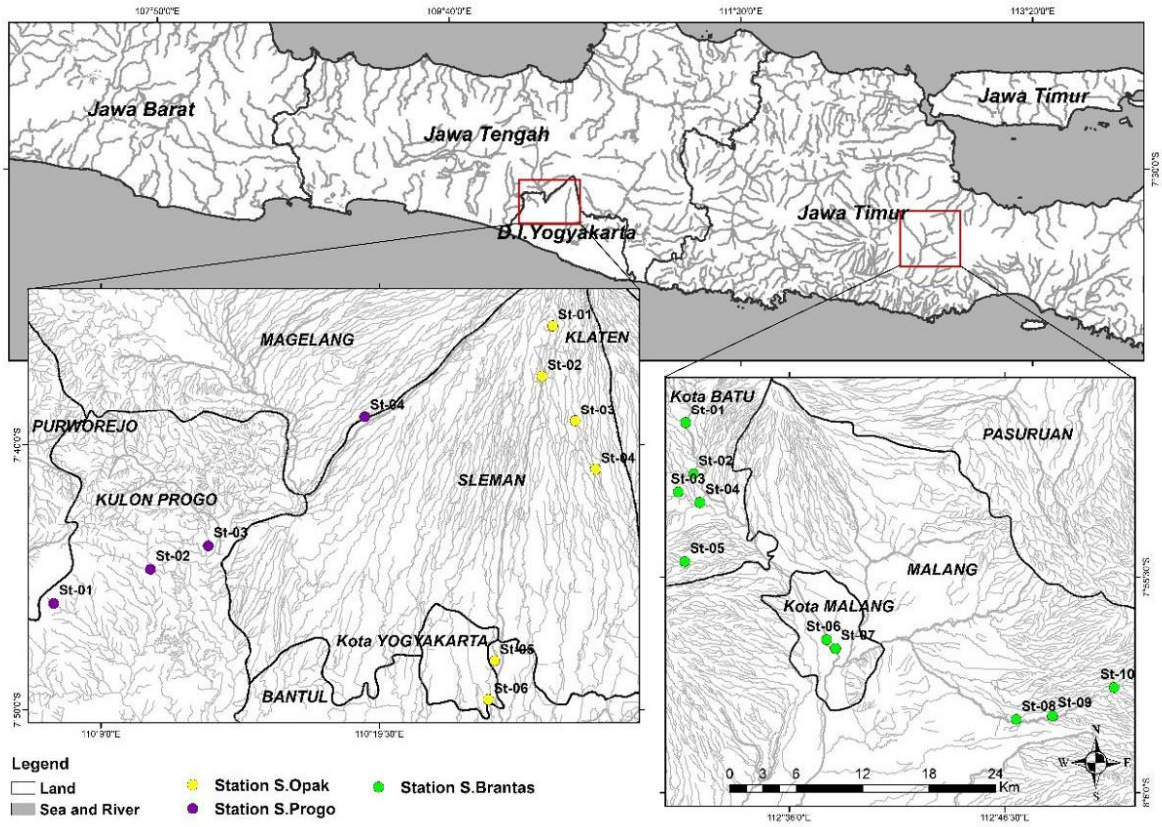

Figure 1. Maps of Opak-Progo Rivers (left) in Special Region of Yogyakarta and Brantas River (right) in East Java. Color circles indicate sampling stations.

Data analysis. The density of macroinvertebrate was calculated according to Brower et al (1990). One-way ANOVA test followed by Post Hoc test using LSD was used to compare biological and environmental data among the three rivers. The relationship between environmental parameters and macroinvertebrates was analyzed descriptively using principal component analysis (PCA).

Results

Abundance, composition and taxa richness of macroinvertebrate. A number of 1,342 individuals of macroinvertebrates was found in Brantas River belonging to 45 genera in 29 families and 11 orders from 10 sites. As for Opak River, a total of 661 individuals macroinvertebrates were collected from 6 sites, comprising 39 genera 21 families in 7 orders, and in Progo River, a total of 516 individuals of macroinvertebrates consisting of 55 genera in 29 families and 10 orders were obtained. The mean abundance of macroinvertebrates in Brantas River (1,491 ind m^{-2}) was higher compared to Opak River (1,224 ind m^{-2}) and Progo Rivers (1,433 ind m^{-2}) (Figure 2).

In terms of abundance the major macroinvertebrate orders in almost all sampling sites were Ephemeroptera, Trichoptera and Diptera with different composition (Figures 3, 4 and 5). In Brantas River Order Diptera dominated as much as 52% of total individual number followed by Ephemeroptera (24.3%) and Trichoptera (20%) (Figure 3). While in Opak River (Figure 4) and Progo River (Figure 5), the first dominant order was Ephemeroptera (47%) and (36.6%), following by Trichoptera (33.9% and 30.6%) and Diptera (12.6% and 21.12%). In general these three orders were the dominant orders of the community in the three rivers. Other orders were also present in the three rivers, such as Coleoptera, Lepidoptera and Plecoptera. There were orders that were exclusively found only in one river such as Arachnida, Amphipoda, Neuroptera and Oligochaeta in Brantas River, and Decapoda in Progo River.

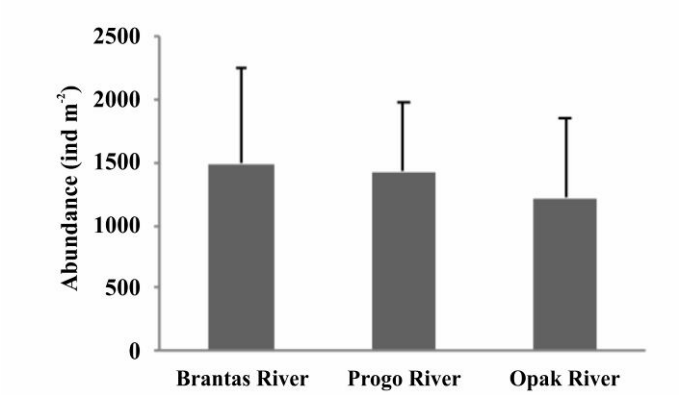

Figure 2. Mean abundance of macroinvertebrates (ind m^{-2}) of the three rivers in Jawa Island, Indonesia.

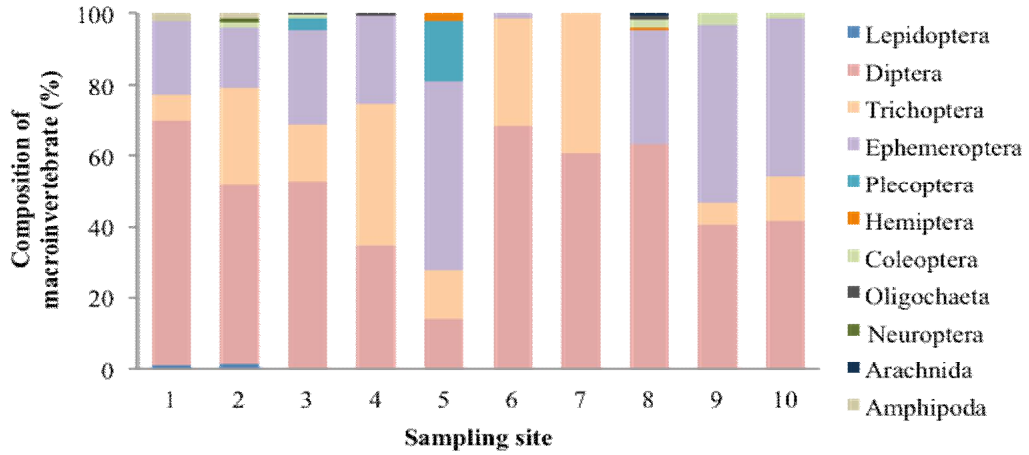

Figure 3. Order composition of macroinvertebrates in Brantas River, Jawa Island, Indonesia.

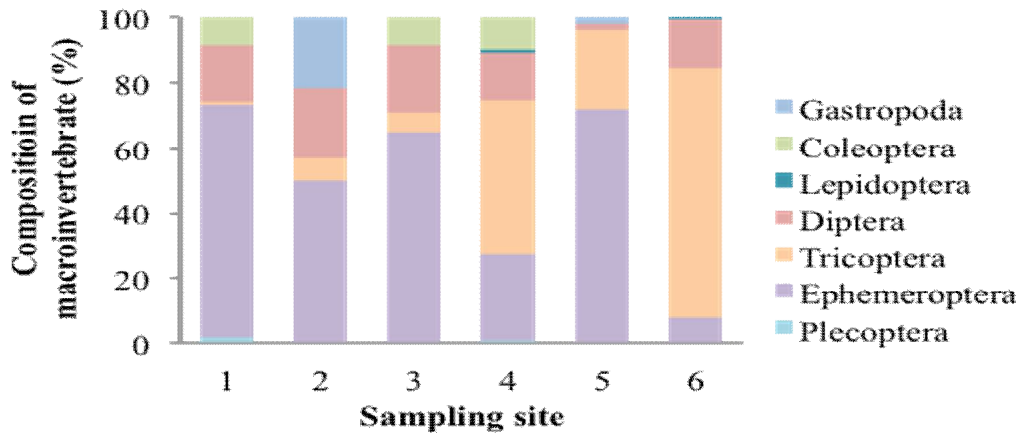

Figure 4. Order composition of macroinvertebrates in Opak River, Jawa Island, Indonesia.

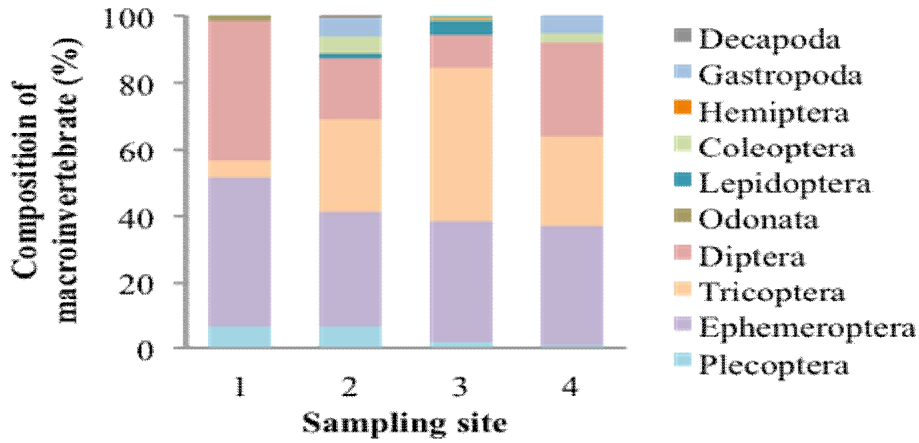

Figure 5. Order composition of macroinvertebrates in Progo River, Jawa Island, Indonesia.

In terms of family, 29, 21 and 29 families were found in Brantas, Opak and Progo rivers respectively (Figure 6). Eight families could be obtained in all of rivers. Fourteen families were only present in two rivers. Twenty seven families exclusive occurred in one river, with thirteen of these only in Brantas River, ten in Opak River, and four in Progo River.

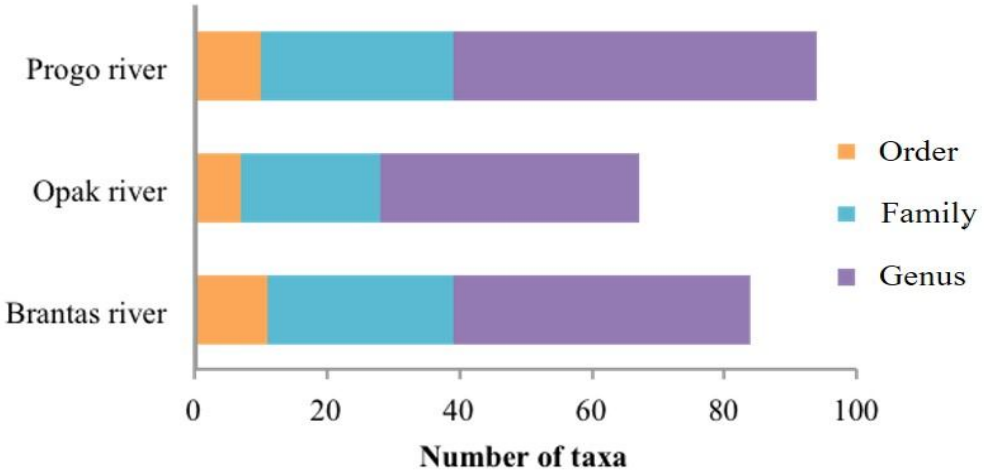

Figure 6. Taxa richness of the three rivers in Jawa island, Indonesia according to order, family and genus.

A total of 132 taxa were collected with six of them were spread across in all rivers. Nineteen taxa were shared by two of rivers. Then, sixty-nine taxa were exclusive, with thirty-two taxa only in Brantas River, fifteen taxa only in Opak River and twenty-two only in Progo River. As for taxa richness in Brantas, Opak and Progo Rivers were collected as much as 45, 39 and 55 taxa respectively. There were found a range of taxa about 1 to 9 taxa/family in the Brantas River, around 1 to 10 taxa/family in Opak River, about 1 to 13 taxa/family in Progo River. Chironomidae was the most dominant family of order Diptera in Brantas River with 9 taxa. A total of 559 individual of Chironomidae were collected, and it was 41.65% of collected individuals. While Opak River was dominated by Hydropsychidae with 33.89% of collected individuals, followed by family Baetidae (33.13%). In Progo River the two dominant families were Hydropsychidae and Leptophlebiidae with 29.46% and 24.4% of total individuals, respectively.

Environmental parameters. Variation in environmental parameters were noted in the three rivers. From ten sampling sites in Brantas River, six of them had canopy cover around 10 to 100%. It was greater than those in Opak and Progo Rivers. Four of six sampling sites in Opak River had canopy cover 10-75%, while Progo River only had one of four sampling sites with canopy cover around 85%. As for anthropogenic activities

around river, there were similarities among the three rivers such as forestry, agriculture, plantation, sand mining, tourism, residential areas and others. Physicochemical factors of Brantas, Opak and Progo Rivers were significantly different in temperature, pH, DO and current velocity ($p < 0.05$), but not for COD (Table 1). Based on Post Hoc test using LSD (Least Significant Differences), Brantas River had significantly different environmental parameters compared to the other two rivers.

Table 1

Mean±SE (minimum and maximum value in parentheses) of the physicochemical parameters in Brantas, Opak and Progo Rivers – Jawa Island, Indonesia

Parameter	*Brantas River**	*Opak River*	*Progo River*	*p-value*
Altitude (masl)	909.9±297.33 (430-1268)	377.33±284.28 (95-873)	266±132.99 (126-444)	0.000*
Temperature (^oC)	22.74±2.81 (18.2-26.9)	28.55±2.12 (25.2-31.6)	26.3±4.23 (20.7-30.9)	0.007*
pH	7.39±0.59 (6.36-8.04)	6.49±0.29 (6.1-6.8)	6.41±0.66 (5.45-6.96)	0.003*
DO (mg L^{-1})	7.52±0.81 (5.8-8.4)	6.15±0.63 (5.1-6.8)	5.98±0.44 (5.5-6.4)	0.001*
COD (mg L^{-1})	67.93±4.13 (62.61-75.92)	66.04±4.45 (61.75-74.2)	67.76±2.74 (65.18-70.34)	0.806^{ns}
Current velocity (m s^{-1})	0.96±0.29 (0.5-1.4)	0.42±0.19 (0.04-0.55)	0.45±0.26 (0.15-0.75)	0.001*

*Significantly different (one-way ANOVA test at $p = 0.05$); masl = meter above sea level.

Relationships between environmental parameters and macroinvertebrate community. Plot diagram results from PCA showing the relationships between environmental condition and macroinvertebrate community are shown in Figures 7-9. The results of PCA show that there were 67%, 75% and 94% of total variable that explained by first two component (factors) in Brantas, Opak and Progo Rivers, respectively. The relationship between taxa richness of macroinvertebrate community and environmental parameters in the three rivers were different. Taxa richness of macroinvertebrate in Brantas River was seemed to be affected by canopy cover and altitude (Figure 7). Whereas in Opak River, taxa richness was closely related to COD, DO and canopy cover (Figure 8). Yet, in Progo River none of environmental parameters could be detected to be the factor affecting taxa richness (Figure 9).

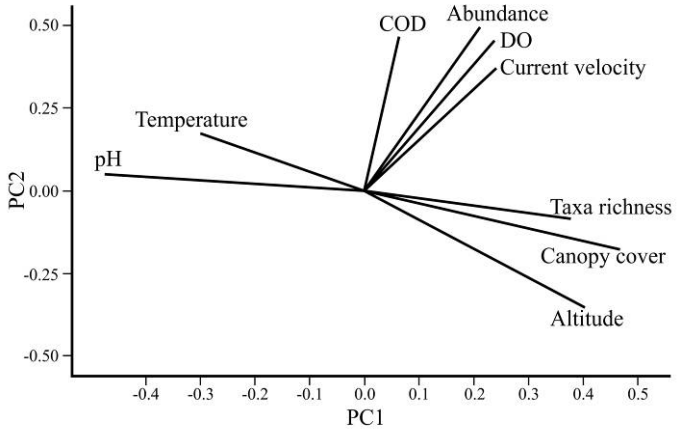

Figure 7. Plot diagram of Principal Component Analysis to show relationships between environmental parameters with macroinvertebrates in Brantas River, Jawa Island, Indonesia.

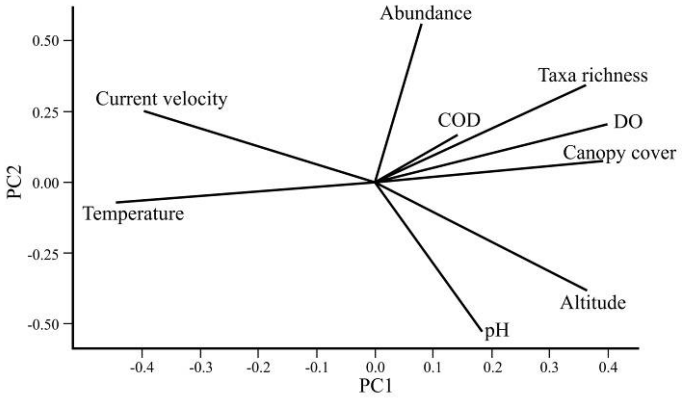

Figure 8. Plot diagram of Principal Component Analysis to show relationships between environmental parameters with macroinvertebrates in Opak River, Jawa Island, Indonesia.

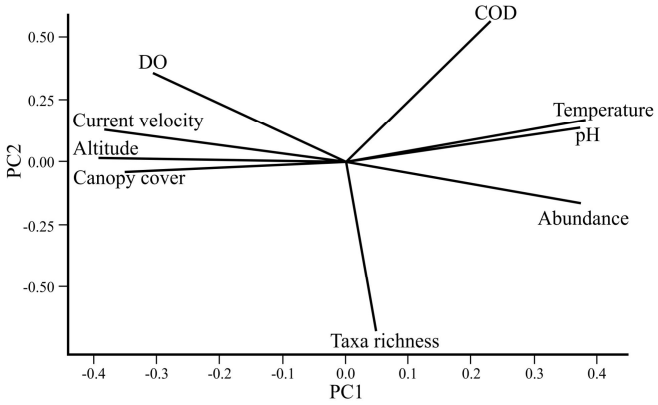

Figure 9. Plot diagram of Principal Component Analysis to show relationships between environmental parameters with macroinvertebrates in Progo River, Jawa Island, Indonesia.

Discussion. As mentioned above the physicochemical parameters between Brantas, Opak and Progo Rivers were significantly different, except for COD. The significant differences in these parameters could be attributed to natural conditions between rivers which are affected by different degree of anthropogenic activities. According to Chibana (2008) a river has its own unique natural conditions. River could be also influenced by altitude, slope gradient, channel width, water depth, coverage canopy and others (Flores & Zafaralla 2012). The discrepancies in physicochemical parameters directly affect the biological composition of stream and rivers (Cooper et al 2015; Tamiru et al 2017).

Brantas River showed the highest average abundance of macroinvertebrates compared to other rivers. It was probably related to environmental parameters since almost all environmental parameters measured in Brantas River showed significantly different with those in the other two rivers (see Table 1). The temperature in Brantas River was relatively low and DO was relatively high since the sites were in higher altitude with good canopy cover. As a consequence these conditions support macroinvertebrate abundance. Some studies have proven that higher DO and low temperature was better physicochemical condition for macroinvertebrate (Gerami et al 2016; Anzani et al 2013; Krisanti et al 2017). The abundance of macroinvertebrates is also related to food, in this case organic matter availability (Skala 2012). The presence of organic matter in water might be indicated by COD (Li et al 2017), and in Brantas the COD is quite high. In addition, the better condition of canopy cover could be the factor behind the availibility of organic matter as food for macroinvertebrates (Dosskey et al 2010; Knapik et al 2015).

Souto et al (2011) proved that macroinvertebrate composition in a river was the result of its adaptation to environmental variables. In this study, macroinvertebrates

composition among the three rivers is different and showed variation in terms of order (Figure 3-5), family or genera. In general three dominant orders were obtained in the three rivers, i.e. Ephemeroptera, Trichoptera and Diptera. With wide variation of environmental condition of the rivers, it can be aid that these three orders have wide tolerance level although not in all species of them. Family Baetidae was collected in almost all sampling sites in all of rivers. It belongs to tolerant organism compared to other families of order Ephemeroptera (Alhejoj et al 2014). Family Hydropsychidae of order Trichoptera was the dominant one in Opak and Progo Rivers. This condition is similar to the research finding by Lenat (1993). This family as well as order Diptera are believed to have wide tolerance range (Kranzfelder & Ferrington 2018).

Small number of Oligochaeta, Neuroptera, Arachnida, Amphipoda were exclusively found at some sites in Brantas River. The presence of these organisms in river ecosystem could be indicator of special ecological condition. In this study Oligochaetes were discovered in several sampling sites with high COD. Kang et al (2017) found in their study that Oligochaetes could survive at site with high organic matter. Some other studies also showed that many taxa of Oligochaetes had wide ecological tolerance (Ragi & Jaya 2014; Nazarhaghighi et al 2014). As for Amphipoda and Neuroptera, each of them were found one individual in several sampling sites with altitude 900 m above sea level and environmental condition with little anthropogenic impact. Some taxa of Amphipoda were reported to be highly sensitive to pollution (Sallenave 2015), whereas Neuroptera only has limited environmental tolerance because they were difficult to accept sudden changes (Stoaks et al 1983). The Arachnida was found in Brantas River at sampling site without canopy cover but there were found fairly in wide riparian zone. Graham et al (2003) discovered many spiders associated with freshwater ecosystem. It was caused by the presence of aquatic insects which shift from an aquatic larval to terrestrial reproductive adult stage becoming food source for riparian consumers such as Arachnida (Paetzold et al 2011).

The Decapoda and Odonata were exclusively collected only in Progo River. Odonata was occured in river surrounded by forest with a lot of vegetation and little human activities. Purba & Yulminarti (2018) in their study found many Odonata on vegetated river banks. The presence of vegetation was one of factors affecting the Odonata abundance (Siregar & Bakti 2016) since the prey was also abundant in such ecological condition (Hanum et al 2013). Whereas Decapoda was found in the banks of river dam with sand and gravel-cobble substrate enriched with plant and leaf litter. These condition was the preferred habitat for Decapoda (Annawaty et al 2016; Dwiyanti et al 2017). Overall the differences in number and composition of macroinvertebrate communities in three rivers seem to be influenced by various factors such as organic matter, substrate type and the changes in environmental conditions. This finding is similar to Fisesa et al (2014).

Conclusions. Macroinvertebrate community in three rivers of Jawa Island, Indonesia (Brantas, Opak and Progo) showed different composition and taxa richness. The discrepancy might be caused by the environmental conditions of the rivers. According to PCA analyses the taxa richness in Brantas River was related to altitude and canopy cover, and in Opak River was to DO, COD and canopy cover. However, in Progo River the analysis failed to detect any environmental parameter related to it.

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References

Agouridis C. T., Wesley E. T., Sanderson T. M., 2015 Aquatic macroinvertebrates: biological indicators of stream health. University of Kentucky College of Agriculture, Food and Environment, pp. 1-5.

Alhejoj I., Salameh E., Bandel K., 2014 Mayflies (order Ephemeroptera): an effective indicator of water bodies conditions in Jordan. International Journal of Scientific Research in Environmental Sciences 2(10):361-370.
Annawaty A., Wowor D., Farajallah A., Setiadi D., Suryobroto B., 2016 Habitat preferences and distribution of the freshwater shrimps of the genus *Caridina* (Crustacea: Decapoda: Atyidae) in Lake Lindu, Sulawesi, Indonesia. Hayati Journal of Biosciences 23(2):45-50.
Anzani Y. M., Effendi H., Wardiatno Y., 2013 [Macrozoobenthos as bioindicator of water quality of Ciambulawung river]. Prosiding Pertemuan Tahunan Masyarakat Limnologi, pp. 101-115. [in Indonesian]
APHA, 2012 Standard methods for the examination of water and waste water. 22nd edition, American Public Health Association, American Water Works Association, Water Environment Federation.
Brower J. E., Zar J. H., von Ende C. N., 1990 Field and laboratory methods for general ecology. Boston, Mass.: WCB McGraw-Hill, 237 pp.
Chessman B., 2003 SIGNAL 2.iv – a scoring system for macro-invertebrate ('water bugs') in Australian rivers. Monitoring River Heath Initiative Technical Report no 31, Department of the Environment Heritage Canberra, Australia, 34 pp.
Chibana T., 2008 Urban river management: harmonizing river ecosystem conservation. In: Urban environmental management and technology. Hanaki K. (ed), cSUR-UT Series: Library for Sustainable Urban Regeneration, vol 1. Springer, Tokyo, pp. 47-66.
Collier K. J., 1995 Environmental factors affecting the taxonomic composition of aquatic macroinvertebrate communities in lowland waterways of Northland, New Zealand. New Zealand journal of Marine and Freshwater Research 29(4):453-465.
Connolly N. M., Crossland M. R., Pearson R. G., 2004 Effect of low dissolved oxygen on survival, emergence, and drift of tropical stream macroinvertebrates. Journal of the North American Benthological Society 23(2):251-270.
Cook S. E. K., 1976 Quest for an index of community structure sensitive to water pollution. Environmental Pollution 11(4):269-288.
Cooper S. D., Page H. M., Wiseman S. W., Klose K., Bennett D., Even T., Sadro S., Nelson C. E., Dudley T. L., 2015 Physicochemical and biological responses of streams to wildfire severity in riparian zones. Freshwater Biology 60(12):2600-2619.
Dosskey M. G., Vidon P., Gurwick N. P., Allan C. J., Duval T. P., Lowrance R., 2010 The role of riparian vegetation in protecting and improving chemical water quality in streams. Journal of the American Water Resources Association 46(2):261-277.
Duan X., Wang Z., Tian S., 2008 Effect of streambed substrate on macroinvertebrate biodiversity. Frontiers of Environmental Science and Engineering în China 2(1):122-128.
Dwiyanti D., Fahri, Annawaty, 2017 [First record on freshwater prawn *Macrobrachium scabriculum* (Heller, 1862) from Batusuya, Donggala, Sulawesi, Indonesia]. Natural Science: Journal of Science and Technology 6(3):254-262. [in Indonesian]
Eady B. R., Rivers-Moore N. A., Hill T. R., 2013 Relationship between water temperature predictability and aquatic macroinvertebrate assemblages in two South African streams. African Journal of Aquatic Science 38(2):163-174.
Effendi H., Romanto, Wardiatno Y., 2015 Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI. Procedia Environmental Sciences 24:228-237.
Everaert G., De Neve J., Boets P., Domingues-Granda L., Mereta S. T., Ambelu A., Hoang T. H., Goethals P. L. M., Thas O., 2014 Comparison of the abiotic preferences of macroinvertebrates in tropical river basins. PLoS ONE 9(10):e108898.
Fisesa E. D., Setyobudiandi I., Krisanti M., 2014 [Water quality condition and community structure of macrozoobenthos in Belumai River, Deli Serdang District, North Sumatra Province]. Depik 3(1):1-9. [in Indonesian]
Flores M. J. L., Zafaralla M. T., 2012 Macroinvertebrate composition, diversity and richness in relation to the water quality status of Mananga River, Cebu, Philippines. Philippine Science Letters 5(2):103-113.
Gerami M. H., Patimar R., Negarestan H., Jafarian H., Mortazavi M. S., 2016 Temporal variability in macroinvertebrates diversity patterns and their relation with environmental factors. Biodiversitas 17(1):36-43.

Graham A. K., Buddle C. M., Spence J. R., 2003 Habitat affinities of spider living near a freshwater pond. The Journal of Arachnnology 31(1):78-89.
Hanum S. O., Salmah S., Dahelmi, 2013 [Dragonflies species in Kandi Wildlife Park Area, Sawahlunto City, West Sumatra]. Jurnal Biologi Universitas Andalas 2(1):71-76. [in Indonesian]
Hauer F. R., Resh V. H., 2017 Macroinvertebrates. In: Methods in stream ecology. Volume 1 (Third edition): Ecosystem structure. Hauer F. R., Lamberti G. A. (eds), Academic Press, New York, pp. 297-319.
Jacobsen D., 2003 Altitudinal changes in diversity of macroinvertebrates from small streams in the Ecuadorian Andes. Archiv fur Hydrobiologie 158(2):145-167.
Jacobsen D., Cressa C., Mathooko J. M., Dudgeon D., 2008 Macroinvertebrates: composition, life histories and production. In: Tropical stream ecology. Dudgeon D. (ed), Elsevier Inc., Academic Press London, pp. 65-105.
Jiang X. M., Xiong J., Qiu J. W., Wu J. M., Wang J. W., Xie Z. C., 2010 Structure of macroinvertebrate communities in relation to environmental variables in a subtropical Asian river system. International Review of Hydrobiology 95:42-57.
Jonsson M., Burrows R. M., Lidman J., Faltstrom E., Laudon H., Sponseller R. A., 2017 Land use influences macroinvertebrate community composition in boreal headwaters through altered stream conditions. Ambio 46(3):311-323.
Kang H., Bae M. J., Lee D. S., Hwang S. J., Moon J. S., Park Y. S., 2017 Distribution patterns of the freshwater Oligochaete *Limnodrilus hoffmeisteri* influenced by environmental factors in streams on a Korean nationwide scale. Water 9(12):921.
Knapik H. G., Fernandes C. V. S., de Azevedo J. C. R., dos Santos M. M., Agnol P. D., Fontane D. G., 2014 Biodegradability of anthropogenic organic matter in polluted rivers using fluorescence, UV, and BDOC measurements. Environmental Monitoring and Assessment 187:104.
Kranzfelder P., Ferrington L. C., 2018 Chironomidae (Diptera) species diversity of estuaries across a land use gradient on the Caribbean coast of Costa Rica. Revista de Biologia Tropical 66(3):1118-1134.
Krisanti M., Wardiatno Y., Anzani Y. M., 2017 Assessing the ecological status of the Cisadane River's headwaters using benthic macroinvertebrates. IOP Conference Series: Earth and Environmental Science 54:012023.
Lenat D. R., 1993 A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water-quality ratings. Journal of the North American Benthological Society 12(3):279-290.
Li F., Cai Q., Jiang W., Qu X., 2012 Macroinvertebrate relationships with water temperature and water flow in subtropical monsoon streams of Central China: implications for climate change. Fundamental and Applied Limnology 180(3):221-231.
Li J., Luo G., He L. J., Xu J., Lyu J., 2017 Analytical approaches for determining chemical oxygen demand in water bodies: a review. Critical Reviews in Analytical Chemistry 48(1):47-65.
Li L., Zheng B., Liu L., 2010 Biomonitoring and bioindicators used for river ecosystems: definitions, approaches and trends. Procedia Environmental Sciences 2:1510-1524.
Linares M. S., Faccioli G. G., Freitas L. M., 2013 Benthic macroinvertebrate community structure and seasonal variation in a neotropical stream in the State of Alagoas, Brazil. Biota Neotropica 13(3):50-54.
Lyons J., 2006 A fish-based index of biotic integrity to assess intermittent headwater streams in Wisconsin, USA. Environmental Monitoring and Assessment 122(1-3): 239-258.
McCafferty W. P., 1983 Aquatic entomology: the fishermen's and ecologists' illustrated guide to insects and their relatives. Jones and Bartlett Publisher, London, UK, 448 pp.
Merritt R. W., Cummins K. W., 1996 An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Company, New York, 862 pp.
Mushthofa A., Muskananfola M. R., Rudiyanti S., 2014 [The analysis of macrozoobenthos community structure as bioindicator of water quality of Wedung River Demak District]. Diponegoro Journal of Maquares 3(1):81-88. [in Indonesian]

Nakin M. D. V., Bovungana A. Q., Majiza V. N., 2017 Spatial and temporal variations in the distribution of benthic macroinvertebrates along the Vuvu River, South Africa. WIT Transactions on Ecology and the Environment 220:47-56.
Nazarhaghighi F., Timm T., Nadoushan R. M., Shabanipour N., Fatemi M. R., Moradi A. M., 2014 Oligochaetes (Annelida, Clitellata) in the Anzali International Wetland, north-western Iran. Estonian Journal of Ecology 63(3):130-144.
Paetzold A., Smith M., Warren P. H., Maltby L., 2011 Environmental impact propagated by cross-system subsidy: chronic stream pollution controls riparian spider populations. Ecology 92(9):1711-1716.
Pescador M. L., Richard B. A., 2004 Guide to mayfly (Ephemeroptera) nymphs of Florida. Florida Department of Environmental Protection, Tallahassee, 168 pp.
Pescador M. L., Rasmussen A. K., Richard B. A., 2000 A guide to the stoneflies (Plecoptera) of Florida. Florida Department of Environmental Protection, Tallahassee, 94+70 pp.
Purba W. C., Yulminarti, 2018 [The composition and abundance of dragon flies (Ordo: Odonata) on three habitat type in Buluh Cina Village Siak District Kampar Regency Riau Province]. Jurnal Riau Biologia 3(1):17-22. [in Indonesian]
Purwati S. U., 2015 [Cisadane bioindicator characteristics: study to assess the Cisadane quality of use macrozoobenthos]. Ecolab 9(2):47-104. [in Indonesian]
Putri A. M. S., Suryanti, Widyorini N., 2016 [The relation of sediment texture to organic matter and macrozoobenthos abundance in the estuarine of Banjir Kanal Timur River]. Saintek Perikanan 12(1):75-80. [in Indonesian]
Ragi M. S., Jaya D. S., 2014 Distribution and diversity of Oligochaetes in selected ponds of Thiruvananthapuram District, Kerala, South India. Advances in Ecology 2014:138360.
Rahayu S., Widodo R. H., van Nordwijk M., Suryadi I., Verbist B., 2009 [Water monitoring in watershed region]. Bogor, Indonesia. World Agroforestry Centre - Southeast Asia Regional Office, 104 pp. [in Indonesian]
Richardson J. S., 2003 Identification manual for the dragonfly larvae (Anisoptera) of Florida. Florida Department of Environmental Protection, Tallahassee, 114 pp.
Sahidin A., Setyobudiandi I., Wardiatno Y., 2014 [Macrozoobenthos community structures of Tangerang coastal waters, Banten]. Depik 3(3):226-233. [in Indonesian]
Sallenave R., 2015 Stream biomonitoring using benthic macroinvertebrates. NM State University, Circullar 677:1-3.
Schoen J., Merten E., Wellnitz T., 2013 Current velocity as a factor in determining macroinvertebrate assemblages on wood surfaces. Journal of Freshwater Ecology 28(2):271-275.
Selvanayagam M., Abril R., 2016 Use of benthic macro invertebrates as a biological indicator in assessing water quality of River Puyo, Puyo, Pastaza, Ecuador. American Journal of Life Sciences 4(1):1-12.
Sengupta M., Dalwani R., 2008 Benthic invertebrates – a crucial tool in biomonitoring of lakes. Proceedings of Taal 2007: The 12th World Lake Conference, pp. 95-98.
Shimabukuro E. M., Henry R., 2011 Controlling factors of benthic macroinvertebrates distribution in a small tropical pond, lateral to the Paranapanema River (São Paulo, Brazil). Acta Limnologica Brasiliensia 23(2):154-163.
Siregar A. Z., Bakti D., 2016 Diversity and distribution of Odonata in University Sumatera Utara, Medan, Indonesian. International Journal of Scientific and Technology Research 5(5):229-234.
Skala I., 2012 Distribution of macroinvertebrates in relation to the quantity and quality of organic matter in streams in the western Czech Republic. Ecohydrology and Hydrobiology 12(3):199-209.
Souto R. M. G., Facure K. G., Pavanin L. A., Jacobucci G. B., 2011 Influence of environmental factors on benthic macroinvertebrate communities of urban streams in Vereda habitats, Central Brazil. Acta Limnologica Brasiliensia 23(3):293-306.
Stoaks R. D., Neel J. K., Post R. L., 1983 Observations on North Dakota sponges (Haplosclerina: Spongillidae) and sisyrids (Neuroptera: Sisyridae). The Great Lakes Entomologist 16(4):171-176.

Sudarso J., Wardiatno Y., 2015 [Assessment of river quality status with macrozoobenthos indicators]. Pena Nusantara, 397 pp. [in Indonesian]
Sudarso J., Wardiatno Y., Sualia I., 2008 [The effect of heavy metal contamination in sediment on benthic macroinvertebrate community: a case study in Saguling Reservoir, West Java]. Jurnal Ilmu-Ilmu Perairan dan Perikanan Indonesia 15(1):49-69. [in Indonesian]
Tamiru S. M., Asfaw S. L., Yilma A. M., 2017 Correlation study of some physico-chemical parameters and benthic macroinvertebrates metrics on the ecological impacts of floriculture industries along Wedecha River, Debrezeit, Ethiopia. Journal of Coastal Life Medicine 5(10):433-440.
Tjokrokusumo S. W., 2006 [Benthic macroinvertebrates as indicator of aquatic pollution]. Jurnal Hidrosfer Indonesia 1(1):8-20. [in Indonesian]
Uherek C. B., Gouveia F. B. P., 2014 Biological monitoring using macroinvertebrates as bioindicators of water quality of Maroaga stream in the Maroaga cave system, Presidente Figueiredo, Amazon, Brazil. International Journal of Ecology 2014:308149.
Vandra B., Sudarno, Nugraha W. D., 2016 [Analysis study on self purification ability at Progo River in biological oxygen demand (BOD) and dissolved oxygen (DO) perspective]. Jurnal Teknik Lingkungan 5(4):1-8. [in Indonesian]
Varnosfaderany M. N., Ebrahimi E., Mirghaffary N., Safyanian A., 2010 Biological assessment of the Zayandeh Rud River, Iran, using benthic macroinvertebrates. Limnologica – Ecology and Management of Inland Waters 40(3):226-232.
Wardiatno Y., Qonita Y., Mursalin, Zulmi R., Effendi H., Krisanti M., Mashar A., Hariyadi S., Hakim A. A., Sahidin A., Widigdo B., Nursiyamah S., 2017 Determining ecological status of two coastal waters in western Java using macrozoobenthic community: a comparison between north part and south part. IOP Conference Series: Earth and Environmental Science 54(1):012071.
Yunitawati, Sunarto, Zahidah H., 2012 [The relationships between substrate characteristics and macrozoobenthic community structure in Cantigi River, Indramayu Regency]. Jurnal Perikanan dan Kelautan 3(3):221-227. [in Indonesian]

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Authors:
Majariana Krisanti, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia, e-mail: krisanti.m@gmail.com
Luk Luk Il Maknuun, Master Program in Aquatic Resources Management, Graduate School, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia, e-mail: luklukilma94@gmail.com
Yunita Magrima Anzani, Department of Aquatic Resources Management, Faculty of Agriculture, University of Tanjungpura, Pontianak, West Kalimantan, Indonesia, e-mail: yunitamagrimaanzani@gmail.com
Arief Sabdo Yuwono, Department of Civil and Environmental Engineering, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia, e-mail: arief.sabdo.yuwono@gmail.com
Rahayu Widyastuti, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia, e-mail: oety76@yahoo.com
Yusli Wardiatno, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Kampus IPB Darmaga, Bogor 16680, Indonesia, e-mail: yusli@ipb.ac.id
Dewi Wulandari, Department of Environmental Engineering, Indonesian Islamic University, Jalan Kaliurang Km. 14.5, Krawitan, Umbulmartani, Kec. Ngemplak, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55584, Indonesia, e-mail: dewi.wulandari@uii.ac.id

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