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Community structure of dragonflies (Odonata) in Gunung Bromo's Forest Area with Special Purpose (FASP), Karanganyar, Central Java, Indonesia

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Abstract. *Astuti A, Nayasilana IN, Sugiyarto, Budiharjo A. 2022. Community structure of dragonflies (Odonata) in Gunung Bromo's Forest Area with Special Purpose (FASP), Karanganyar, Central Java, Indonesia. Biodiversitas 23: 2493-2501.* Dragonflies are one component of biodiversity in Indonesia, which function both as predators and bioindicators of water quality. Dragonfly habitat is widespread ranging from highland forest areas, lowland forests, reservoirs, lakes, rivers, swamps, and rice fields to settlements. One location that becomes dragonfly habitat is in the Gunung Bromo's Forest Area with Special Purpose (FASP), Karanganyar, Central Java, Indonesia. This study aims to determine the community structure and habitat preferences of dragonflies in Gunung Bromo's FASP. Data resulting from this study is expected used as a database for Gunung Bromo's FASP managing. The study was conducted along the Bamban river which is located in the Gunung Bromo's FASP area, in June-July 2019. Dragonflies were collected in 14 observation stations. At each observation, station transects were 100 m in length and 10 m in width. Data collection included the dragonflies species, the individual numbers, and environmental factors both abiotic and biotic factors. Data analysis included the diversity, evenness, dominance and similarity of dragonfly species. Principal Component Analysis (PCA) was applied to determine the dragonfly abundance pattern and Canonical Correspondence Analysis (CCA) was applied to determine the relationship between dragonflies and their environmental factors. The results showed there were 23 species of dragonflies in the Gunung Bromo's FASP with a diversity index of 1.96. PCA results indicate the abundance of dragonflies is not much different in each species. Meanwhile, CCA results show almost of the dragonflies in the Gunung Bromo's FASP are influenced by abiotic and biotic factors, except on *Orthetrum sabina* and *Copera marginipes*. They are assumed have unspecific habitat preferences.

Keywords: Diversity, dragonflies, forest, habitat preferences, river

INTRODUCTION

Indonesia is one of three countries with the highest level of biodiversity in the world (von Rintelen et al. 2017). One of Indonesia's most biodiverse taxa is insects (Insecta). Insects are animals with the largest number of species (Wajnberg and Desouhant 2018). Dragonfly is one of the animal groups that belong to the class Insecta (Janssen et al. 2018). Dragonfly, which comes from the order of Odonata, is the most primitive group of insects. Dragonflies have been discovered and known since the Carboniferous era, approximately 290 million years ago, and they still survive to this day (Rathod et al. 2012; Bora and Meitei 2014). There are approximately 5000 species of dragonflies (Sonawane et al. 2020), and 750 species can be found in Indonesia (Susanti 1998). Dragonflies act as predators in the ecosystem during their naiad and adult phases (Pamungkas and Ridwan 2015). During the naiad phase, dragonflies are predators of mosquito larvae which are harmful vectors to human life (Saha et al. 2012). Meanwhile, in the adult phase, dragonflies act as natural enemies to agricultural pests (Rahaman et al. 2014; Indiati and Rahayu 2017). Apart from their role as predators, dragonflies have long been recognized as bioindicators of the quality of aquatic habitats and the environment, owing to their sensitivity to habitat changes (Martín and Xavier Maynou 2016; Seidu et al. 2017). Dragonfly habitats range from 0 to 3000 m above sea level and include rivers, lakes, rice fields, reservoirs, swamps, forests, and settlements (Payra et al. 2017).

Gunung Bromo forest area, or *Wana Wisata Gunung Bromo*, is one of the landscapes in Karanganyar Regency and is home to various dragonfly species (Pamungkas et al. 2015). It is because a river flows through the forest area. The river, which is constantly flowing with water throughout the seasons, can support the dragonfly's survival. In 2014, the research on the diversity and distribution of dragonflies was conducted at the *Gunung Bromo* Tourism Center (*Wana Wisata Gunung Bromo*). The study results revealed that there were 21 species of dragonflies from 7 different families in the forest area of *Gunung Bromo* (Pamungkas et al. 2015). At the time the research was carried out, *Gunung Bromo* Tourism Area was still included in the forest area managed by the

PERHUTANI company (BKPH Lawu Utara: KPH Surakarta) (Pamungkas et al. 2015).

Since April 2018, the Minister of Environment and Forestry (*LHK*) of the Republic of Indonesia has issued Decree No. 177/MENLHK/SETJEN/PLS.0/4/2018 concerning Designation of *Gunung Bromo* Tourism Area as a Forest Area with Special Purpose (FASP; known as *KHDTK*) for Education and Research of Universitas Sebelas Maret (UNS). This decree became the basis for UNS to have the authority to manage and develop the forest area of ±122.78 hectares. According to the Regulation of the Indonesian Minister of Environment and Forestry No. P.15/MENLHK/SETJEN/KUM.1/5/2018, FASP managemen t is a sustainable, comprehensive, independent, and integrated forest management system for research, development, forestry education and training, as well as religion and culture purposes. Thus, to formulate an appropriate management and development strategy for Gunung Bromo's FASP, information about the current state of the area and its potential resources is required.

Gunung Bromo's FASP area has changed significantly in recent years due to forest fires and the conversion of land from forest to rice fields or plantations. The increasing demand for agricultural and plantation land is the primary factor contributing to the loss of habitat for various fauna (Faruk et al. 2013). Land conversion is frequently linked to changes in and reductions in biodiversity (McGill 2015; Newbold et al. 2015). Understanding the interaction between habitats and their use by a species of organism is critical for comprehending the conservation status of that species. It is because the interaction between organisms and their habitats can be used to determine the effect of natural habitat changes on the population of an organism, including dragonflies.

Therefore, research on the dragonfly community structure in Gunung Bromo's FASP is now considered essential to ascertain the species and composition of dragonflies in the area and their preferred habitats for living and breeding. Additionally, the results of this research are expected to serve as a database and basic consideration for dragonfly conservation efforts and management and development of Gunung Bromo's FASP while also preserving the area's existing habitat.

MATERIALS AND METHODS

Study areas

The research was conducted from June to July 2019 in the Gunung Bromo's FASP, Karanganyar, Central Java, Indonesia. The dragonfly data collection occurred along the Bamban river and was divided into two locations based on their use. The first location was a Bamban river surrounded by an agricultural area (fields). The second location was a Bamban river surrounded by a forest area where humans' activities were still rarely found (Figure 1).

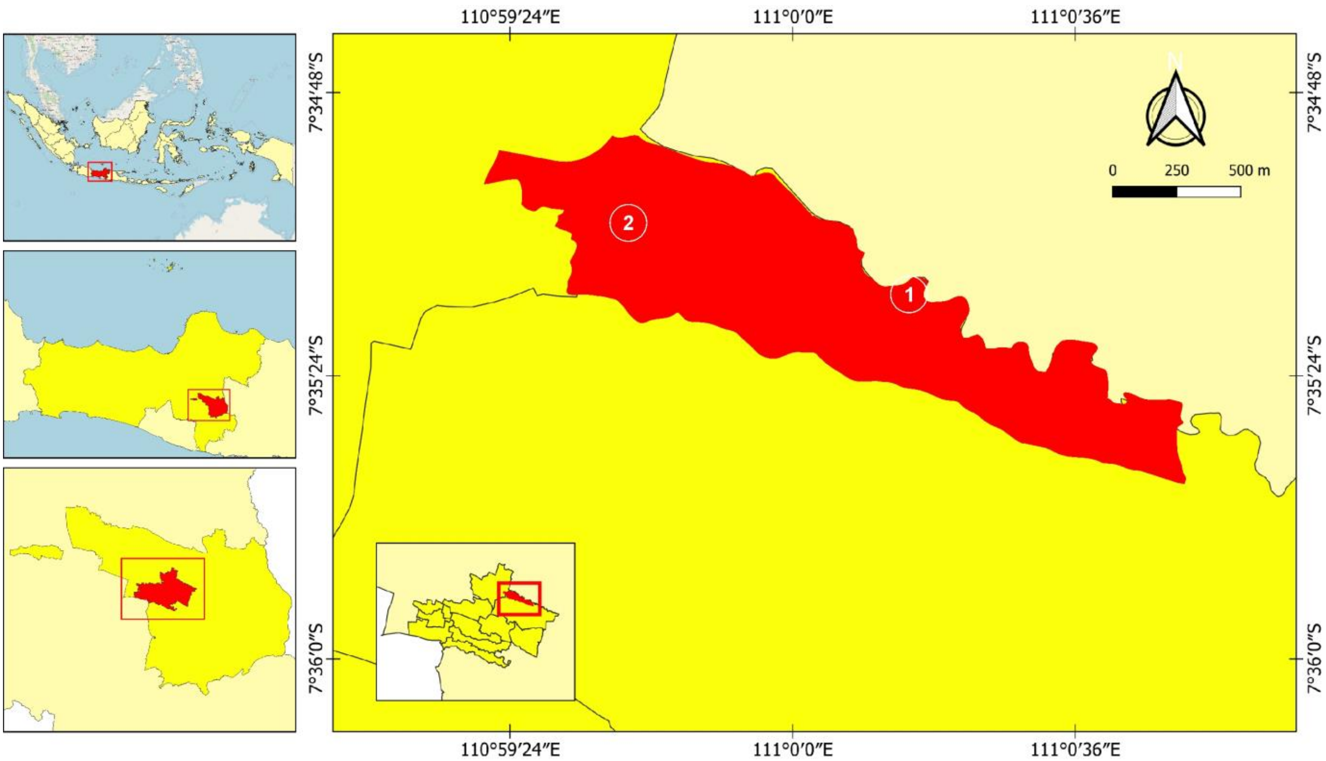


Figure 1. Research location at Gunung Bromo's FASP, Karanganyar, Central Java, Indonesia. 1. Agricultural area, 2. Forest area

Procedures

The data collection of the dragonfly

Eight observation stations were located in the agricultural area and 8 in the forest area. The number of observation stations is selected based on how far the location can be surveyed. A 100-meter-long and 10-meter-wide path was marked at each observation station to collect dragonfly data. There were 3 repetitions done on different days at each observation station. The time for dragonfly observation was chosen based on their active period, between 08.00-11.59 a.m. and 03.00-05.00 p.m. Dragonfly observations were conducted during their adult stage. The parameters taken included the species of dragonflies found, the number of individuals of each species, and the activity of dragonflies (eating, perching, and reproducing). Books are used to identify dragonfly species: Handlist of Malaysian Odonata by Lieftinck (1954), Dragonflies of Peninsular Malaysia and Singapore by Orr (2005) and Naga Terbang Wendit by Rahadi et al. (2013).

The data collection of the environmental factor

Two environmental factors were measured in this study: abiotic and biotic factors. The abiotic factors considered were location altitude, air temperature, water temperature, air humidity, light intensity, water pH, and dissolved oxygen levels in the water. Abiotic factor measurements were done in the morning at each observation station. Meanwhile, biotic factors were determined by analyzing the vegetation of riparian plants at each observation station (Oliveira-Junior et al. 2019).

The checkered line method was used to collect data on the vegetation. It was accomplished by making a plot at each observation station. The plots included 2x2 m for seedlings/undergrowth, 5x5 m for saplings, 10x10 meters for poles, and 20x20 m for trees (Figure 2). The data taken included the species and number of individuals of each species found in the plot.

Data analysis

The data analysis included the analysis of diversity, evenness, dominance, relative abundance, the similarity of dragonflies, and analysis of vegetation structure at the observation sites. The data obtained from vegetation analysis were used to determine the density and area of vegetation cover.

Figure 2. Plot analysis of vegetation. Plot A: 20x20 m, plot B: 10x10 m^2, plot C: 5x5 m^2 and plot D: 2x2 m^2

Relative abundance of dragonfly

Relative abundance of dragonflies was calculated using the formula:

$$RA = \frac{\text{Number of individual s of one species}}{\text{Total number of all individual s counted}} \text{ x 100 \%}$$

Similarity of dragonfly species

If the same species was spotted twice on the same transect, it is was counted as one dragonfly. Similarity of dragonfly species was calculated using the Jaccard similarity index:

$$SI = \frac{c}{a+b+c} \text{ x 100 \%}$$

Where:
a: Number of species recorded from site 1
b: Number of species recorded from site 2
c: Number of species recorded from both site

In this study, the analysis of dragonflies' diversity, evenness, and dominance was carried out using *PAST* software, version 3.18. In addition to *PAST* software, the researchers also employed the Principal Component Analysis (PCA) to describe the pattern of dragonfly abundance (using data from the calculation of relative abundance) and Canonical Corresponding Analysis (CCA) to determine the relationship between dragonflies and their habitat (biotic factors and abiotic factors) in Gunung Bromo's FASP.

RESULTS AND DISCUSSION

The diversity of dragonflies

According to the research findings, 23 species of dragonflies were discovered, including 15 species of Anisoptera and 8 species of Zygoptera (Table 1). The dragonflies discovered belonged to 6 distinct families. The Libellulidae was the most common family, with the members found as many as 13 species. It is consistent with Shende and Patil (2013), who state that the Libellulidae family is the most common and largest family of dragonflies (Odonata) because it has the largest number of members. Apart from Libellulidae, there were 4 species of the Coenagrionidae family, followed by the Gomphidae and Chorocyphidae families with 2 species each, and the Platycnemididae and Protoneuridae families each with 1 species.

Among the 23 dragonfly species discovered, two were endemic, namely *Paragomphus reinwardtii* and *Heliocypha fenestrata* (Figure 3). *Paragomphus reinwardtii* is included in infraorder Anisoptera, endemic to Java and Bali (Lieftinck 1954). The body of *P. reinwardtii* is dominated by black and yellow stripes. They have bluish-green compound eyes. They also have anal appendages in the shape of a fishing hook; therefore, this dragonfly is often called the Javan fishing dragonfly (*capung pancing jawa*). The common habitat for *P. reinwardtii* breeding is in river areas in lowland forests with a maximum elevation of 850 m above sea level (Lieftinck 1954).

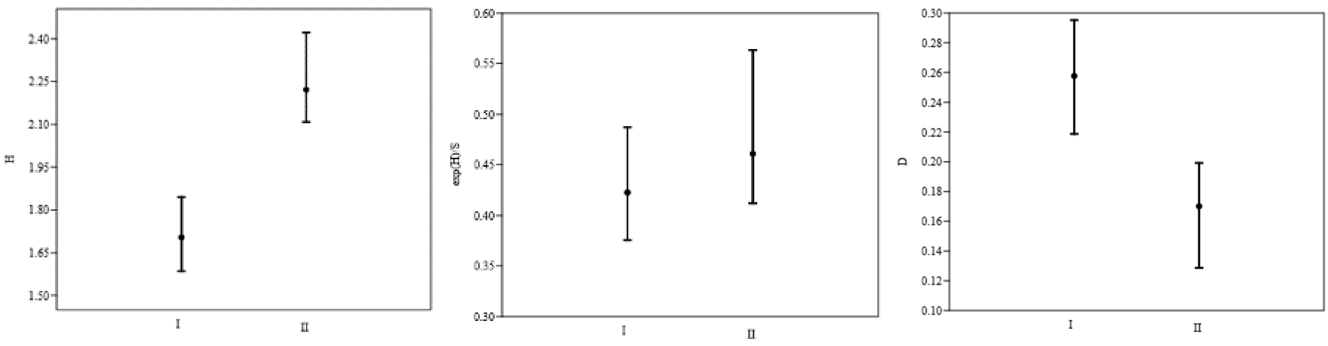
Heliocypha fenestrata is a dragonfly endemic to Java that belongs to the Zygoptera suborder. The males have a predominantly black body and wings, with a slight pink hue on their thorax. The females have a brownish-black body with transparent brown wings. *Heliocypha fenestrata* can be found at an altitude of 0-1000 m above sea level. Their habitat is in rocky streams in shady lowland forests and cultivated areas (Lieftinck 1954).

As illustrated in Figure 4, more dragonfly species were found in forest areas than in agricultural areas. The forest area contained 20 species, while the agricultural area contained 13 species. Several dragonflies could only be found in forest areas, including *Ictinogomphus decoratus*, *P. reinwardtii*, *Cratilla lineata*, *Neurothemis terminata*, *Tetrathemis irregularis*, *Neurothemis ramburii*, *Orthetrum glaucum*, *Diplacodes trivialis*, *Libellago lineata*, and *Prodasineura autumnalis*. In contrast, some dragonflies could only be found in the agricultural area, namely *Crocothemis servilia*, *Trithemis aurora*, and *Agriocnemis pygmaea*.

Table 1. Relative abundance of dragonflies in Gunung Bromo's FASP, Karanganyar, Central Java, Indonesia

Subordo	Famili	Species	Agricultural area (%)	Forest area (%)
Anisoptera	Gomphidae	*Ictinogomphus decoratus*	0.00	1.37
	Gomphidae	*Paragomphus reinwardtii*	0.00	0.68
	Libellulidae	*Orthetrum sabina*	24.42	15.07
	Libellulidae	*Cratilla lineata*	0.00	1.37
	Libellulidae	*Potamarcha congener*	8.29	4.11
	Libellulidae	*Orthetrum testaceum*	0.46	8.90
	Libellulidae	*Neurothemis terminata*	0.00	3.42
	Libellulidae	*Tholymis tillarga*	0.92	1.37
	Libellulidae	*Pantala flavescens*	1.38	0.68
	Libellulidae	*Tetrathemis irregularis*	0.00	0.68
	Libellulidae	*Neurothemis ramburii*	0.00	2.74
	Libellulidae	*Orthetrum glaucum*	0.00	0.68
	Libellulidae	*Diplacodes trivialis*	0.00	1.37
	Libellulidae	*Crocothemis servilia*	2.30	0.00
	Libellulidae	*Trithemis aurora*	0.46	0.00
Zygoptera	Chlorocyphidae	*Heliocypha fenestrata*	2.76	15.75
	Chlorocyphidae	*Libellago lineata*	0.00	1.37
	Coenagrionidae	*Pseudagrion rubriceps*	12.90	2.05
	Coenagrionidae	*Pseudagrion pruinosum*	2.76	3.42
	Coenagrionidae	*Agriocnemis femina*	0.92	0.68
	Coenagrionidae	*Agriocnemis pygmaea*	0.92	0.00
	Platycnemididae	*Copera marginipes*	41.47	32.88
	Protoneuridae	*Prodasineura autumnalis*	0.00	1.37

Figure 3. Endemic species were found. *Paragomphus reinwardtii* (A) and *Heliocypha fenestrata* (B)



A **B** **C**

Figure 5. A. Diversity index of Dragonflies; B. Evenness index of Dragonflies; C. Dominance index of Dragonflies. I: Agricultural area; II: Forest area

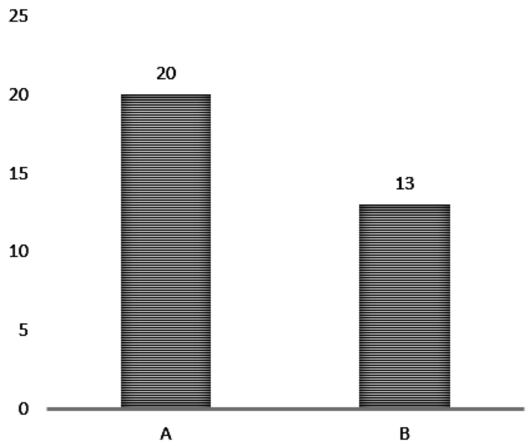


Figure 4. Comparison of species of dragonflies found in Gunung Bromo's FASP, Karanganyar, Central Java, Indonesia. A. Forest Area; B. Agricultural Area

The diversity index (H) of dragonflies in Gunung Bromo's FASP was 1.96. Based on Figure 5, it can be seen that the diversity index of dragonflies in the forest area (II) was higher than in the agricultural area (I). The forest area had a diversity index of 2.22, while the agricultural area had a diversity index of 1.70. The study conducted by Herlambang et al. (2016) also showed the same results, where the value of dragonfly diversity in the river area of the forest was higher than the plantation or agriculturals area. The high diversity of dragonflies in the forest area was caused by several abiotic and biotic factors, such as the availability of shelter and more varied feed since the vegetation composition was also more diverse than in the agricultural area.

The evenness index (E) and dominance index (D) of dragonflies in Gunung Bromo's FASP are shown in Figure 5. The value of the evenness index can describe the stability of a community in a certain area. The agricultural area had an evenness index of 0.42, while the forest area had 0.46. It showed that the dragonfly community in the agricultural and forest areas was relatively stable. Meanwhile, the dominance index can determine the level of dominance of a species in its community. The agricultural area had a dominance index of 0.26, which was higher than the forest area, which only had a dominance index of 0.17. The smaller value of the dominance index indicates the smaller dominance of a species in a location.

These results indicated that the dominance index and the evenness index values were interrelated. The fact that the forest area had a higher evenness index and a lower dominance index revealed that the dragonfly community was inclined to be more stable in forest areas. In contrast, the species dominance in that area was considered lower than the agricultural area. According to Krebs (1989), the smaller the value of the evenness index, the more uneven the distribution of organisms in the community, which means it is dominated by certain species, so that it can disrupt the stability of the existence of organisms in the community.

In addition, this study also identified the relative abundance of each species of dragonfly found (Figure 6 and Table 1). Figure 6 shows the pattern of abundance of dragonflies in Gunung Bromo's FASP, which was analyzed using Principal Component Analysis (PCA). Based on the pattern shown in Figure 6, it can be seen that *Copera marginipes* (CM) and *Orthetrum sabina* (OS) were the species of dragonflies with the highest abundance value. *Copera marginipes* had an abundance value of 38.02%, *O. sabina*'s value of 20.66%, followed by *Pseudagrion rubriceps* (PR), *H. fenestrata* (HF), and *Potamarcha congener* (PC), which were up to 8.54%, 7.99%, and 6.61%. Meanwhile, for the other species of dragonflies, the abundance values were not much different, namely in the range of 0.28% to 3.86% (Table 2).

Copera marginipes species (Figure 7), with the highest abundance value, is a dragonfly from the family Platycnemididae, which can be found in various habitats because it is very tolerant of changes in water quality. The male *C. marginipes*' body is dominated by black, with irregular yellow stripes on their synthorax. Meanwhile, the female's body is paler than the male's. They also have transparent wing venation with dark brown pterostigma. The distinct characteristic of this dragonfly species is their yellow legs. During the immature phase, the bodies of both male and female dragonflies are white, quite look like ghosts. Therefore, this dragonfly is often called the yellow-footed ghost dragonfly.

Meanwhile, *O. sabina* (Figure 7) was the dragonfly with the second-highest abundance value. This dragonfly species is a part of the infraorder Anisoptera, which is included in the Libellulidae family. They have greenish-blue compound eyes. Their thorax's color is yellowish-green with black stripes. The abdomen is 30-35 mm long, dominated by black and white patches on the top and sides of segments 4-6. Similar to *C. marginipes*, their high tolerance level to environmental changes makes *O. sabina* very easy to find at the altitude of 0-2400 m above sea level (Lieftinck 1954). This dragonfly species is also called the cosmopolitan dragonfly because it can also be found in urban areas.

The similarity of dragonfly species

The similarity index shows the similarity of dragonfly species found in different habitats. According to Soerianegara and Indrawan (1978), the similarity index value ranges from 0-100%, and two communities can be said to be similar if they have a similarity index value of around 50-100%. In this study, there were 10 species of dragonfly found in both research locations. The results of calculating the similarity index of dragonflies in the agricultural area and forest area was 43.48%. It indicated that the dragonfly communities in the forest area and the agricultural area were relatively different because the agricultural and forest area had different habitat conditions, both in terms of the constituent vegetation and abiotic factors.

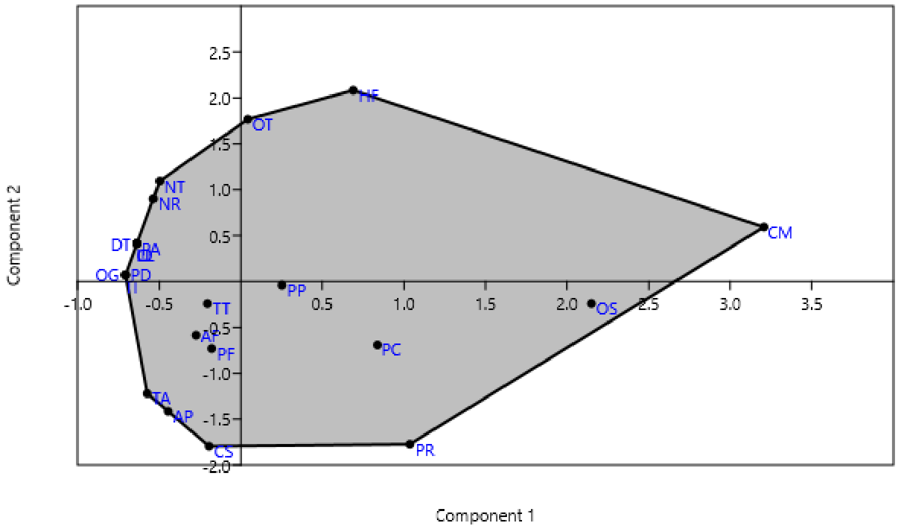


Figure 6. PCA results that describe the pattern of dragonfly abundance in the Gunung Bromo's FASP, Karanganyar, Central Java, Indonesia. OS (*Orthetrum sabina*); CM (*Copera marginipes*); CL (*Cratilla lineata*); HF (*Heliocypha fenestrata*); PC (*Potamarcha congener*); OT (*Orthetrum testaceum*); NT (*Neurothemis terminata*); PR (*Pseudagrion rubriceps*); ID (*Ictinogomphus decoratus*); PP (*Pseudagrion pruinosum*); PD (*Paragomphus reinwardtii*); TT (*Tholymis tillarga*); PF (*Pantala flavescens*); LL (*Libellago lineata*); TI (*Tetrathemis irregularis*); NR (*Neurothemis ramburii*); OG (*Orthetrum glaucum*); AF (*Agriocnemis femina*); AP (*Agriocnemis pygmaea*); DT (*Diplacodes trivialis*); PA (*Prodasineura autumnalis*); CS (*Crocothemis servilia*); TA (*Trithemis aurora*)

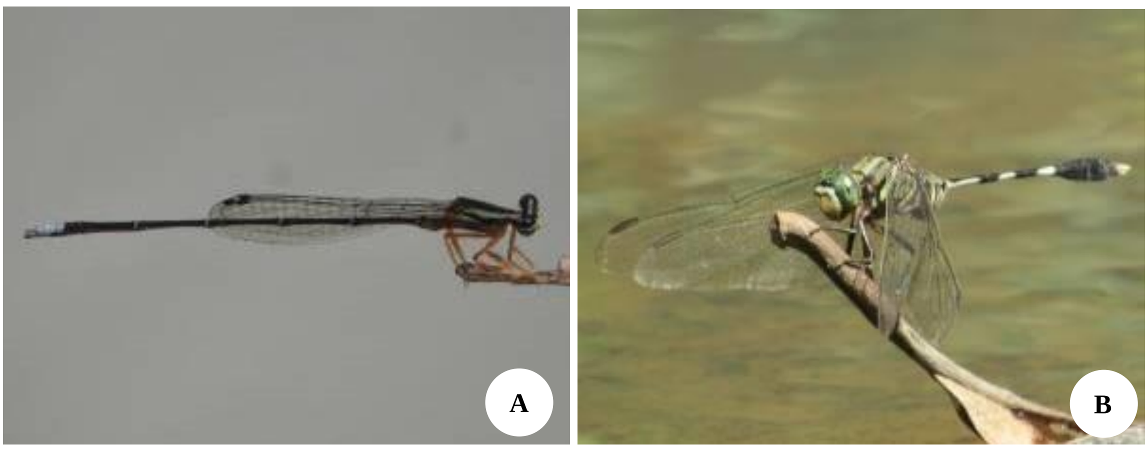


Figure 7. *Copera marginipes* (A) and *Orthetrum sabina* (B)

The relationship between dragonflies and environmental factors

Canonical Corresponding Analysis (CCA) is a non-parametric method in statistical analysis that can be used to determine the relationship of certain taxa and environmental factors in ecological research (Wang et al. 2012). Likewise, this study employed CCA to determine the influence/relationship of environmental factors and the presence of dragonflies in Gunung Bromo's FASP. Environmental factors included both abiotic and biotic factors. Air temperature, water temperature, pH, water DO (Dissolved Oxygen), air humidity, elevation, and light intensity were all measured as abiotic factors. Meanwhile, the biotic factors measured were the density and coverage of seedlings, saplings, poles, and trees. According to the results of abiotic and biotic factors measurements, it can be concluded that water DO, air humidity, and the coverage and density of stakes, poles, and trees were all higher in forest areas than in agriculturals. Meanwhile, the agricultural area's air temperature, water temperature, pH, light intensity, seedling coverage, and seedling density were higher than the forest area's (Table 2).

Figure 8 depicts the CCA results for the relationship between dragonflies and abiotic factors. The green line represents abiotic factors, while the blue circle represents the dragonfly species discovered. The greater the number of circles in or near the line of abiotic factors, the greater their influence on the presence of dragonflies. Based on the results of CCA, it can be seen that most dragonflies in Gunung Bromo's FASP were influenced by abiotic factors. *Prodasineura autumnalis* (PA), *T. irregularis* (TI), *C. lineata* (CL), *N. ramburii* (NR), *N. terminata* (NT), *Orthetrum testaceum* (OT), and *H. fenestrata* (HF) are the species of dragonflies affected by water DO and humidity. These results were in accordance with the direct observations, where those species of dragonflies were mostly found in forest areas, while some were only found in forest areas with relatively high DO values of water and air humidity.

Paragomphus reinwardtii (PD), *D. trivialis* (DT), *Pantala flavescens* (PF), *T. aurora* (TA), *Crocothemis servilia* (CS), *Agriocnemis femina* (AF), and *A. pygmaea* (AP) are the species of dragonflies that are influenced by the air temperature. In accordance with the field observations, those dragonfly species were found in locations with high air temperatures.

Meanwhile, *O. sabina* (OS) and *C. marginipes* (CM), located close to ordinate 0, are species whose presence is not influenced by any abiotic factors. It follows the results of field observations, where both could be found in all research locations. Thus, it can be seen that *O. sabina* and *C. marginipes* did not have specific habitat preferences and could be found in almost all types of habitat.

Figure 9 depicts the CCA results for the relationship between dragonflies and biotic factors. The green line represents biotic factors, while the blue circle represents the dragonfly species discovered. According to the figure above, it can be seen that each species of dragonfly had a different preference for the biotic factors. Based on the results of CCA, it was known that the presence of *C. servilia*, *A. pygmaea*, and *T. aurora* was affected by seedling density. *Pantala flavescens*, *Tholymis tillarga*, and *A. femina* were the dragonfly species whose presence was influenced by the seedling coverage. *Orthetrum glaucum*, *L. lineata*, *T. irregularis*, and *N. ramburii* were influenced by the pole density. *Ictinogomphus decoratus* and *O. testaceum* were affected by the pole coverage. *Diplacodes trivialis* and *P. reinwardtii* were affected by the density of the stake. *Heliocypha fenestrata*, *C. lineata*, and *P. autumnalis* were affected by the sapling coverage. *Neurothemis terminata* was affected by the tree coverage. Meanwhile, *O. sabina*, *P. congener*, *C. marginipes*, *P. rubriceps*, and *Pseudagrion pruinosum* were the species without any preferred biotic factors in particular.

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Table 2. Environmental factors of Gunung Bromo's FASP, Karanganyar, Central Java, Indonesia

Environmental factors	Agricultural area	Forest area
Abiotic factors		
Dissolved Oxygen/DO (mg/L)	6.60	11.67
Water temperature (ºC)	32.59	30.40
Air temperature (ºC)	36.54	32.90
pH	8.78	8.57
Elevation (m asl.)	315.00	251.67
Humidity (%RH)	41.08	58.23
Light intensity (lux)	16,195	11,041.67
Biotic factors		
Seedling coverage (%)	87.50	68.75
Seedlings density (indv/m^2)	121.72	49.88
Sapling coverage (%)	47.46	65.63
Saplings density (indv/m^2)	0.27	0.39
Poles coverage (%)	1.81	19.53
Pole density (indv/m^2)	0.02	0.03
Tree coverage (%)	8.09	58.92
Trees density (indv/m^2)	0.003	0.019

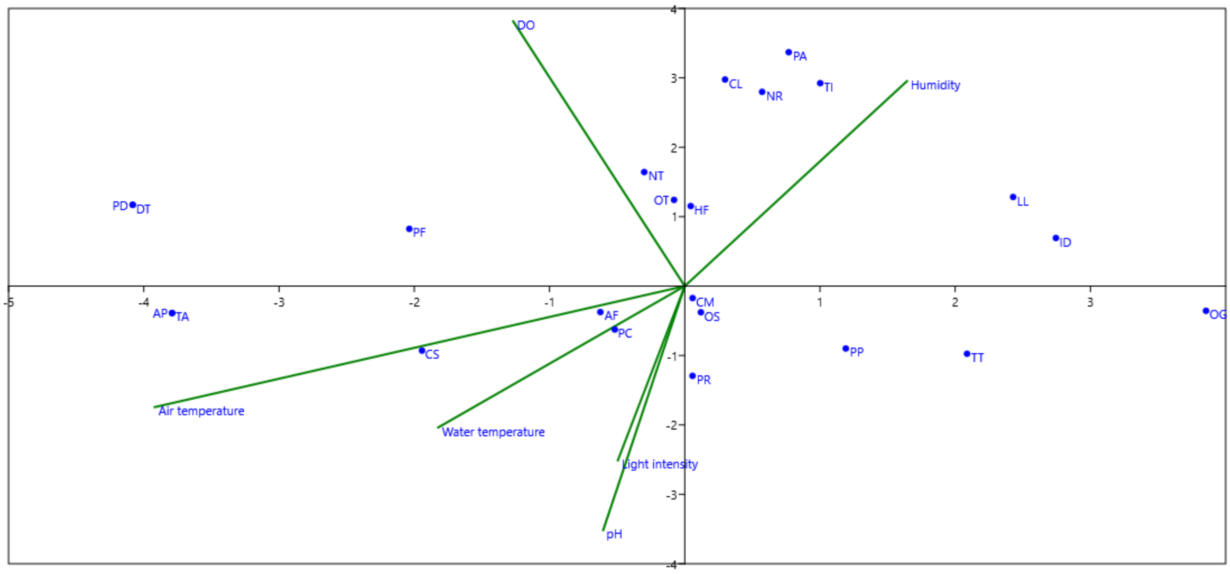

Figure 8. CCA graph showing the relationship between dragonflies and abiotic factors

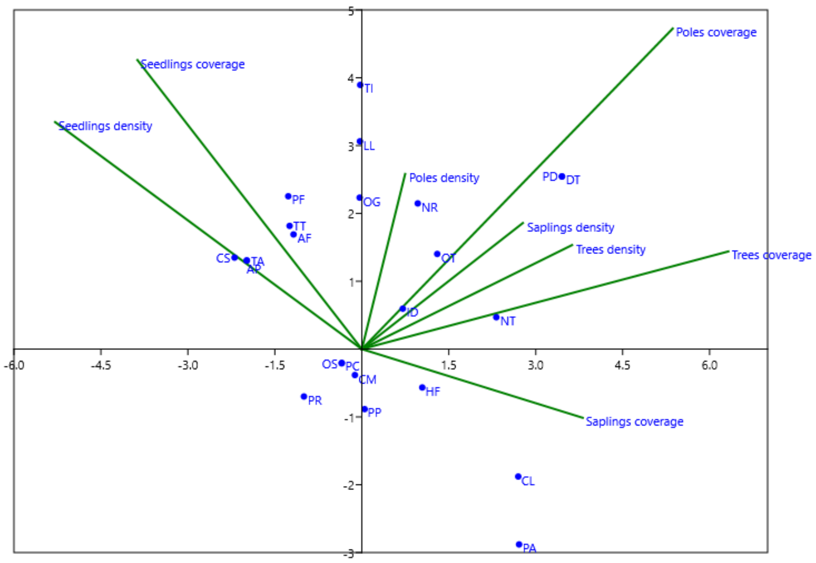

Figure 9. CCA graph showing the relationship between dragonflies and biotic factors

The CCA results are generally consistent with field observations. *Crocothemis servilia*, *A. pygmaea*, *T. aurora*, *P. flavescens*, *T. tillarga*, and *A. femina* were the species that were often found above and between the dense seedlings. *Orthetrum glaucum*, *L. lineata*, *T. irregularis*, *N. ramburii*, *I. decoratus*, and *O. testaceum* were often found perched in the areas shaded by poles. *Paragomphus reinwardtii*, *C. lineata*, and *P. autumnalis* were often found perched at the tip of or around the stake. In addition, there was *N. terminata*, which was often found perched on the branches of trees and dense bamboos. Based on the results, it can be seen that the diversity of dragonflies in the forest area is higher than in the agricultural area. It can be caused by several factors, such as human activities, feed availability and the composition of the vegetation.

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