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Original research article

The Model of Odonate Diversity Relationship with Environmental Factors Based on Path Analysis

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Abstract

This study aims to analyze and describe the relationship between altitude, aerial variables (temperature, light intensity, humidity), water qualities (water temperature, pH, BOD, COD, DO, TOM, and water velocity), and vegetation with the diversity of Odonate assemblages. Odonate samplings were conducted at six survey sites based on altitude and vegetation characteristics. Measurement of altitude, aerial variables, water qualities and vegetation characteristics were replicate in the first day and third day. Analysis of correlations of all environmental factors with the odonate diversity was done through structural equation model using Partial Least Squares (PLS), Open source Smart Software and Microsoft Excel. The aerial variables and water qualities affected indirectly on odonate diversity. The aerial variables directly or with interaction to other factor affected the water qualities and vegetation characteristics. The vegetation characteristics directly influenced to odonate diversity. Water flow affected water quality, light intensity affected the aerial, while morning period observation affected the odonate diversity. Predictive relevance (Q2) for a model designed amounted to 99.95%, while the rest of 0.05% are explained by other variables.

1. Introduction

Indonesia is a tropical country with diverse natural resources and house of a huge number of insect species (Darnaedi and Noerdjito, 2007). One of the insect groups in this country that gained public attention from entomologist is Odonata (Orr, 2004). This grup plays important roles in creating a balance in the food chain of the agricultural area. In addition, their sensitivity to environmental fluctuation makes odonate species excellent biological indicators of environmental conditions. Several studies have reported that dragonflies are often successfully used as an indicator for water quality (Clark and Samways, 1996; Samways et al., 1996). Based on the research report, there are more than 5680 odonate species in the world that have been identified (Kalkman et al., 2008). However, there are not available recent data of number of species in Indonesia.

Odonata is the insect group that morphologically varied from the color, body size, and shape of the wing. There are two group of Odonata, dragonflies and damselflies, both are very common in the environment around with different range of landscape use. Many species have a narrow distribution range, and habitat specialists, including dragonflies that inhabit the alpine mountains, watersheds and river waterfall in the tropical rain forest. The highest diversity is found in flowing waters in the tropical rain forest, Oriental and Neotropical regions most specious.

Dragonflies are predators both the nymph and imago phases. The adults are a type of predator and active natural enemies in the agriculture and plantation habitats. Odonate adults and nymphs are also preyed upon by a variety of organisms among other birds, bats, reptiles and fishes. The young nymph stages feed on Protozoas, mosquito larvae, small crustaceans (i.e. Daphnia sp., Cyclops sp.) and other small animals. Larvae experiencing feed on tadpoles, small fishes, water beetles, and other odonate nymps of different species as well as the same species (cannibalism).

In scientific publications, research journals to review the diversity of information and the role of dragonflies, especially in Indonesia is very limited. Studies on the diversity of dragonfly either merely as a knowledge or other utilization in Indonesia still needs to be developed. Dragonflies are one of the types of insects wealth of Indonesia who rarely get public attention, both from the point role or utilization. The existence and type of their counterparts in Indonesia have not been fully identified.

In their life cycle adults lay eggs in less contaminated water, later the eggs hatching into nymphs that live in the water. Odonate is a group of insects that undergo incomplete metamorphosis. According to Theischinger & Hawking (2006) in the life cycle of the odonate species, there are three phases of development: egg, nymph and imago. Egg and nymph stages of development occur in the water, while imago lives in aerial

Environmental degradation as a result of land use changes, pollution, and the use of pesticides have pushed population of Odonata. If such condition persists in the future, it will lead to the breakdown of the food chain in an ecosystem, especially agricultural ecosystems, which in turn will be followed by explosions of pests and the extinction of several species. Such conditions can reduce the existing biodiversity including Odonata.

Cordoba (2008), stated that during the period 1994-2007 in scientific publications, especially insect, Odonata is one of seven insects orders which gained remarkable publication. Nevertheless, the frequency of publication still ranks sixth named after the other order as follows: Hymenoptera, Lepidoptera, Coleoptera, Diptera, and Orthoptera. However, studies evaluating the relationship of environmental factors with a dragonfly is few. The study of environmental factor relations with dragonfly generally uses a multivariate approach to identify the factors that most influence on the distribution of dragonfly. The analysis technique used is usually using current correlation analysis (Hornung and Rice, 2003) or correspondence analysis (Samways and Steytler, 1996). In this study, the relationship of environmental factors with odonate group of species described using path analysis so that the relationship between the parameters are explained in more detailed. The focus of this research on environmental factors, while the compositional and diversity of dragonflies are not discussed because it has been published in other studies.

2. Materials and methods

The research was conducted in October 2011 to January 2012. The research was located in Brantas River Watershed (BRW) and surrounded area in Malang. The points of observation location chosen for the study site at the Brantas River Basin is in the upstream area and the middle area of Batu in Malang. Sampling was conducted at four sites, there were

1. Wendit Residential Area (WR)

   This site is geographically located at 7057'S and 1120 40'E, 435 m in altitude. The river widths at this location range from 10 to 30 meters, with muddies riverbed. Existing vegetation around the river flow is dominated by kale plants.
2. Wendit paddy fields (WP)

   This site is located at 500 meters northern of WR. The river widths at this location range from 10 to 20 meters, with muddies riverbed. Existing vegetation around the river flow is kale and rice paddy field.
3. City Center Park (CC)

   This site is geographically located at 7058'S and 1120 38'E, 441 m in altitude, represent a location close to human activities such as residential area, traffic area and local tourist destination. The river widths at this location range from 10 to 20 meters, with rocky and muddies riverbed. Existing vegetation around the river flow is grass and shrubs.
4. Sengkaling (SK)

   This site is geographically located at 7054'S and 1120 35'E, 584 m in altitude. The river widths at these locations range from 10 to 20 meters, with rocky and muddies riverbed. Existing vegetation around the river flow is grass and shrubs.
5. Talun Coban (CT)

   This site geographically located at 7045'S and 1120 30'E, 1295 m in altitude. The river widths at these locations range from 5 to 30 meters, with rocky and sandy riverbed. Existing vegetation around the river flow is shrubs and tree stands.
6. Sumber Brantas (SB)

   This site geographically located at 7045'S and 1120 32'E, 1970 m in altitude. The river widths at these locations range from 1 to 2 meters, with a rocky riverbed. Existing vegetation around the river flow is grass and shrubs.

Measurement of environmental factors at each point of observation, performed at each time of observation, around the discovery of a dragonfly on a plot of observations that have been determined. Measurement of environmental factors included altitude, aerial abiotic variables (temperature, light intensity, humidity), water qualities (water temperature, pH, BOD, COD, DO, TOM, and the velocity of water), and vegetation were done in the study sites. All measures were duplicate on the first and third day. Analysis of correlations of all environmental factors with the odonate diversity was done through structural equation model using Partial Least Squares (PLS), Open source Smart Software and Microsoft Excel.

3. Result

The results showed that the air temperature, water temperature, light intensity and air humidity were highest in WP, while the lowest temperature was observed in SB. The pH level of the water was highest in SB, while the lowest was in SK. The BOD and COD levels were highest in SK while the lowest was in SB. The highest DO was found in SK while the lowest at WR. The TOM has highest level at CC, while the lowest was at SB. The highest flow velocity was found in WP, while the lowest in SK (Table 1).

Parameter	WR	WP	SK	CC	CT	SB
Temperature (°C)	29.1	29.4	28.6	28.8	26	24.6
Water temperature (°C)	24.5	24.5	23.8	23.98	19.78	15.69
Light intensity (Lux)	995	1039	963	1063	1008	316
Humidity	90.3	90.5	85.3	85.4	81.5	77.4
pH	7.3	7.3	6.97	7.01	7.96	8.12
BOD (mg/l)	6.6	6.6	6.68	6.7	2.2	1.85
COD (MG/l)	14.9	14.79	17.64	18.45	3.641	2.148
DO (mg O_2/L)	3.9	4.01	5.07	5.2	6.4	6.1
TOM (mg/L)	2.1	2.2	8.3	8.5	0.4	0.5
Water velocity (m/s)	4	3.9	6.8	5.3	4.8	4.3

Note: WR = Wendit Residential Area, WP = Wendit Paddy Field, CC = City Center Park, SK = Sengkaling, CT = Coban Talun, SB = Sumber Brantas).

Indicators for the water quality variable were presented as follows: the temperature of the water (k1), pH (k2), BOD (k3), COD (k4), DO (k5), TOM (k6), flow velocity (k7). Variable geography has an altitude indicator (g). Indicators for aerial variables were temperature (i1), light intensity (i2), humidity (i3). Indicators for vegetation variable were the number of species and diversity index. Indicators for diversity variable was the number of odonate species in the morning (d1), the number of odonate species in the afternoon (d2), the odonate diversity in the morning (d3) and the odonate diversity in the afternoon (Figure 1).

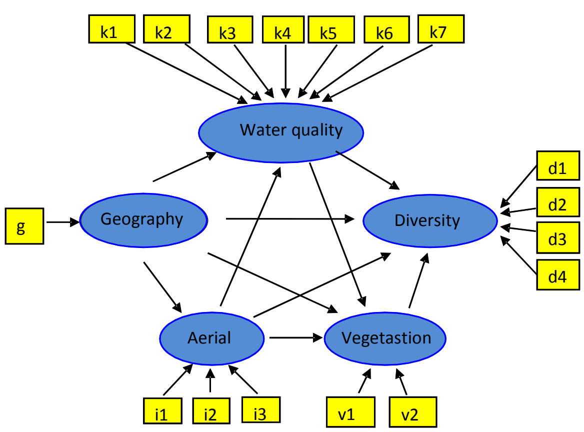

Figure 1. Hypothetical structural model of environmental factors, vegetation and odonate diversity relationships in Sub DAS Brantas Area

Statistical analysis to design a model of the relationship between environmental factors, vegetation and odonate diversity (Figure 1) indicated that the variable of the water qualities [temperature (k1), pH (k2), BOD (k3), COD (k4), DO (k5), TOM (k6)], aerial variables (temperature), vegetation variable (number of species (v1), odonate diversity [number of odonate species in morning period (d1), number of odonate species in afternoon period (d2), and diversity index dragonfly in afternoon period (d3)] did not interact significantly ($p > 0.05$). Furthermore, the model was improved by excluding indicators that had no significant effect. The intermediate model of the relationships explained the interaction between altitude (g), the sunlight intensity (i2), humidity (i3), vegetation diversity, water flow (k7), and the odonate diversity on morning period (d3).

Based on test results Goodness of Fit on structural model of the inner model using predictive relevance (Q2) and the coefficient of determination (R2) each endogenous variable, can be explained as follows:

1. A geography variable (altitude) interacted with the aerial result R2 values at 0.881, meaning that the aerial was affected by geography amounted to 88.1%.
2. The altitude and aerial interacted with vegetation at 0.174, meaning that the vegetation was influenced by the geography and aerial amounted to 17.4%.
3. The altitude, aerial and vegetation interacted with the water quality by 0.815. This meant vegetation was affected by the altitude, aerial and water quality at 81.5%.
4. The altitude, aerial variables, water quality and vegetation interact with a diversity of odonate species by 0.974. This meant the odonate diversity was influenced by geography (altitude), aerial variables, water quality and vegetation amounted to 97.4%.

From the calculations, the predictive relevance (Q2) of 99.95%, so the final model was fit (greater than 80%). The remaining 0.05% was explained by other variables (Figure 2).

Based on the final construction of the model and the t-test results of inner model, the intermediate model was converted into a final model of relationship of environmental factors, vegetation and odonate with indicators that affect directly and indirectly (Figure 3)

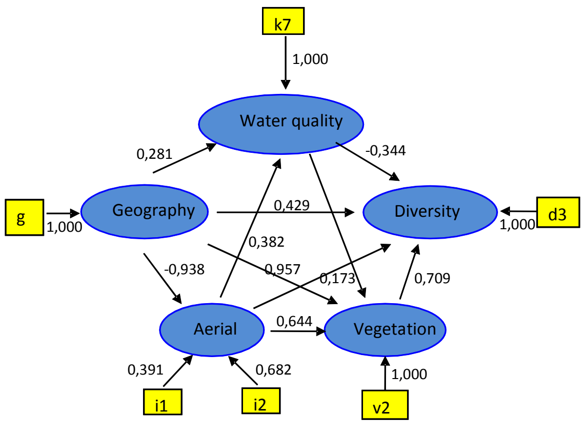

Figure 2. Intermediate structural model of environmental factors, vegetation and odonate diversity relationships in Sub DAS Brantas Area

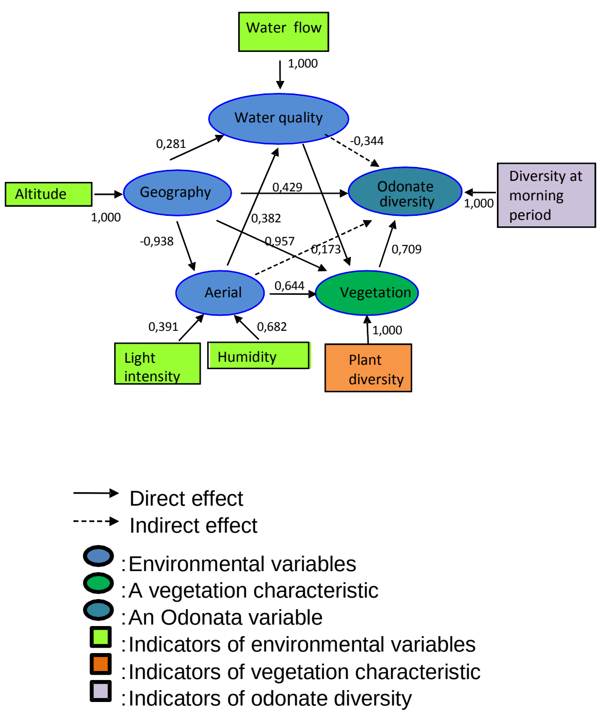

Figure 3. Final structural model of environmental factors, vegetation and odonate diversity relationships in Sub DAS Brantas Area

Based on the model, of the relationship between environmental variables, vegetation and odonate diversity (Figure 3), explained several correlation as follows: (i) the significant indicator on water quality was flow velocity, (ii) the significant indicator on geography variable was the altitude, (iii) the significant indicators on the aerial variables was the intensity of light and humidity, (iv) the significant indicator on the odonate diversity is a odonate diversity in the morning period. A geography variable (altitude) had direct effect on the water quality, the aerial variable, vegetation and odonate diversity. The altitude interacted with water quality, the aerial variable and vegetation affecting the odonate diversity. The aerial variable and water quality did not affect directly on odonate diversity but those affected indirectly trough the interaction with vegetation. The vegetation affected directly to odonate diversity.

4. Discussion

Several studies showed that the structural model dragonfly diversity clarifies the interaction between several variables. Each variable consists of several indicators. Water quality variables, geography, aerial variables, and vegetation supposed to influence the diversity of dragonflies. The similarity of structure and composition of odonate species found in each study sites due to their adaptation to the environment and these interactions might affect the diversity of odonate species. Based on the results of statistical testing, the environment variables observed in the field with their interactions determining the diversity of odonate species were the altitude, aerial, water quality, and vegetation around the site observation.

Krebs (2001), states that the density and abundance of populations in an ecosystem is influenced by very complex factors, including competition among species, food availability and physiological stress environment. According to Hellawell (1986), the state of habitat and aquatic environment may determine the diversity of odonate species from time to time. Furthermore, Silsby (2001), stated that the presence of Odonata in a region largely determined by the quality of the water environment in these places. During the development of the life, Odonata lives in two different places. During the phase of eggs and nymphs, they live in aquatic environments, while the adult stage lives on land.

This research showed that the water quality parameters have indirect effect on odonate species by interaction with vegetation. Habitat parameters that affect the growth of eggs and nymphs of dragonflies are water temperature, dissolved oxygen, pH, flow velocity, conductivity, type of substrate and vegetation around its habitat (Corbet, 1999) as well as the availability of food resources (Basset, 1995). Yaherwandi (2005), stated that the wealth of plant diversity forms a better community structure so that the habitat of a region capable of providing a variety of resources such as alternative host, the source of food for the survival and diversity of certain insects.

Other studies have shown a strong connection between the diversity of plants in the marsh area with a population of odonate species (Hornung and Rice, 2003) because the health or quality of the swamp greatly affects the diversity of odonate species. These results are consistent with previous studies which stated that the reproductive success of odonate species influenced by the structure, diversity and richness of vegetation that can be associated with the requirements for the process of oviposition on substrate specific (Lenz, 199l), the vegetation gives directions guide the odonate species to site selection to perform the reproduction process (Buskirk & Sherman, 1985; MacKinnon & May, 1994).

The concentration of dissolved oxygen in the water (DO) and temperature directly affect the abundance of odonate species larvae. A level of dissolved oxygen in the water affects the behavior, metabolism and survival of larvae of Odonata (Corbet, 1999; Hofmann and Mason, 2005). Variations in oxygen availability in the lacustrine zone (low oxygenation) and lotic zone (high oxygenation) environment determines the species diversity of Odonata (Simmons and Voshell, 1978; Corbet, 1999). Water temperature also has an effect on the abundance and development of odonate larvae (Corbet, 1999). Places with high temperatures, such as hot springs tend to decrease the abundance and diversity of odonate species (Corbet, 1999). The importance of abiotic factors such as water temperature and dissolved oxygen levels for the presence of larvae of several species such as Enallagma sp., Homeura sp. and Telebasis sp. has also known to be very sensitive to variations in water dissolved oxygen concentration and temperature throughout the year (Hornung and Rice, 2003).

5. Conclusion

The aerial variables directly or with interaction to other factor affected the water qualities and vegetation characteristics. The vegetation characteristics directly influenced to odonate diversity. Water flow affected water quality, light intensity affected the aerial variables, while morning period observation affected the odonate diversity. Water flow affected water quality, light intensity affected the aerial, while morning period observation affected the odonate diversity.

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Appendix

No.	Species	WR	WP	SK	CC	CT	SB	Abundance
1	*Agriocnemis pygmaea*	710	622	136		137		1605
2	*Agriocnemis femina*	769	641	134				1544
3	*Pantala flavescens*	358	341	135	195	316	83	1428
4	*Orthetrum sabina*	325	333	172	189	272	78	1369
5	*Crocothemis servillia*	260	283	89	31	58	15	736
6	*Brachythemis contaminata*	297	247					544
7	*Pseudagrion microcephalum*	169	270			88		527
8	*Orthetrum glaucaum*					354	146	500
9	*Orthetrum pruinosum*					326	150	476
10	*Pseudagrion pruinosum*	74	157	70		69	15	385
11	*Pseudagrion rubriceps*	77	236					313
12	*Diplacoides trivialis*				11	203		214
13	*Crocothemis erythraea*		178					178
14	*Copera marginipes*		60	48		66		174
15	*Rhodothemis rufa*	141						141
16	*Neurothemis ramburii*	22	35	35				92
17	*Libellago lineata*		60	15				75
18	*Anax gutatus*		67					67
19	*Ictinogomphus decoratus*		62					62
20	*Potamarcha congener*		46	6				52
21	*Rhinocypha bisignata*		49					49
22	*Tholymis tillarga*	17	28					45
23	*Zyxomma obtusum*	20						20
	Total							10596

Note:
WR = Wendit Residential Area, WP = Wendit Paddy Field, CC = City Center Park, SK = Sengkaling, CT = Coban Talun, SB = Sumber Brantas).