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Research Article

The Influence of Agrochemicals on Macroinvertebrate Community Structure in Various Agricultural Rivers in Jember Regency

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ABSTRACT
The intensive use of agrochemicals in agricultural areas of Jember's Regency presents a potential threat to the freshwater ecosystem's community. The use of the benthic macroinvertebrates community may provide a key to monitor the extent of agrochemical impact to maintain valuable ecosystem services. Macroinvertebrates community structure and environmental factors were studied from September–December 2020 in Jember Regency by comparing three different types of agricultural rivers (organic, semi-organic, and conventional). Five community indices (taxa, individuals, Simpson dominancy index, Margalef species richness, and Shannon diversity index) were used to compare the macroinvertebrates community structure between sites. Using community composition and physicochemical properties (bare sediment, width, depth, water current, pH, conductivity, dissolved oxygen (DO), and temperature), we generated CCA triplot and correlogram plot to investigate the grouping and the correlation between variables and sites. Results on macroinvertebrate composition showed the importance of using sensitive taxa-group and community indices as an indicator of environmental changes. The family of Tipulidae, Naididae, Cysticidae, and Nereididae demonstrated relation to semi-organic agricultural rivers. Temperature and water current correlate to the presence of clean water indicator species such as Philorheitridae and Chironomidae, as observed in organic agricultural rivers. Conventional and semi-organic agricultural rivers were grouped and largely contributed by the 5 families including Ampullariidae, Pachychillidae, Baetidae, Enchytraidae, and Gomphidae. Correlogram plot suggests a complex interaction between macroinvertebrate community and environmental variables. It can be concluded that the intensive use of agrochemicals may lead to a detrimental change toward the diminished quality of freshwater community and environment.

INTRODUCTION

Agricultural sectors in Jember's Regency of East Java serve as a backbone of the economy by primarily producing crop commodities including rice. With over 86.685 ha (26.32 %) of total land being used as paddy fields (Dinas Pertanian Dan Ketahanan Pangan Jawa Timur 2013), the use of pesticides and fertilizers to increase crop production were inevitably high. This raises a concern about the detrimental effects of pesticides and fertilizers on the organism, ecosystem, and environment. Agricultural and pesticide utilization has been reported to negatively impact the freshwater ecosystem leading to environmental contamination (Chimwanza et al. 2006; Wu et al. 2018; Stoyanova & Harizanova 2019). Moreover, high erosion (because of the loss of vegetation), steeply plain fields, high rate of rainfall, and ineffective farming methods may lead to the deterioration of water reservoirs in soil. Thus, the pesticides and other contaminants could flow along with the organic materials via water runoff because of rain plash erosion and decrease of natural vegetation. Pesticides and fertilizers could represent a significant stressor in the freshwater ecosystem. However, linking the degree of exposure to the observed impact could be challenging, mainly due to the complex interaction within the ecosystem (Jasem 2011).

The community of macroinvertebrates in the freshwater river is generally considered as a bioindicator of environmental changes due to its sensitivity to organic pollution (Ghaly & Ramakrishnan 2015), habitat degradation (Wu et al. 2018), and pesticide contamination (Berenzen et al. 2005). The distribution, species richness, and population of the macroinvertebrate community may reflect the changes in the freshwater ecosystem due to its specificity to the agrochemicals. In this study, we used the community structures of benthic macroinvertebrates as primers to investigate the potential influence of pesticide runoff in conventional, semi-organic, and organic agricultural types in Jember Regency. To the best of our knowledge, there has never been a thorough analysis using multiple ecological indices to investigate the pattern of the impact on community structures of macroinvertebrates in various agricultural rivers in Jember. We aim to evaluate the influence of the degree of pesticides and fertilizers on the macroinvertebrate community, while also analyze the interacting factors that significantly correlate to the structures of its community.

MATERIALS AND METHODS

Study area and sampling time

The study was conducted on 3 rivers located within various agricultural types, i.e., conventional (K), semi-organic (SO), and organic (O) which divided into 9 subsampling sites (K1, K2, K3 for conventional type; SO1, SO2, SO3, for semi-organic type; and O1, O2, O3 for organic type) in Panti district (-8.616667 S, 113.5767 E) and Sumber Jambe district (-8,12259 S; 113,63308 E) (Figure 1).

The conventional type was managed using agrochemical fertilizers and pesticides, the semi-organic type was utilized by agrochemical fungicides as pest control, whereas the organic type was managed by organic fertilizer as a source of nutrients (Table 1).

These areas were used for paddy crops, the biggest crop commodity in East Java (Fadil 2017; BPS Provinsi Jawa Timur 2021). The observed rivers were directly connected to agricultural areas and channeling the paddy fields in the seeding period. The observed rice fields were irrigated by the adjacent

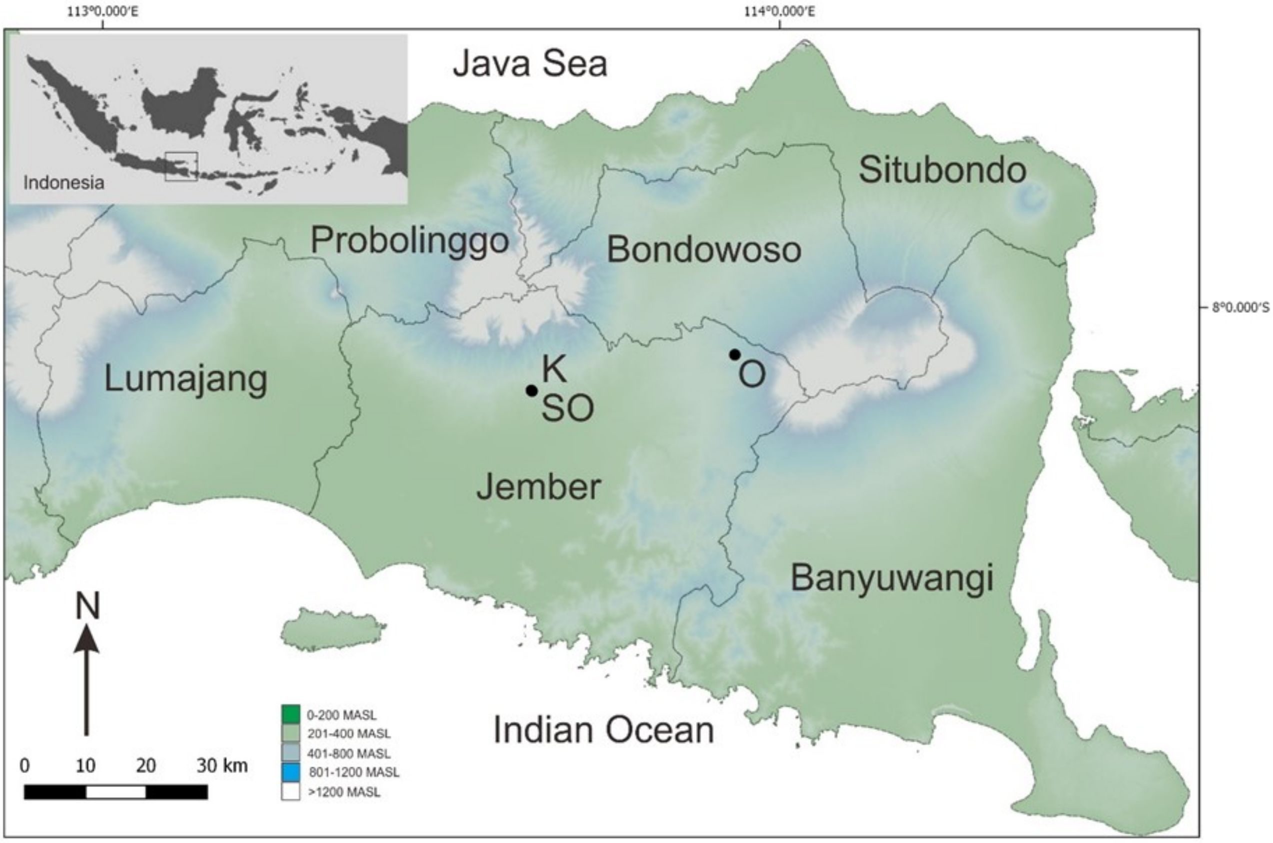

Figure 1. Geographical map showing the study area of 3 agricultural types in Jember Regency along with their corresponding altitude. Abbreviations are as follows: (K) conventional, (SO) semi-organic, and (O) organic.

Sites	Types	Fertilizer		Pesticide		Fungicide	
		Brand	Application	Brand – Active compound	Application	Brand – Active compound	Application
K1–K3	Conventional	Phonska©	16.66 kg/ha; every 2 weeks (week-5 toweek -9)	Fenite© – Emamectin benzoate	200 ml/ season (June–August)	Zole© – difenoconazole	200 ml/ season (June –August)
SO1–SO3	Semi-organic	Organic	125 kg/ha; every 2 weeks, (week-3 to week-9)	–	–	Zole© – difenoconazole	200 ml/ season (May–July)
O1–O3	Organic	Organic	222.22 kg/ha; every 2 weeks, (week-3 to week-9)	–	–	–	–

upstream rivers throughout the year. Using 1x1 meter plots for each agricultural type, preliminary vegetation analysis covering the seedling type (height = 0–1.5 m) by important value index (Odum & Barrett 1971), revealed a various types of plant species that may support and represent various benthic communities (Table 2). The plot locations were chosen randomly by considering the distance to the river bank. The yearly precipitation is 250 mm^3 which can reaching up to 349 mm^3 in the rainy period (BPS Jember 2021). The study was conducted from September–October 2020.

Table 2. List of plant species and important value index (IVI) values for each type of agricultural types. Abbreviations are as follows: (K) conventional, (SO) semi-organic, and (O) organic.

Plant species	Agricultural type		
	K	SO	O
Acmella paniculata	–	–	8.19
Ageratum conyzoides	18.84	–	–
Althenanthera philoxiroides	17.23	32.59	–
Chromolaena odorata	25.92	–	–
Clinopodium vulgare	–	–	94.56
Coffea canephora	–	–	21.48
Cyperus iria	–	36.02	–
Eleusine indica	–	36.02	–
Emilia sonchifolia	–	–	26.10
Euchinochloa colona	–	135.16	23.79
Euphorbia hirta	12.28	–	–
Gomphrena sp.	17.23	–	–
Ipomoea lacunosa	12.28	–	–
Kyllinga brevifolia	34.87	–	26.10
Micania micrantha	–	–	23.02
Oryza sativa	23.51	32.51	29.95
Oxalis barrelieri	18.84	–	19.95
Paspalum conjugatum	86.42	–	–
Phyllanthus niruri	24.45	27.71	–
Setaria plicata	–	–	26.87
Zea mays	8.14	–	–

Survey and data collection

The subsampling sites were chosen to represent the best overall diversity of benthic macroinvertebrates. The distance for each subsampling site within each of the agricultural types is up to 100 m, where we address (i) habitat characteristics, (ii) physicochemical properties, and (iii) macroinvertebrate species. The selected habitats were agricultural areas with various degree of agrochemicals exposure (Table 1). Each subsampling site represents the habitat in the inlet (denoted by 1), middle (denoted by 2), and outlet (denoted by 3) flows. Physicochemical properties including bare sediment, width, depth, water current, pH, conductivity, dissolved oxygen (DO), and temperature were measured.

Bare sediment was estimated by using 1x1 meter plot to observe the composition and proportion of sediment. The width of the river was measured using a ribbon meter stretched to each of the river edges. The depth of the river was measured using a rope with a weighted load. Water currents were estimated based on the buoy traveling time within a certain distance which then converted into velocity (m/s). The estimation of pH, conductivity, DO, and the temperature was based on Aquacombo HM3070 (Transintrument). We collected the samples using a hand net square with a frame size of 25 x 40 cm and a mesh size of 500 µm. For each species obtained in each subsampling site, we collected the voucher specimens and preserved them in bottles filled with 70% ethanol for identification purposes in the laboratory. The physicochemical properties and samples were collected 3 times within the same subsampling sites.

Identification and analyses

The collected samples were rinsed off and cleaned from debris. Samples were sorted out and placed in a plain-colored container using a brush. We identified the samples up to the family level using literature and identification books (Lehmkuhl 1979; Gooderham & Tsyrlin 2002). The data were tabulated in Microsoft Excel 2017.

Five community indices (taxa, individuals, Simpson dominancy index, Margalef species richness, and Shannon diversity index) were used to compare the macroinvertebrates' community structure between sites. For the Simpson dominancy index (Brower et al. 1997) we used the equation as follows,

$$Id = \frac{\Sigma n_i(n_i - 1)}{N(N-1)} \quad \ldots(1)$$

where Id is the Simpson dominancy index, n_i is the individual number of particular species-i, and N is the total individual number of all species found. For the Margalef species richness (Farris 1976) we used the equation as follows,

$$\text{Dmg} = \frac{S-1}{\ln N} \quad \ldots(2)$$

where Dmg is the Margalef index, S is the total number of species and N is the total number of individuals. For the Shannon-Wiener diversity index (Odum & Barrett 1971) we used the equation as follows,

$$H = -\Sigma n_i . N^{-1} . \ln(ni.N^{-1}) \ldots(3)$$

where H is the Shannon-Wiener index, n_i is the individual number of particular species-i, and N is the total individual number of all species found.

The relative abundance is estimated and represented in Bubble Plot using ggplot2 R-packages (Wickham 2016) analyzed in R v.3.4.1 (R Core Team 2013). Community structures were analyzed based on taxa, individuals, Simpson dominancy index, Margalef species richness, and Shannon diversity index using PAST software (Dasgupta 2013). Moreover, to see the variations and grouping of subsampling sites using macroinvertebrate community composition and physicochemical properties, a Canonical Correspondence Analysis (CCA) triplot was analyzed using PAST software (Dasgupta 2013). Apart from that, the correlation matrix using the results on community indices (i.e., taxa, individuals, Simpson dominancy index, Margalef species richness, and Shannon diversity index) and physicochemical factors (i.e., water currents, depth, pH, bare sediments, temperature, width, conductivity) were estimated using Pearson correlation and interpreted using Correlogram plot using corrplot R-packages (Levy 2021) analyzed in R v.3.4.1 (R Core Team 2013).

RESULTS AND DISCUSSION

Results

Environmental variables

Bare sediments were varied from 17–83.32 % throughout various agricultural rivers. The width and depth of the river correspond with the water current variables. Most of the rivers have strong water currents capable to sweep away the litter, except in K2, K3, SO2, and SO3 which show slow currents. Various agricultural rivers were buffered within a pH of 6.94–7.58. Low conductivity was detected in SO2 and SO3 (35.02–37.07 µmhos/cm). The dissolved oxygen in all the observed sites ranged from 7.16–8.4 mg/L. Temperature ranges from 23.88–29.43 °C. The environmental variables in each of the three agricultural rivers are shown in Table 3.

Macroinvertebrate composition

Three agricultural rivers were characterized by the abundance of benthic taxa. In conventional type, K1 and K2 were dominated by Ampullariidae (40.5–62 %) except K3 which concurrently dominated by Pyralidae (25.3 %) and Ampullariidae (27.5 %). In Semi-organic type, SO1 was dominated by Naididae (72.4 %) followed by Chironomidae (10.3 %). SO2 was mostly contributed by Pachychillidae (16 %), Naididae (20 %), and Gecarcunidae (24 %). SO3 was dominated by Pachychillidae (43 %), followed by Naididae (29 %), Cordulidae (14 %), and Lumbriculidae (14 %). Organic type shows a relatively stable abundance of taxa with O1 mostly dominated by Simuliidae (58 %); O2 mostly contributed by Hirudinidae (26 %) and Philorheithridae (22.0 %); and O3 dominated by Ampullariidae (27%) and Chironomidae (20%). The relative abundance of macroinvertebrates in each of the three agricultural rivers is shown in Table 4 and the Bubble Plot (Figure 2).

Table 3. Mean (± SE) of environmental variables in each of three agricultural rivers in Jember Regency. This data was used for further Canonical correspondence analysis (CCA) and Correlation matrix.

Parameter	Agricultural type								
	Conventional			Semi-organic			Organic		
	K1	K2	K3	SO1	SO2	SO3	O1	O2	O3
Bare sediments (%)	28.32 ± 2.87	75 ± 5	25 ± 5	17 ± 2.89	71.67 ± 10.39	83.32 ± 2.89	36.67 ± 5.76	73.32 ± 5.76	73.32 ± 5.76
Width (m)	2.05 ± 0.80	0.52 ± 0.06	2.38 ± 0.34	2 ± 0.77	0.62 ± 0.08	0.6 ± 0.80	0.41 ± 0.08	0.72 ± 0.09	0.59 ± 0.22
Depth (m)	0.21 ± 0.06	0.35 ± 0.14	0.37 ± 0.11	1 ± 0.19	0.52 ± 0.056	0.34 ± 0.06	0.23 ± 0.05	0.47 ± 0.09	0.66 ± 0.11
Water current (m/s)	0.11 ± 0.07	0.05 ± 0.02	0.07 ± 0.03	0.1 ± 0.09	0.05 ± 0.01	0.03 ± 0.09	0.22 ± 0.06	0.14 ± 0.03	0.15 ± 0.04
pH	7.53 ± 0.01	7.33 ± 0.10	7.48 ± 0.01	7.53 ± 0.01	7.1 ± 0.006	6.94 ±0,04	7.58 ± 0.04	7.22 ± 0.05	7.49 ± 0.09
Conductivity (µmhos/cm)	169.8 ± 0.3	163.6 ± 0.55	160.67 ± 0.65	169.8 ± 0.87	35.02 ± 0.81	37.07 ± 3.48	93.42 ± 7.74	129 ± 0.25	129.25 ± 0.59
Dissolved oxygen (mg/L)	7.76 ± 2.3	7.45 ± 0.96	7.83 ± 3.27	7.16 ± 1.97	7.73 ± 1.36	7.51 ± 5.24	7.9 ± 4.75	8.4 ± 1.07	7.98 ± 4.64
Temperature (°C)	23.88 ± 0.38	25.21 ± 0.37	24.72 ± 0.33	23.88 ± 0.38	28.05 ± 0.11	28.4 ± 0.14	29.43 ± 1.33	25.36 ± 1.40	25.21 ± 0.71

Table 4. Relative abundance (%) of macroinvertebrates in each of three agricultural rivers in Jember Regency.

Order	Family	Agricultural type								
		K1	K2	K3	SO1	SO2	SO3	O1	O2	O3
Araneae	Tetragnathidae	–	–	1.1	–	–	–	0.4	–	–
Architaenioglossa	Ampullariidae	40.5	62.0	27.5	–	12.0	29.0	2.7	13.0	27.0
Arhynchobdellida	Erpobdellidae	–	4.0	–	–	–	–	–	–	–
	Hirudinidae	0.8	–	–	–	–	–	–	26.0	–
Basommatophora	Planorbidae	0.8	6.0	–	–	–	–	0.4	4.4	3.0
Caenogastropoda	Pachychilidae	1.6	2.0	1.1	–	16.0	43.0	–	11.0	2.4
Coleoptera	Dytiscidae	–	–	–	1.72	–	–	–	–	–
Diptera	Ceratopogonidae	12.7	–	–	–	–	–	–	–	1.8
	Chaoboridae	–	–	–	–	–	–	–	1.1	–
	Chironomidae	–	6.0	1.1	10.3	–	–	15.0	2.2	20.0
	Empididae	–	–	–	8.6	–	–	–	–	–
	Psychodidae	–	2.0	–	–	–	–	–	–	–
	Simuliidae	–	–	–	–	–	–	58.0	2.2	–
	Tipulidae	–	–	1.1	5.1	–	–	–	3.3	0.6
Decapoda	Gecarcinucidae	–	–	–	–	24.0	–	–	–	–
Ephemeroptera	Baetidae	1.6	–	–	–	12.0	–	–	–	–
	Caenidae	–	–	16.5	–	–	–	–	8.9	7.8
	Leptophlebiidae	5.6	–	–	–	–	–	6.5	–	7.8
Geophilomorpha	Geophilidae	–	–	–	–	–	–	–	–	0.6
Haplotaxida	Enchytraeidae	–	16.0	–	–	4.0	–	–	–	–
	Naididae	–	–	–	72.4	20.0	–	–	–	–
Hemiptera	Coreidae	–	–	–	–	–	–	0.4	–	–
	Corixidae	–	–	–	–	–	–	0.4	–	0.6
	Mesovelliidae	0.8	–	–	–	–	–	–	–	–
Lepidoptera	Pyralidae	3.1	–	25.3	–	8.0	–	–	–	–
Littorinimorpha	Pomatiopsidae	–	–	–	–	4.0	–	–	–	–
	Hidrobiidae	–	–	–	–	–	–	–	3.3	–
Lumbriculida	Lumbriculidae	–	–	–	–	–	14.0	–	–	–
Moniligastrida	Moniligastridae	–	2.0	–	–	–	–	1.1	1.1	4.8
Neotaenioglossa	Thiaridae	–	–	–	–	–	–	–	1.1	–
Odonata	Telephlebiidae	–	–	1.1	–	–	–	–	–	–
	Corduliidae	–	–	–	–	–	14.0	–	–	–
	Gomphidae	3.1	–	–	–	–	–	–	–	–
	Petaluridae	–	–	1.1	–	–	–	–	–	–
	Platycnemididae	–	–	–	–	–	–	–	–	0.6
Phyllodocida	Nereididae	–	–	–	1.72	–	–	–	–	–
Sphaeriida	Sphaeriidae	–	–	–	–	–	–	–	–	0.6
Trichoptera	Hydrobiosidae	–	–	17.6	–	–	–	–	–	–
	Hydropsychidae	0.8	–	–	–	–	–	6.1	–	3.6
	Lepidostomatidae	–	–	–	–	–	–	5.0	–	–
	Philorheithridae	4.8	–	6.6	–	–	–	4.2	22.0	19.0
	Polycentropodidae	23.8	–	–	–	–	–	–	–	–

Variations in macroinvertebrate grouping

The CCA triplot shows a site grouping based on the macroinvertebrate community composition and environmental variables (Figure 3). Several families demonstrate the specific relation to SO1 including a family of Tipulidae, Naididae, Cysticidae, and Nereididae. Within Nereididae, *Tubifex* sp. was encountered at the highest abundance. For the environmental variables, the river depth was the primary factor to group SO1 from other sites. SO2 was like SO1 but was mostly contributed by Tipulidae, Pomatiopsidae, and Corduliidae, and environmental variable of river width. Other environmental variables including temperature and water current correlate to the presence of clean water macroinvertebrate indicators such as Philorheitridae and Chironomidae, as observed in organic type (i.e., O1, O2, O3). Apart from that, conventional type (i.e., K1, K2, K3) and semi-organic type (i.e., SO3) were grouped and largely contributed by 5 families, i.e., Ampullariidae, Pachychillidae, Baetidae, Enchytraidae, and Gomphidae.

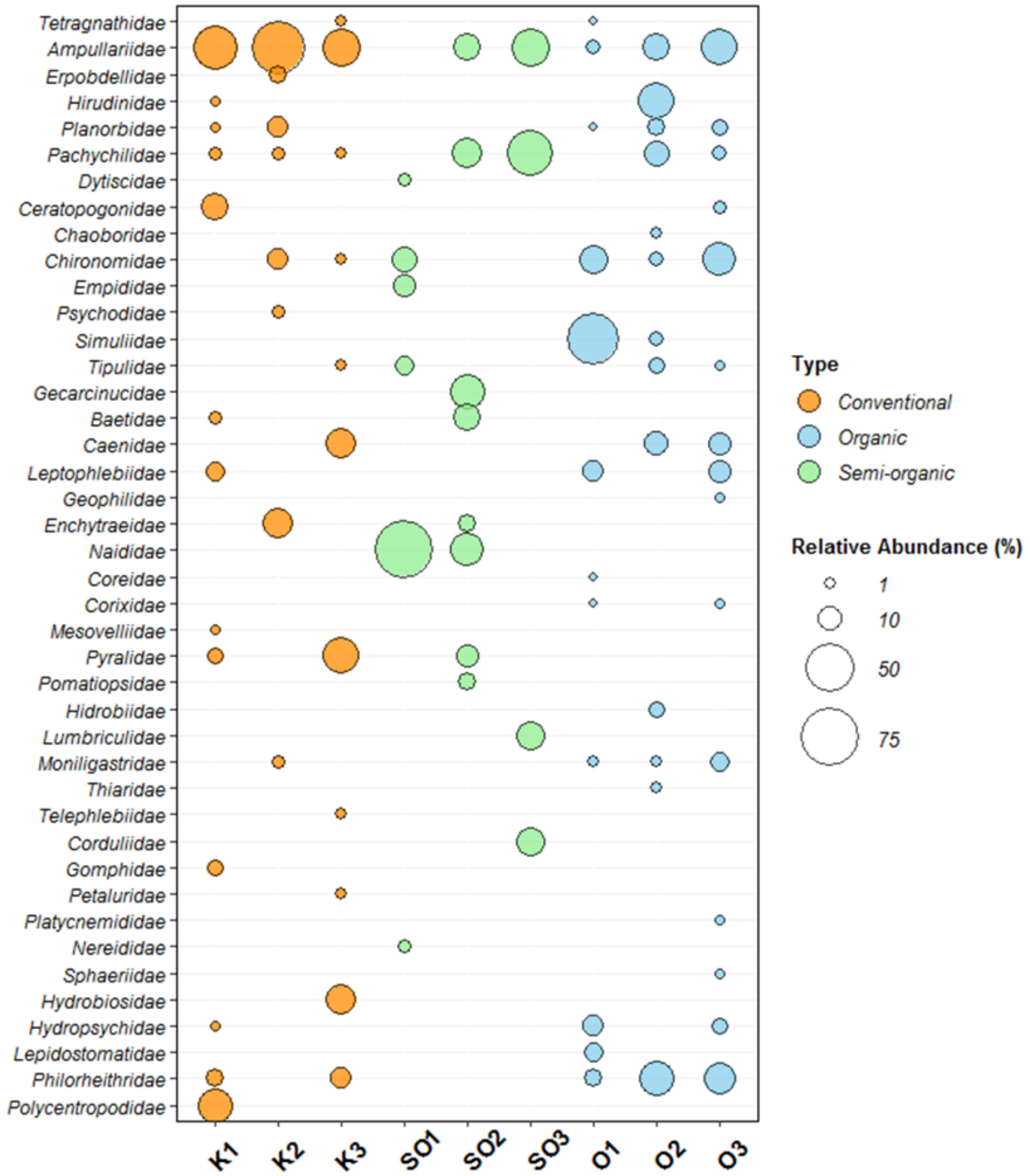

Figure 2. Bubble plot depicting relative abundance (%) of macroinvertebrates in each of three agricultural rivers in Jember Regency.

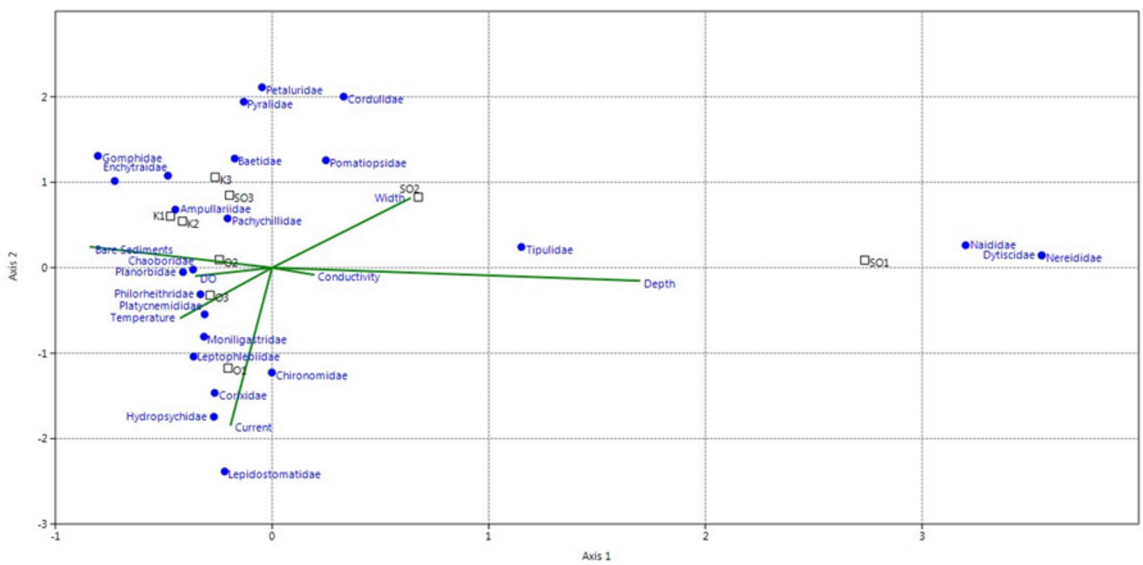

Figure 3. Canonical Correspondence Analysis (CCA) triplot showing the site grouping based on macroinvertebrate community composition and environmental variables from three agricultural rivers in Jember Regency

Ecological indices and correlation with environmental variables

The total individual in organic type was relatively higher among other agricultural types with the highest individual were in O1, followed by O3 and K1. The number of taxa in organic type was found to be higher than other agricultural types with the highest taxa richness in O3, followed by O2 and K1. The total individual and taxa richness is further confirmed in the Shannon diversity index and Margalef species richness shows the highest in O2, suggesting a stable diversity and integrated taxa. Semi-organic type of SO2 also has a high diversity of taxa, although the total individual was low. Simpson dominancy index shows that all agricultural type has high dominancy especially for K2, SO1, and O1. Six graphs showing the individual, taxa, Shannon diversity index, Margalef species richness, and Simpson dominancy index in each of three agricultural rivers in Jember Regency are shown in Figure 4.

Further investigation on the driver of community structure based on the correlation between community indices (Figure 4) and environmental variables (Table 3) showed that each type of agricultural river shows various patterns and correlations (Figure 5). In the conventional river, bare sediment is negatively correlated with all of the indices and factors. Depth is also negatively correlated with individuals, taxa, and Margalef species richness, with the addition of temperature that is negatively correlated with the Shannon diversity index. On the contrary, width, dissolved oxygen, and pH are positively correlated with all the indices and factors. In addition, water current is positively correlated with all the community indices and factors, except for the Simpson dominancy index.

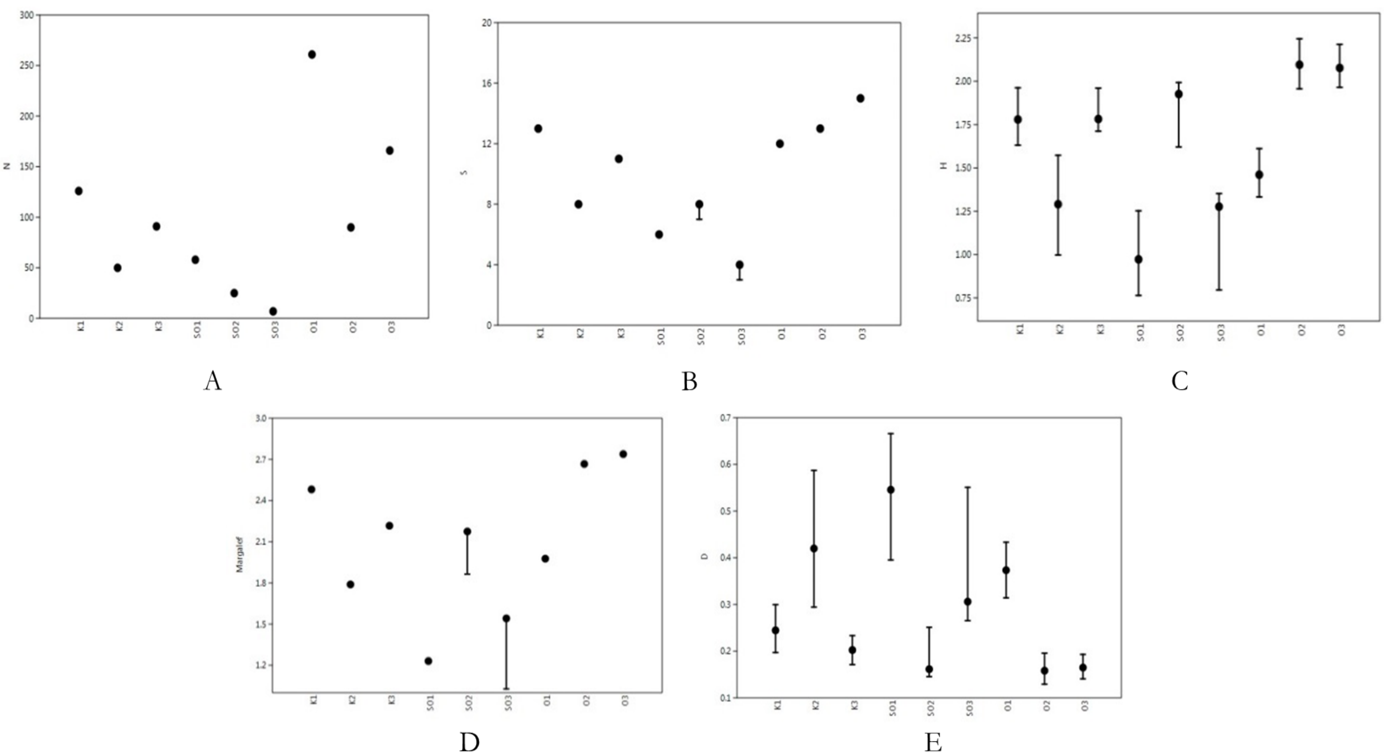

Figure 4. Graphs showing five ecological indices including: A) individual, B) taxa, C) Shannon diversity index, D) Margalef species richness, and E) Simpson dominancy index of macroinvertebrate in each of agricultural rivers in Jember Regency.

In the semi-organic river, width and conductivity are negatively correlated with Shannon diversity index, Simpson dominancy index, and Margalef species richness. Besides, water current, depth, and pH are negatively correlated with the Simpson dominancy index. Dissolved oxygen is negatively correlated with taxa and individuals, while bare sediments and temperature are negatively correlated with individuals. Out of 5 indices and factors, all the abiotic factors are positively correlated with individuals and the Simpson dominancy index only.

In the organic river, water current, temperature, and pH are negatively correlated with almost all the community indices and factors. In contrast, width is positively correlated with all the community indices and factors, whereas water current, temperature, bare sediments, conductivity, and depth, are positively correlated with several community indices and factors. The correlogram across the various agricultural river is shown in Figure 5.

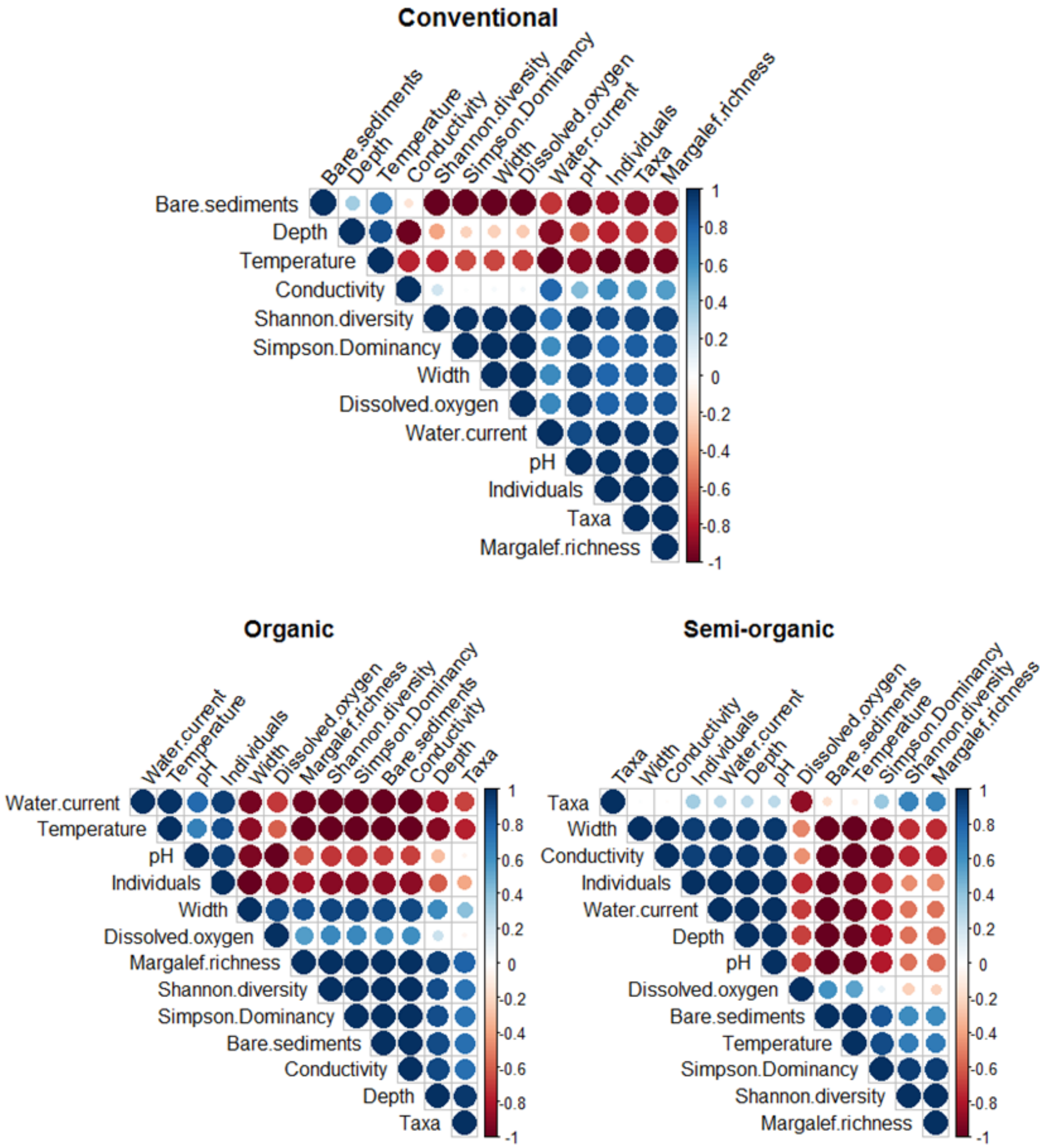

Figure 5. Correlation matrix shown in a Correlogram plot using community indices and environmental variables of macroinvertebrates analyzed for each type of agricultural river in Jember Regency.

Discussion

Based on relative abundance (Table 3; Figure 2), it is revealed that the agrochemical exposure may potentially suppress the macroinvertebrate abundance in conventional and semi-organic types, except for the family of Ampullariidae and Pachychilidae. The macroinvertebrate composition in organic type showed the dominance of specific taxa, although a high abundance of Ampullariidae across three types of agricultural rivers was still observed. In organic type, the dominance of this family was compensated by a higher diversity of macroinvertebrate taxa compare to the conventional type or semi-organic type. As the CCA triplot suggests (Figure 3), the absence of several taxa in the macroinvertebrate community might be influenced by the decrease of dissolved oxygen produced from the roots of the nearby vegetations. Roots may provide an oxygen supply through the decomposition of organic substances. Moreover, the dissolved oxygen from the re-aeration process is difficult to occur in a river with gentle wind and slow-streamed water, as observed in conventional and semi-organic rivers (Table 2). These factors resulting in the decreased of macroinvertebrate composition but invites the tolerant macroinvertebrate which can survive in hypoxic conditions. In accordance with our results, Toft et al. (2003) report the increase of tolerant macroinvertebrate in hypoxic and low dissolved oxygen condition; De Marco et al. (2001) report the increase of macroinvertebrate density which is related to the increase of temperature, conductivity, and neutral pH; and De Neiff & Carignan (1997) report that *Eichhornia crassipes* occurrence has a positive correlation with the dissolved oxygen concentration and conductivity, but negatively correlated with temperature and turbidity.

Based on community indices, it showed that intensive pesticide utilization in conventional type (i.e., K2) significantly decreased the macroinvertebrate diversity (Figure 4C). It might be due to the utilization of inorganic fertilizers, pesticides, fungicides, or other agrochemicals. As previously reported, inorganic fertilizer used in conventional type (i.e., Phonska®) was responsible to cause blooming algae (Ghaly & Ramakrishnan 2015) and water drinking contamination (Follett & Hatfield 2001). The semi-organic type shows different influence patterns. The low diversity of macroinvertebrate taxa in SO1 (Figure 4C) is likely due to the close distance to adjacent conventional rivers, vulnerable to the agrochemical exposure indicated by low dissolved oxygen and high conductivity (Table 2). Nonetheless, it shows the increase of macroinvertebrate diversity especially in SO2 (Figure 4C).

It was previously reported that reducing the use of agrochemicals may increase macroinvertebrates and the quality of other soil biotic (Berenzen et al. 2005; Musonge et al. 2020). Still, the use of active substance Zole© (difenoconazole; triazole group fungicides) in conventional and semi-organic types could decrease the macroinvertebrate diversity evidenced by the absence of some clean water species indicator in organic type (Table 3). It might be due to the properties of difenoconazole having stable photochemistry and a low biodegradability rate. The previous study shows that these fungicide groups caused physiological and cytotoxic effects in ciliate protozoa, *Tetrahymena pyriformis*, based on the observation of morphology, behavior, and regeneration time (Maurya et al. 2019). In SO3, the reduced quality in ecological indices is likely due to the close distance to the adjacent conventional rivers, like SO1. The organic type shows the highest abundance mainly contributed by the Ampullariidae family. Within this family, the Golden apple snail (*Pomacea canaliculata*) has wide toleration across various agricultural types. The high abundance of this species demonstrate that it could fastly reproduce, has a low number of natural predators, and could suppress other species population by occupying the same ecological niche (Estebenet & Martín 2002; Yusa et al. 2006; Joshi et al. 2017), ultimately known as invasive species in Asia (Naylor 1996; Pallett 2016; Joshi et al. 2017). The location of the organic type was far isolated from agrochemicals exposure resulting in a high diversity of macroinvertebrates (Bickham et al. 2000), especially in O2 and O3. It can be concluded that the impact on the macroinvertebrate community was less detrimental in organic type than other sites with intensive agrochemical exposure (Kartikasari 2013).

Based on the correlation matrix (Figure 5), it can be observed that width and water current are concurrently involved in increasing the community indices and factors (positively correlated) across each type of agricultural type. Interestingly, dissolved oxygen and pH are observed to influence the community indices and factors in conventional type (positively correlated), but not observed in semi-organic and organic types (negatively correlated). Correlation matrix among the community indices and factors, and abiotic factors shows that some of the factors did correlate well to each other, and some of the others did not, suggesting a complex abiotic response to taxa variations.

CONCLUSION

Based on our results on macroinvertebrate composition, it is suggested that it is important to use sensitive taxa-group and community indices as an indicator of environmental changes. Several families, i.e., Tipulidae, Naididae, Cysticidae, and Nereididae demonstrated relation to semi-organic type. For environmental variables, i.e., temperature and water current, may correlate to the presence of clean water indicator species such as Philorheitridae and Chironomidae, as observed in organic agricultural rivers. Conventional and semi-organic agricultural rivers were grouped and largely contributed by the 5 families including: Ampullariidae, Pachychillidae, Baetidae, Enchytraidae, and Gomphidae. Complex interaction between macroinvertebrate community and environmental variables were found by Correlogram plot. It can be concluded that the intensive use of agrochemicals may lead to a deterioration of environmental services and quality of freshwater community and environment.

AUTHORS CONTRIBUTION

A.S.K. collected, analyzed the data, and wrote the manuscript. L.S.. analyzed the data and wrote the manuscript. H.P. designed the research and supervised all the process.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the content and there is no financial interest to report. We declare that the manuscript is original work, and is not under review at any other publication.

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