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Effect of Altitude on Odonata Biodiversity in the Paddy Field of Sleman Regency, Special Region of Yogyakarta

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ABSTRACT
Odonata acts as a natural enemy in the paddy field ecosystem. The Odonata diversity is highly related to habitat condition. This research analyzed the effect of altitude on the diversity of Odonata in paddy field ecosystems in Sleman Regency, Special Region of Yogyakarta. This research was conducted in Palagan and Cangkringan at four different altitude levels: 160-250 masl, 260-350 masl, 360-450 masl, and 460-550 masl. The Odonata sample was obtained from purposive sampling and identified using the Wendit Flying Dragon reference book. The specimens obtained were 2,342 individuals, consisting of 13 species, 11 genera, three families, and two suborders. The Shannon-Wiener index showed the highest Odonata diversity index at an altitude of 360-450 masl. In contrast, the evenness index analysis showed that they varied in each altitude coordinate. Correlation analysis showed that the altitude coordinate of the paddy fields was positively correlated with the biodiversity index and evenness index of Odonata, with the correlation value obtained less than 0.5.

Keywords: *Diversity, Dragonfly, Evenness Index, Paddy Field, Shannon-Weiner.*

1. INTRODUCTION

Insects are a component of biodiversity that has many roles in an ecosystem. Paddy field ecosystem is an artificial wetland valuable ecosystem for human life as a producer of basic foodstuffs. Various types of insects become biotic components of the constituent ecosystem of paddy fields. Insects can act as paddy pests, and others act as predators and parasitoids [1]. One of the insects that act as predators in the paddy field ecosystem comes from a member of the order Odonata.

Odonata is a natural enemy of the paddy field ecosystem. Odonata is an order of carnivorous insects with a medium to large size. Consisting of a long head (cephalon), chest (thoracic), and abdomen, Odonata generally has six limbs [2]. Odonata has a chewing mouth type and large compound eyes [2]. Based on the scientific classification, the order Odonata has two sub-orders, namely Anisoptera (dragonflies) and Zygoptera. It can generally see from its morphological characteristics to distinguish between Anisoptera and Zygoptera. Anisoptera has a pair of fused compound eyes, a larger body size than Zygoptera, as well as a larger front wing size than the hind wings. Zygoptera has a separate pair of compound eyes and a relatively smaller body size [3]. Odonata has a crucial role as a natural enemy for some pests in the paddy fields ecosystem. Odonata can suppress the population of insects that have the potential as agricultural pests as prey [4]. Sleman Regency has an altitude between 100-1000 masl with an area of 57,482 ha, of which 50,392 ha is an area of paddy fields, which has paddy production reached 289,070 tons in 2017 [5].

The higher the altitude of a place, the humidity and temperature will also affect the number of insect populations. The paddy field area in Sleman Regency is an area of a large monoculture farming system with different heights supporting various live and nesting insects. However, according to Purwantiningsih *et al*. (2012), a monoculture farming system can reduce the diversity of local plants. A decrease in the diversity of insects in paddy fields can reduce various types of plant species used as microhabitats for these insects. If the diversity of paddy field insects decreases, it will decrease the diversity of dragonflies as their natural predators [6].

Based on this description, it was important to research the diversity of Odonata in paddy fields with various altitude levels. Therefore, this study aims to determine the diversity of Odonata in the paddy fields of Sleman and to determine the effect of altitude on the diversity of Odonata. This study provided any informations about the diversity of Odonata at various altitudes in Sleman and should be the reference for further research about the diversity of Odonata as a natural enemy of paddy field pests.

2. METHOD

2.1. Research time and location

This research was conducted in Palagan and Cangkringan, Sleman, Special Region of Yogyakarta, in January 2020. The paddy field area is chosen close to the irrigation flow. Four altitude categories were selected at each location, including an altitude of 160-250 masl, 260-350 masl, 360-450 masl, and 460-550 masl.

2.2. Insect sample collection and identification

The sample was collected using a purposive sampling method, and there were three sampling points at each location. Sampling was carried out three times a day, so it took eight days for sampling at all research locations. After obtaining the dragonfly sample, preservation was carried out, and the smaller dragonfly was put into papilot paper measuring 10 cm x 15 cm. The larger dragonfly was inserted into papilot paper measuring 15 cm x 20 cm. The identification process was carried out in the laboratory using the Wendit Flying Dragon reference book, the morphological characteristics of the samples were observed. After that, the obtained dragonfly species were recorded, and then the sample was transferred from papilot paper to styrofoam without damaging the sample; then, the specimen was preserved using a drying box and lamp for 5-7 days.

2.3. Study Area

This study was conducted from December 2019 to January 2020. This research was carried out in Sleman, especially in the Palagan and Cangkringan lines. Four paddy fields with an altitude of about 150-250 masl, 260-350 masl, 360-450 masl, and 460-550 masl were chosen in every line as sampling sites of this study (Figure 1).

There are six varieties of paddy including, Sahera, Ketan, Inpari 30, IR 64, Melon, and Legowo. The type of irrigation used is river except in P2, which uses water wells. The most common vegetation found was grasses (Table 1).

2.4. Environmental Parameter Measurement

The environmental parameters measured were air temperature, light intensity, and air humidity. The air temperature was measured using a thermometer. Light intensity was measured using a lux meter (Smart Sensor Digital Lux Meter AS803). Humidity was measured using an analog hygrometer.

2.5. Data Analysis

Odonata diversity was determined using species diversity and species evenness. At each sampling point, the total individuals obtained were calculated and tabulated. Then the next step, species diversity, and evenness of species were calculated. Species diversity was calculated using the Shannon-Wiener index (H'). The evenness of species was calculated by the Evenness index (E').

2.5.1. Diversity Index (H') and Evenness Index (E')

The Shannon-Wiener diversity index (H') is calculated using the Equation (1), where pi is proportion of the number of 1st individuals to the total number of individuals [7]. The evennes index (E') is calculated using the Equation (2), where S is total species found [8, 9].

$$H' = -\sum_{i=1}^{s} pi \ln pi \quad (1)$$

The classification of Shannon-Wiener diversity values is as follows H' less than 1, diversity level in one location is classified as low one, if H' between 1 to 3, the community is classified as moderate level, and H' more than 3, the community classified as the high level [7].

$$E' = \frac{H'}{In\ S} \quad (2)$$

The range of evenness index values is 0 (uneven) to 1 (evenly). If E' is less than 0.5, the population is threatening. When the value of E' is between 0.5 to 0.75, the population is unstable. If the value of E' is between 0.75 to 1.0, the population is in a stable condition [10].

Table 1. The sampling sites description of the study of Odonata diversity in Sleman, Yogyakarta

Sampling location	Altitude (masl)	Paddy Varieties	Irrigation Type	Vegetation
Palagan Line				
P4	479	Sahera	River	Cassava, dashen, and grasses
P3	420	Ketan	River	Paddy, grasses, chili plants, silk trees, and banana trees
P2	320	Inpari 30	Water well	Sugarcane and grassess
P1	240	IR 64	River	Lemongrass, elephant grasses, cassava, and banana trees
Cangkringan Line				
C4	460	Melon	River	Grasses, coconut trees, and banana trees
C3	423	Legowo	River	Bushes, grasses, and coconut trees
C2	300	Sahera	River	Bushes and grasses
C1	213	IR 64	River	Bushes, grasses,and trees with canopy

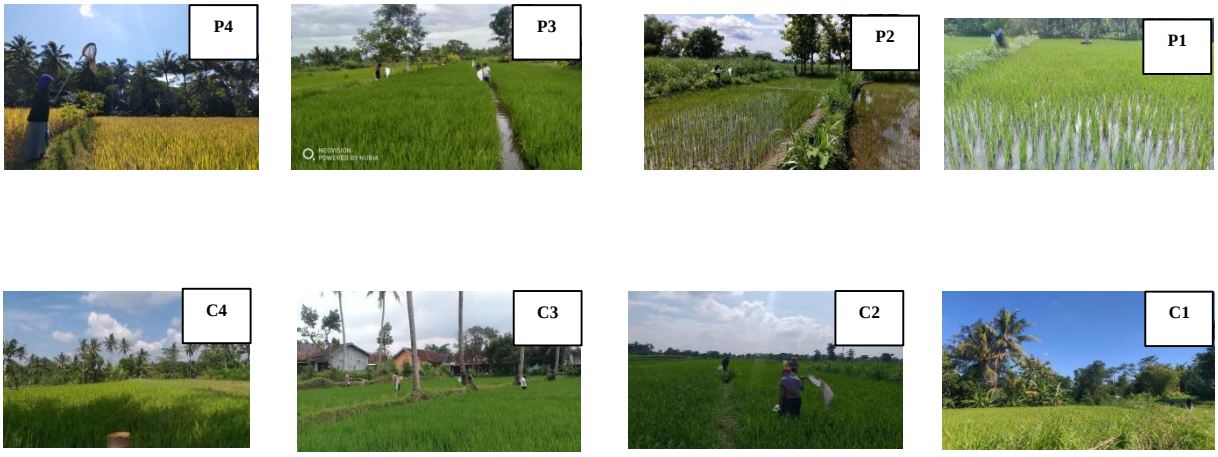


Figure 1. Sampling location in the paddy fields of Sleman, Yogyakarta. The picture above is to clarify the sampling location with vegetation as shown in table 1. P indicates the sampling location in Palagan, with the height of each sampling point being P4 (479 masl), P3 (420 masl), P2 (320 masl), and P1 (240 masl). C indicates the sampling location in Cangkringan, with the height of each sampling point being C4 (460 masl), C3 (423 masl), C2 (300 masl), and C1 (213 masl

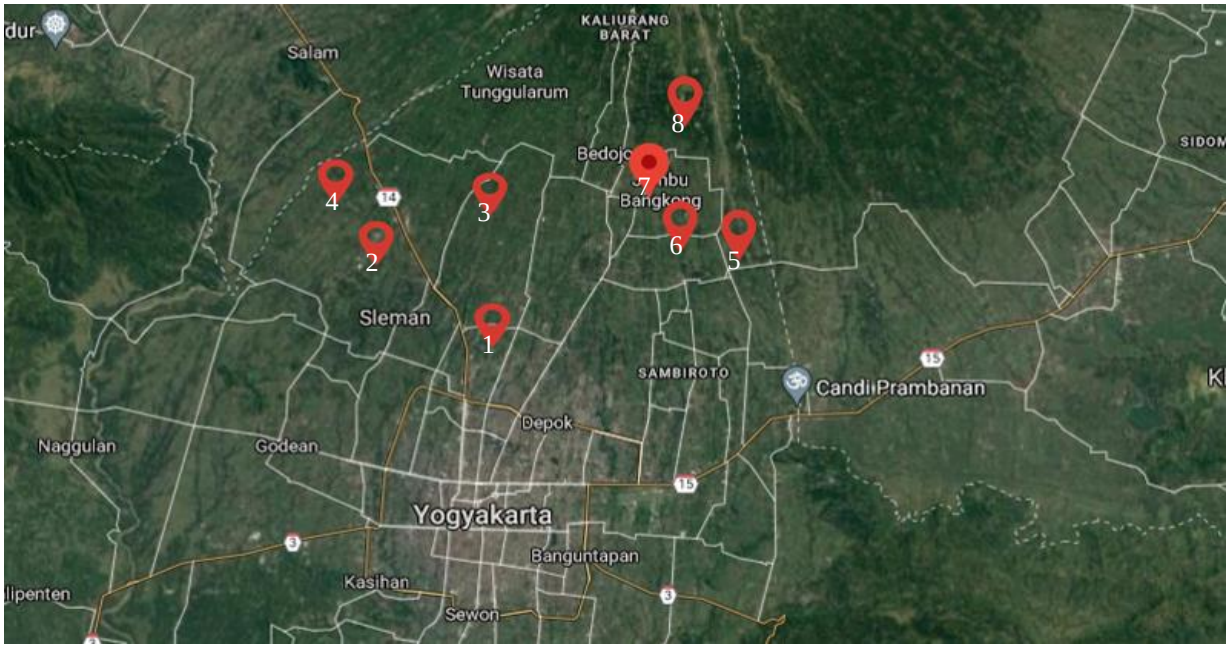


Figure 2. Sampling location in the paddy fields in Palagan and Cangkringan Sleman, Yogyakarta via GPS. Description: 1. P1 (240 masl), 2. P2 (320 masl), 3.P3 (420 masl), 4. P4 (479 masl), 5.C1 (213 masl), 6.C2 (300 masl), 7.C3 (423 masl), 8.C4 (460 masl).

2.5.2. Data Analysis

The data correlation between altitude and total individual, total species, evenness index, and diversity index were analyzed by Microsoft Excel.

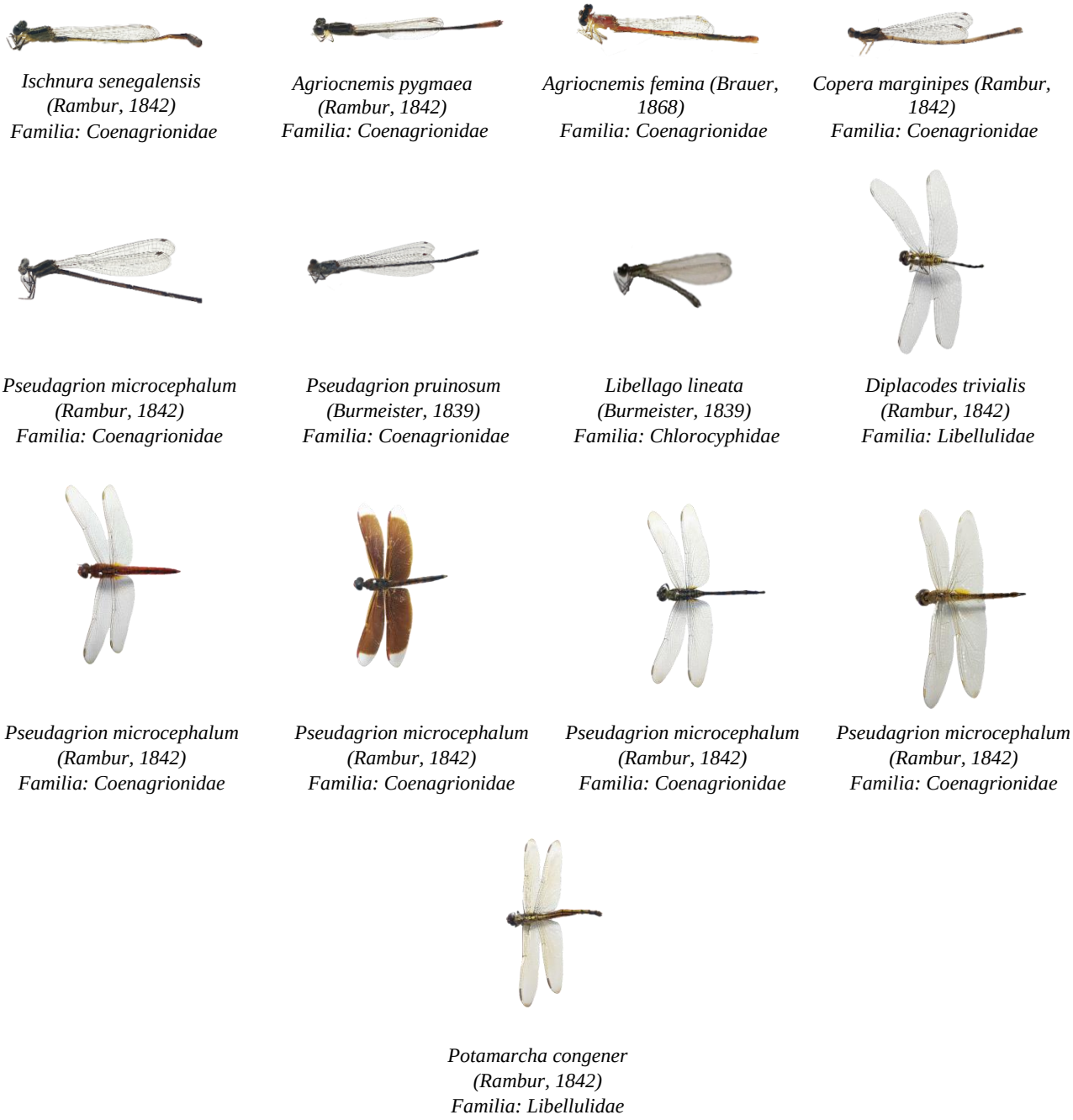
3. RESULT AND DISCUSSION

3.1. Description of Species Collected

Based on this research, the Odonata have been collected 2,342 individuals consisting of thirteen species from eleven genera that belonged to three families (Figure 3). In this study, two suborders were observed including, Anisoptera and Zygoptera. The two suborders consist of 6 species from Coenagrionidae, 6 species from Libellulidae, and 1 species from Chlorocyphidae. The dominant family of the Anisoptera and Zygoptera suborder is Libellulidae and Coenagrionidae, respectively. Species belonging to the Coenagrionidae family namely *Ischnura senegalensis, Agriocnemis pygmaea, Agriocnemis femina, Copera marginipes, Pseudagrion microcephalum, Pseudagrion pruinosum. Ischnura senegalensis* has the body part of the synthorax is blue, and there is a thick black line on the upper side. Black abdomen on the upper side except for the light blue 8th segment. The upper limbs are blue, and the lower limbs are black. The yellowish-green color dominates the female body, habitat in the paddy fields [3]. *Agriocnemis pygmaea* has a pale green sinthorax, and on the top, there are thick black stripes. The compound eyes are black on the top and green on the bottom. Abdomen on top black and underside pale green segments 8-10 orange, transparent wings [3]. *Agriocnemis femina* is red all over with a thick black stripe on the upper abdomen in female. The male has a green and black body and on the upper part of the abdomen, there are spots on the abdomen and legs [11]. *Copera marginipes,* the male dragonfly, has a dominant black body on the top and yellow on the bottom. The female has a paler body with light brown compound eyes on the top and white on the bottom. Synthorax is brown with a few black stripes. Brown abdomen with thin black stripes. *Pseudagrion microcephalum,* the male has a blue and black synthorax. The thorax has a V-shaped notch. In females, the prothorax is longer. In the 3rd and 5th segments of the abdomen, there is a paler colored segment [12]. *Pseudagrion pruinosum* has a body that is dominated by black. The compound eyes are black on the top and red-orange on the bottom. Has a synthorax and abdomen, which is blue with white spots, the abdomen is brownish yellow on the underside [3].

Species belonging to the Libellulidae family are *Diplacodes trivialis, Crocothemis servillia, Neurothemis ramburii, Orthetrum sabina,* Pantala flavescens, *Potamarcha congener*. *Diplacodes trivialis* has a grayish blue synthorax and abdomen, transparent wings with black veins and black pterostigma in males. The female has a pale yellowish blue synthorax slightly grayish, pale yellowish blue abdomen and transparent wings with black pterostigma [3]. *Crocothemis servillia* has an orange-red color all over its body except for the wings of the male dragonfly. The female has a yellowish brown body all over her body except for the wings with purplish compound eyes on the top [3]. *Neurothemis ramburii* has

a dark red velvet wing color in adult males and yellow-brown in females [13]. *Orthetrum sabina* has compound eyes turquoise, synthorax yellowish green with six black stripe, and brownish -black legs [3]. *Pantala flavescens* have a reddish-yellow body. The compound eyes are red on the top and yellow on the bottom. The thorax and abdomen are reddish yellows with black lines that expand like blotches [3]. *Potamarcha congener* has a dominant thorax blue-black. The upper part of the eye is brownish-red [14]. Species belonging to the Chlorocyphidae family is *Libellago lineata*. *Libellago lineata* has a small size, black, wings longer than the abdomen in males with black legs. The female has a light brown body and brown limbs [3].



Ischnura senegalensis (Rambur, 1842) Familia: Coenagrionidae

Agriocnemis pygmaea (Rambur, 1842) Familia: Coenagrionidae

Agriocnemis femina (Brauer, 1868) Familia: Coenagrionidae

Copera marginipes (Rambur, 1842) Familia: Coenagrionidae

Pseudagrion microcephalum (Rambur, 1842) Familia: Coenagrionidae

Pseudagrion pruinosum (Burmeister, 1839) Familia: Coenagrionidae

Libellago lineata (Burmeister, 1839) Familia: Chlorocyphidae

Diplacodes trivialis (Rambur, 1842) Familia: Libellulidae

Pseudagrion microcephalum (Rambur, 1842) Familia: Coenagrionidae

Pseudagrion microcephalum (Rambur, 1842) Familia: Coenagrionidae

Pseudagrion microcephalum (Rambur, 1842) Familia: Coenagrionidae

Pseudagrion microcephalum (Rambur, 1842) Familia: Coenagrionidae

Potamarcha congener (Rambur, 1842) Familia: Libellulidae

Figure 3. Odonata species found in the Sleman paddy fields, Yogyakarta

Table 2. Distribution and abundance of Odonata in the paddy fields of Sleman, Yogyakarta

No	Species	P4	P3	P2	P1	C4	C3	C2	C1
1	*Pantala flavescens*	250	139	38	50	201	53	542	139
2	*Orthetrum sabina*	70	77	71	156	112	38	36	51
3	*Ischnura senegalensis*	-	155	-	-	-	-	-	-
4	*Agriocnemis pygmaea*	-	50	1	-	7	-	-	-
5	*Agriocnemis femina*	-	44	-	-	1	-	-	-
6	*Diplacodes trivialis*	-	4	-	-	-	-	-	-
7	*Pseudagrion pruinosum*	-	-	-	1	-	-	-	5
8	*Neurothemis ramburii*	-	-	-	1	19	6	-	3
9	*Copera marginipes*	-	-	-	-	4	-	-	-
10	*Libellago lineata*	-	-	-	-	-	-	-	2
11	*Pseudagrion microcephalum*	1	-	-	-	-	-	-	-
12	*Crocothemis servilia*	-	7	3	1	-	-	1	-
13	*Potamarcha congener*	-	2	1	-	-	-	-	-

P4: Palagan 4 460-550 masl; P3: Palagan 3 360-450 masl; P2: Palagan 2 260-350 masl; P1: Palagan 1 160-250 masl; C4: Cangkringan 4 460 -550 masl; C3: Cangkringan 3 360-450 masl; C2: Cangkringan 2 260-350 masl; C1: Cangkringan 1 160-250 masl.

3.2. Odonata Distribution, Abundance, and Diversity

In the Palagan paddy field area, *Pantala flavescens* had the highest population abundance and the species, while the species with the lowest abundance of popolation were *Pseudagrion microcephalum* and *Pseudagrion pruinosum*. Meanwhile, in Cangkringan the species with high population abundance was *Pantala flavescens*, and the species with the lowest population was *Agriocnemis femina* (Table 2). The highest diversity index in P3 was 1.60, while the lowest diversity index was in C2 at 0.25. The highest evenness index in C3 was 0.79, and the lowest evenness index was in C2 at 0.22. The correlation between height and total individuals, total species, diversity index (H'), and evenness index (E') were 0.17; -0.09; 0.32; 0.52 (Table 3).

Table 3. Correlation between total individuals, total species, diversity index (H'), and evenness index (E') of odonata with altitude in the paddy fields of Sleman, Yogyakarta

	P4	P3	P2	P1	C4	C3	C2	C1	Correlation
Total of Individual (N)	321	478	114	209	344	97	579	201	0.17
Total of Species (S)	3	8	5	5	6	3	3	6	-0.09
Diversity index (H')	0.55	1.60	0.84	0.61	0.98	0.87	0.25	0.83	0.32
Evenness index (E')	0.50	0.77	0.52	0.44	0.47	0.79	0.22	0.46	0.52

The results of this study consisted of 13 species, 11 genera, 3 families, and 2 suborders. The dominant family of the Anisoptera and Zygoptera suborder is Libellulidae and Coenagrionidae, respectively. Libellulidae and Coenagrionidae are also recorded as dominant families in various locations, for example, it can be found in freshwater ecosystems, around river waters, agricultural areas, parks and gardens. [15][16][17][18][19]. Those showed that those families have a wide range of habitats and are adaptable to various environmental conditions [20]. In addition, Libellulidae and Coenagrionidae are also known as aggressive predators and almost prey on all kinds of insects and other organisms as long as the prey's body size is proportional to the predator [21]. The Anisoptera suborder is more dominant than the Zygoptera suborder because the range of habitat tolerance is wider [22]. As many as 2 of the 13 species observed were found in all sampling locations.

The species are P*antala flavescens* and *Orthetrum sabina*. *Pantala flavescens* is known as a cosmopolitan migratory insect [23]. Ichikawa *et al.* (2016) [24] reported that the critical temperature required for egg development of *P. flavescens* is 14.3ºC. Eggs of *P. flavescens* can hatch within five days at a temperature of 30-35^{0}C. A decrease in temperature causes the eggs to take longer to hatch [24]. All sampling locations met the critical temperature for developing *P. flavescens* eggs, where the lowest temperature measured was 25^{0}C, higher than the critical temperature. Naiad and imago of *O. sabina* are resistant to changes in environmental conditions. This dragonfly species can survive in waters with high enough salinity [22]. *P. flavescens* and *O. sabina* were found in abundance in most sampling locations. *P. flavescens* was not very abundant in P2 and P1. At that location, the most abundant species is *O. sabina*, *P. flavescens* species may lose in competition with *O. sabina*. The waters in P2 and P1 are close to settlements, so that household waste is observed in the waters. These conditions are more favorable for *O. sabina* species because the naiads of this species are resistant to environmental changes. *O. sabina* is not very abundant in C3 and C2. At that location, the water flow is not too strong. *P. flavescens* species prefer habitats with calm or moderate water flow [22], so that *P. flavescens* was found to be more abundant than *O. sabina*.

Some species are only found in one location. *Ischnura senegalensis, Diplacodes trivialis, Copera marginipes, Libellago lineata, Pseudagrion microcephalum. I. senegalensis* and *D. trivialis* were found in P3 only. The paddy fields use “Mina Padi” as the irrigation system so that the paddy was flooded. The area of the waters is positively correlated with the species richness and abundance of dragonflies and damselflies [25]. Paddy fields at this location also have maximum humidity and high light intensity. That causes the paddy fields in P3 to become the preferred habitat for many types of dragonflies and damselflies. *C. marginipes* species are found in C4 only. C. marginipes is a damselfly species that prefered bright and sunny habitat [26]. The Paddy field in C4 has high light intensity and few large trees, so there is little shade. *L. lineata* species are found in C1 only. The paddy fields at this location are adjacent to rivers and *L. lineata* are often found on the banks of rivers with flowing water and moderate light intensity [3]. Around the paddy fields in C1, there is a lot of shade from the trees so that the light intensity is not too high. *P. microcephalum* species are found in P4 only. Damselflies of the *P. microcephalum* species are often found in habitats with high light intensity and many plants [3]. The paddy fields at this location have a high enough light intensity to be suitable as a habitat for *P. microcephalum*.

Table 4. Temperature, humidity, and light intensity in the paddy fields of Sleman, Yogyakarta

Location	Temperature (°C)	Air Humidity (%)	Light intensity (Lux)
P4	25 - 32	15 - 46.5	25.550 - 109.300
P3	28 - 32	19 - 52	45.730 - 124.800
P2	30 - 34	35 - 45	96.720 - 111.600
P1	29.5 - 35.5	30 - 44	94.710 - 104.500
C4	27 - 31	28 - 46	18.780 - 132.200
C3	28 - 32	30 - 54	44.690 - 116.400
C2	27.5 - 32	35 - 47	27.680 - 120.800
C1	32 - 38	30 - 40	106.100 - 141.000

The Shannon-Wiener diversity index (H') is commonly used to estimate species richness and abundance in environmental studies [27]. Paddy fields in P3 have a moderate biodiversity index value, while the other seven locations have a low. It is caused because paddy fields in P3 used a *Minapadi* irrigation system so that the water area is more expansive than other paddy fields. The presence of water is an important factor for Odonata because the naiad phase lives in water for a long time (up to one year) [28]. The maximum humidity and light intensity at this location is also high. Around the paddy fields, there is also a lot of vegetation and many types of insects so that the prey of dragonflies and damselflies is abundant. Paddy fields in P3 have the highest species richness compared to other locations. The highest number of specimens is C2, but it has the lowest H` value. This is because in C2 only three species were found and dominated by *Pantala flavescens* while the other two species were only found in small numbers.

The evenness index (E') is used to estimate the degree of evenness of species in a community [29]. The values of E' for P4, P3, P2, and P1 are depressed, stable, unstable, and depressed, respectively. *Pantala flavescens* dominate P4 paddy fields, and only three species were found. P2 and P1 paddy fields are dominated by *Orthetrum sabina* species, so that the species distribution is uneven. The paddy fields in P3 are dominated by three species, namely *P. flavescens, O. sabina*, and *I. senegalensis*. The water area is wide at this location because it uses the *Minapadi* system. In addition, many other types of insects were observed that provided sufficient food for the dragonfly and damselfly.

For the Cangkringan lane, only paddy fields at C3 have a stable E' value, while the other three locations have a depressed E' value. In C3 paddy fields are dominated by *P. flavescens* but other species can also be found. Other paddy fields in Cangkringan are dominated by P. *flavescens* so that other species lose the competition and are only found in very small numbers. Correlation analysis is used to determine the relationship between two variables [30]. The results of the correlation analysis showed that the altitude has a positive correlation with the biodiversity index (H') and the evenness index (E'). It is because, at the highest location, it rains several times. Precipitation will increase the availability of water for Odonata. However, the highest H' and E' values are not owned by the paddy fields with the highest elevation. The correlation value obtained is also weak (below 0.5). It is because various factors influence Odonata's biodiversity, so in-depth research is needed on the factors that influence the abundance of Odonata.

The environmental parameters observed at each sampling location are temperature, humidity and light intensity. The environmental parameters in Palagan, which include temperature, humidity, light intensity, are in the range of 25-35°C, 15-52%, and 25.550 – 132.200 lux. Environmental parameters in Cangkringan include temperature, humidity, light intensity, which ranges between 27-35°C, 28-54% and 18.780-141.000 lux. The range of environmental parameters in Palagan and Cangkringan is not significantly different.

Based on the discussion above, it can be concluded that Odonata which had the highest value of diversity, was found in P3 while the lowest value of diversity, was found in C2. Besides, Odonata which had the highest value of evenness, was found in C3, while the lowest value of evenness, was found in C2. The altitude of the paddy fields affects the diversity of Odonata. It is indicated by a positive correlation between altitude and biodiversity index, and evenness index. However, the correlation value obtained is relatively small, less than 0.5.

AUTHOR'S CONTRIBUTIONS

N.S., A.N., A.C.W., R.B.A., A.S., B.E.Y., O.A.S., and S.S. conducted the research. All authors wrote the manuscript and listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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