 DOI: 10.11598/btb.2022.29.1.1662

NEUSTON DIVERSITY AND DENSITY AS BIOINDICATOR FOR WATER QUALITY

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Received 9 September 2021 / Accepted 12 December 2021

ABSTRACT

Lakes and waterfalls are freshwater ecosystems having important roles in ecology, tourism and economic aspects. Among living organisms existing in lakes and waterfalls is neuston. Neuston lives on the surface and below the surface of the waters. Neuston can be used as a bioindicator for water quality due to the neuston's high level of sensitivity toward pollutants. The purpose of this study was to determine the density and diversity of neuston as a bioindicator for water quality in the lake and waterfall. The methods used were survey and observation. The study was carried out by using purposive sampling at two locations, namely the lake and waterfall of Situ Gunung, Sukabumi, with a sampling area of 1 x 1 m^2. The samples obtained were put into bottles containing 70% alcohol to be identified in the laboratory. Environmental parameters measured were air and water temperature, water pH, water depth, turbidity, water flow velocity, dissolved oxygen, substrate and weather conditions. The results obtained indicated that the lake and waterfall of Situ Gunung, Sukabumi had highest neuston densities were shown by *Gerris lacustris* and *Dineutus assimilis*. The lowest neuston densities were shown by *Metrobates hesperius*, *Gerris comatus*, *Aquarius remiges* and *Trepobates pictus*. This study showed that the environmental parameters of the lake and waterfall of Situ Gunung, Sukabumi can still support the survival of the existing neustons.

Keyword: density, diversity, neuston

INTRODUCTION

Freshwater ecosystems are divided into lentic/flooded freshwater ecosystems and lotic/flowing freshwater ecosystems. The examples of lentic freshwater ecosystems are lakes and swamps, while that of lotic freshwater ecosystems are waterfalls and rivers (Diantari *et al*. 2017; Ramadhan *et al*. 2016). The existence of the lake is considered important because it has an ecological, social, and economic roles for the surrounding environment (Postel & Carpenter 1997; Chen *et al*. 2020; Heino *et al*. 2021; Robert *et al*. 2020). The lake also acts as a habitat for several living organisms, such as neuston (Asnil *et al*. 2013; Ramadhan *et al*. 2016).

According to Mulyono (2018), neuston floats on water (epineuston) or below the water surface (hyponeuston). Hyponeuston lives at a depth of about 0 - 10 cm (Rumnasih 2016). Neuston has a level of sensitivity to several contaminants so neuston can be used as a direct indicator for water contamination (Oktarina 2015) and as a bioindicator for water quality. The upper part of the waters is the most susceptible part to environmental exposure, which in turn will impact the neuston. Pollution often causes the formation of artificial stratification in lakes, where a body of water (hypolimnetic zone) is isolated. However, the hypolimnetic zone caused the contaminants trapped within the bottom of the waters and sediment masses (Sutrisno & Hamdani 2013; Williams 2001; Winton *et al*. 2019; Perron *et al*. 2014; Donyinah 2019).

Waterfalls are a form of lotic freshwater ecosystem and are generally used as natural tourist objects (Siswantini & Mulyana 2017). The waterfall and lake in the Situ Gunung area, Sukabumi have an important role as one of

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tourist attractions in Kadudampit District, Sukabumi, West Java Province, Indonesia (Soetopo 2011). Situ Gunung as a tourist object cannot be separated from tourists activities which will affect the surrounding environment, including the neuston community. Therefore, the purpose of this study was to determine environmental factors influencing the density and diversity of neuston as water quality bioindicator in the lake and waterfall in Situ Gunung, Sukabumi.

MATERIALS AND METHODS

The study was conducted in June 2021 at Situ Gunung, Gunung Gede Pangrango, Kadudampit District, Sukabumi. The methods used were survey and observation. The tools used were rope, wooden stick, measuring tape, thermometer, turbidimeter, DO meter, loop, field guide as an identification guide, stopwatch, plastic bottle, sample bottle, sample plastic, camera, net 1 x 1 m^2, identification key book and stationery. The materials used were 70% alcohol, labeling paper and universal pH indicator paper (1 - 14).

The study was conducted in two study locations, namely lake and waterfall in the shallowest part. Each location was represented by three observation stations based on differences in environmental conditions. Sampling was carried out three times at each station. Neuston collection was carried out at locations and stations that were purposively determined as a pick-up point sized 1 x 1 m^2. Neuston samples were taken by using a 1 x 1 m^2 net which was placed on the water surface. The net captured neustons which went through the filtration following the horizontal movement of the surface water in the lake and waterfall. Subsequently, the neustons sample was put into a bottle containing 70% alcohol. Samples were identified in the field and photographed for documentation.

Environmental parameters measured were air and water temperature, water pH, water depth, water turbidity, water flow velocity, dissolved oxygen, substrate and weather conditions. The air temperature was measured using a calibrated air thermometer. Water temperature measurements were carried out using a DO meter. The pH of the water was measured using universal pH indicator paper (1 - 14). The water depth of the lake and waterfall was measured using a long wooden stick. The mark of the water depth was then measured by using a measuring tape. Water turbidity was measured by using a calibrated turbidity meter. Water flow velocity was measured by using floating method from the edge of the lake and waterfall. A rope was tied to a bottle and a 1-meter-long wooden stick. The bottle was floating at the water surface. The time taken from the moment the bottle was tied up to the wooden stick until the rope was stretched straight, was recorded by a stopwatch. The water flow velocity is expressed in m/s unit. The formula for calculating the water flow velocity is as follows:

$$\text{Flow Velocity} = \frac{\text{Rope Length (m)}}{\text{Time (s)}}$$

Dissolved oxygen was measured three times using a DO meter. The substrate is the surface on which an organism lives. The substrate sample of the lake was taken using the Ekman Grab, while the substrate of the waterfall can be seen directly because the water depth is quite shallow. The substrate was determined by looking at its composition. The types of water substrates are sand, mud, rocks, lime, and others. Weather was determined by looking at the weather situation at the lake and waterfall environment. There are three kinds of weather conditions, namely sunny, cloudy, and rainy. Data analysis was carried out by determining the Simpson index using the formula as follows:

1. Density

$$B = \frac{T \times P}{A \times S}$$

where:
T = quadrant area (1 m^2 = 10,000 cm^2)
P = area of the taking transect (m^2)
A = number of individual species
S = number of taking transects

2. Diversity

$$D_s = 1 - D \rightarrow D_s = 1 - \frac{\Sigma \text{ Ni (ni} - 1)}{\text{N (N} - 1)}$$

where:
Ds = Simpson's diversity index

D = dominant index
ni = number of individuals species
N = total number of individuals

RESULTS AND DISCUSSION

There were six species of neuston found in the lake and waterfall of Situ Gunung. Four species were existed in the lake, namely *Gerris lacustris*, *Metrobates hesperius*, *Gerris comatus*, and *Aquarius remigis* (Fig. 1), while two species were found in the waterfall, namely *Dineutus assimilis* and *Trepobates pictus* (Fig. 2).

Neuston species found in the lake and waterfall are different, depending on the habitat. *Gerris lacustris* and *Gerris comatus* are found in lakes due to their lentic habitat preferences. According to Ye *et al.* (2017), *Gerris* species inhabit several lentic habitats such as ponds, lakes and backwaters of streams. The habitat preference of *Gerris lacustris* is a high level of water depth, covered with vegetation, which is in agreement with a study conducted by Olosutean and Ilie (2013) who found that *Gerris lacustris* is correlated with water depth and have adaptation benefits from the presence of vegetation cover. The surface of the lakeside of Situ Gunung is covered with aquatic plants and the depth is relatively higher (58 - 93 cm) compared to the water depth of the waterfall (25 - 64 cm). In addition, *Gerris comatus* is a characteristic organism for lentic water. *Gerris comatus* is often found together with *Gerris marginatus* and *Gerris buenoi* (Damgaard *et al.* 2014; Pintar & William 2020). However, the last two species mentioned are not found in the lake.

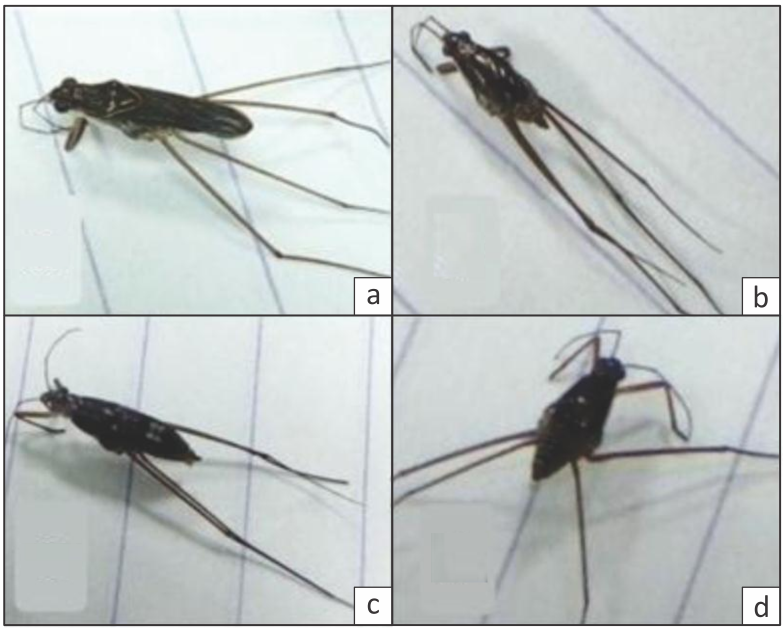

Figure 1 Neuston species found in the lake of Situ Gunung
Notes: a. *Gerris lacustris*; b. *Metrobates hesperius*; c. *Gerris comatus*; d. *Aquarius remigis*

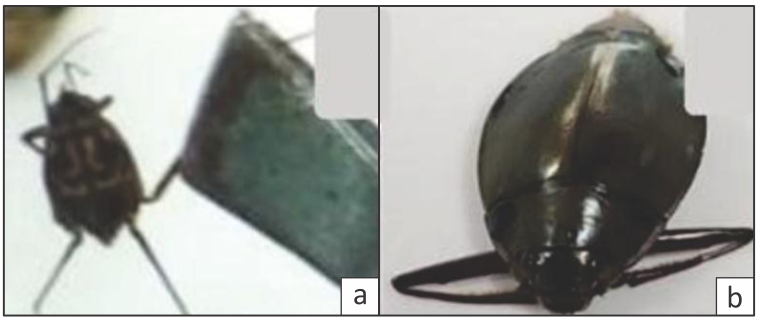

Figure 2 Neuston species found in the waterfall of Situ Gunung
Notes: a. *Trepobates pictus*; b) *Dineutus assimilis*

Aquarius remigis were found in the lake of Situ Gunung, which fact is different from the statement of Ye *et al.* (2017) that *Aquarius* species are mostly confined to lotic habitats, such as water springs and rivers. *Aquarius* species can live in two different kinds of freshwater, both lentic and lotic. *Aquarius* species are semi-aquatic insects and opportunistic predators that live on the water surface of lakes, rivers, and the border between rivers and lentic habitats (Ditrich & Papáček 2016; Guterres *et al.* 2019). *Metrobates hesperius* were found in the lake because there are aquatic plants on the surface of the lakeside of Situ Gunung. *Metrobates hesperius* lays eggs on the leaves of the floating aquatic plants (Taylor 2009; Ikawa *et al.* 2012; Finet *et al.* 2018). The lake as a habitat supports the survival and distribution of these species.

Dineutus assimilis and *Trepobates pictus* were found on the surface of a waterfall. *Dineutus assimilis* prefers both lotic and lentic waters, such as river surfaces, lakeshores and lakes (Gustafson & Miller 2015; MacLean 2013; Webster & DeMerchant 2012). Habitat preferences of *Trepobates pictus* were waters with slow water flow with eutrophic, muddy and rocky conditions in lotic waters (Naranjo *et al.* 2010; Taylor & McPherson 2006; Wooden 2019; Chordas 2017). The diversity index value (Ds) of neuston species obtained in the lake and waterfall for each station in Situ Gunung is presented in Table 1. Diversity index of 0.50 means low diversity, diversity index value of 0.50 to 0.75 means moderate diversity index, while diversity index of 0.75 to 1 means high diversity index (Nento *et al.* 2018).

Table 1 Neuston diversity and total individuals in the lake and waterfall of Situ Gunung

Location	Station 1		Station 2		Station 3	
	Ds	TI	Ds	TI	Ds	TI
Lake	0.00	4	0.11	18	0.70	5
Waterfall	0.47	10	0.00	6	0.48	7

Notes: Ds = Diversity, TI = Total Individuals

Table 1 shows that neuston diversity index value (Ds) varies among stations. The highest neuston diversity index in the lake occurred at station 3 with a value of 0.70 (moderate) with a total of 5 inviduals and 3 neuston species, namely *Gerris lacustris*, *Gerris comatus* and *Aquarius remigis*. Neuston diversity index value in the lake at station 2 was 0.11 (low) with a total of 18 individuals and 2 neuston species, namely *Gerris lacustris* and *Metrobates hesperius*. The lowest neuston diversity index in the lake occurred at station 1 with a value of 0.00 (low). In station 1, only one neuston species was found, namely *Gerris lacustris* with a total of 4 individuals. The highest neuston diversity index in the waterfall occurred at station 3 with a value of 0.48 (low), where 2 neuston species were found, namely *Dineutus assimilis* and *Trepobates pictus* with a total of 7 individuals. The lowest neuston diversity index in the waterfall occurred at station 2 with a value of 0.00 (low), where 1 neuston species was found, namely *Dineutus assimilis* with a total of 6 individuals. The neuston diversity index in the waterfall at station 1 was 0.47 (low) with a total of 10 individuals and 2 neuston species, namely *Dineutus assimilis* and *Trepobates pictus*. The different values of diversity index with total individuals obtained was due to dominant species in the lake and waterfall of Situ Gunung, namely *Gerris lacustris* and *Dineutus assimilis*.

Table 2 Neuston density in the lake and waterfall of Situ Gunung

Location	Neutston species	Neuston density (individu/m^2)
Lake	*Gerris lacustris*	0.24
	Metrobates hesperius	0.01
	Gerris comatus	0.01
	Aquarius remigis	0.01
Waterfall	*Dineutus assimilis*	0.18
	Trepobates pictus	0.05

The highest neuston density neuston in the lake was shown by *Gerris lacustris* with a value of 0.24 individu/m^2. The three other neuston species, namely *Metrobates hesperius*, *Gerris comatus*, and *Aquarius remigis* showed the same density value of 0.01 individu/m^2 (Table 2). On the lake surface of Situ Gunung at stations 1 to 3, there are aquatic plants. *Gerris lacustris* prefers to live on aquatic plants available on the lake surface of Situ Gunung. According to Yee (2016), *Gerris lacustris* spends most of its life on the surface of the water. In the lake of Situ Gunung there were two species of *Gerris*, namely *Gerris lacustris* and *Gerris comatus*. *Gerris* species can be found in almost all aquatic habitats from water springs to tropical seas (Yurtseven *et al.* 2016). At the waterfall of Situ Gunung, the highest neuston density was shown by *Dineutus assimilis* with a value of 0.18 individu/m^2 and *Trepobates pictus* with a value of 0.05 individu/m^2. The common aquatic insects found in Indonesian freshwater are of the Order Odonata, Coleoptera, Trichoptera, Hemiptera, Ephemeroptera, Plecoptera and Lepidoptera (Mahajoeno *et al.* 2001; Candra *et al.* 2014). In the lake and waterfall of Situ Gunung, we found Orders Hemiptera and Coleoptera.

Every species found in the lake of Situ Gunung belongs to Gerridae family. According to Dwitawati *et al.* (2015), Gerridae family is classified as having a low tolerance for pollutants. Meanwhile, *Gerris lacustris*, *Gerris comatus*, *Metrobates hesperius* and *Aquarius remigis* belong to the Order Hemiptera. Hemiptera insects often move rather than being settled in an unwanted location (Mercer *et al.* 2017; Peterson *et al.* 2017; Wooden 2019). The predominant presence of Hemiptera insects indicates that the lake is relatively less polluted (Majumder 2013). The pollution that contaminates the lake of Situ Gunung is thought to come from household wastes and human recreational activities. Aquatic insects are a good bioindicator for detecting pollution. Aquatic insects are also useful for fish food and biocontrol agents (Dalal & Gupta 2016; Ito *et al.* 2017). Therefore, long-term monitoring of aquatic insects is needed to evaluate water quality.

Table 3 shows that the pH values in the lake of Situ Gunung for all stations are relatively constant, namely 6 (acid). The standard pH for clean water quality ranges from 6.5 to 9.0. The pH value in the lake of Situ Gunung which is below the clean water standard is suspected to have been polluted by household wastes due to the closeness with the mainland, hence acidic pH value. The acidic pH value is not within the suitable environment for the neuston's life. Neuston can develop well in the pH range of 6.8-8.5 (Gundo 2010; Pratami *et al.* 2018). pH affects dissolved oxygen levels. The lowest dissolved oxygen level for the lake of Situ Gunung location was found at station 2, which was 3.28 mg/L. The acidic pH causes an increase in toxic substances in the water and decreases dissolved oxygen levels (Pratami *et al.* 2018).

Dissolved oxygen plays an important role in the respiration process of most aquatic organisms (Hariyani *et al.* 2017; Pratami *et al.* 2018). The average of dissolved oxygen level in the lake of Situ Gunung was 3.62 mg/L. Dissolved oxygen levels also indicate the level of pollution waters. Dissolved oxygen levels below 5 ppm mean low pollution levels (Hariyani *et al.* 2017). The low dissolved oxygen level shown in the lake of Situ Gunung indicated that the pollution level was low enabling neuston organisms such as water insects to obtain the needed oxygen for the respiration process.

The lake of Situ Gunung showed the highest water turbidity value at station 1, which was 11.97 NTU. The high value of water turbidity is presumably caused by the existing fishing activities by humans and aquatic plants on the lake surface at station 1. Penetration of sunlight into the lake waters can be hindered by the high value of water turbidity (Pratami *et al.* 2018). The lowest value of water turbidity was shown at station 2, which was 4.44 NTU. The different value of water turbidity at station 2 compared to the other two stations is presumably caused by the utilization of station 2, which function is docking place for boats. Also, only a few of aquatic plants were existing in station 2.

The measurement of environmental parameters of the waterfall of Situ Gunung showed air and water temperatures of 20.7 ºC and 17.9 °C, respectively, indicating a cold-water habitat for insects (Table 4). In the environment of the lake of Situ Gunung, the air and water temperatures of 29 ºC and 28 °C, respectively, indicating a warm-habitat for insects (Table 3).

According to Mujiono *et al.* (2019), the higher the place is, the colder the temperature. The average of water pH of the waterfall of Situ Gunung is 6 (acidic) with average of Dissolved Oxygen value of 7.77 mg/L. Dissolved oxygen levels are high in the waterfall because the waterfall is located on a hill surrounded by natural forests and has low pollution levels. Meanwhile, the lake water is murky indicating water pollution that affects dissolved oxygen levels. In addition, the murky water can cause the increase of oxygen uptake from the air into the water causing the increase of dissolved oxygen in the water (Diantari *et al.* 2017; Mujiono *et al.* 2019; Irby *et al.* 2015).

Table 3 Environmental parameters obtained from the lake of Situ Gunung

Environmental parameter	Station			Mean
	1	2	3	
Water pH	6	6	6	6
Air temperature (°C)	29	29	29	29
Water temperature (°C)	28.03	27.93	27.93	27.97
Water depth (cm)	58	71	93	74
Water turbidity (NTU)	11.97	4.44	11.85	9.42
Water flow velocity (m/s)	0.009	0.022	0.0085	0.013
Dissolved Oxygen (mg/L)	4.24	3.28	3.33	3.62
Substrate	Mud and rocky	Mud and rocky	Mud and rocky	
Weather	Cloudy and rainy	Cloudy and rainy	Cloudy and rainy	

Table 4 Environmental parameters obtained from the waterfall of Situ Gunung

Environment	Station			Mean
	1	2	3	
Water pH	6	6	6	6
Air temperature (°C)	20.8	20.8	20.5	20.7
Water temperature (°C)	17.9	17.9	17.9	17.9
Water depth (cm)	25	53.33	64.33	47.56
Water turbidity (NTU)	0.41	0.46	0.51	0.46
Water flow velocity (m/s)	0.49	0.58	0.13	0.40
Dissolved Oxygen (mg/L)	7.54	7.71	8.05	7.77
Substrate	Rocky	Rocky	Rocky	
Weather	Sunny	Sunny	Sunny	

The water flow of the stations at waterfall of Situ Gunung showed an average of water flow velocity of 0.40 m/s which affects the presence of swimming-type aquatic insects. Due to the high value of water flow velocity and the presence of rocky substrate, the water insects hide behind rocks (Leba *et al.* 2013). According to Diantari *et al.* (2017), the rocky substrate can affect the water flow velocity in a stream. The lake water's flow velocity of 0.01 m/s causes the lake to be predominated by neustons with floating ability. The average water turbidity of the waterfall of Situ Gunung was 0.46 NTU with an average water depth of 47.56 cm. Meanwhile, the lake showed an average turbidity of 9.42 NTU with an average water depth of 74 cm (Table 3). Our study showed that sunlight easily penetrated the waterfall. However, the murky lake water hindered the sunlight penetration into the lake. Small value of water turbidity can support filter-feeder organisms and affect the activities of the existing Orders Hemiptera and Coleoptera (Ebenebe *et al.* 2016; Marpaung *et al.* 2014).

CONCLUSION

Six neuston species were identified in Situ Gunung, namely four species in the lake of Situ Gunung and two species in the waterfalls of Situ Gunung. The four neuston species in the lake namely *Gerris lacustris*, *Metrobates hesperius*, *Gerris comatus* and *Aquarius remigis,* while the two neuston species waterfalls namely *Dineutus assimilis* and *Trepobates pictus*. The highest neuston densities in the lake and waterfalls were represented by *Gerris lacustris* and *Dineutus assimilis*, respectively. Neuston diversity in the lake and waterfalls of Situ Gunung was low. Environmental parameters of the lake and waterfalls of Situ Gunung were still in the normal range, except low water pH indicating polluted waters environment. Therefore, long-term monitoring at the waters of Situ Gunung is needed for evaluating water quality parameters that support the life of aquatic organisms.

ACKNOWLEDGMENTS

The author would like to thank the assistant of the Ecology Laboratory of Universitas Negeri Jakarta who assisted us in analyzing water quality parameters of our study. Special gratitudes are also delivered to the Officials of the Taman Nasional Gunung Gede Pangrango Center for allowing us to conduct this study.

REFERENCES

Asnil A, Mudikdjo K, Hardjoamidjojo S, Ismail A. 2013. Analisis kebijakan pemanfaatan sumberdaya danau yang berkelanjutan (Studi kasus Danau Maninjau Sumatera Barat). J Nat Res Environ Manage 3(1):1-9.

Candra Y, Langoy M, Koneri R, Singkoh MF. 2014. Kelimpahan serangga air di Sungai Toraut Sulawesi Utara. Jurnal MIPA 3(2):74-8.

Chen Y, Ke X, Min M, Cheng P. 2020. Disparity in perceptions of social values for ecosystem services of urban green space: A case study in the East Lake Scenic Area, Wuhan. Public Health Front 8:1-11.

Chordas SW. 2017. Literature record checklist of true bugs (Hemiptera) for Arkansas, USA. Journal of the Arkansas Academy of Science 71:224-31.

Dalal A, Gupta S. 2016. A comparative study of the aquatic insect diversity of two ponds located in Cachar District, Assam, India. Turk J Zool 40(3):392-401.

Damgaard J, Moreira FFF, Zettel H, Weir TA. 2014. Molecular phylogeny of the pond skaters (Gerrinae). Discussion of the fossil record and a checklist of species assigned to the subfamily (Hemiptera: Heteroptera: Gerridae). Insect Syst Evol 45(3):251-81.

Diantari NPR, Ahyadi H, Rohyani IS, Suana IW. 2017. Diversity of Ephemeroptera, Plecoptera, and Trichoptera as bioindicator of water quality in Jangkok River, West Nusa Tenggara. Indonesian Journal of Entomology 14(3):135-42.

Ditrich T, Papáček M. 2016. Differences in prey capture in semiaquatic bugs (Heteroptera: Gerromorpha). Entomol Sci 19(1):34-41.

Donyinah SK. 2019. Persistent Organic Pollutants. London (UK): IntechOpen Ltd. 108 p.

Dwitawati DA, Sulistyarsi A, Widiyanto J. 2015. Biomonitoring kualitas air Sungai Gandong dengan bioindikator makroinvertebrata sebagai bahan petunjuk praktikum pada pokok bahasan pencemaran lingkungan SMP Kelas VII. Florea: Jurnal Biologi dan Pembelajarannya 2(1):41-6.

Ebenebe CI, Ihuoma JN, Ononye BU, Ufele AN. 2016. Effect of physicochemical properties of water on aquatic insect communities of a stream in Nnamdi Azikiwe University, Awka, Nigeria. Int J Entomol Res 1(7):32-6.

Finet C, Decaras A, Armise ́n D, Khila A. 2018. The Achaete-Scute complex contains a single gene that controls bristle development in the semi-aquatic bugs. *Proc. R. Soc. B.* 285: 20182387.

Gundo MT. 2010. Kerapatan, keanekaragaman dan pola penyebaran gastropoda air tawar di Perairan Danau Poso. Media Litbang Sulteng 3(2):137-43.

Gustafson G, Miller K. 2015. The new world whirligig beetles of the genus *Dineutus* Macleay, 1825 (Coleoptera, Gyrinidae, Gyrininae, Dineutini). ZooKeys 476:1-135.

Guterres APM, Cunha EJ, Godoy BS, Silva RR, Juen L. 2019. Co-occurrence patterns and morphological similarity of semiaquatic insects (Hemiptera: Gerromorpha) in Streams of Eastern Amazonia. Ecol Entomol 45(1):1-12.

Hariyani D, Slamet A, Santri DJ. 2017. Jenis-jenis protista di Danau Teluk Gelam Kabupaten OKI Provinsi Sumatera Selatan. Jurnal Pembelajaran Biologi: Kajian Biologi dan Pembelajarannya 4(2):126-36.

Heino J, Alahuhta J, Bini LM, Cai Y, Heiskanen AS, Hellsten S, Kortelainen P, Kotamäki N, Tolonen KT, Vihervaara P, Vilmi A, Angeler DG. 2021. Lakes in the era of global change: moving beyond single-lake thinking in maintaining biodiversity and ecosystem services. Biol Rev 96:89-106.

Ikawa T, Okabe H, Cheng L. 2012. Skaters of the seas– comparative ecology of nearshore and pelagic Halobates species (Hemiptera: Gerridae), with special reference to Japanese species. Mar Biol Res 8(10):915-36.

Irby SD, Marjorie AM, Friedrichs DF, Hinson KE. 2018. The competing impacts of climate change and nutrient reductions on dissolved oxygen in Chesapeake Bay. Biogeosciences 15: 2649-68.

Ito EE, Ugbomeh IL. 2017. Environmental effect of resort centres on the distribution of aquatic insect fauna in Ethiope River, Delta State, Nigeria. J Coast Life Med 5(11):468-73.

Leba GV, Koneri R, Papu A. 2013. Keanekaragaman serangga air di Sungai Pajowa Kabupaten Minahasa, Sulawesi Utara. Jurnal MIPA 2(2):73-8.

MacLean DB. 2013. Inventory of Aquatic and Semiaquatic Coleoptera from the Grand Portage Indian Reservation, Cook County, Minnesota Portage Indian Reservation, Cook County, Minnesota. Gt Lakes Entomol 46(1):104-15.

Mahajoeno E, Efendi M, Ardiansyah. 2001. Keanekaragaman larva insekta pada sungai-sungai kecil di hutan Jobolarangan. Biodiversitas 2:133-9.

Majumder J, Das RK, Majumder P, Ghosh D, Agarwala BK. 2013. Aquatic insect fauna and diversity in urban fresh water lakes of Tripura, Northeast India. Middle-East J Sci Res 13(1):25-32.

Marpaung SM, Muhammad F, Hidayat JW. 2014. Keanekaragaman dan kemelimpahan larva insekta akuatik sebagai bioindikator kualitas air di Sungai Garang, Semarang. Jurnal Akademika Biologi 3(4):1-8.

Mercer N, Kaller MD, Stout MJ. 2017. Diversity of arthropods in farmed wetlands in the Gulf of Mexico Coastal Plain and effects of detrital subsidies. J Fresh Ecol 32(1):163-78.

Mujiono N, Afriansyah, A, Putera, AK, Atmowidi, T, Priawandiputra, W. 2019. Keanekaragaman dan komposisi keong air tawar (mollusca: gastropoda) di beberapa situ Kabupaten Bogor dan Kabupaten Sukabumi. Limnotek: Perairan Darat Tropis di Indonesia. 26 (2): 65-76.

Mulyono M, Firdaus R, Alka CM. 2018. Sumber daya hayati laut Indonesia: Sebuah pengantar sumber daya hayati laut Indonesia Volume 1. Jakarta (ID): STP Press.

Naranjo C, Riviaux SM, Moreira FFF, Court RC. 2010. Taxonomy and distribution of aquatic and semiaquatic Heteroptera (Insecta) from Cuba. Rev. Biol. Trop. 58(3):897-907.

Nento R, Sahami F, Nursinar S. 2013. Kelimpahan, keanekaragaman dan kemerataan Gastropoda di ekosistem mangrove Pulau Dudepo, Kecamatan Anggrek, Kabupaten Gorontalo Utara. The NIKe Journal 1(1):41-7.

Oktarina A, Syamsudin TS. 2015. Keanekaragaman dan distribusi makrozoobentos di perairan lotik dan lentik Kawasan Kampus Institut Teknologi Bandung, Jatinangor Sumedang, Jawa Barat. Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia. 12 September 2015, Jakarta, Indonesia: p. 227-35.

Olosutean H, Ilie DM. 2013. *Gerris lacustris* (Linaeus 1758) and *Gerris costae* (Herrich-Schäffer 1850) species-habitat relations on montainous tributaries of Viseu River (Maramures, Romania). Transylv Rev Syst Ecol Res 15(1):11-18.

Perron T, Chételat J, Gunn J, Beisner BE, Amyot M. 2014. Effects of experimental thermocline and oxycline deepening on methylmercury bioaccumulation in a Canadian Shield Lake. Environ Sci Technol 48(5):2626-34.

Peterson MG, Lunde KB, Chiu MC, Resh VH. 2017. Seasonal progression of aquatic organisms in a temporary wetland in northern California. West N Am Nat 77(2):176-88.

Pintar MR, William JRJr. 2020. A comparison of aquatic and semiaquatic Heteroptera (Hemiptera) inhabiting natural habitats and experimental mesocosms at the University of Mississippi field station. Aquat Insects 41(1):76-84.

Postel S, Carpenter S. 1997. Freshwater Ecosystem Services. In Daily, G. (Ed). Nature's Services: Washington DC (US): Island Press. p. 195-214.

Pratami VAY, Setyono P, Sunarto S. 2018. Keanekaragaman, zonasi serta overlay persebaran bentos di Sungai Keyang, Ponorogo, Jawa Timur. DEPIK Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan 7(2):127-38.

Ramadhan F, Rijaluddin AF, Assuyuti M. 2016. Studi indeks saprobik dan komposisi fitoplankton pada musim hujan di Situ Gunung, Sukabumi, Jawa Barat. Al-Kauniyah 9(2):95-102.

Robert WS, Bonnie K, Stephen P, Rajendra P, Kirsten R, Maggie R. 2020. Ecosystem services of earth's largest freshwater lakes. Ecosyst Serv 41:101046.

Rumnasih A. 2016. Perbandingan komunitas zooplankton di daerah litoral dengan Estuari Cipatireman, Pantai Sindangkerta, Kecamatan Cipatujah, Kabupaten Tasikmalaya. [Skripsi]. Bandung (ID): Fakultas Keguruan dan Ilmu Pendidikan, Universitas Pasundan.

Siswantini W, Ayuni D, Mulyana A. 2017. Pengaruh komunikasi pemasaran, pengalaman dan kualitas jasa terhadap citra dan kepuasan serta dampaknya pada loyalitas wisatawan nusantara (survei tempat rekreasi air terjun di Kabupaten Bogor). Jurnal Organisasi dan Manajemen 13(1):71-85.

Soeprobowati TR, Hidayat JW, Baskoro K. 2011. Diatom epipelik sebagai bioindikator kualitas perairan Danau Rawa Pening. Jurnal Sains dan Matematika 19(4):107-18.

Soetopo A. 2011. Mengenal Lebih Dekat: Wisata Alam Indonesia. Jakarta (ID): Pacu Minat Baca.

Sutrisno S, Hamdani A. 2013. Pengamatan pola stratifikasi di Danau Maninjau sebagai potensi tubo belerang. Limnotek: perairan darat tropis di Indonesia 20(2):129-40.

Taylor SJ, McPherson JE. 2006. Gerromorpha (Hemiptera: Heteroptera) in Southern Illinois: Species assemblages and habitats. Gt Lakes Entomol 39(1):1-26.

Taylor SJ. 2009. Concurrent phenologies of three semiaquatic bugs (Heteroptera: Gerridae, Veliidae) on a small river in Central Illinois, USA. Psyche 2009:1-5. doi:10.1155/2009/562471

Webster RP, DeMerchant I. 2012. New Coleoptera records from New Brunswick, Canada: Gyrinidae, Carabidae, and Dytiscidae. ZooKeys 179:1-10.

Williams W. 2001. Anthropogenic salinisation of inland waters. Hydrobiologia 466:329-37.

Winton RS, Calamita E, Wehrli B. 2019. Reviews and syntheses: Dams, water quality and tropical reservoir stratification. Biogeosciences 16:1657-71.

Wirosarjono S. 1974. Masalah-masalah yang dihadapi dalam penyusunan kriteria kualitas air guna berbagai peruntukan. PPMKL-DKI Jaya, Seminar Pengelolaan Sumber Daya Air. Bandung (ID): Lembaga Ekologi Universitas Padjadjaran. p. 27-9.

Wooden PLS. 2019. Influence of the annual flood pulse of the Atchafalaya River and updates on the ecology of floodplain aquatic and semi-aquatic hemiptera and their associates. [Thesis]. Baton Rouge (US): Louisiana State University.

Yee KL. 2016. Occurrence of aquatic Macroinvertebrates from Paleik"IN", Sintkaing Township. Yadanabon University Research Journal 7(1):1-12.

Ye Z, Zhen Y, Damgaard J, Chen P, Zhu L, Zheng C, Bu W. 2018. Biogeography and diversification of Holarctic water striders: Cenozoic temperature variation, habitat shifting and multiple intercontinental dispersals. Syst Entomol 43(1): 19-30.

Yurtseven I, Serengil Y, Pamukçu P. 2016. Seasonal changes in stream water quality and its effects on macroinvertebrate assemblages in a Forested watershed. Appl Ecol Environ Res 14(1):175-88.