Comparison of Damselfly (Odonata: Zygoptera) diversity in wet dune slack habitat with canopied and non-canopied areas of Gumuk Pasir Parangkusumo, Yogyakarta, Indonesia

A C Nicolla1*, A N Irsyad1, W Firdasia1, Z Sarifah1, E I Nilamsari1, N Umah1, R Daradwinta1, and S Sukirno2

1 Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia
2 Entomology Laboratory, Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia

* Corresponding author: andracare199@mail.ugm.ac.id

Abstract. Gumuk Pasir Parangkusumo is one of the unique eolian ecosystem in Yogyakarta. This place which mostly formed by dune which in the rainy season is flooded by water, thus forming a pool called wet dune slack. Damselflies (Odonata: Zygoptera) are closely related to the occurrence of water. The aim of this research is to compare the diversity of damselflies in canopied and non-canopied areas on Gumuk Pasir Parangkusumo, Yogyakarta, Indonesia. The method which used in this research was the descriptive method with active exploration techniques around the wet dune slack to the vegetation formation. The result showed that there are 4 species of damselflies in canopied area and 5 species of damselflies in non-canopied area. The diversity index (H’) is 1.18 in canopied area and 1.01 in non-canopied area. The highest relative abundance of the species in canopied area is Ischnura senegalensis (45.65%) whereas in non-canopied area is Agriocnemis pygmaea (62.34%). The non-canopied areas has conditions more suitable for damselflies’s life.

Keywords. diversity, gumuk pasir parangkusumo, odonata, wet dune slack, zygoptera

1. Introduction

Indonesia is one of the countries with the greatest biodiversity after Brazil and Madagascar. This is because 25% of the world's various species are in Indonesia, one of which are insects [1]. Odonata is one of the orders in the class Insecta with quite high diversity. This can be proven by the presence of more than 900 types of dragonflies in Indonesia or 15% of the total types of dragonflies in the world. Java Island has 150 species of dragonflies with 18% or 26 types of which are endemic [2]. Odonata can be divided into 2 suborders, those are Anisoptera (dragonflies) and Zygoptera (damselflies). Dragonflies has characteristics of relatively large body size, the size of the rear wing is larger than the front wing, the position of the wing stretches when alighted, and is able to fly with a wide cruise area. While damselflies has the characteristics of having a pair of separate compound eyes, body size smaller than dragonflies, the size of the front and rear wings are equal, and the position of the wings folded when alighted [3, 4]. Dragonflies are also known as their role as bioindicators of water quality because of their sensitivity of the changes on it. This is because dragonfly nymphs cannot live in polluted water, so changes in dragonfly populations indicate pollution in the area. Dragonflies are generally found in various places such as agricultural areas, grasslands, and most are found around the waters. This is
because while still in the form of nymphs, the life span of dragonflies is spent in the water so that habitats that have the carrying capacity for the survival of the dragonflies are around the water [5, 6].

Gumuk Pasir Parangkusumo is one of the well-known natural phenomena in Bantul Regency, Yogyakarta. This form of sand dune is quite unique because it has a crescent shape (barchan type) where this form is only found in Southeast Asian sand dune. This causes the sand dune to become a valuable asset for Indonesia so that they need to be preserved [7]. Gumuk Pasir Parangkusumo is formed from sand material derived from volcanic ash carried by river currents and then flows into the South Coast. There are 4 rivers that flow into the South Coast, namely the Progo, Winongo, Opak, and Oyo Rivers. The ocean waves will choose lightweight sand to be carried inland, while heavier sand is deposited along the coastline forming alluvial coastal plains. The dry sand will be blown by the wind towards the mainland and deposited in a vegetated place to form sand dunes [8]. Commonly, sand dunes have a high temperature, minimal vegetation, strong winds, and high salt content. In addition, high daily temperatures and fast winds accelerate the evaporation of water so that the water content in the soil is very small [9]. This certainly causes dragonflies will be difficult to adapt to the environment of Gumuk Pasir Parangkusumo.

Dune slack is a hollow or valley that formed between the back of the dune where ground water is close to the surface and the conditions vary greatly depending on the season. Dune slacks are protected habitats on the European continent and have been the focus of research in the UK in recent decades because of their existence, which is threatened by climate change, abrasion, human activity, afforestation, grazing, pollution and eutrophication [10-12]. In seasons with high rainfall intensity, dune slack will be inundated by water called wet/humid dune slack [13, 14]. Wet dune slack is a wetland ecosystem in the coastal sand dune system. Hydro-ecological conditions in the dune slack produce a unique niche and habitat for several species of living things [15, 12]. One of the interesting organisms to study is damselflies. Furthermore, the physical conditions of the environment, such as vegetation and canopy cover can influence the existence of dragonflies [16]. The vegetation found in Gumuk Pasir Parangkusumo is dominated by evergreen trees, so it can be one of the habitats of damselflies. There is no prior information about the diversity of damselflies that is able to live and adapt in these habitats. Therefore research is needed to compare the diversity of damselflies in canopied and non-canopied areas of wet dune slack in this sand dune landscape.

2. Research Method
This research was conducted from January-April 2019 with six research station for sampling. The research method used is descriptive method with direct collection using insect nets. The collection was carried out in the areas around the Gumuk Pasir Parangkusumo by dividing the study area into three station of each canopy (C1, C2, C3) and non-canopy (NC1, NC2, NC3) area. The research procedure consisted of 4 stages include sampling, specimen preservation, identification, and data analysis.

Data collection was carried out 4 times at 13 January, 26 January, 31 March, and 6 April. Data collection using visual observation in the morning (08.00-12.00 AM) and afternoon (14.00-18.00 PM) when damselflies are mostly active. The damselflies that have been identified were only counted and taken pictures with camera during subsequent samplings, whereas the unidentified species were placed in the triangle envelope with the wings were folded and preserve it. Samples were identified with references using the guide book from Naga Terbang Wendit: Keanekaragaman Capung Perairan Wendit, Malang, Jawa Timur [17], Dragonflies of Yogyakarta: Jenis Capung Daerah Istimewa Yogyakarta [18] and other literatures that supporting identification process by considering the body shape, eye shape, and color [19].
Figure 1. Six research stations for sampling at Gumuk Pasir Parangkusumo (Source: Google Earth)

Data analysis of species diversity was calculated by the Shannon-Wiener Index formula [20]:

\[ H' = -\sum_{i=1}^{n} (p_i)[\ln(p_i)] \]

- \( H' \) = Shannon–Wiener Index
- \( N \) = Total individuals of population sampled
- \( n_i \) = Total individuals belonging to the \( i \) species

3. Result and Discussion

3.1. Diversity of damselflies in Gumuk Pasir Parangkusumo

This research was conducted in January - February 2019 in Gumuk Pasir Parangkusumo during the rainy season. The results of the research obtained data on a number of members of the Suborder Zygoptera, which is in canopied areas obtained 1 family of Coenagrionidae (4 species), and in the non-canopied areas obtained 2 families i.e. Coenagrionidae (4 species) and Lestidae (1 species). Species abundance were classified into three categories: (i) Abundant (> 50 individuals); (ii) Common (25-49 individuals) and (iii) Rare (< 24 individuals) [21].

From this research, 121 individuals of damselflies were recorded with 46 individuals in canopied areas, and 77 in non-canopied areas. In canopied areas have been found \( A. \) femina (14 individuals), \( A. \) pygmaea (9 individuals), \( I. \) senegalensis (21 individuals), and \( P. \) microcephalum (2 individuals). The most common species is \( I. \) senegalensis as they contributed 45.65% of the total individuals (46 individuals) and the species most rarely found is \( P. \) microcephalum (4.35%) (Table 1).

Family Coenagrionidae is one of the damselflies family which has the largest population and can live in various habitats. Most of them are rather weak fliers so they have low cruising range with short migration distance, and when perched, the body is usually horizontal and the wings are placed together above the body [22, 23].
Table 1. Odonata species found at Gumuk Pasir Parangkusumo with their relative abundance (%) and diversity index (H')

| CANOPIED AREAS No | Family             | Species                              | Number of individuals | Pi in Pi | Relative abundance |
|-------------------|--------------------|--------------------------------------|-----------------------|----------|--------------------|
| 1                 | Coenagrionidae     | Agriocnemis femina (Brauer, 1868)     | 14                    | -0.36    | 30.43              |
| 2                 | Coenagrionidae     | Agriocnemis pygmaea (Rambur, 1842)   | 9                     | -0.32    | 19.57              |
| 3                 | Coenagrionidae     | Ischnura senegalensis (Rambur, 1842) | 21                    | -0.36    | **45.65**          |
| 4                 | Coenagrionidae     | Pseudagrion microcephalum (Rambur, 1842) | 2                    | -0.14    | **4.35**           |
| **Total individuals** |                    |                                      | **46**                |          |                    |
| **H'**            |                    |                                      | **1.18**              |          |                    |
| **Total Species** |                    |                                      | **4**                 |          |                    |

| NON-CANOPIED AREAS No | Family             | Species                              | Number of individuals | Pi in Pi | Relative abundance |
|-----------------------|--------------------|--------------------------------------|-----------------------|----------|--------------------|
| 1                     | Coenagrionidae     | Agriocnemis femina (Brauer, 1868)     | 2                     | -0.09    | **2.60**           |
| 2                     | Coenagrionidae     | Agriocnemis pygmaea (Rambur, 1842)   | 48                    | -0.29    | **62.34**          |
| 3                     | Coenagrionidae     | Ischnura senegalensis (Rambur, 1842) | 20                    | -0.35    | 25.97              |
| 4                     | Coenagrionidae     | Pseudagrion microcephalum (Rambur, 1842) | 2                    | -0.09    | **2.60**           |
| 5                     | Lestidae           | Lestes praeomorsus (Hagen in Selys, 1862) | 5                    | -0.18    | 6.49               |
| **Total number**      |                    |                                      | **77**                |          |                    |
| **H'**                |                    |                                      | **1.01**              |          |                    |
| **Total Species**     |                    |                                      | **5**                 |          |                    |

*I. senegalensis* is a damselflies belongs to the family Coenagrionidae, also known variously as The Marsh or Senegal Bluetail. These damselflies are usually found in reservoirs, streams, and paddy fields or are generally found in open areas either non-shady or shady areas. This species can be found in the sand dune area because there are some areas that have been converted and used by the community as paddy fields [24], we also found a stream flow not far from the sand dunes area.

From the non-canopied areas we recorded 5 species i.e. *A. femina* (2 individuals), *A. pygmaea* (48 individuals), *I. senegalensis* (20 individuals), *P. microcephalum* (2 individuals), *L. praeomorsus* (5 individuals). *A. pygmaea* was the most common species as they contributed 62.34% of the total individuals (77 individuals) and the species most rarely found is *A. femina* and *P. microcephalum* (2.60%) (Table 1).

*A. pygmaea* is the most common damselflies from Coenagrionidae, also known as Wandering Midget, Pygmy Dartlet or Wandering Wisp. This species usually found in grass and paddy fields, and also breeds in marshes, pond and sluggish brooks [18, 25]. The diversity index (H') is 1.18 (canopy) and 1.08 (non-canopy), therefore the species diversity in this area considered as low diversity [21]. There is only a slight difference of species composition in the two habitats where *A. femina, A. pygmaea, I. senegalensis*, and *P. microcephalum* are found in both habitats, whereas *L. praeomorsus* is only found in non-canopied areas.

*L. praeomorsus* which is belongs to family Lestidae, generally prefer to inhabit shallow swamp habitats and pristine alluvial, they usually perching with their wings half open [26, 27]. Gumuk Pasir Parangkusumo is a landscape with pristine alluvial, because the sand material comes from the volcanic ash of Mount Merapi. The volcanic ash is carried by rain water which then flows into rivers around the Yogyakarta region such as the Opak River and Oyo River in the east and Progo River in the west. After the sand reaches the sea, it will be hit by the waves of the sea so that the volcanic ash material becomes...
fine grains of sand and settles on the south coast and then blown by the wind. Then, fine sand that is formed is carried by the sea waves to the beach and then carried along the coast (longshore current), when arrived at the beach, the wet sand is drained by the sun. Dry sand is blown by the wind to land and settles on land [28].

There are 5 species of Lestidae recorded in Java Island, and 2 species in Yogyakarta. This is a new discovery of L. praemorsus in this habitat after it was previously discovered at Pond in Paliyan Wildlife Sanctuary, Gunung Kidul District of Yogyakarta [18]. Habitat specifications in the pond in Paliyan Wildlife Sanctuary and in the Gumuk Pasir Parangkusumo have similar habitats, and are associated with the discovery of this species in places with high light intensity. The temperature range in the Paliyan Wildlife Sanctuary is 24-31.8°C, while the Gumuk Pasir Parangkusumo have a temperature range of 28-36°C, also both of these habitats have low humidity and high light intensity [29, 30]. This damselflies is known for its ability to survive in harsh environments and high light intensity (such as during the dry season) this is evidenced by only the discovery of L. praemorsus in non-canopy places (Table 1) [31, 18].

The most important environmental factors in the life of damselflies are temperature, humidity and light intensity. These three factors influence the behavior and life cycle of damselfly in addition to water quality. Temperature and humidity affect the metamorphosis of all dragonflies, including damselfly. The intensity of light affects the behavior of finding prey and mating [32]. In addition, light intensity also plays an important role for adaptation in the form of the evolution of wing pigmentation in damselflies. Wing pigmentation is part of the thermal adaptation in addition to functioning to attract partners [33].

![Figure 2. Lester praemorsus perched on grass](image1)

![Figure 3. The male and female of Ischnura senegalensis on wheel position](image2)

3.2. Gumuk Pasir Parangkusumo and the forming of wet dune slack as damselflies habitat

Gumuk Pasir Parangkusumo which is used as site of this research is a landscape of sand dune formed by the process of wind or also called aeolean morphology in the form of sand dune like a crescent moon (barchan). Barchan type is the only formation of sand dunes in Southeast Asia [7, 34].

According to Kidd (2001) [35], vegetation cover is a most influential factor in the morphological changes of sand dunes. The presence of cover vegetation will cause the wind speed to be restrained, so that deposition material will be trapped on the face of the vegetation and the wind will experience a decrease in acceleration (wind jump) to form turbulent winds behind the vegetation. The wind turbulence is grinding, so that deflationary holes are formed behind the vegetation. Without this barrier vegetation, sand easily moves by wind power. The deflation hole (blowout) that forms the longer will get deeper and wider. In this sand dune area there are several types of vegetation cover, i.e. in-situ and ex-situ. In-situ vegetation is a natural vegetation of sand dune includes Pandanus tectorius, Urena lobata, Sida acuta, Calotropis gigantea, Ipomea per-caprae, Spinifex littoreu, and Cyperus sp.; whereas the ex-situ vegetation is a reforestation with Casuarina equisetifolia and Accacia longifolia [8, 36, 37].
As a region with a tropical climate that only has two seasons, i.e. the rainy season and the dry season, Gumuk Pasir Parangkusumo will experience a dry period that occurs in the southeast monsoon season which blows around April to September, then the rainy season will occur in October to March where deflation holes will be filled with rain water due to high rainfall intensity. This natural process will cause standing water to form in the deflation hole, this phenomenon also known as wet dune slack [10, 38].

The presence of damselflies is closely related to the presence of water. They use flowing or standing water as habitat for the pre-adult phase. Specific habitats have an important role related to the ecology and the presence of the dragonflies. In this study, we recorded damselflies populations in canopy and non-canopy standing water habitats. This was done to determine the effects of light intensity and temperature on damselfly activities. In addition, to find out the habits of one of the rare species found in this habitat, Lestes praemorsus which is resistant to harsh environmental temperatures. Standing water habitat with a canopy is an area that has a cover in the form of tree vegetation, whereas non-canopy is an open area without vegetation cover.

![Wet dune slack of Gumuk Pasir Parangkusumo](image)

**Figure 4.** Wet dune slack of Gumuk Pasir Parangkusumo

3.3. The morphological, habitats, and habits of damselflies found in Gumuk Pasir Parangkusumo

3.3.1. *Agriocnemis femina*. **Morphology:** The length of male abdomen about 16-17 mm, hindwing length 10-11 mm. Compound eyes are black underside and green upper side. Males have a small body dominated by black and green color. Green thorax with thick black lines on the sides and top of the synthorax, between which there is a thin green line. Thorax will be covered gradually with white powder at maturity. Abdomen has a black color above and green below. Anal appendages have an orange color with cerci shorter than paraprocts. The female abdomen length 18 mm, hindwing length 11 mm. Female shows many color variations (polymorphism), but their color always more robust than males. Young female have a bright red-black color, whereas adult female have a black-green-yellowish green color. **Habitats:** Inhabit edges of wetlands with short herbage and grassy banks. Anecdotal observations suggest that males occasionally grasp female *A. pygmaea* for mating. **Habits:** Active in the morning (diurnal) to look for prey and reproduce, perching on the plants around the water [39, 17, 18].

3.3.2. *Agriocnemis pygmaea*. **Morphology:** The length of male abdomen about 16-17 mm, hindwing length 9.5-10 mm. Male have compound eyes with black color upper side and pale apple green underside. Synthorax pale green with thick black lines on the top. Abdomen has a black color above and green below, S8-S10 orange with cerci longer than paraprocts. The pterostigma of the forewings is pale yellow and black on the hindwings. The female abdomen length 16-17 mm, and hindwing length 9.5-10 mm.
Overall the females are similar to males. Compound eyes are brown above and green below. Prothorax does not have a square lobe formation and the posterior edge of the female prothorax is smaller than that of A. femina, so it looks thin. **Habits:** This species are often found among water plants such as water spinach, water hyacinth and grasses in waterlogged areas. Also often found in paddy fields and can be found throughout the year. **Habits:** Active in the morning (diurnal) to look for prey and reproduce, fly around aquatic plants and perch on leaves [40, 17, 18].

3.3.3. *Ischnura senegalensis.* **Morphology:** The length of male abdomen about 21-23 mm and hindwing 13-15 mm. Compound eyes with black color on the upperside and pale green to yellow underside. Green synthorax on the side, black upperside with pair of green stripes. Abdomen with black color dorsally from S1-S6 and S9-S10, the entire S7 is black and S8 is light blue, on the ventral side; S1-S2 and S9-S10 is light blue, S3-S6 is yellowish brown. The paraprocts bend upwards and longer than cerci. The legs are black upperside and bluish underside. The pterostigma of the forewings is brownish gray and black on the hindwings. The female abdomen length 20-24 mm, and hindwing 14-16 mm. Female shows many color variations (polymorphism) and dominated by yellowish green color. Abdomen with black color above and the size larger than male’s abdomen. Some individuals look similar with the male, but the color more yellowish green and the others are orange on the thorax. The legs are black upperside and brownish yellow underside. **Habits:** Found in paddy fields, between water plants, wet meadows, short grasslands bordering marshes, swamps and in the surrounding ditches. **Habits:** Active flying during the morning (diurnal), flying around aquatic plants or rice, and perching on the leaves. Voracious predators, often preying on other smaller odonates. Copula seen on lily pads or in vegetation near water; the female lays eggs in standing water [40, 17, 18].

3.3.4. *Pseudagrion microcephalum.* **Morphology:** Medium-sized damselfly, male body dominated by light blue color. The length of male abdomen about 27 mm and hindwing 17 mm. Compound eyes with light blue underside, black upperside, and the frons with blue color. The upper side of the synthorax has thin black stripes. The black abdomen on the top and light blue on the side of S1-S7, the S8-S10 is blue with black patches on the top side of the S10, and between the segment is blue. Anal appendages are black and cerci longer than paraproct. Both wings are transparent with black venation, and a brown pterostigma. The legs are blackish blue. The length of female abdomen about 29 mm and hindwing 20 mm. Female body color is paler than males. Compound eyes is brownish green underside and brown upperside. Ssynthorax bluish green with light brown stripes on the top. Abdomen black on the upperside and pale green on the underside. **Habits:** This species can easily be found in aquatic plants around waters with high light intensity. **Habits:** Active flying during the morning (diurnal). This species usually breeds in ponds, lakes and streams. Conducting daytime copulations for more than an hour with tandem [41, 42, 17, 18].

3.3.5. *Lestes praemorsus.* **Morphology:** Damselfly with medium size. The length of male abdomen about 32-35 mm and hindwing 21-22 mm. Males have blue compound eyes, blue thorax covered with white powder with irregular black patches. The abdomen is black at the top and blue-white at the bottom. anal appendages are white. transparent wings with brown pterostigma. The length of female abdomen about 30-32 mm and hindwing 20-21 mm. Females are similar to males, but the colors are duller. **Habits:** This species can be found in ponds or puddles with high light intensity but it is not common. **Habits:** This species usually perched on the grass around the waters with open wings typical of the family Lestidae. The female lays eggs on the emerging grass stalks, which are put in the water underneath [40, 18].

4. Conclusion
The results showed that damselflies which found in Gumuk Pasir Parangkusumo were 46 individuals in canopied areas, and 77 individuals in non-canopied areas. There are 5 species of damselflies (*Agriocnemis femina, Agriocnemis pygmaea, Ischnura senegalensis, Pseudagrion microcephalum,*...
Lestes praemorsus) that inhabit in canopied areas, the most common species is Ischnura senegalensis (45.65%) and the most rarely found species is Pseudagrion microchepalum (4.35%). In the non-canopied areas, the most common species is Agriocnemis pygmaea (62.34%) and the most rarely found species is Pseudagrion microchepalum and Agriocnemis femina (2.60%).

The Shannon-Wiener diversity index value for both areas shows a medium scale where the value for canopied areas were 1.18 and for non-canopied areas was 1.01, which means that both areas has good condition as habitat of damselflies but the canopy area still has better productivity as a habitat while supporting the life of damselflies. It is caused by the light intensity that can affect the behavior of finding prey and mating.

References
[1] Hartika W, Diba F, and Wahdina 2017 Keanekaragaman Jenis Capung (Odonata) pada Ruang Terbuka Hijau Kota Pontianak (Diversity of Dragonflies (Odonata) in the Urban Forest in Pontianak City) J. Hut. Lest. 5 156-163 (In Indonesian)
[2] Herlambang A E N, Hadi M, and Tarwojo U 2016 Struktur Komunitas Capung di Kawasan Wisata Curug Lawe Benowo Ungaran Barat Bioma 18 70-78 (In Indonesian)
[3] Heckman C W 2008 Encyclopedia Of South American Aquatic Insect: Odonata-Anisoptera. Illustrated Keys To Known families, genera, species in south (Olympia Washington, USA: Springer Science and Business Media B.V.)
[4] Pamungkas D W, and Ridwan M, 2015 Keragaman Jenis Capung dan Capung Jarum (Odonata) Di Beberapa Sumber Air Di Magetan, Jawa Timur (Diversity of Dragonfly and Damselfly (Odonata) in Some Water Springs in Magetan, East Java Pros. Sem. Nas. Masy. Biodiv. Indo. 1 1295-1301 (In Indonesian)
[5] Suriyana, Adi D W, and Hardiyanti W D 2014 Inventarisisasi Capung (Odonata) di Sekitar Sungai dan Rawa Moramo, Desa Sumber Sari Kecamatan Moramo Kabupaten Selatan Sulawesi Tenggara Biowallacea 1 51-64 (In Indonesian)
[6] Wijayanto A G, Nafisah N A, Laily Z, and Zaman M N 2016 Inventarisisasi Capung (Insecta: Odonata) dan Variasi Habitatnya di Resort Tegal Bunder dan Teluk Terima Taman Nasional Bali Barat (TNBB) Sem. Nas. Pend. Sain. 427-434 (In Indonesian)
[7] Fakhruddin M, Poniman A, and Malikusworo H 2010 Dinamika Pemanfaatan Lahan Bentang Alam Gumuk Pasir Pantai Parangtritis, Kabupaten Bantul J. IIm. Geomat. 16 43-60 (In Indonesian)
[8] Budiyantri G 2011 Teknologi Konservasi Lanskap Gumuk Pasir Pantai Parangtritis Bantul DIY Conservation Technology of Sand Dunes Landscape in Parangtritis Beach Bantul (DIY) J. Lans. Indo. 3 97-101 (In Indonesian)
[9] Qurniawan T F, and Epriyurahman R 2013 Keragaman Jenis Amfibi dan Reptil Gumuk Pasir, Propinsi Daerah Istimewa Yogyakarta Zoo Indonesia 22 9-16 (In Indonesian)
[10] Davy A J, Hiscock K M, Jones M L M, Low R, Robins N S, and Stratford C 2006 Ecohydrological guidelines for wet dune habitats (UK: Environment Agency)
[11] Nature Conservation Committee 2007 Second Report by the UK under Article 17 on the implementation of the habitats JNCC Peterborough www.jncc.gov.uk/article17 [Accessed 20 July 2020]
[12] Stratford C and Rooney P 2017 Coastal Dune Slack Hydro-ecology J. Coastal Conserv. 21 573-576.
[13] Grootjans A P, Ernst W H O, Stuyfzand P J 1998 European Dune Slacks: Strong Interactions of Biology, Pedogenesis and Hydrology TREE 13 96–100
[14] Stratford C J, Robins N S, Clarke D, Jones L, and Weaver G 2013 An Ecohydrological review of Sand Dunes Slacks on the Est Cost of England and Wales Ecohydrology 6 162-171
[15] Pethick J, 1984 An Introduction to Coastal Geomorphology (New York: British Library Cataloguing in Publication Data) pp 126-142
[16] Theischinger G and John H 2006 The Complete Field Guide to Dragonfly of Australia (Australia:
CSIRO Publishing)
[17] Rahadi W S, Bambang P, Magdalena, Bernadeta P, and Tabita M 2013 Naga Terbang Wendit, *Keanekaragaman Capung Perairan Wendit, Malang, Jawa Timur* (Malang: Indonesia Dragonfly Society) pp 109-116 (*In Indonesian*)
[18] Setiyono J, Dinarsih S, Oscilata E N R, and Budi N S 2017 *Dragonflies of Yogyakarta, Jenis Capung Daerah Istimewa Yogyakarta* (Yogyakarta: Indonesia Dragonfly Society) pp 100-103, 108-109, 114-115 (*In Indonesian*)
[19] Iswandar D 2018 Diversity of Dragonflies (*Odonata*) in Swamp Ecosystem University of Lampung *Agricultura* 1 101-109
[20] Shannon, C E and Weaver W 1949 *The mathematical theory of communication* (Urbana, IL: University of Illinois Press)
[21] Wahizatul-Afzan A, Julia J, and Amirrudin A 2006 Diversity and Distribution Of Dragonflies (*Insecta: Odonata*) In Sekayu Recreational Forest, Terengganu *J. Sustain. Sci. Manag.* 1 97-106
[22] Borror D J, Triplehorn C A, and Johnson N F 1992 *Pengenalan Pelajaran Serangga Edisi Keenam* (Yogyakarta: Gadjah Mada University Press) (*In Indonesian*)
[23] Chovanec A 2000 Constructed Inshore Zones as River Corridors through Urban Areas-the Danube in Vienna: Preliminary Results *Regulated Rivers: Research and Management* 16 175–87
[24] Mawarni A, and Hadisusanto S 2019 Distribution and Abundance of Plankton in Wet Dune Slacks of Gumuk Pasir Parangtritis, Bantul, DIY *Biospecies* 12 77–89
[25] Subramanian K A, Emiliyamma K G, Babu R, Radhakrishnan C, and Talmale S S 2018 *Atlas of Odonata (Insecta) of the Western Ghats, India* (India: Zoological Survey of India) pp 142–143, 168
[26] Orr A G 2003 A Guide to The Dragonflies of Borneo: Their Identification and Biology (Borneo: Natural History Publication)
[27] Orr A G 2005 A Pocket Guide to Dragonflies of Peninsular Malaysia and Singapore (Kinabalu: Natural History Publication)
[28] Sihotang W M, Subardjo P, and Saputro S 2014 Analisa Pengaruh Parameter Oseanografi terhadap Sebaran Gumuk Pasir Di Pantai Parangtritis tahun 2005-2009 *J. Oseanografi* 3 246-256 (*In Indonesian*)
[29] Oktavianto E and Handayani T 2017 Analisis Vegetasi Strata Semak Di Zona Inti Gumuk Pasir Desa Parangtritis Kecamatan Kretek Kabupaten Bantul Yogyakarta Sebagai Sumber Belajar Biologi SMA Kelas X. *J. Ris. Da.* 1 37-54 (*In Indonesian*)
[30] Yudha D S, Epriulrahman R, Asti H A, Azhar H, Wisudhaningrum N, Lestari P, Markhamah S, dan Sujadi I 2019 Di Suaka Margasatwa Paliyan, Gunungkidul, Yogyakarta *J. Biol. Udayana* 23 59–67 (*In Indonesian*)
[31] Baskoro K, Irawan F, Kamaludin N 2018 *Odonata Semarang Raya, Atlas Biodiversitas Capung di Kawasan Semarang* (Semarang: Departemen Biologi UINS) pp 40 (*In Indonesian*)
[32] Corbet P S 1980 Biology of Dragonflies *Ann. Rev. Entomol.* 25 189-217
[33] Svensson E I, and Waller J T 2013 Ecology and Sexual Selection: Evolution of Wing Pigmentation in Calopterygid Damselflies In Relation to Latitude, Sexual Dimorphism, and Speciation *The American Naturalist* 182 174-195
[34] Putro S and Prasetyowati S H 2020 Sedimentasi di Gumuk Pasir Parangtritis Berdasarkan Tutupan Lahannya *Geomedia: Majalah Ilmiah dan Informasi Geokegofrani* 18(1) 1-11
[35] Kidd R 2001 Coastal Dune Management: A Manual of Coastal Dune Management and Rehabilitation Techniques *NSW Government* 114
[36] Nuraini F, Sunarto, and Langgeng W S 2016 Pengaruh Vegetasi Terhadap Dinamika Perkembangan Gumuk Pasir Di Pesisir Parangkusumo *Geomedia* 14 1–11 (*In Indonesian*)
[37] Santosa L W 2016 Keistimewaan Yogyakarta Dari Sudut Pandang Geomorfologi (Yogyakarta: UGM Press) (*In Indonesian*)
[38] Rahayu N D, Bandi S, dan Nurhadi B 2018 Analisis Pengaruh Fenomena Indian Ocean Dipole (Iod) Terhadap Curah Hujan Di Pulau Jawa. *J. Geodesi UNDIP* 7 57–67 (*In Indonesian*)

[39] Nair M V, 2011 *Dragonflies & Damselflies of Orissa and Eastern India* (Government of Orissa: Wildlife Organization, Forest & Environment Department) pp 252

[40] Subramanian A K 2009 *Dragonflies of India: A Field Guide* (India: Vigyan Prasar)

[41] Fraser F C, 1933 *Fauna of British India, Odonata 1* (London: Taylor & Francis Ltd) pp 490

[42] Subramanian A K 2005 *Dragonflies and Damselflies of Peninsular India: A Field Guide* (Indian Academy of Science, Bangalore, India: Project Lifescape)