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Community structure and habitat characteristics of dragonflies (Odonata) in tropical lowland forest of Ujung Kulon national park

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Abstract
Information about dragonflies and its habitat in Ujung Kulon National Park is poorly studied. The objective of this study was to inventory the dragonflies community structure in various habitats in the Ujung Kulon National Park and describe the contribution of habitat characteristics on the dragonfly communities structure. In this study, we surveyed the dragonfly communities in five locations, includes natural ponds, a shady small stream in the forest, and river habitat. We measured several habitat characteristics and analyzed its contribution to the variation of the dragonfly communities structure using canonical correspondence analysis. Twenty five of dragonflies species (classified into 2 families of Anisoptera suborder and 6 families of Zygopetra Suborder) were recorded in this study. Structure of the dragonfly community in among habitat type showed dissimilarity. Aquatic habitat type, conductivity, total dissolved solids, complexity of water substrate, the width of aquatic habitat, and canopy covering contributed to the variation of dragonfly communities structure. This study provided the new information about variation of the structure of dragonfly communities in various habitat types in this conservation area.

Keywords: Community structure, dragonfly, habitat, Ujung Kulon

Introduction

Ujung Kulon National Park (TNUK) is a lowland tropical forest ecosystem that still preserved. It region lies from 6°30'- 6°52' S and 102°02' - 105°37 E. Information and publication about dragonfly community and their habitat in Ujung Kulon is still limited and poorly studied. The latest publication about the checklist of dragonflies in Ujung Kulon was reported by [1, 2, 3]. Generally this problem like as gaps of knowledge on the ecology and biology of Indonesian tropical forest Odonata [4].

Structure of dragonfly community in TNUK can be influenced by diversity of aquatic and riparian habitat. Habitat characteristics influenced structure of dragonfly community [5, 6] . For example, increasing of aquatic habitat width affected on the increasing of Anisoptera species richness but did not affect on Zygoptera species richness [7]. Removal riparian vegetation affected on the changing of dragonflies community structure [8, 9]. Riparian vegetation correlated with physicochemical water quality and determine dragonfly diversity [9]. Water temperature and pH have a role in structuring the adult dragonfly assemblage [10]. Aquatic habitat is very important to the dragonflies life cycle. Their eggs were deposited in water and nymph spent their all life in water [5].

Dragonflies have a specific response to habitat and grouped based on the specialization of their habitat [11-14]. The dragonflies that have been inventoried in this study can be classified according to their habitat characteristics. The life stages of many dragonflies species depend on specific habitat to survive [5, 15]. Some dragonfly species can be used as a bioindicator for freshwater and forest ecosystem [10, 12, 16, 17] and can be a tool for evaluated wetland condition [18].

The objective of this study was to inventory the dragonflies community structure in various habitat in TNUK and describing the contribution of habitat characteristics on dragonfly communities structure. The research was expected to provide an important contribution for conservation of dragonflies by providing a habitat information. Dragonfly data of this research in TNUK can be used as one of the efforts to reassemble data on the diversity of dragonflies in Java Island.

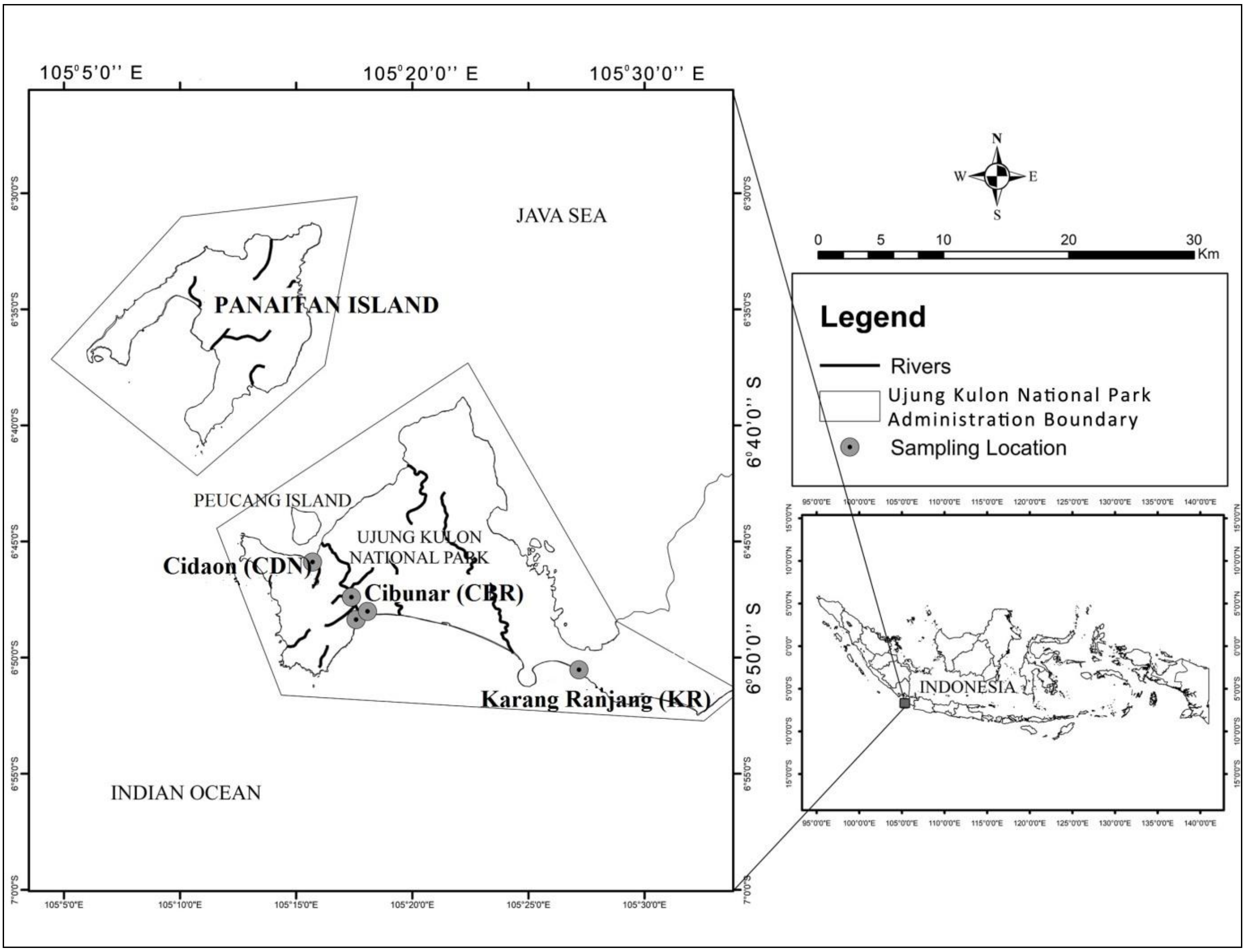

Fig 1: Location of dragonflies sampling in Ujung Kulon Peninsula. source of map www.ujungkulon.org/tentang-tnuk/letak-dan-luas. Edited in Arc GIS 10.5

Materials and Methods

Time and location of study

The survey was conducted in August 2018, during the dry season. According to Dolný *et al.* 2011 [16], there was no significant difference in the diversity of dragonflies in Indonesia tropical forest between the dry season and the rainy season. This study was conducted in Ujung Kulon Peninsula, Banten, Java Island, Indonesia. This area was categorized as protected and conservation area of Ujung Kulon National Park. We set up five sampling locations (Figure 1). First sampling is in a freshwater natural pond that located in coastal forest, Karang Ranjang (KR) Resort area (060 50'29,4" S, 1050 27'11,0" E). We only found one pond habitat in this survey. The width of pond is 30 m and 30 m length size. This pond has muddy and sands substrate and also some plant litter. Pond water depth is 0.1 - 0.2 m. The Riparian area was dominated by coastal vegetation understory, such as *Thespesia populnea* (Malvaceae), and *Myristica sp* and *Ficus sp*. Pond is sunniest habitat (vegetation canopy covering < 30%). The dragonflies collected at 30 m long transect as long as the maximum size of this pond.

The second sampling location was determined in Cibunar Resort (CBR1). The location was sampled at 100 m transects along a small stream in the forest in Cibunar Resort (06^0 48' 20,85" S, 105^0 17'36,05" E). The canopy covering in this location is dense (canopy covering is > 60 %). Water streams flow slowly, and its width of 0.5 to 1.5 m, water depth 0.1-0.14 m. The compositions of river substrate were found includes: rocky substrate, leaf, twigs and large rocks.

The third (CBR2) and fourth sampling (CBR3) located on the same river. Both are 1000 m apart. This selection is based on differences in the character of habitats, CBR2 as shaded rivers and CBR 3 as sunniest rivers. The third location (06^0 48' 01,89" S, 105^0 17'48,59" E) was overgrown with large trees, with canopy covering 30-60 %. The width of river ranged from 5 to 7 m and average water depth 0.22 m. The fourth location (06^0 48' 01,89" S, 105^0 17'48,59" E) is sunniest river , there are no trees in 100 m areas from this edge river. The width of river is 3-3.2 m and water depth 0.1 - 0.5 m. Shrubs and grass that growth on the water's edge submerged in water. Both of these locations have almost the same substrate characteristics. There are several leaves, twigs, logs and rocks. The fifth location (06^0 45'49,5" S, 105^0 15' 52,1" E) is in a river located in Cidaon area (CDN). Habitat condition of this location similar to the third location (CBR2). Width of the river ranged from 3.0 - 4.3 m and water depth 0.1-0.22 m.

Dragonfly survey method

The transect method was used to collect data. Dragonfly was collected on 100 m long transects or along with aquatic habitats if its size less than 100 m. The transect width is 2 m, 1 m on the edge and 1 m on the water body from the edge. The first point at each transect was marked as point sampling location. Dragonfly was observed for 1 hour based on

Oliveira-Junior *et al.* 2017 [9]. The number of individuals was recorded. Dragonflies were observed directly using binoculars and the camera and then identified using a field guide. Dragonflies that cannot be identified directly, were captured using insect nets, and its some morphology documented such venation of the wings, lateral, dorsal and ventral view of the dragonfly body using a Canon EOS 1300D camera. Dragonfly specimens were identified using Fraser 1934 [19] and Orr 2005 [20]. Some other species that not found in both field guide was confirmed by a preserved specimen photo published by Natural Biodiversity Center and Natural History Museum in Global Biodiversity Information Facility website (www.gbif.org). Some species includes *Prodasineura delicatula* and *Heliocypha fenestrata* based on occurrence dataset in www.gbif.org [21, 22]. *Libellago sumatrana Euphaea variegata* and *Vestalis luctuosa* based on specimen photos in Natural History Museum [23-25]. *Nososticta insignis* was identified based on Seehausen and Theischinger [26]. The classification of Zygoptera based on Djikstra *et al.* 2014 [27]. Some information about global distribution, endemicity and conservation status was added from IUCN database.

Measuring habitat parameters

Measuring habitat parameter includes riparian vegetation structure, water structure and water parameters. Type of water ecosystem was categorized based on the existence of flowing water (0 = stagnant or lentic ecosystem, 1= flowing water or lotic ecosystem). Determining the structure of riparian vegetation and water structures based on Peck *et al*. 2006 [28]. The measured vegetation parameters include the complexity of the vegetation structure and the estimation of tree canopy covering the water's body. These parameters were measured in a plot 5 m x 5 m at each transect. The complexity of vegetation structure was determined based on vegetation strata vertically includes: (1) canopy layer vegetation or trees with high more than 5 m, (2) understory layer: shrubs and herb with a height of 0.5 to 5 m and (3) ground layer: e.g. grass. Vegetation structure quantified by making a scale of vegetation complexity with a range of 0-3 which shows the number of existing vegetation structures (e.g. 0 = no vegetation, 1 = there are only 1 types of vegetation structures, for example, only understorey layer, 2 = understorey and ground layer, 3= canopy layer, understorey and ground layer). The estimation of the tree canopy covering on the water's body was estimated by measure the length and width of the canopy that covering the waters body then divided by the area of the waters on the 5 m long transect. The presence of water vegetation and the submerged plant was noted. Width of the water, and water depth was measured using a measuring stick. Water substrate composition was determined in 1 m2 plot that located at near the water's edge, at the start, mid and end of the transect. Listed substrate composition includes: (1) mud, (2) sand, (3) rock, (4) gravel, plant substrate: (5) leaves litter, (6) twigs or logs. structure. Water substrate complexity quantified based on the number of types of substrate. For example, 1= only one type of water substrate, 2 = rock, gravel and plant substrate, 3= mud, sand and plant substrate, 4= mud, sand, gravel, leaves litter, 5=mud, sand, gravel, leaves litter and log and 6 = all type of water substrate present. Psychochemical of water was measured includes conductivity, total dissolved solids, and pH. Submerged plant and water vegetation were noted (0= present, 1= absent).

Data analysis

The similarity of species composition in each sampling location was measured by analysis of similarity (ANOSIM) with the Bray-Curtis method. Data of species occurrence per day was made as replication. The analysis was constructed with the Vegan package in R program (R Core Team 2018). The Bray-Curtis similarity index value was used to analyze the similarity value of dragonfly composition in each habitat using PAST software. Dragonflies species were grouped based on the habitat characteristics at each species. Canonical Correspondence Analysis (CCA) was used to evaluate the effect of environmental parameters on the composition of the dragonfly [29]. CCA was constructed in PAST 3.22 software. A cluster of dragonfly species was constructed using hierarchy analysis using package factoextra, with euclidean dissimilarity calculation methods and grouped by Ward linkage method using the R program (R Core Team 2018).

Results and Discussion

Twenty five species of dragonflies were recorded in this survey (Table 1). Thirteen species belong to Anisopteran suborder and two families: Libellulidae and Aeshnidae. Twelve species belong to damselflies (Zygopteran suborder). All damselflies species classified into six families: Calopterygidae, Chlorocyphidae, Coenagrionidae, Euphaidae, Platycnemididae, and Protoneuridae. Each habitat of the sampling location showed dissimilarity of structure dragonfly community significantly (R = 0.997, p-value 0.0016, ANOSIM with the Bray-Curtis similarity index). Natural ponds habitat has a lowest similarity (0.03-0.13) compared to other habitats. Composition species in river habitat CBR2 and CDN have the highest similarity index (Table 2)

Table 1: List of dragonflies species found in Ujung Kulon National Park.

Species	KR	CBR 1	CBR 2	CBR 3	CDN	Total
Aeshnidae						
Gynacantha basigutatta Rambur, 1842	4	0	0	0	0	4
Libellulidae						
Agrionoptera insignis (Rambur,1842)	11	4	0	0	0	15
Brachydiplax chalybea Brauer, 1868	4	0	0	0	0	4
Camacinia gigantea (Brauer, 1867)	12	0	0	0	0	12
Nesoxenia lineata (Selys, 1868)	8	0	0	0	0	8
Neurothemis ramburii (Kaup in Brauer, 1866)	3	3	19	11	4	40
Orthetrum chrysis (Selys, 1891)	0	4	16	21	8	49
Orthetrum sabina (Drury, 1773)	2	0	0	7	0	9
Pantala flavescens (Fabricius, 1798)	3	0	0	0	0	3
Tetrathemis irregularis Brauer, 1868	0	0	5	0	3	8
Tholymis tillarga (Fabricius, 1798)	5	0	0	0	0	5
Tramea transmarina Brauer, 1867	7	0	0	0	0	7

Zyxomma obtusum Albarda, 1881	9	0	0	0	0	9
Calopterygidae						
Vestalis luctuosa (Burmeister, 1839)	0	0	19	0	33	52
Chlorocyphidae						
Heliocypha fenestrata (Wiedemann in Burmeister, 1839)	0	0	8	41	24	73
Libellago sumatrana (Albarda in Selys, 1879)	0	0	0	71	15	86
Coenagrionidae						
Pseudagrion pruinosum (Burmeister, 1839)	0	0	0	18	0	18
Pseudagrion microcephalum (Rambur, 1842)	0	0	0	17	2	19
Euphaidae						
Euphaea variegata Rambur, 1842	0	0	9	30	11	50
Platycnemididae						
Coeliccia membranipes (Rambur, 1842)	0	4	0	0	0	4
Copera marginipes (Rambur, 1842)	3	0	0	11	8	22
Copera vittata (Selys, 1863)	0	7	0	0	19	26
Prodasineura autumnalis (Fraser, 1922)	0	0	6	26	0	32
Prodasineura delicatula (Lieftinck, 1930)	0	7	17	0	18	42
Protoneuridae						
Nososticta insignis (Selys, 1886)	0	12	3	0	11	26
Total number of individuals	71	41	102	253	156	623
Total number of species	12	7	9	10	12	25
Total number of Anisopteran	11	3	3	3	3	13
Total number of Zygopteran	1	4	6	7	9	12

Note: KR:Karang Ranjang, CBR1: small streams in the forest Cibunar , CBR2: opennes river habitat in forest Cibunar , CBR3: shady river habitat in forest Cibunar, CDN: shady river in forest Cidaon

Natural pond showed a higher Anisoptera species richness compared to another habitat. Nine species only found at the natural pond includes *Gynacantha basigutata*, *Brachydiplax chlaybea*, *Camacinia gigantea*, *Nesoxenia lineata*, *Orthetrum chrysis*, *Pantala flavescens*, *Tholymis tillarga*, *Tramea transmarina*, and *Zyxomma obtusum*. Meanwhile, damselflies species or Zygoptera suborder more found in flowing water habitat. Some dragonflies were clasified as crepsucular dragonflies. These dragonfly includes: *G. basiguttata*, *Z. obtusum*, and *T. tillarga*. Crepuscular species were recorded in 05.00-06.00 pm. Only one species damselfly (*Copera marginipes*) was found in natural pond habitat. Small streams in the forest (CBR1) have a lower number of species (seven species) compared to another flowing water habitat. *Coelicia membranipes* was noted as specific species to this habitat. This species preferred small streams with denser canopy covering. River habitat (CBR2, CBR3 and CDN) showed the highest total number of Zygopteran (11 species). *Pseudagrion pruinosum* is specific species for sunniest river location (CBR3). Some Zygopteran were more abundance in sunniest river compared to the shady river. These species includes: *Libellago sumatrana, Pseudagrion microcephalum Euphaea variegata, Heliocypha fenestrata, Copera marginipes*, and *Prodasineura autumnalis*. Another zygopteran such as *Copera vitata, Nososticta insignis*,and *Vestalis luctuosa*, were found in habitat with medium to shadier (canopy covering >30%) (CBR1, CBR2 and CDN). The ratio of species number of Anisoptera with Zygoptera from highest to lowest were: Ponds (KR), Small streams (CBR1), sunniest river (CBR3) and shadier river (CBR2 and CDN) respectively.

Canonical Correspondence Analysis produces two axes. habitat characteristics contribute 80.36% to variations in the structure of dragonfly communities. Total dissolved solids, water conductivity, the width of the aquatic habitat, water substrate complexity have the higher correlation in axis 1. In the second axis canopy covering have the higher correlation in determining the variation of dragonflies community (Table 2).

The variation of dragonflies community structure correlated to the width of aquatic habitat (Table 3). Dijkstra and Lempert 2003 [30] and de Marco Júnior *et al.* 2015 [7] stated that the abundance and species richness was correlated with the width of the aquatic habitat. Our results exhibited that Anisoptera species dominated in a natural pond that has wider aquatic habitat compared to small streams or river in the forest. This finding can be related to de Marco Junior *et al.* 2015 [7] states that the large body size dragonflies such as more anisopteran will dominate wider waters and a low canopy covering. Anisopteran is less common in patches in forests that have a dense canopy covering. Our CCA analysis showed that canopy covering have the contribution to dragonflies community structure. The result of CCA ordination map at the second axis showed that more of dragonflies distributed a long gradient canopy covering (Fig. 2). Some damselflies exhibited a higher abundance in low or no canopy cover compared to habitat with a higher canopy covering. Higher abundance species included *Heliocypha fenestrata, Libellago sumatrana, Pseudagrion microcephalum, Euphaea variegata, Copera marginipes,* and *Prodasineura autumnalis* (Table 1 and Fig. 2). Canopy covering can be a primary factor in structuring dragonfly community [12, 31].

Water ecosystem type includes flowing water ecosystem (lotic) and stagnant water ecosystem (lentic) contributes to structuring dragonfly community. In our CCA analysis, water ecosystem showed the high correlation value to variation of dragonflies structure (Table 3). This research exhibits the dissimilarity of dragonflies composition in lotic (stream and river) and lentic water (pond). Total species of Anisoptera was high in pond habitat compare to river and streams habitat. Meanwhile, damselflies species richness was high in flowing water ecosystem (Table 1). This condition was similar to Seidu *et al.* 2019 [6] and Renner *et al.* 2016 [32] stated the lentic ecosystem was dominated by Anisoptera while Zygoptera dominated in the lotic ecosystem.

The higher TDS and Conductivity also correlated to Anisoptera species richness. Both factor have the highest correlation CCA value. We recorded a higher species richness of Anisoptera in pond compared to other habitat (Table 1). Only one species of damselflies recorded in pond. We have measured TDS and electric conductivity in pond was high.

TDS and electric conductivity factor related to habitat selection to laying eggs and development phase of nymphs. Mendes *et al.* 2018 [33] showed that TDS and conductivity affected on the Nymph of Anisoptera. Conductivity also influences the existence of other water macroinvertebrates [34]. Although this study does not collect and correlate nymphs with water quality, adult dragonflies assemblage can be a bioindicator of water quality [11, 17].

Our CCA showed that dragonfly communities structure was influenced by complexity of aquatic substrates. In ordination map of CCA, damselflies species was dominated in aquatic habitat with a higher water substrates such as leaves litter, plant twigs, fallen trees, and submerged plants (Table 3 and Fig. 2). The complexity of aquatic substrates related to laying eggs behaviour of damselfly as endophytic. Damselfly requires a substrate such as plant tissue, leave litter, or log to deposit their eggs while Anisoptera are exophytic [5]. We have been observed *N. insignis*, *H. fenestrata*, laying eggs in leaves litter and plant substrate in water. *Libellago sumatrana* and *C. marginipes* laid their eggs in submerged logs and *P. pruinosum* laid her eggs in plant tissue, such as submerged herbs. This study similar to Oliveira-Junior *et al.* 2017 [9] that Zygoptera (damselflies) community have a positive correlation with the quantity of plant substrate in the waters. The complexity of the substrate plays a role in the life cycle of water macrofauna including dragonfly nymphs [35].

Based on our clustering analysis result and CCA ordination map, we classified dragonflies species in Ujung Kulon in to three groups (Fig. 2 and Fig. 3). This classification based on the habitat characteristics with the higher correlation value of CCA analysis. Our study classified dragonfly species into : (1) species of sunniest flowing water habitat, (2) species of shady flowing water habitat and (3) species of sunniest stagnant water habitat. Dijkstra and Lempert 2003 [30] clustered Odonata into four group : species of shadier habitat, species of patchy habitat, species of flowing water and sunnied, and species of standing water. In our classification some of member in group 2 (*C. membranipes, C. vittata, N. insignis, V. luctuosa*) can be categorized as species of shadier and patchy habitat in Dijkstra and Lempert classification.

Based on canopy covering dragonfly communities can be classified into two groups, like as shadier group and sunniest group (Fig. 2 and Fig. 3). Dragonflies of Anisoptera Suborder (group 1) was preferred in sunniest habitat, exception for a few species such as *A. insignis*, *T. irregularis*, and *N. ramburri* can be found in shadier river habitats. Dragonflies which prefer in shadier habitats are specialist as forest dragonflies, while dragonflies more like open habitat as generalist one [36, 37]. Luke *et al.* 2017 [38] and Orr 2006 [39] reported that most endemic dragonflies on Borneo Island are more adapted at waters in the forest habitat. In this study we consider *V. luctuosa*, *P. delicatula*, and *N. insignis*, *C. vitata* as forest specialist dragonflies. These species habitated in patchy and shadier water ecosystem in the forest of Ujung Kulon. *Vestalis luctuosa* has categorized as near threatened damselfly [40] and as flagship species for wetland ecosystem in Sundaland [41].

Table 2: Dissimilarity index of dragonflies composition among all study site based on Bray-Curtis similarity, each habitat of the sampling location showed dissimilarity significantly (R = 0.997, p-value 0.0016)

study sites*	KR	CBR1	CBR2	CBR3	CDN
KR	1.00				
CBR1	0.13	1.00			
CBR2	0.03	0.24	1.00		
CBR3	0.05	0.05	0.28	1.00	
CDN	0.05	0.32	0.55	0.35	1.00

* KR: natural pond in Karang Ranjang, CBR1: small streams in the forest Cibunar, CBR2: opennes river habitat in forest Cibunar, CBR3: shady river habitat in forest Cibunar, CDN: shady river in forest Cidaon

Table 3: Correlations of dragonflies community with environmental factor based on canonical correspondence analysis. Words with bold as factors that have higher correlations

	Axis 1	Axis 2
Eigenvalues	0.78	0.41
Proportion (%)	52.76	27.60
Vegetation structure	0.24	-0.73
Canopy cover	-0.32	-0.95
Water substrate complexity	-0.84	-0.14
Water ecosystem type (flowing or stagnant water ecosystem)	-0.99	-0.14
Channel width	0.93	0.23
Water depth	-0.24	0.85
Submerged plant	-0.24	0.73
Total dissolved solid	1.00	0.03
pH	0.31	-0.66
Conductivity	1.00	0.05

Conclusion

Twenty five species were recorded in this study. Structure of dragonflies community among all habitat types showed dissimilarity. Species richness of Anisoptera was high in pond, while damselflies species richness was high in flowing water habitat: small streams and river in the forest. Water ecosystem type, water conductivity and total dissolved solids value, water substrate complexity, the width of aquatic habitat, and the canopy covering contributed to variation of dragonflies community structure. Protecting the forest and its freshwaters ecosystems are important to conservating the dragonflies diversity. However, further studies including more location surveys and different aquatic habitat are needed to monitoring dragonfly diversity in conserving area of Ujung Kulon National Park. It is necessary to investigate behavioural ecology of dragonflies species.

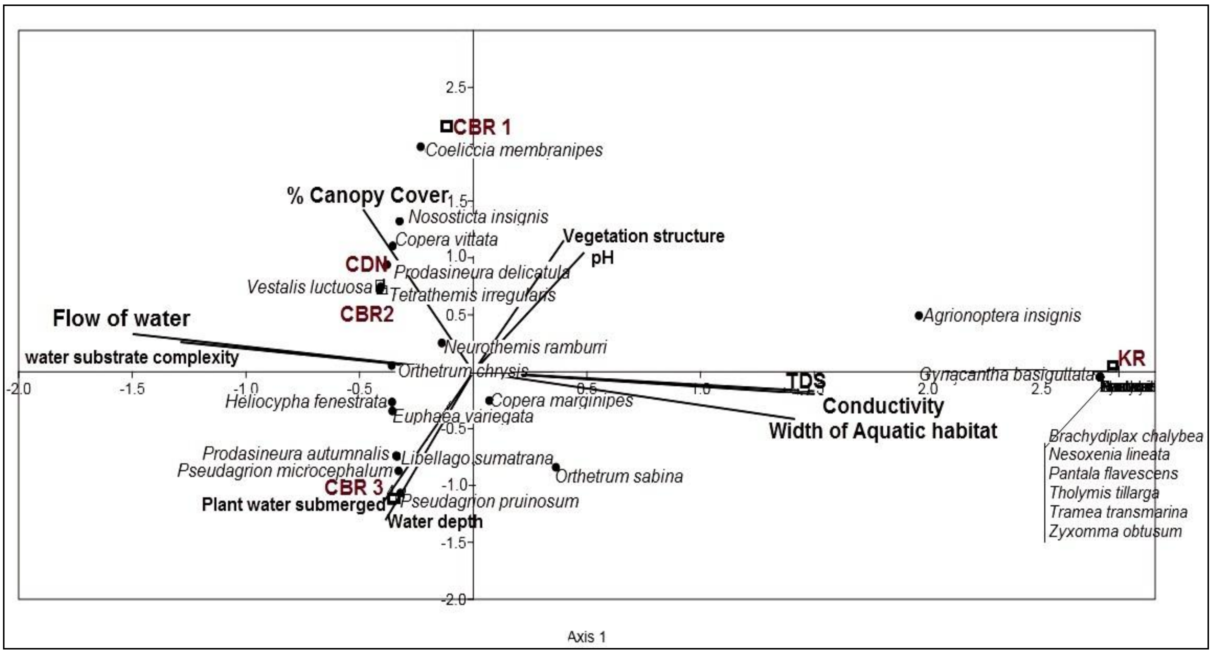

Fig 2: Canonical correspondence analysis triplot of environmental factors and dragonfly community in Ujungkulon National Park. KR: natural pond in Karang Ranjang, CBR1: small streams in the forest Cibunar, CBR2: opennes river habitat in forest Cibunar , CBR3:shady river habitat in forest Cibunar, CDN: shady river in forest Cidaon.

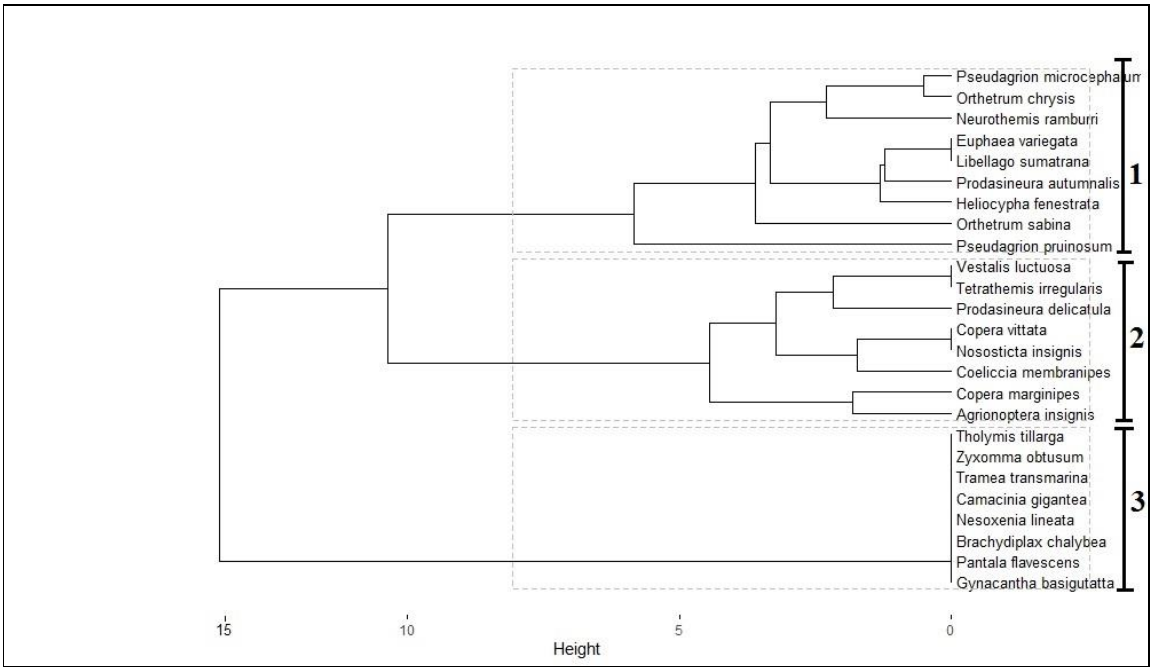

Fig 3: Clustering of dragonflies species based on habitat characteristics

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