The impact of rainfall intensity on the composition of aquatic insect larvae in Lematang River, Indonesia

Novin Teristiandi

Department of Biology, Faculty of Science and Technology, Universitas Islam Negeri Raden Fatah Palembang, Palembang, Indonesia. Corresponding Author: N. Teristiandi, novinteristiandi_uin@radenfatah.ac.id

Abstract. Rainfall can change the environment and force aquatic insects to adapt to the changing ecosystem. The increase in water level leads to rolling substrate and more significant external material input. This research aims to examine the relationship between rainfall levels and the aquatic insect community in Lematang River. This study used ANOVA to analyze the comparisons between richness and abundance in the study area as well as the differences of assemblages at the sampling sites. A linear regression test was used to analyze the impact of rainfall levels on the diversity and abundance of aquatic insect larvae. There were 1213 aquatic insect larvae found, mainly consisting of Diptera, followed by Coleoptera and Trichoptera. The high colonization of Diptera order, especially Chironomidae larvae, was related to the high tolerance to lower pH. The increasing rainfall has a negative impact on the richness and abundance, because it most likely leads to contaminant runoff from coal mining, lower pH levels, and substrate covered by coal fragments.
Key Words: climate change, insects, Lematang, river, South Sumatera.

Introduction. Global warming affects local and international conditions since it leads to climate changes that affect the global environment (Amedie 2013; Butler 2018). The increase in rainfall intensity will predictably lead to a higher incidence of flooding and landslides, decreased biodiversity, destroyed ecosystems, and polluted water catchments (Case et al 2007; Cleary & DeVantier 2011). Consequently, the rainfall intensity pattern aggravates the composition of the aquatic environment in wetlands, lakes, and rivers (Poff et al 2002; Ridzuan et al 2020). A rainfall event is a unique natural disturbance causing some organisms to respond to the change quickly and to adapt to the condition through drift behavior (Kim et al 2018). However, heavy rainfall greatly enhances the possible damages of rivers, leading to changes in benthic assemblages (Carlson et al 2021; Feeley et al 2012; Jones 2013).

Among the diverse aquatic organisms, aquatic insects have been commonly used for impact assessment regarding ecosystem alterations. Aquatic organisms can respond quickly to changes in the environment through species composition modifications (Li et al 2010; Mauricio da Rocha et al 2010). In the tropical aquatic ecosystems, the aquatic insect assemblages mainly consist of Diptera, Odonata, Coleoptera, and Hemiptera, dominated by Chironomidae (Ramadan & Katbeh-Bader 2018).

Some studies found the apparent pattern of the response of the aquatic insect assemblage in river ecosystems, where the richness and density increase during the dry season and decrease in the rainy season (Suhaila et al 2014; Santana et al 2015). Biodiversity is affected by various factors, particularly seasons and rainfall. Consequently, it changes environmental properties (Quadri et al 2019) and aquatic insect community structure (Lytle 2008; Sela & Halpern 2020; Fischer et al 2021). Aquatic insect composition change because of higher reservoir levels due to heavy rainfall, which most likely causes higher external material input, more diverse niches, and a preferable environment for domination by specific organisms.

Lematang river is located near coal mining areas which generate acid mine drainage. The quality of water in Kungkilan river (the tributary of the Lematang river) has been degrading right after streaming through the area of coal mining along with increasing rainfall levels (Suroso et al 2017). Thus, the aim of this paper is to study the impact of rainfall on the aquatic insect community in the river, with the premise that the water levels and flow affect external material input and habitat stability. Furthermore, coal mining in the area potentially affects aquatic insects in the river.

Material and Method

Description of the study sites. Lematang River is located in Lahat Regency, South Sumatra, Indonesia (Figure 1). This research was conducted from September to December 2019. The study area was divided into nine sites, consisting of three upstream sites (L1, L2, and L3), three midstream sites (L4, L5 and L6), and three downstream sites (L7, L8, and L9). Nine sampling sites were selected from three different parts of the catchment (Figure 1). The upstream site included a fast-flowing river section prior to being contaminated by the coal mining area and a riverside part covered by riverbank vegetation. The midstream site consisted of a basin located near a coal mining area with little riverside vegetation. The downstream site was located in West Merapi right after the coal mining area. The river was slow flowing, and had little riparian vegetation covering the surface.

Figure 1. The study area and sampling sites: upstream sites (L1, L2, and L3), midstream sites (L4, L5, and L6), and downstream sites (L7, L8, and L9). Source: Google Earth.

Sampling procedures. *In-situ* measurements were used to assess some physicochemical properties of the water, namely dissolved oxygen (DO) using a DO meter, pH using a pH meter, transparency using a Secchi disc, and water flow using a current meter. The Ekman grab was used to collect sediment and the larvae of aquatic insects. The sediment was collected at 9 sampling sites (L1-L9) in the middle part of the basin and the weight of each sample was 3 kg. The sediment was washed with tap water through a sieve (300 μm pore) for filtering aquatic insects. All samples of aquatic insect larvae were moved to a collecting container with 70% ethanol. The samples were transferred to the ecology laboratory of the Faculty of Biology, Universitas Gadjah Mada, for species identification. The larvae were sorted and identified and counted using a binocular microscope. The identification of aquatic insect larvae was conducted to the genera level.

Data analysis. The abundance of the aquatic insect community, the richness at the sampling site, how the numbers vary in the research areas, and the relative density of taxa (ind m^{-2}) were determined. The aquatic insect assemblages were analyzed using one-way ANOVA and Tukey's honest significance test. The relationship between physicochemical properties and the abundance of aquatic insects was examined using linear regression analysis to observe the rate of a significant relationship, utilizing the SPSS v. 24, at $p<0.05$.

Results and Discussion

The abundance of aquatic insect larvae. The abundance of aquatic insects in Lematang River is summarized in Table 1. The total density of aquatic insects was 1213 ind m^{-2}. The highest density of aquatic insects was found at the upstream site, 653 individuals m^{-2}, and the lowest was found at the midstream site, 147 individuals m^{-2}. The data showed that the upstream site (reference site) had the highest abundance, while the midstream site had the lowest abundance. Aquatic insects representing three orders, Coleoptera, Trichoptera, and Diptera, were collected. The dipteran was represented by three genera, namely *Bezzia*, *Chironomus*, and *Tanytarsus*. The Diptera order could be found in a variety of locations in the study areas. *Stenelmis* and *Optioservus* representing the Coleoptera order were only found at the upstream site. The Trichoptera was represented by *Cheumatopsyche*, and was found only at the downstream site.

6 genera were identified: *Stenelmis*, *Optioservus*, *Cheumatopsyche*, *Bezzia*, *Chironomus*, and *Tanytarsus*. 4 genera were found at the upstream site, namely *Stenelmis, Optioservus*, *Bezzia*, and *Tanytarsus*. A total of three genera were collected at the midstream site, and four genera were collected at the downstream site.

Table 1

The abundance of aquatic insects in Lematang River

		Sampling sites								
		Upstream			*Midstream*			*Downstream*		
Order	*Genus*	*L1*	*L2*	*L3*	*L4*	*L5*	*L6*	*L7*	*L8*	*L9*
Coleoptera	*Stenelmis*	93	40	120	0	0	0	0	0	0
	Optioservus	27	0	0	0	0	0	0	0	0
Trichoptera	*Cheumatopsyche*	0	0	0	0	0	0	0	107	0
Diptera	*Bezzia*	80	13	67	13	0	0	0	53	13
	Chironomus	0	0	0	27	27	13	0	27	13
	Tanytarsus	80	27	107	27	13	27	67	107	27
	Sub total	280	80	293	67	40	40	67	293	53
	Total		653			147			413	

Tanytarsus and *Bezzia* were collected at all sampling sites. *Tanytarsus* had the highest abundance of taxa (480 individuals m^{-2}), while *Optioservus* had the lowest abundance (27 individuals m^{-2}). *Optioservus* and *Stenelmis* were found only at the upstream site. According to the Table 2, Tukey's honest significance test showed a significant difference between the midstream and downstream sites ($p<0.05$). Meanwhile, the abundance of aquatic insects at the midstream site was not significantly different from that at the downstream site. It was indicated that the aquatic insect larvae abundance was significantly higher upstream than at the other sites.

Table 2

The Tukey's honest significance test of insect abundance between sampling sites

Study area		*p-value*
Upstream	Midstream	0.03
	Downstream	0.03
Midstream	Upstream	0.03
	Downstream	0.48
Downstream	Upstream	0.03
	Midstream	0.48

Rainfall intensity and frequency. The rainfall intensity per month during the survey period (September–December 2019) was between 123-409 mm m^{-2}. Figure 2 shows that rainfall intensity at the upstream site was between 154-409 mm m^{-2} per month.

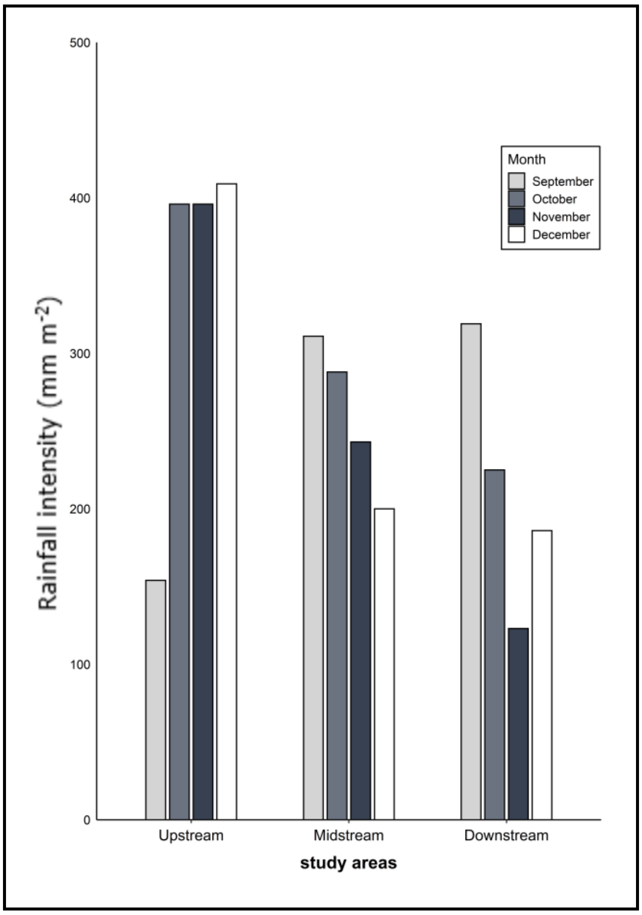

Figure 2. Rainfall intensity at three sampling sites.

The midstream site had a range of rainfall intensity between 229-311 mm m^{-2} per month, while the rainfall intensity at the downstream site was between 123-319 mm m^{-2} per month. The highest rainfall range occurred at the upstream site, and the lowest was at the downstream site. The rainfall frequency (the number of rainy days) in the study area was between 9 and 22 days in a month during the survey period. It was between 13 and 22 days in a month at the upstream site, between 12 and 17 days in a month at the midstream site, and between 9 and 16 days at the downstream site. The highest frequency was at the upstream site and the lowest at the downstream site.

Rainfall impact on the abundance of aquatic insects. The regression analysis results (Table 3) showed that rainfall significantly affected the abundance of aquatic insects in Lematang River ($p<0.05$). Meanwhile, the number of rainy days had no significant effect on the abundance of aquatic insects. It was indicated that rainfall affected the occurrence of aquatic insect larvae in the study area.

Table 3

Multiple regression analysis of rainfall on the abundance of aquatic insect

Parameters	*Mean Square*	*F*	*p-value*
Rainfall intensity	5997	3	0.007
Rainfall frequency	13873	7	0.650

Note: adjusted R^2=0.505

According to Figure 3, the richness of aquatic insects was higher in the rainfall range of 100-200 mm m^{-2} per month. On the contrary, it was lower in rainfall of >300 mm m^{-2} per month, except at the midstream site. Similarly, the abundance of aquatic insect larvae seemed higher in the rainfall range of 100-200 mm m^{-2} per month, and lower in the rainfall range of >300 mm m^{-2} per month in the study area.

The average number of Diptera, Coleoptera, and Trichoptera was calculated for all the taxa. The average abundance of each aquatic insect larvae order seemed to decrease along with the increase in rainfall at all sites. The abundance of aquatic insects decreased at a higher level of rainfall of >300 mm m^{-2} at the upstream and downstream sites, and decreased at the rainfall of 201–300 mm m^{-2} at the midstream site (Figure 4). Mainly, the decreasing number of each aquatic insect in all orders at the study areas was significantly influenced by the rainfall intensity ($p<0.05$).

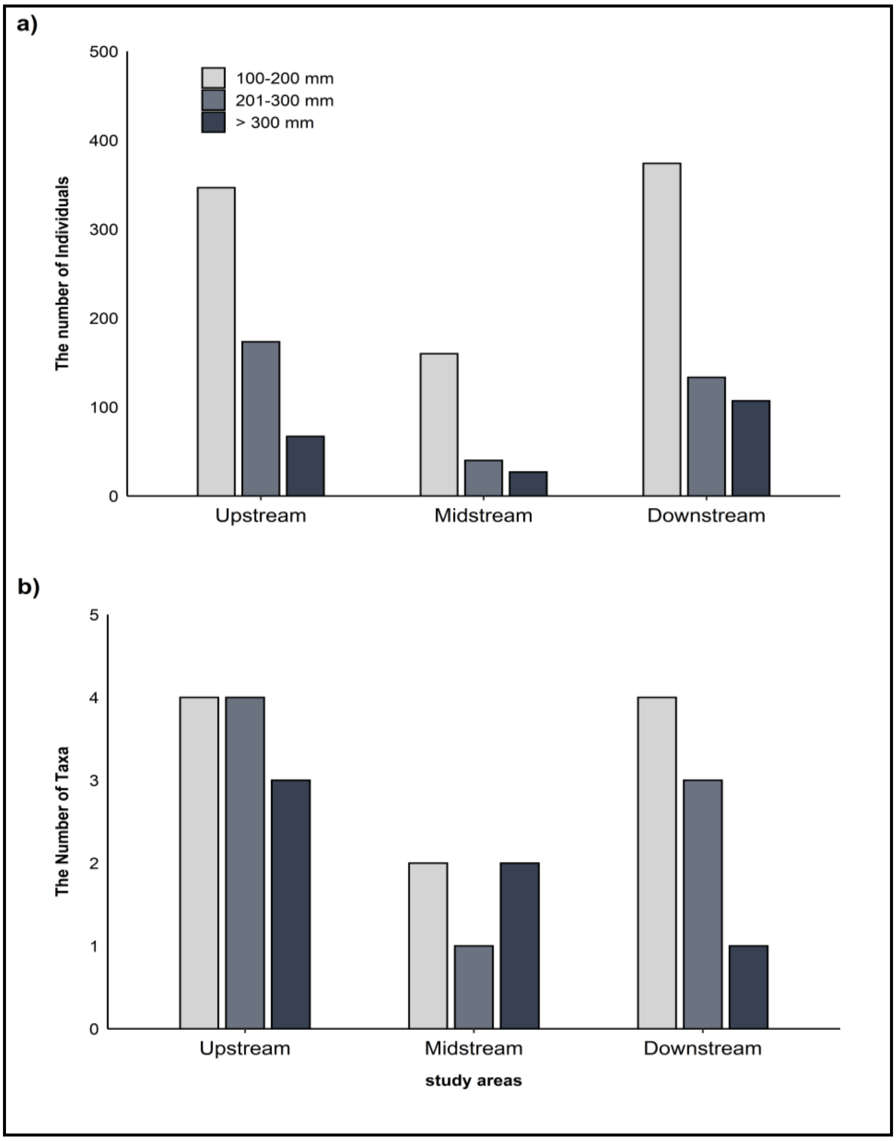

Figure 3. The relationship between rainfall intensity and (a) the abundance of aquatic insects and (b) species, based on rainfall.

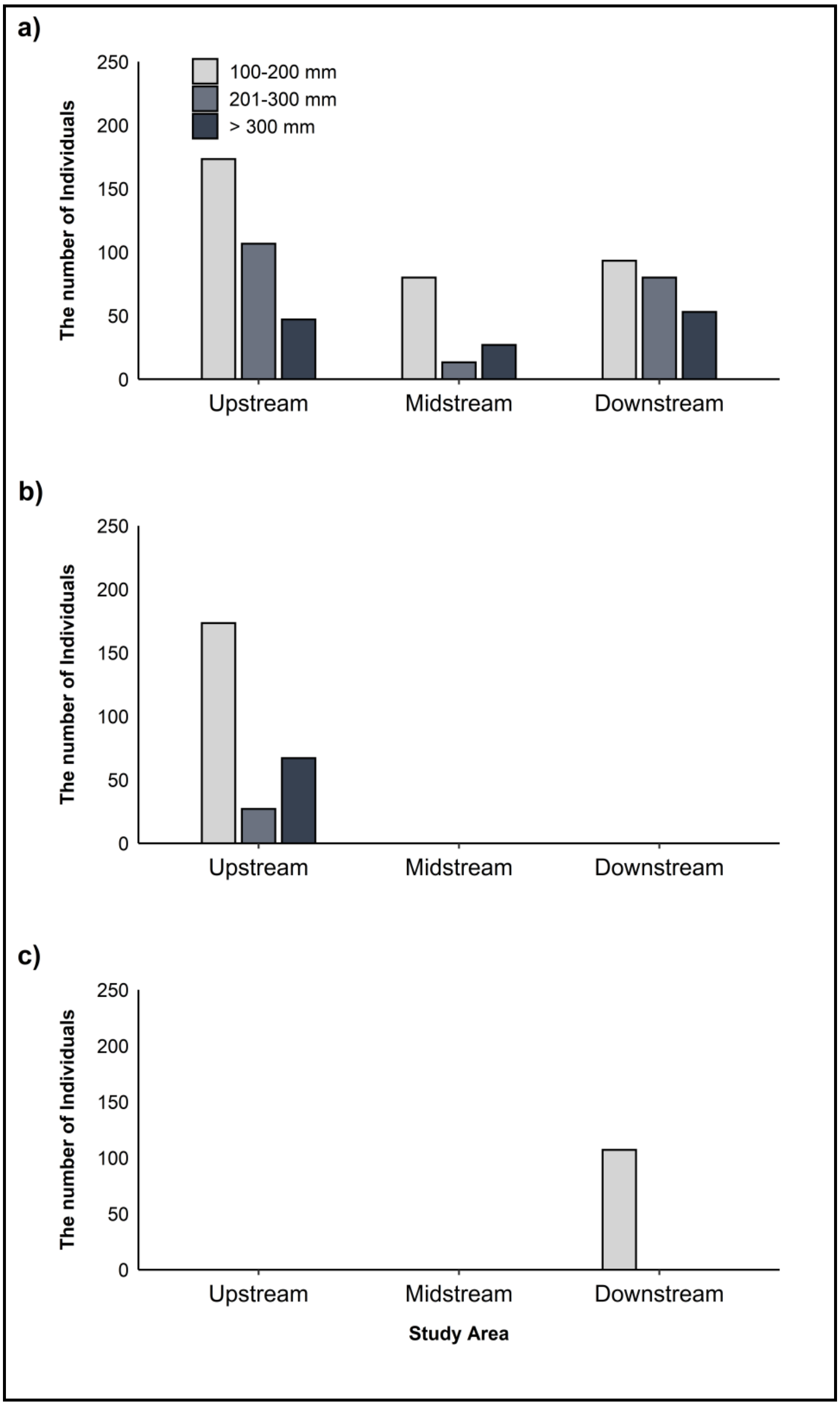

Figure 4. The average abundance of aquatic insect larvae order, (a) Diptera, (b) Coleoptera, and (c) Trichoptera, based on rainfall at the sampling sites.

The impact of environmental factors on the abundance of aquatic insects. Table 4 shows that the parameters of DO, water temperature, water flow, and transparency had no significant effect on the abundance. However, the pH had a considerable influence on the abundance, where pH positively affected the total number of insects.

Table 4
The relationship between selected environmental parameters and the total number of aquatic insects

Parameters	*T*	*Sig.*
Water temperature	0.35	0.73
Water depth	-0.46	0.65
Dissolved oxygen	0.00	1.00
pH	2.29	0.03
Water flow	0.05	0.96
Transparency	0.29	0.77
Combination	-0.35	0.73

Note: R^2=0.27.

The present study found that the lowest abundance of aquatic insect larvae was at the midstream site. In contrast, the upstream site had the highest abundance. The decrease in aquatic insect larvae at midstream was also found in other studies regarding coal mining-impacted waters. The coal mining industry generates a high acid mine drainage (AMD) that affects the biological, chemical, and physical components of the aquatic ecosystem and decreases macroinvertebrate communities (Hogsden & Harding 2012).

Based on the analysis in the three sampling sites using Tukey's HSD, there is a significant difference in the total abundance in the upstream sites since reference sites differed at the midstream and the downstream parts. Similarly, other authors discovered significant differences in the abundance of insects between unaffected and affected sites of coal mining industries (Last 2001; Teristiandi 2018). Additionally, Last (2001) found that AMD affected the abundance more than the species richness.

The community structure and composition of aquatic insect assemblages at midstream and downstream sites changed. The highest order abundance in study areas was Diptera, mainly composed of a tolerant family of Chironomidae. In this study, all of the species at the midstream site were Diptera larvae, *Tanytarsus*, *Bezzia*, and *Chironomus*. The Chironomidae larvae seemed to be tolerant and abundant. Similarly, Wakhid et al (2020) stated that Chironomidae larvae, especially *Chironomus*, are abundant in streams. MacCausland & McTammany (2007) found that the density of aquatic insect larvae assemblages decreased, and consisted of Chironomidae and Ceratopogonidae larvae at sites closed in the coal mining area. Additionally, the acidic characteristics of the AMD could be a stress factor for most insects, excluding Chironomidae larvae, which were more tolerant to polluted rivers with low water pH (Gauthier-Manuel et al 2021) and A continuous discharge of AMD reaching the river can lead to communities migrations (He et al 2019). The following highest number was for *Bezzia*, which was recorded at all sampling sites. The attendance of *Bezzia* was related to the dominance of Chironomidae larvae at all the sampling sites. The existence of *Bezzia* could be caused by high food availability, such as Chironomidae larvae (Collins 1975). On the contrary, Trichoptera order (*Cheumatopsyche*), considered moderately tolerant, was only found at the downstream site (affected site). Similarly, the existence of *Cheumatopsyche* was abundant and increased in a polluted river (Houghtona 2004), particularly in villages and plantation streams (Wakhid et al 2021).

Rainfall intensity significantly affected the abundance of aquatic insect larvae in the study area. This research showed that the number of aquatic insect larvae assemblages decreased along with the increase in rainfall levels. On the contrary, Santana et al (2015) stated that the increase in the diversity and the total number of aquatic insects occurred during the rainy season.

However, some studies found that the increased rainfall frequency can lead to a long-term decrease in aquatic communities. The rainfall intensity has a higher impact on the assemblages than rainfall frequency (Kim et al 2018; Chattopadhyay et al 2021). Based on rainfall intensity at each site, the average abundance of aquatic insect larvae seemed to decrease along with the increase in rainfall at all sampling sites. There were two possible explanations for this observation. Firstly, Lematang River is located near a coal mining area. Increased rainfall and flooding events might have disturbed the hydraulic structures (holding ponds, spillways, ditches, and dams) at mining areas around Lematang river and caused more contaminant surface runoff. It would also influence the mine tailings covers (permafrost, store and release, simple soil covers, etc.) and the dam necessary for long-term storage of tailings and other contaminants after mine closure (Anawar 2013; Bashir et al 2020). This condition could cause lower pH from acid runoff events in mining operations (Iatan 2021). Furthermore, acidic pH might lead to toxic substances in the aquatic ecosystem (Almaniar et al 2021). Secondly, the river substrate attribute was the crucial factor determining the response of aquatic insect larvae to the rainfall. Flooding disturbance to benthic communities is represented mainly by the rolling of the substrate instead of the water flow (Gibson & Shelley 2020). This study also found coal fragments on the substrate at the midstream site when rainfall increased. Furthermore, the contaminated substrate might have influenced the abundance of aquatic insect larvae. Coal disrupts the balance of original living conditions and decreases the quality of environmental properties (Luo et al 2019).

Conclusions. The highest abundance and richness were at the upstream site, and they decreased at the sampling site near the coal mining area. The Chironomidae larvae were dominant at all study areas in the Lematang river. Rainfall influenced the total number of aquatic insect larvae in the Lematang River. The number of insects decreased along with the increasing rainfall in the study area. Flooding events will cause more contaminant surface runoff from the coal mining areas and lower pH at affected sites. Furthermore, the instability and rolling of the substrate at upstream sites affected the decreasing number of aquatic insect larvae.

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Conflict of Interest. The author declares that there is no conflict of interest.

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Author:
Novin Teristiandi, Department of Biology, Faculty of Science and Technology, Universitas Islam Negeri Raden Fatah Palembang, 30126 Palembang, Indonesia, e-mail: novinteristiandi_uin@radenfatah.ac.id

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