ACADEMIA JOURNAL OF BIOLOGY 2025, 47(1): 97–119
DOI: 10.15625/2615-9023/20121

DIVERSITY AND ABUNDANCE OF ODONATES (DRAGONFLIES AND DAMSELFLIES) AND LEPIDOPTERAN (BUTTERFLIES) FAUNA OF KALYANI LAKE PARK, NADIA DISTRICT, WEST BENGAL, INDIA

Sayak Dolai[1,#], Md. Abu Imran Mallick[2,#,*], Narayan Ghorai[3]

[1]Department of Microbiology, Vijaygarh Jyotish Ray College, 8/2, Bejoygarh, Kolkata - 700032, West Bengal, India
[2]Department of Zoology, West Bengal State University, Berunanpukuria, North 24 Parganas - 700126, West Bengal, India
[3]Department of Zoology, West Bengal State University, Berunanpukuria, North 24 Parganas - 700126, West Bengal, India

Received 11 February 2024; accepted 18 March 2025

ABSTRACT

Butterflies, dragonflies and damselflies are indeed important for ecosystem productivity, playing roles in pollination and insect control, contributing to a balanced and thriving ecosystem. Their presence showcases the health and abundance of the ecosystem. Biodiversity protection and conservation are indeed essential aspects of both national and international agendas, as they contribute significantly to the sustainable development of regions and countries. Biodiversity ensures the health and stability of ecosystems, provides ecosystem services crucial for human survival and well-being, and supports various industries such as agriculture, fisheries, and tourism. Lepidoptera and Odonata assemblage along with Kalyani Lake Park of Nadia district in West Bengal has been investigated. The study on dragonflies, damselflies and butterfly species were conducted from August 2021 to September 2023. A modified "Pollard Walk" method was used to record species and abundance. In this survey, 25 species of dragonflies, 10 species of damselflies and 75 species of Butterflies were recorded. Among the odonate species, Libelluidae and Coenagrionidae were the dominant families with the maximum number of species being 23 and 08, respectively. In the case of butterflies, Nymphalidae was the dominant family with 27 species while others have fewer representatives. Relative abundance and diversity indices were calculated for all species groups. However, in the case of the urban forest area, the observed high anthropogenic disturbances create significant biotic pressure on the Kalyani Lake Park. Given the significance of understanding the insect diversity in this study area, a detailed list of recorded Odonata and Lepidoptera from the study would provide valuable insights into the specific species present, their distribution, and their potential interactions with the environment.

Keywords: Abundance, biodiversity, conservation, Odonata, Lepidoptera, Kalyani Lake Park.

Citation: Sayak Dolai, Md. Abu Imran Mallick, Narayan Ghorai, 2025. Diversity and abundance of odonates (dragonflies and damselflies) and lepidopteran (butterflies) fauna of Kalyani Lake Park, Nadia district, West Bengal, India. *Academia Journal of Biology*, 47(1): 97–119. https://doi.org/10.15625/2615-9023/20121

[*]*Corresponding author email*: imranmallick708@gmail.com

[#]These authors have contributed equally to this work and share the first authorship.

INTRODUCTION

Lepidoptera includes butterflies and moths, while Odonata includes dragonflies and damselflies belonging to the class insect. There are indeed valuable groups for studying and monitoring biodiversity in both aquatic and nearby terrestrial habitats (Mallick & Mondal, 2024; Nair, 2011). Both butterflies and odonates play vital roles in ecosystems. They contribute to pollination, serve as bio-indicators of environmental health by responding to pollution, and function as a food source for other organisms (Kawahara & Breinholt., 2014; Syaripuddin et al., 2015; Thomas, 2005; Zaghloul et al., 2020). The specificity of host plants is a common phenomenon in both mature and immature stages of organisms with narrow ecological niches (Nallu et al., 2018). This specialization is often seen in various insects, especially those with distinct feeding habits (Rowe, 2003; Tiple et al., 2005; Verspagen et al., 2020). The choice of host plants can be critical for their survival, development, and reproduction (Ehrlich & Raven, 1964; Verspagen et al., 2020). Both species are recognized as valuable indicators of microhabitat quality and the degree of associated anthropogenic disturbances (Kehimkar, 2016; Salmah et al., 2006). Their sensitivity to environmental changes makes them effective tools for assessing the health and well-being of ecosystems, particularly in response to human impacts and disturbances (Boggs et al., 2003; Kehimkar, 2016). Monitoring these insect populations can offer valuable insights into the overall condition of habitats and the effects of human activities on biodiversity.

Utilizing invertebrate groups as indicators in biodiversity conservation and management provides a practical and informative approach to understanding and predicting the presence and health of various taxa within ecosystems (Oliver & Beattie, 1993; Person, 1994). Their sensitivity, diversity, and interaction with the environment make them valuable tools is preserving Earth's biodiversity (Ramesh et al., 2010). Biodiversity loss is indeed a critical global crisis. The loss of biodiversity threatens the stability and sustainability of ecosystems, which are essential for human survival and well-being (Bonebrake et al., 2010; Kunte et al., 1999; Kocher & Williams, 2000; Koh, 2007; Summerville & Crist, 2001; Tiple, 2006). Environmental degradation, driven by pollution and the introduction of invasive species, significantly contributes to the decline in biodiversity worldwide (Kunte, 1997; Watson et al., 2019). Relating patterns of biodiversity to spatial phenomena is a critical aspect of understanding ecosystems, and community ecology and implementing effective conservation strategies (Clark & Samways, 1996; Clarke et al., 2008). The dependence of species relies on specific environmental conditions for their survival, growth and reproduction (Condit et al., 2002). The interplay of both species-specific environmental dependencies and broader spatial factors in shaping community patterns within and among habitats (Losey & Vaughan, 2006; Wright et al., 1991). Partitioning ecological variation into spatial and environmental components is a crucial analytical approach in understanding the intricate mechanisms that shape patterns of biodiversity within communities (Noss, 1990; Enrlich & Wilson, 1991). This separation helps in unravelling the relative influence of spatial processes versus environmental factors on community structure (Borcard et al., 1992; Condit et al., 2002; Duivenvoorden et al., 2002).

The populations of odonates (dragonflies & damselflies) and lepidopterans (butterflies) in Kalyani Lake Park, Nadia District, West Bengal, India, are facing threats due to habitat destruction, pollution, and climate change. While natural factors have driven extinctions and shaped biodiversity throughout Earth's history, human activities are now the predominant cause of species decline (Ceballos et al., 2015). The rapid growth of human population, industrialization, and urbanization have led to unprecedented

environmental pressures, resulting in a biodiversity crisis (Landers et al., 1988; Meyer & Turner, 1992). This study aims to investigate the diversity and abundance of odonates and lepidopterans in Kalyani Lake Park, to better understand their distribution and conservation status in the region.

Urbanization has far-reaching environmental impacts, leading to habitat degradation and altering ecosystems in decreased plant species diversity, reduced water quality and increased air and soil pollutions. Insects are incredibly significant in terrestrial ecosystems (Adarsh et al., 2014; Chovanec & Waringer, 2006; New. 1991; Pollard & Yates, 1993; Aluri & Rao, 2002; Thomas, 2005), constituting a substantial portion of biodiversity and playing crucial roles in ecological balance and food chains (Nimbalkar et al., 2011). Insects are indeed crucial components of bio-indicators, providing valuable insights into the health and conditions of ecosystems.

Kalyani Lake Park, located in Nadia District, West Bengal, India, indeed offers habitat types that support thriving populations of Odonata and Lepidoptera, vital insect groups. The Park's various habitats create an ideal environment for a wide range of faunal species, including insects, reptiles, birds and mammals (Tiple et al., 2010). Kalyani Lake Park is a freshwater ecosystem with a mix of aquatic and terrestrial habitats. The park covers an area of approximately 50 hectares, with a lake covering 20 hectares. The surrounding vegetation is dominated by tropical deciduous forests, with a canopy cover of about 70%. The park's habitat supports a diverse range of flora and fauna, making it an ideal location for studying Odonata and Lepidoptera.

The insect orders Odonata and Lepidoptera exhibit distinct life cycles. Odonata undergo incomplete metamorphosis, with larvae (nymphs) developing through a series of instars (typically 8−17) before emerging as winged adults, without a pupal stage (Dwari & Mondal., 2017). In contrast, Lepidoptera undergo complete metamorphosis, with a distinct pupal stage preceding adulthood. While odonate species are renowned for their agile flight capabilities, Lepidoptera captivate us with their diverse array of colors and patterns (Kalkaman et al., 2008). Despite their aquatic larval stage, many adult odonates venture into terrestrial habitats for activities such as foraging and roosting, demonstrating a broader ecological range beyond water-adjacent areas viz. rivers, streams, lakes, pools, and rice fields (Tiple et al., 2012; Kalkman et al., 2020) and form one of the important invertebrate predators (Sharma et al., 2007). Worldwide there are more than 28,000 species of butterflies, with about 80 percent found in tropical regions (Robbins & Oplar, 1997; Ghazanfar et al., 2016; Paulson et al., 2024) documented both the dragonflies and damselflies, about 6,407 species belonging to 652 genera in all over the world. Later Mitra (2005) and Subramanian (2005) recorded 499 and 463 species for Indian fauna, respectively. At present, the Indian subcontinent hosts about 1,504 species of butterflies (Tiple, 2011) of which 107 are Papilionids (swallowtails), 109 Pierids (white and yellows), 521 Nymphalids (brush-footed butterflies), 443 Lycaenids (blues) and 321 are Hesperids (Skippers). Odonata fauna of India is known by 3 suborders, 17 families, 139 genera and 499 species and subspecies (Prasad & Varshney, 1995; Mallick & Ghorai, 2024). Mitra (2005) recorded 499 and later on 463 species were confirmed by Subramanian (2009). Fraser (1933, 1934, 1936) mentioned 536 species of Odonates from British India in the three volumes of his book entitled 'Fauna of British India'. In the post-independence era, Prasad & Varshney (1995) mentioned fewer number species than earlier as a result of partition (i.e., see Koli et al., 2015; Prasad, 1995; Tiple et al., 2012). In West Bengal, the studies on odonates were initiated with the documentation of 22 species from Kolkata by Selys (1891). Previous studies have documented the faunal listing of odonates in West Bengal. In Kolkata, researchers such as Lahiri & Mitra (1972), Ram et al. (1982), Mitra (1983), Gupta et al. (1995), Dwan (2014) have contributed to our

understanding of odonate diversity. More recent studies in Kolkata have been conducted by Mallick & Ghorai (2024), Payra & Tiple (2016, 2019), Payra et al. (2017) have focused on Medinipur. Additionally, Nayak & Roy (2016) and Nayak (2020) have explored odonate faunal listing in Burdwan. Dwan (2021) reported 239 species belonging to 114 genera and 17 families of odonates from West Bengal and the Libellulidae family has high species richness. The diversity of Odonata in any region is influenced by two major determinants (Eslami et al., 2021). Several studies on butterflies have been conducted throughout the state to date (Mukherjee & Mondal, 2020; Dey, 2021; Mallick, 2023; Mallick & Malakar., 2023; Mallick & Ghorai., 2023). Day & Ghosh (2016), Chakraborty et al. (2018) and Day (2021) compiled 33 species, 26 species and 106 species of butterflies respectively from Nadia district. The abundance of the Nymphalidae family compare to Pieridae and Papilionidae butterflies in Kalyani Lake Park of Nadia district can indeed be linked to the prevalence of their respective larval food plants in the region. This association underscores the vital relationship between butterflies and their larval host plants, which significantly influences their distribution and diversity within a study area.

The objective of this study, recording the availability, diversity and numbers of odonate and butterfly fauna in Kalyani Lake Park, West Bengal, is a crucial step in understanding and conserving the biodiversity of the study area. By enhancing our understanding of the local biodiversity and the factors influencing it, our research will contribute to the creation of informed and sustainable conservation plans, ultimately ensuring the conservation of this natural habitat and the ecosystem services it provides for both wildlife and human communities.

MATERIALS AND METHODS

Study Site

The present studies were conducted in Kalyani Lake Park, West Bengal, India (88^{o}0.45'E longitudes and 22^{o}0.98'N latitude) from August 2021 to September 2023 to assess the diversity of odonate and butterfly species (Fig. 1). Kalyani Lake Park highlights its diverse and versatile habitat, making it an excellent environment for odonates and butterflies. The park's features, including the lake, lakeside marsh habitat, ponds, canopy-forming trees, grassland patches, bushes, and flowering plants, offer a range of ecological niches and resources that attract and sustain a rich diversity of insect life. The presence of a lake and associated wetlands provides breeding grounds for odonates, while the flowering plants serve as nectar sources for both butterflies and odonates. Additionally, the abundance of native canopy-forming trees and fragmented grassland patches contribute to the park's appeal as a suitable habitat for various insect species (Fig. 2). The availability of host plants is particularly crucial for butterflies, as they play a vital role in their life cycle. The park's abundance of host and nectar plants supports the growth and sustenance of butterfly populations, enhancing the overall biodiversity and ecological balance within the study area. Preserving and conserving such versatile habitats as Kalyani Lake Park is essential to maintaining healthy insect populations and overall ecosystem health, highlighting the importance of sustainable management and conservation efforts.

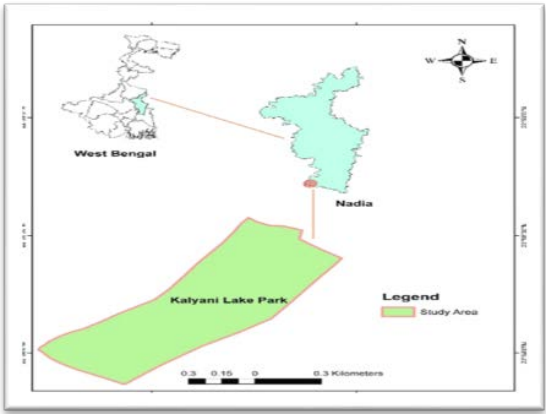


Figure 1. Map of the study area

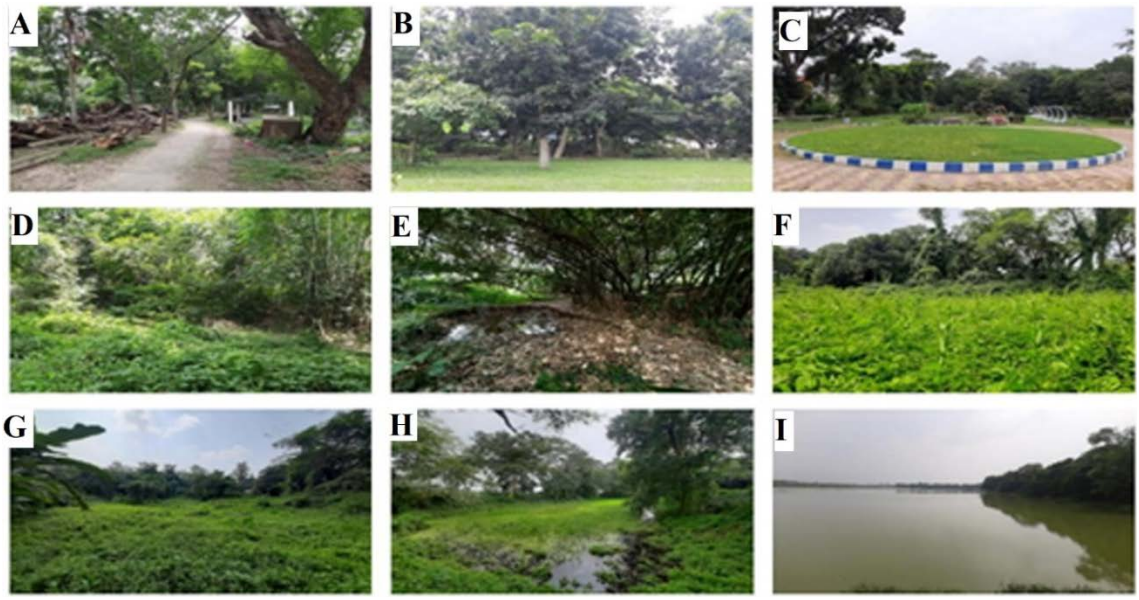


Figure 2. Type of Microhabitats in the study area; A. Picnic spot area with tall and canopy forming trees, B. Segmented natural grass lawn surrounded by medium height trees and shrubs; C. Man-made grass lawn for beautification; D. Forest patches with different types of native plant along with very deep undergrowth; E. Bamboo zone with no underground along with isolated shallow pond; F. A ground full of Fiddlehead fern; G. A land with deep undergrowth, surrounded by various native plants; H. Isolated pond with water cabbage, water hyacinth, southern cattail and surrounded by tall trees; I. wide Lake surrounded by canopy forming trees

Survey methods

The study was conducted from August 2021 to September 2023, employing a modified "Pollard Walk" method (Pollard, 1977; Pollard & Yates, 1993) to survey odonates and butterflies in the study area. Two line transects, measuring 500 meters and 350 meters, were established to representatively sample the area's biodiversity and ecology. These transects were strategically placed to cover various habitats within the study area, including aquatic and terrestrial ecosystems.

A total of four transects (two 500-meter and two 350-meter) were set up to record species and abundance, ensuring adequate representation of all habitats. Weekly one-day field surveys were conducted to facilitate detailed and frequent observations of changes in the study area. Species identification was done using authentic literature for odonates (Subramanian, 2005; Nair, 2011; Fraser, 1933, 1934, 1936; Mitra, 2002; Subramanian & Babu, 2017) and suitable keys for butterflies (Kunte, 2000; Evans, 1932; Wynter-Blyth, 1957; Haribal, 1992; Kehimkar, 2008). Scientific and English common names were written following the catalogue by Varshney & Smetacek (2015). Photographs were taken using a Nikon D3400 DSLR camera (70−300 mm lens) and a Samsung Galaxy M21 cell phone camera during the survey.

Statistical analysis methods

Data were arranged to obtain the following parameters:

Relative abundance

Ra = ((n/N)*100), where n is the total number of odonates of a particular species and N is the total number of odonates of all species (Mallick, 2023).

The diversity indices were calculated using Simpson's diversity index, Shannon Wiener diversity index, Margalef's Richness index and

Evenness index. The input for the data analysis was a relative abundance matrix of family, genera and species across seasons (Shannon, 1948; Shannon & Weaver, 1949; Simpson, 1949; Pielou, 1969. Magurran, 1988; Rohmare et al., 2016; Rathod & Parasharya, 2018). The specimens of dragonflies and damselflies were classified into four categories based on their frequency of occurrence during the survey including Abundant (AD), Common (CD), Frequent (FD), and Rare (RD). Similarly, the butterfly specimens were categorized as Abundant (AB), Common (CB), Frequent (FB), and Rare (RB). This classification system allows for a standardized way to report the frequency and abundance of each species during the survey.

Measurement of diversity

The type of diversity used here is alpha diversity which is the diversity of species within a community or habitat that diversity index was calculated by using the - Shannon Wiener diversity index.

Shannon Winner diversity index (H')

$H' = \{-\sum Pi\ (\ln)pi\}$,

$[Pi = n/N]$

S = number of individuals of species; N = total number of all individuals in the sample; Ln = logarithm to base e.

Measurement of species richness

Margalef's Richness index = $[(S - 1)/\ln(n)]$

S = total number of species; N = total number of all individuals in the sample; Ln = Natural logarithm.

Dominance and Simpson index

$(1 - D) = \sum n*(n - 1)/N*(N - 1)$

Where N is the number of individuals of taxon I

Dominance 1 - Simpson index ranges from 0 to 1.

Simpson Index 1-D. Measures evenness of the community from 0 to 1 dominance and Simpson indices are often interchangeably.

Pielou Evenness Index (J)

$J = H'/\text{Log}\ (S)$

Microsoft Excel 2013 was used in the calculation of diversity and analysis of the diversity with biodiversity software such as PAST (Hammer et al., 2001).

RESULTS

The community study revealed distinct differences between odonate and butterfly species in the study area. In terms of individual abundance, odonates outnumbered butterflies with 2,379 individuals compared to 1693 (Tables 1 & 2). However, butterflies exhibited higher richness with 75 taxa, whereas odonates had 35 taxa (Table 3, Appendix 1, 2). The richness index also showed a significant difference, with butterflies scoring 22.919 and odonates scoring 10.069. Evenness indices indicated that odonates had a more even distribution of species, with a score of 0.89, whereas butterflies had a score of 0.66. Dominance indices revealed that butterflies were more dominated by a few species, with a score of 0.975, compared to odonates with a score of 0.871. Diversity metrics also showed differences between the two groups. The Simpson diversity index was higher for odonates (0.128) than butterflies (0.0245), indicating lower diversity among butterflies. Conversely, the Shannon Wiener index was higher for butterflies (3.927) than odonates (2.581), indicating higher diversity among butterflies. Finally, the effective number of species (ENS) was significantly higher for butterflies (50.803) than odonates (13.218), further highlighting the difference in diversity between the two groups (Table 3). The dragonfly and damselfly specimens were categorized as Abundant (AD, when more than 60 individuals present), Common (CD, when 21 to 60 individuals present), Frequent (FD, when 6 to 20 individuals present) and Rare (RD, when only 1 to 5 individuals present) according to their presence in the total survey (Fig. 3). The butterfly specimens were categorized as Abundant (AB, when more than 35 individuals are present), Common (CB, when 15 to 35 individuals are present), Frequent (FB, when 6 to 14 individuals are present) and Rare (RB, when only 1 to 5

individuals present) according to their presence in the total survey (Fig. 4). The relative abundance of the Odonates and butterflies species collected from the study area. The species-to-genus ratio (S/G) determines the distribution of odonates and butterflies among genera and is calculated to be 1, 1.278, 1, 1.6 and 1 for Gomphidae, Libellulidae, Macromiidae, Coenagrionidae and Platycnemididae, respectively (Table 4, for odonates) while 1.167, 2, 1.143, 0.9 and 1.688 for Hesperiidae, Papilionidae, Pieridae, Lycaenidae and Nymphalidae, respectively (Table 5, for butterflies).

Table 1. List of dragonflies and damselflies of Kalyani Lake Park

SL. NO.	Family	Scientific name	Common name	Dominance	No. Encounter
Suborder: Anisoptera (Dragonflies)					
OA01	Gomphidae	*Ictinogomphus rapax* (Rambur, 1842)	Indian Common Clubtail	CD	39
OA02	Libellulidae	*Acisoma panorpoides* (Rambur, 1842)	Trumpet-Tail	FD	11
OA03	Libellulidae	*Aethriamanta brevipennis* (Rambur, 1842)	Scarlet Marsh Hawk	AD	69
OA04	Libellulidae	*Brachydiplax chalybea* (Brauer, 1868)	Rufous-backed Marsh Hawk	CD	21
OA05	Libellulidae	*Brachydiplax farinosa* (Kruger, 1902)	Black-Tailed Dasher	FD	14
OA06	Libellulidae	*Brachydiplax sobrina* (Rambur, 1842)	Little Blue Marsh Hawk	AD	88
OA07	Libellulidae	*Brachythemis contaminata* (Fabricius, 1793)	Ditch Jewel	AD	646
OA08	Libellulidae	*Bradinopyga geminata* (Rambur, 1842)	Granite Ghost	FD	19
OA09	Libellulidae	*Crocothemis servilia* (Drury, 1770)	Ruddy Marsh Skimmer	CD	41
OA10	Libellulidae	*Diplacodes trivialis* (Rambur, 1842)	Blue Ground Skimmer	CD	42
OA11	Libellulidae	*Lathrecista asiatica* (Fabricius, 1798)	Asiatic Blood Tail	RD	1
OA12	Libellulidae	*Neurothemis fulvia* (Drury, 1773)	Fulvous Forest Skimmer	FD	17
OA13	Libellulidae	*Neurothemis tullia* (Drury, 1773)	Pied Paddy Skimmer	RD	2
OA14	Libellulidae	*Orthetrum pruinosum* (Burmeister, 1839)	Crimson-tailed Marsh Hawk	RD	3
OA15	Libellulidae	*Orthetrum sabina* (Drury, 1770)	Green Marsh Hawk	AD	161
OA16	Libellulidae	*Pantala flavescens* (Fabricius, 1798)	Wandering Glider	FD	17

SL. NO.	Family	Scientific name	Common name	Dominance	No. Encounter
OA17	Libellulidae	*Potamarcha congener* (Rambur, 1842)	Yellow-tailed Ashy Skimmer	CD	39
OA18	Libellulidae	*Rhodothemis rufa* (Rambur, 1842)	Rufous Marsh Glider	AD	92
OA19	Libellulidae	*Rhyothemis variegata* (Linnaeus, 1763)	Common Picturewing	FD	18
OA20	Libellulidae	*Tholymis tillarga* (Fabricius, 1798)	Coral-tailed Cloudwing	FD	17
OA21	Libellulidae	*Tramea limbata* (Desjardins, 1832)	Black Marsh Trotter	RD	1
OA22	Libellulidae	*Tramea basilaris* (Palisot de Beauvois, 1805)	Red Marsh Trotter	RD	3
OA23	Libellulidae	*Urothemis signata* (Rambur, 1842)	Greater Crimson Glider	CD	26
OA24	Libellulidae	*Zyxomma petiolatum* (Rambur, 1842)	Brown Dusk Hawk	CD	21
OA25	Macromiidae	*Epophthalmia vittata* (Burmeister, 1839)	Common Torrent Hawk	FD	11
Suborder: Zygoptera (Damselflies)					
OZ01	Coenagrionidae	*Agriocnemis kalinga* (Nair & Subramanian, 2014)	Indian Hooded Dartlet	RD	1
OZ02	Coenagrionidae	*Agriocnemis pygmaea* (Rambur, 1842)	Pygmy Dartlet	AD	144
OZ03	Coenagrionidae	*Ceriagrion cerinorubellum* (Brauer, 1865)	Orange-tailed Marsh Dart	AD	105
OZ04	Coenagrionidae	*Ceriagrion coromandelianum* (Fabricius, 1798)	Coromandel Marsh Dart	AD	442
OZ05	Coenagrionidae	*Ischnura senegalensis* (Rambur, 1842)	Senegal Golden Dartlet	CD	39
OZ06	Coenagrionidae	*Mortonagrion aborense* (Laidlaw, 1914)	Emerald-eyed Dartlet	RD	1
OZ07	Coenagrionidae	*Pseudagrion microcephalum* (Rambur, 1842)	Blue Grass Dart	CD	59
OZ08	Coenagrionidae	*Pseudagrion rubriceps* (Selys, 1876)	Saffron-faced Blue Dart	AD	156
OZ09	Platycnemididae	*Onychargia atrocyana* (Selys, 1865)	Black Marsh Dart	FD	11
OZ10	Platycnemididae	*Pseudocopera ciliata* (Selys, 1863)	Pied Bush Dart	RD	2

*Table 2***.** List of butterflies of Kalyani Lake Park

SL. NO.	Subfamily	Scientific name	Common name	Dominance	No. Encounter
Family: Hesperiidae (Skippers)					
L01	Coeliadinae	*Badamia exclamationis* (Fabricius, 1775)	Brown Awl	RB	1
L02	Pyrginae	*Tagiades japetus* (Stoll, 1781)	Common Snow Flat	RB	2
L03	Hesperiinae	*Ampittia dioscorides* (Fabricius, 1793)	Indian Bush Hopper	RB	3
L04	Hesperiinae	*Borbo cinnara* (Wallace, 1866)	Rice Swift	CB	20
L05	Hesperiinae	*Hyarotis adrastus* (Stoll, 1780)	Tree Flitter	RB	1
L06	Hesperiinae	*Iambrix salsala* (Moore, 1866)	Chestnut Bob	CB	26
L07	Hesperiinae	*Matapa aria* (Moore, 1866)	Common Redeye	FB	13
L08	Hesperiinae	*Oriens gola* (Moore, 1877)	Common Dartlet	AB	53
L09	Hesperiinae	*Parnara guttatus* (Bremer & Grey, 1852)	Straight Swift	RB	3
L10	Hesperiinae	*Parnara ganga* (Evans, 1937)	Evan's Swift	CB	28
L11	Hesperiinae	*Pelopidas mathias* (Fabricius, 1798)	Variable Swift	FB	7
L12	Hesperiinae	*Pelopidas agna* (Moore, 1865)	Obscure Branded Swift	CB	16
L13	Hesperiinae	*Suastus gremius* (Fabricius, 1798)	Indian Palm Bob	FB	13
L14	Hesperiinae	*Telicota bambusae* (Moore, 1878)	Dark Palm Dart	RB	4
Family: Papilionidae (Swallowtails)					
L15	Papilioninae	*Graphium agamemnon* (Linnaeus, 1758)	Tailed Jay	CB	33
L16	Papilioninae	*Graphium doson* (C. & R. Felder, 1864)	Common Jay	CB	19
L17	Papilioninae	*Pachliopta aristolochiae* (Fabricius, 1775)	Common Rose	FB	13
L18	Papilioninae	*Papilio clytia* (Linnaeus, 1758)	Common Mime	CB	22
L19	Papilioninae	*Papilio demoleus* (Linnaeus, 1758)	Lime Swallowtail	AB	45
L20	Papilioninae	*Papilio polytes* (Linnaeus, 1758)	Common Mormon	AB	69
Family: Pieridae (Whites & Yellows)					
L21	Coliadinae	*Catopsilia pomona* (Fabricius, 1775)	Common Emigrant	AB	63
L22	Coliadinae	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	CB	32
L23	Coliadinae	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	AB	39

SL. NO.	Subfamily	Scientific name	Common name	Dominance	No. Encounter
L24	Pierinae	*Appias libythea* (Fabricius, 1775)	Striped Albatross	AB	40
L25	Pierinae	*Cepora nerissa* (Fabricius, 1775)	Common Gull	CB	21
L26	Pierinae	*Delias eucharis* (Drury, 1773)	Common Jezebel	CB	31
L27	Pierinae	*Leptosia nina* (Fabricius, 1793)	Psyche	AB	40
L28	Pierinae	*Pareronia valeria* (Fabricius, 1787)	Common Wanderer	CB	18
Family: Lycaenidae (Blues & Hairstreaks)					
L29	Curetinae	*Curetis thetis* (Drury, 1773)	Indian Sunbeam	RB	1
L30	Miletinae	*Spalgis epius* (Westwood, 1851)	Apefly	RB	1
L31	Polyommatinae	*Anthene emolus* (Godart, 1824)	Common Ciliate Blue	CB	39
L32	Polyommatinae	*Anthene lycaenina* (R. Felder, 1868)	Pointed Ciliate Blue	FB	6
L33	Polyommatinae	*Castalius rosimon* (Fabricius, 1775)	Common Pierrot	FB	8
L34	Polyommatinae	*Chilades lajus* (Stoll, 1780)	Lime Blue	AB	71
L35	Polyommatinae	*Luthrodes pandava* (Horsfield, 1829)	Plains Cupid	AB	67
L36	Polyommatinae	*Lampides boeticus* (Linnaeus, 1767)	Pea blue	RB	2
L37	Polyommatinae	*Neopithecops zalmora* (Butler, 1870)	Quaker	CB	31
L38	Polyommatinae	*Prosotas nora* (C. Felder, 1860)	Common Lineblue	FB	6
L39	Polyommatinae	*Pseudozizeeria maha* (Kollar, 1844)	Pale Grass Blue	CB	22
L40	Polyommatinae	*Tarucus nara* (Kollar, 1848)	Striped Pierrot	CB	23
L41	Polyommatinae	*Zizula hylax* (Fabricius, 1775)	Tiny Grass Blue	FB	14
L42	Theclinae	*Arhopala amantes* (Hewitson, 1862)	Large Oakblue	RB	1
L43	Theclinae	*Iraota timoleon* (Stoll, 1790)	Silverstreak Blue	RB	2
L44	Theclinae	*Loxura atymnus* (Stoll, 1780)	Yamfly	CB	30
L45	Theclinae	*Mahathala ameria* (Hewitson, 1862)	Falcate Oakblue	AB	59
L46	Theclinae	*Rapala manea* (Hewitson, 1863)	Slate Flash	CB	17
L47	Theclinae	*Rathinda amor* (Fabricius, 1775)	Monkey Puzzle	AB	60
L48	Theclinae	*Spindasis vulcanus* (Fabricius, 1775)	Common Silverline	RB	3
Family: Nymphalidae (Brush-footed Butterflies)					
L49	Acraeinae	*Acraea violae* (Linnaeus, 1758)	Tawny Coster	FB	8
L50	Biblidinae	*Ariadne ariadne* (Linnaeus, 1763)	Angled Castor	CB	27
L51	Biblidinae	*Ariadne merione* (Cramer, 1777)	Common Castor	FB	11

SL. NO.	Subfamily	Scientific name	Common name	Dominance	No. Encounter
L52	Charaxinae	*Charaxes solon* (Fabricius, 1793)	Black Rajah	RB	1
L53	Danainae	*Danaus chrysippus* (Linnaeus, 1758)	Plain Tiger	CB	32
L54	Danainae	*Danaus genutia* (Cramer, 1779)	Common Tiger	FB	13
L55	Danainae	*Euploea core* (Cramer, 1780)	Common Crow	AB	64
L56	Danainae	*Tirumala limniace* (Cramer, 1775)	Blue Tiger	AB	34
L57	Heliconiinae	*Phalanta phalantha* (Drury, 1773)	Common Leopard	RB	3
L58	Limenitidinae	*Euthalia aconthea* (Cramer, 1777)	Common Baron	FB	6
L59	Limenitidinae	*Euthalia lubentina* (Cramer, 1777)	Gaudy Baron	RB	1
L60	Limenitidinae	*Moduza procris* (Cramer, 1777)	Commander	CB	29
L61	Limenitidinae	*Neptis hylas* (Linnaeus, 1758)	Common Sailer	CB	33
L62	Limenitidinae	*Neptis jumbah* (Moore, 1858)	Chestnut-streaked Sailer	FB	12
L63	Nymphalinae	*Hypolimnas bolina* (Linnaeus, 1758)	Great Eggfly	CB	27
L64	Nymphalinae	*Junonia almana* (Linnaeus, 1758)	Peacock Pansy	CB	17
L65	Nymphalinae	*Junonia atlites* (Linnaeus, 1763)	Grey Pansy	CB	19
L66	Nymphalinae	*Junonia iphita* (Cramer, 1779)	Chocolate Pansy	CB	23
L67	Nymphalinae	*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	FB	11
L68	Nymphalinae	*Vanessa cardui* (Linnaeus, 1758)	Painted Lady	RB	1
L69	Satyrinae	*Elymnias hypermnestra* (Linnaeus, 1763)	Common Palmfly	CB	19
L70	Satyrinae	*Lethe europa* (Fabricius, 1775)	Bamboo Treebrown	RB	1
L71	Satyrinae	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	RB	2
L72	Satyrinae	*Melanitis phedima* (Cramer, 1780)	Dark Evening Brown	FB	9
L73	Satyrinae	*Mycalesis mineus* (Linnaeus, 1758)	Dark-branded Bushbrown	AB	63
L74	Satyrinae	*Ypthima baldus* (Fabricius, 1775)	Common Five-ring	CB	33
L75	Satyrinae	*Ypthima huebneri* (Kirby, 1871)	Common Four-ring	AB	56

Table 3. Diversity indices of odonate and butterfly species recorded in the study area

	Odonate species	Butterfly species
Individual	2,379	1,693
Taxa (S)	35	75
Richness Index [(S-1)/in(n)]	10.069	22.919
Evenness Index [H/lnS]	0.89	0.66
Dominance (D)	0.871	0.9754
Simpson Diversity Index (1-D)	0.128	0.024
Shannon Weaner Index (H)	2.581	3.927
Effective number of Species (ENS)	13.218	50.803

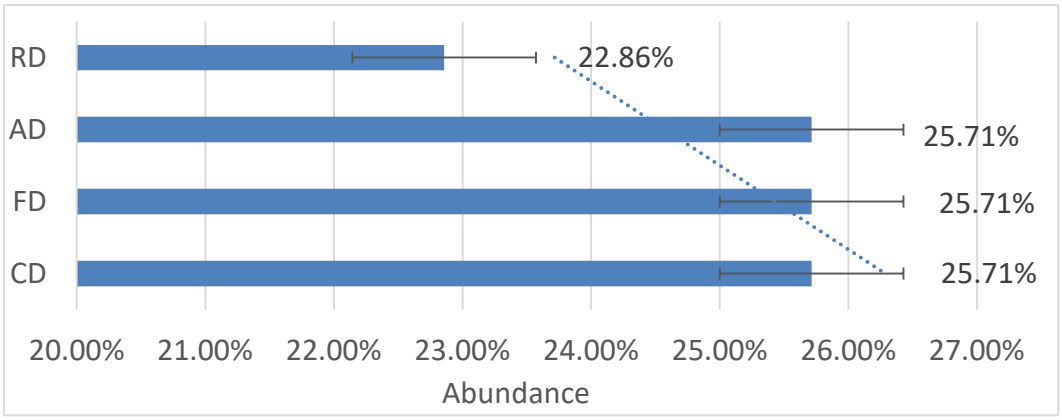


Figure 3. Abundance of odonate species in the study area

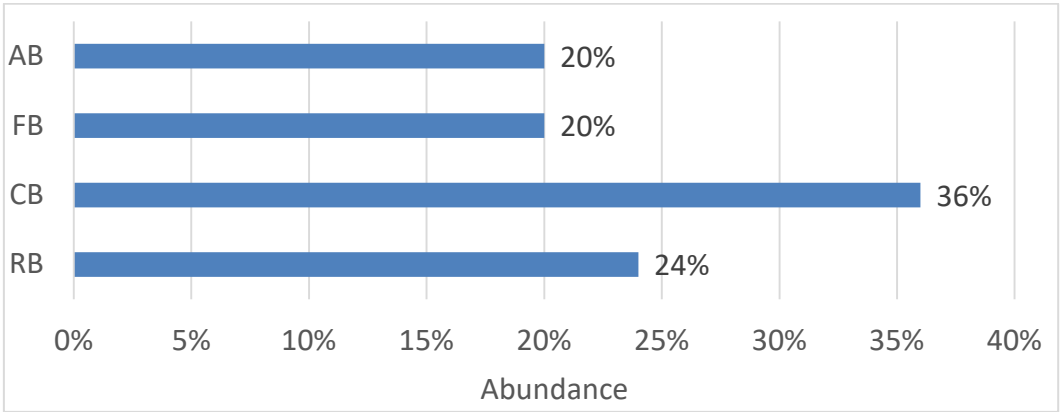


Figure 4. Abundance of butterfly species in the study area

During the study period, 35 species of odonates were recorded, including 25 species of dragonflies (Sub-order: Anisoptera) belonging to 3 families and 10 species of damselflies (Suborder: Zygoptera) belonging to 2 families. In the case of Anisopterans, 25 species were recorded belonging to three families namely Gomphidae (1 species), Macromiidae (1 species) and Libellulidae (23 species). In the case of Zygoptera, 10 species were recorded belonging to two families namely: Coenagrionidae (8 species) and Platycnemididae (2 species). The highest diversity of odonates was recorded belonging to

the family Libellulidae (65.71%), followed by Coenagrionidae (22.86%), Platycnemididae (5.71%), Gomphidae (2.86%) and Macromiidae (2.86%). It was observed that, among the Anispoteran, *Brachythemis contaminata* and *Orthetrum sabina* were the most common species, whereas among the Zygopteran, *Ceriagrion coromandelianum* and *Pseudagrion rubriceps* were the most common species.

During the study period, 75 species of butterflies belonging to 5 families were recorded. Among those, 27 species were recorded belonging to the family Nymphalidae (36%), 20 species were recorded belonging to the family Lycaenidae (27%), 14 species were recorded belonging to the family Hesperiidae (19%), 08 species were recorded belonging to the family Pieridae (10%) and 06 species were recorded belonging to the family Papilionidae (8%). During the study period, 75 species of butterflies belonging to 18 sub-families were recorded. It was observed that, among the family Hesperiidae, *Oriens gola* was the most common and for the rest of the families, Papilionidae, Pieridae, Lycaenidae and Nymphalidae, *Papilio polytes*, *Catopsilia pomona*, *Chilades lajus* and *Euploea core* were most common species respectively.

Table 4. Species to genus ratio for the recorded odonate species in the study area

SL. No.	Family name	No of Genus (G)	No. of Species (S)	S/G
1	Gomphidae	1	1	1
2	Libellulidae	18	23	1.278
3	Macromiidae	1	1	1
4	Coenagridae	5	8	1.6
5	Platycnemidae	2	2	1

Table 5. Species to genus ratio for the recorded butterfly species in the study area

SL. No.	Family name	No of Genus(G)	No. of Species (S)	G/S
1	Hesperiidae	12	14	0.857
2	Papilionidae	3	6	0.5
3	Pieridae	7	8	0.875
4	Lycaenidae	20	18	1.11
5	Nymphalidae	16	27	0.59

DISCUSSION

The community study revealed significant differences in the diversity and abundance of odonate and butterfly species in the study area. Odonates outnumbered butterflies in terms of individual abundance, but butterflies exhibited higher richness and diversity. The evenness indices indicated a more even distribution of odonate species, while dominance indices revealed that butterflies were dominated by a few species. The species-to-genus ratio (S/G) analysis showed that odonates were more evenly distributed among genera, while butterflies had a more varied distribution. The highest diversity of odonates was recorded in the family Libellulidae, while Nymphalidae had the highest diversity among butterflies. The most common odonate species were *Brachythemis contamina* and *Orthetrum sabina*, while *Ceriagrion coromandelianum* and *Pseudagrion rubriceps* were the most common among damselflies. Among butterflies, *Oriens gola* was the most common species in the family Hesperiidae, while *Papilio polytes*, *Catopsilia pomona*, *Chilades lajus*, and *Euploea core* were the most common species in the families Papilionidae, Pieridae, Lycaenidae, and Nymphalidae, respectively.

In disturbed and human-impacted sites like gardens, lakes, small ponds and grasslands is a concerning observation. It underscores the significant impact of human activities on

natural habitats and biodiversity (Tiple, 2006), the constant disturbances from plastic pollution and landscaping activities at the study site. The combination of plastic pollution and habitat alteration through vegetation removal can have severe impacts on biodiversity and ecosystem health. To improve the habitat for Odonata (dragonflies and damselflies) and butterflies in the study area and address the decline in their populations due to vegetation issues in the pond and lake. The availability of larval host plants and adult nectar plants plays a crucial role in determining the habitat preferences of butterflies. The rich diversity of Odonata (dragonflies & damselflies) and Lepidoptera (butterflies), particularly the Nymphalids (brush-footed butterflies) and Libellulids (Skimmer dragonflies), in the Nadia district of Kalyani Lake Park, suggests a diverse array of floral species and a well-developed terrestrial habitat. The presence of a mixed flora dominated by herbs and shrubs in the studied site within a tropical climate is significant for supporting a diverse range of insect populations, including Lepidoptera (butterflies). The diversity of riparian plants in Kalyani Lake Park is likely to be crucial for terrestrial odonates, particularly damselflies. These plants provide essential habitats and resources for the various life stages of odonates, contributing significantly to their overall diversity in the park.

The presence and diversity of butterfly species in a study area can serve as important indicators of ecosystem health and biodiversity. Butterflies are sensitive to environmental changes, making them bioindicators. Their presence reflects a diverse and balanced ecosystem, while declines may signal environmental disturbances or habitat degradation. Shedding light on factors contributing to species abundance or rarity, providing a deeper understanding of butterfly dynamics in the studied environment. Exploring the potential influence of human activity, climatic and geographic restrictions, vegetation, or pollution on species distribution within the study habitat is crucial for a comprehensive understanding of ecological dynamics and potential conservation implications. They play a crucial role in transferring pollen from the male parts (anthers) to the female parts (stigma) of flowers, facilitating the process of pollination. This process is vital for the reproduction of flowering plants, including many crops that we rely on for food. Similarly, dragonflies are valuable environmental indicators, particularly in aquatic ecosystems. Their presence, abundance, and behavior can provide insights into the health and quality of freshwater habitats. Changes in dragonfly populations can signal alterations in water quality, habitat degradation or other environmental stressors, making them important bio-indicators for monitoring ecosystem health. Odonates species demonstrate heightened adaption linked to their reliance on the lake environment or the shelter provided by riparian plants. Conversely, other species may exhibit significant adaptability to artificial environments. Likewise, specific butterfly families show heightened diversity due to their adaptability and the abundance of diverse host plants in the study area. Habitat destruction due to urban development and unsustainable management of natural resources pose significant threats to native butterfly and odonate populations. Identifying species most vulnerable to diversity reducing factors in our research involves a nuanced assessment. Preliminary observations suggest that butterfly and odonates species may be particularly susceptible. The factor with the most apparent influence on biodiversity within our study area is the single plastic pollution impact.

The presence of a diverse range of plants, including shrubs, herbs, and trees in Kalyani Lake Park, enhances the overall biodiversity and provides a favorable environment for insects, including odonates (dragonflies and damselflies) and butterflies. Different plant species offer various nectar sources, providing food for adult insects, while also serving as breeding and habitat sites. A well-balanced mix of vegetation contributes to a healthy ecosystem, supporting the life cycles of different insect species and promoting

biodiversity in the study area. It's essential for the sustainability of insect populations and the overall ecological balance of the study area. The habitat selection by butterfly and odonate species is primarily influenced by the presence of host plants and nectar plant species. The diverse association of individual butterflies and odonates species in the study area suggests moderately rich vegetation for shrub species. However, a limited number of nectar plant species were observed during the study period, with records from Papilionidae, Pieridae, and Hesperiidae. The study area is predominantly covered by a variety of wild herbs, shrubs, fruit plants, and trees including *Ficus* sp., *Cassia fistula*, *Citrus lemon*, *Calotropis* sp., *Lantana camara*, *Mangifera indica*, *Areca catechu*, *Euphorbia hirta*, *Abutilon indicum*, *Cicer arietinum*, *Chrysopogon* sp., *Oxalis corniculata*, *Ricinus communis*, and various types of grass, providing essential resources and breeding sites for butterfly species and odonates species in the study area (Mallick & Malakar 2023).

The rapid decline of butterfly and odonates populations, especially in areas like Kalyani Lake Park of Nadia District of West Bengal, is distressingly accurate (Day, 2021; Mallick & Malakar, 2023). Human activities, driven by increasing urbanization, pollution, overgrazing, and habitat loss, are taking a severe toll on their habitats and ultimately on their populations. Habitat loss due to deforestation for urban development is indeed a significant concern. The fragile ecosystems suffer from alterations in local climate, a consequence of human interventions. These changes greatly impact the butterfly community and other wildlife in the area. To mitigate the negative effects by planting endemic trees, plants, and supporting local wildlife through conservation efforts is vital. Such actions can help in preserving the remaining biodiversity and preventing common species from facing extinction. Insects, including butterflies and odonates, play crucial roles in ecosystem services like pest control, nutrient cycling, and pollination. Efforts to conserve their populations are essential for maintaining the overall health and balance of the ecosystem. Saving and conserving these beautiful and essential creatures like butterflies for future generations is a worthy and achievable goal.

These findings suggest that the study area supports a diverse range of odonate and butterfly species, with different distribution patterns and abundance. The differences in diversity and abundance between odonates and butterflies may be attributed to various factors such as habitat preferences, food availability, and environmental conditions. The scenario we described is unfortunately a common and concerning issue not only in India but in many rapidly developing regions around the world. Here are some specific challenges faced in India due to urbanization, pollution, overgrazing and land degradation. Butterfly and odonate species exhibited sensitivity to environmental changes likely due to factors such as habitat alteration, climate fluctuations, or pollution. Loss of prime habitat is a significant threat to a wide range of wildlife, including dragonflies, damselflies and butterflies. Habitat loss and degradation have profound effects on these insect populations and their ecosystems. Planting endemic trees and plants that support local wildlife is a highly effective and protective approach to mitigate the adverse effects of urbanization and development on biodiversity. Indicator species or groups play a prominent role in nature management, conservation biology, and environmental monitoring. Extending large-scale, multi-taxa conservation plans to encompass lake systems is crucial for achieving a balanced approach between agricultural, development, and nature conservation. Establishing a sustainable network of local experts and volunteers is instrumental in effectively conserving and monitoring butterfly, dragonfly, and damselfly species and their habitats in these critical ecosystems. Our emphasis on research, pollution control, legislation, and education aligns with the fundamental pillars of successful conservation efforts. These

strategies are indeed integral in preserving biodiversity and fostering a sustainable coexistence with the environment.

Acknowledgements: We are thankful to the honorable Chairman of Kalyani Municipality (Kalyani, West Bengal) for giving us permission to explore and work with the diversity of the Kalyani Lake Park. Thanks to Sri Dibyendu Sekhar Das, the Executive Officer of Kalyani Municipality, for his encouragement and support. We also thank our family members for their continuous support.

REFERENCES

Adarsh C. K., Aneesh K. S. & Nameer P. O., 2014. A preliminary checklist of odonates in Kerala Agricultural University (KAU) campus, Thrissur District, Kerala, southern India. *Journal of Threatened Taxa*, 6(8): 6127–6137. http://dx.doi.org/10.11609/JoTT.03491.6127-37

Aluri J. S. R. & Rao S. P., 2002. Psychophily and evolution consideration of *Cadaba fructicosa*. *The journal of the Bombay Natural History Society*, 99: 59–63.

Boggs C. L., Watt W. B. & Ehrlich P. R. (Eds.)., 2003. *Butterflies: ecology and evolution taking flight*. University of Chicago Press. http://dx.doi.org/10.7208/chicago/9780226063195.001.0001

Bonebrake T. C., Ponisio L. C., Boggs C. L. & Ehrlich P. R., 2010. More than just indicators: a review of tropical butterfly ecology and conservation. *Biological conservation*, 143(8): 1831–1841. http://dx.doi.org/10.1016/j.biocon.2010.04.044

Borcard D., Legendre P., & Drapeau P., 1992. Partialling out the spatial component of ecological variation. *Ecology*, 73(3): 1045–1055. http://dx.doi.org/10.2307/1940179

Chakraborty U., Sarkar S. & Bhadra K., 2018. Butterfly diversity in and around Kalyani, A suburban city near Kolkata, West Bengal. *Bionotes*, 20(2): 66–67.

Ceballos G., Ehrlich P. R., Barnosky A. D., García A., Pringle R. M. & Palmer T. M., 2015. Accelerated modern human–induced species losses: Entering the sixth mass extinction. *Science advances*, 1(5): e1400253. doi: 10.1126/sciadv.140253

Chovanec A. & Waringer J., 2001. Ecological integrity of river–floodplain systems-assessment by dragonfly surveys (Insecta: Odonata). *Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management*, 17(4–5): 493–507. http://dx.doi.org/10.1002/rrr.664

Clark T. E. & Samways M. J., 1996. Dragonflies (Odonata) as indicators of biotope quality in the Kruger National Park, South Africa. *Journal of applied ecology*: 1001–1012.

Condit R., Pitman N., Leigh Jr E. G., Chave J., Terborgh J., Foster R. B. ... & Hubbell S. P., 2002. Beta-diversity in tropical forest trees. *Science*, 295(5555): 666–669. http://dx.doi.org/10.2307/2404681

Clarke A., Mac Nally R., Bond N. & Lake P. S., 2008. Macroinvertebrate diversity in headwater streams: a review. *Freshwater biology*, 53(9): 1707−1721.

Dawn P., 2014. Taxonomic study of Odonata (Insecta) in Kolkata and surroundings, West Bengal, India. *Journal of Entomology and Zoology Studies*, 2(3): 147–152.

Dawn P., 2021. A new species of *Cephalaeschna* Selys, 1883 (Odonata: Anisoptera: Aeshnidae) from Neora Valley National Park, West Bengal, India. *Zootaxa*, 4949(2): 371–380. http://dx.doi.org/10.11646/zootaxa.4949.2.1032

Dey R., 2021. Preliminary checklist of butterfly (Insecta, Lepidoptera, Papilionoidea) species around Haringhata dairy farm, Nadia district, West Bengal including range extension of Prosotas bhutea (de Niceville,[1884]) for southern West Bengal, India. *Cuadernos de Biodiversidad*, (61): 1−16. http://dx.doi.org/10.14198/cdbio.2021.61.01

Dey T. & Ghosh S., 2016. A study on the diversity and abundance of Butterfly fauna in urban green areas of Krishnagar, Nadia, West Bengal. *Journal of Entomological and Zoology Studies*, 4(4): 117–122.

Dwari S., Mondal A. K. & Chowdhury S., 2017. Diversity of butterflies (Lepidoptera: Rhopalocera) of Howrah district, West Bengal, India. *Journal of Entomology and Zoology Studies*, 5(6): 815–828.

Duivenvoorden J. F., Svenning J. C. & Wright S. J., 2002. Beta diversity in tropical forests. *Science*, 295(5555): 636–637.

Ehrlich P. R., & Raven P. H., 1964. Butterflies and plants: a study in coevolution. *Evolution*, 586–608. http://dx.doi.org/10.2307/2406212

Ehrlich P. R., & Wilson E. O., 1991. Biodiversity studies: science and policy. *Science*, 253(5021): 758–762. doi: 10.1126/science.253.5021.758

Eslami Z., Ebrahimi M., Kiany, M. & Sadeghi S., 2021. Ecological drivers of Odonata beta diversity in arid and semi-arid regions of the central plateau of Iran. *Insect Conservation and Diversity*, 14(1): 40–51. doi: 10.1111/icad.12464

Evans W. H., 1932. The Identification of Indian Butterflies, Bombay Natural History Society, Bombay. Today and Tomorrow's Printers and Publishers, New Delhi: 454 p. http://dx.doi.org/10.12691/aees-8-5-19

Fraser F. C., 1933. The fauna of British India, including Ceylon and Burma. Odonata. Pt. 1. London: Taylor and Francis. 423 p.

Fraser F. C., 1934. The Fauna of British India including Ceylon and Burma, Odonata.. *Taylor and Francis, London*, xxiii + 398 pp., col. Pls. I–IV excl..

Fraser F. C., 1936. The Fauna of British India including Ceylon and Burma, Odonata. Taylor and Fancis Ltd., London, 1936; I: 461.

Ghazanfar M., Malik M. F., Hussain M., Iqbal R. & Younas M., 2016. Butterflies and their contribution in ecosystem: A review. *Journal of Entomology and Zoology Studies*, 4(2): 115–118.

Gupta I. J., De M. L. & Mitra T. R., 1995. Conspectus of Odonata fauna of Calcutta. *Records of Zoological Survey of India*, 95: 107–121.

Hammer O., 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontol electron*, 4, 9.

Haribal M., 2000. *The Butterflies of Sikkim Himalaya and their natural history*. Natraj Publishers.

Kehimkar I., 2008. *The Book of the Indian Butterflies*. Bombay Natural History Society and Oxford University Press.

Kehimkar I. D., 2016. *Butterflies of India: BNHS Field Guides*. Bombay Natural History Society.

Kalkman V. J., Clausnitzer V., Dijkstra K. D. B., Orr A. G., Paulson D. R. & van Tol J., 2008. Global diversity of dragonflies (Odonata) in freshwater. *Freshwater animal diversity assessment*: 351–363. http://dx.doi.org/10.1007//978-1-4020-8259-7-38

Kalkman V. J., Babu R., Bedjanič M., Conniff K., Gyeltshen T., Khan M. K., Subramanian K. A. & Orr A. G., 2020. Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. *Zootaxa*, 4849(1): 1–84. http://dx.doi.org/10.11646/Zootaxa.4849.1.1

Kocher S. D. & Williams E. H., 2000. The diversity and abundance of North American butterflies vary with habitat disturbance and geography. *Journal of biogeography*, 27(4): 785–794. http://dx.doi.org/10.1046/j.1365-2699.2000.00454.x

Koh L. P., 2007. Impacts of land use change on South-east Asian forest butterflies: a review. *Journal of applied ecology*, 44(4): 703–713. http://dx.doi.org/10.1111/j.1365-2664.2007.01324.x

Koli V. K., Bhatnagar C. & Shekhawat D. S., 2015. Diversity and Species Composition of Odonates in Southern Rajasthan, India. *In Proceedings of the Zoological Society*, 68: 202–211. Springer India. http://dx.doi.org/10.1007//s12595-014-0103-x

Kunte K. J., 1997. Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in northern Western Ghats. *Journal of biosciences*, 22: 593–603. http://dx.doi.org/10.1007/BF02703397

Kunte K., 2000. Butterflies of Peninsular India Universities Press (India) Limited.

Kunte K., Joglekar A., Utkarsh G. & Padmanabhan P., 1999. Patterns of butterfly, bird and tree diversity in the Western Ghats. *Current Science*, 577–586.

Lahiri A. R. & Mitra T. R., 1972. A note on *Acanthagyna dravida* (Lieftinck) (Insecta: Odonata: Aeshnidae). *Journal of Bombay Natural History Society*, 69: 438–439.

Lander E. S. & Waterman M. S., 1988. Genomic mapping by fingerprinting random clones: a mathematical analysis. *Genomics*, 2(3): 231–239. http://dx.doi.org/10.1016/0888-7543(88)90007-9

Losey J. E. & Vaughan M., 2006. The economic value of ecological services provided by insects. *Bioscience*, 56(4): 311–323. http://dx.doi.org/10.1641/0006-3568

Magurran A. E., 1988. *Ecological diversity and its measurement*. Princeton university press. http://dx.doi.org/10.1007/978-94-015-7358-0

Mallick M. A. I., 2023. Abundance, habitat preference and seasonal patterns of different butterfly species (Order: Lepidoptera): A preliminary study in West Bengal State University (WBSU) campus, West Bengal, India. *Int. J. Adv. Res. Biol. Sci*, 10(3): 6–21. http://dx.doi.org/10.22192/ijarbs.2023.10.03.002

Mallick M. A. I., 2023. A Preliminary Study on Status, Guild and Diversity of Avifaunal Species in and around Serampore, Jolkol, Hooghly District, West Bengal, India. *World Scientific News*, 179: 93–111.

Mallick M. A. I. & Ghorai N., 2023. Temporal distribution pattern of butterflies in an unfenced location at Serampore, Hooghly, West Bengal, India. *Nova Geodesia*, 3(3): 126–126. doi: 10.55779/ng33126

Mallick M. A. I. & Ghorai N., 2024. Biodiversity and relative abundance preliminary assessment of Odonata (Insecta) fauna in and around Serampore, Jolkol, Hooghly, West Bengal, India. *World Scientific News*, 187: 47–65.

Mallick M. A. I. & Mondal A., 2024. A preliminary assessment: seasonal variations of damselfly and dragonfly abundance in Serampore, Jolkol, West Bengal, India. *Biodiversity*, 25: 11–16. http://dx.doi.org/10.1080/14888386.2023.2271446

Mallicka M. A. I & Malakar R., 2023. Diversity and abundance of butterfly in Kalyani Lake park, West Bengal, India: A reconnaissance. *e-planet*, 21(1): 60–70.

Meyer W. B. & Turner B. L., 1992. Human population growth and global land-use/cover change. *Annual review of ecology and systematics*, 23(1): 39–61. http://dx.doi.org/10.1146/annurev.es.23.110192.000351

Mitra T. R., 1983. A list of Odonata of Calcutta. *Entomologist's Monthly Magazine*, 119: 29–31.

Mitra T. R., 2002. Geographical distribution of Odonata (Insecta) of eastern India. Zoological Survey of India.

Mitra T. R., 2005. Evolutionary adaptations in morphology and ecology of *Tholymis tillarga* (Fabricius) and *Bradinopyga geminata* (Rambur) (Insecta: Odonata). *Records of the Zoological Survey of India*, 104(1–2): 101–104.

Mukherjee K. & Mondal A., 2020. Butterfly diversity in heterogeneous habitat of Bankura, West Bengal, India. *Journal of Threatened Taxa*, 12(8): 15804–15816.

https://doi.org/10.11609/jott.5136.12.8.15804-15816

Nair M. V., 2011. *Dragonflies and Damselflies of Orissa and Eastern India Wildlife Organisation*. Forest and Environment Department, Government of Odisha, 252 pp.

Nallu S., Hill J. A., Don K., Sahagun C., Zhang W., Meslin C., … & Kronforst M.R., 2018. The molecular genetic basis of herbivory between butterflies and their host plants. *Nature ecology & evolution*, 2(9): 1418–1427. http://dx.doi.org/10.1038/s41559-018-0629-9

Nayak A. K., 2020. Additions to the Odonata (Insecta) fauna of Asansol-Durgapur Industrial Area, West Bengal, India. *Journal of Threatened Taxa*, 12(3): 15391–15394. http://dx.doi.org/10.11609/jott.5138.12.3.15391-15394.

Nayak A. K. & Roy S., 2016. An observation on the Odonata fauna of the Asansol-Durgapur Industrial Area, Burdwan, West Bengal, India. *Journal of Threatened Taxa*, 8(2): 8503–8517. http://dx.doi.org/10.11609/jott.2572.8.2.8503-8517

New T. R., 1991. *Butterfly conservation*. Oxford University Press.

Nimbalkar R. K., Chandekar S. K. & Khunte S. P., 2011. Butterfly diversity in relation to nectar food plants from Bhor Tahsil, Pune District, Maharashtra, India. *Journal of Threatened Taxa*, 3(3): 1601–1609. http://dx.doi.org/10.11609/JoTT.02612.1601-9

Noss R. F., 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation biology*, 4(4): 355–364. http://dx.doi.org/10.1111/j.1523.1739.1990.tb00309.x

Oliver I. & Beattie A. J., 1993. A possible method for the rapid assessment of biodiversity. *Conservation biology*, 7(3): 562–568. http://dx.doi.org/10.1046/j.1523-1739.1993.07030562.x

Payra A., Das G. N., Pal A., Patra D. & Tiple A., 2017. New locality records of a rare dragonfly *Gynacantha khasiaca* Maclachlan, 1896 (Odonata Aeshnidae) from India. *Biodiversity Journal*, 8(1): 27–32.

Payra A. & Tiple A., 2016. Notes on the occurrence of *Mortonagrion aborense* Laidlaw, 1914 (Odonata: Coenagrionidae) from lower West Bengal, India. *Journal of Threatened Taxa*, 8(7): 9038–9041. http://dx.doi.org/10.11609/jott.1992.8.7.9038-9041

Payra A. & Tiple A., 2019. Odonata Fauna in adjoining coastal areas of Purba Medinipur District, West Bengal, India. *Munis Entomology and Zoology Journal*, 14(2): 358–367.

Paulson D., Schorr M. & Deliry C., 2024. World Odonata List. Available from: http://www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resources/dragonflies/world-odonata-list2/ (accessed 6 May 2024).

Person R. V., Peterson B. R. & Lightner D. A., 1994. Bilirubin conformational analysis and circular dichroism. *Journal of the American Chemical Society*, 116(1): 42–59. doi: 10.1021/ja00080a006

Pielou E. C., 1969. An introduction to mathematical ecology. Wiley Interscience, New York, USA, 294 pp.

Pollard E., 1977. A method for assessing changes in the abundance of butterflies. *Biological conservation*, 12(2): 115–134. http://dx.doi.org/10.1016/0006-3207(77)90065-9

Pollard E. & Yates T. J., 1993. *Monitoring butterflies for ecology and conservation: The British butterfly monitoring scheme*. Springer Science & Business Media.

Prasad M. & Varshney R. K., 1995. A check-list of the Odonata of India including data on larval studies. *Oriental insects*, 29(1): 385–428. http://dx.doi.org/10.1080/00305316.1995.10433748

Prosenjit D., 2021. Dragonflies and damselflies (Insecta: Odonata) of West

Bengal, an annotated list of species. *Oriental Insects*, 56(1): 81–117. http://dx.doi.org/10.1080/00305316.2021.1908188

Ram R., Srivastava V. D., Prasad M., 1982. Odonata (Insecta) Fauna of *Calcutta* and surroundings. *Records of Zoological Survey of India*, 80: 169–196. http://dx.doi.org/10.26515/rzsi/v80/i1-2/1982/161723

Ramesh T., Prakash R. & Shukla K. K., 2010. Life cycle energy analysis of buildings: An overview. *Energy and buildings*, *42*(10): 1592–1600. http://dx.doi.org/10.1016/j.enbuild.2010.05.007

Rathod D. M., & Parasharya B. M., 2018. Odonate diversity of Nalsarovar Bird Sanctuary-a Ramsar site in Gujarat, India. *Journal of Threatened Taxa*, 10(8): 12117–12122. https://doi.org/10.11609/jott.4017.10.8.12117-12122

Robbins R. K. and Opler P. A., 1997. Biodiversity II, understanding and protecting our biological resources. Joseph Henry Press, Washington DC. http://dx.doi.org/10.17226/4901

Rohmare V. B., Rathod D. M. & Parasharya B. M., 2016. Diversity and population dynamics of Odonata (Insecta: Odonata) in rice growing area of Central Gujarat. *Journal of Biological Control*, 149–157. https://doi.org/10.18641/jbc/30/3/97792

Root T. L. & Schneider S. H., 2006. Conservation and climate change: the challenges ahead. *Conservation biology*, 20(3): 706–708. http://dx.doi.org/10.1046/j.1440-6055.2003.00341.x

Rowe R., 2003. Dragonflies: Behavior and Ecology of Odonata. *Australian Journal of Entomology*, 42(2): 210–211.

Selys Longchamps, E. de., 1891. Odonates in 'Viaggio Di Leonardo Fea in Birmania e Regional Viccine. *Annali del Museo civico di storia naturale Giacomo Doria*, 2(10): 433–518.18. http://dx.doi.org/10.1111/j.1523-1739.2006.00465.x

Salmah M. R. C., Tribuana S. W. & Hassan A. A., 2006. The population of Odonata (dragonflies) in small tropical rivers with reference to asynchronous growth patterns. *Aquatic Insects*, 28(3): 195–209. http://dx.doi.org/10.1080/01650420600922315

Shannon C. E., 1948. A mathematical theory of communication. *Bell System Technical Journal*, 27: 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x.

Shannon C. E. & Weaver W., 1949. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana. https://doi.org/10.4236/chnstd.2018.74024

Sharma G., Sundararaj R. & Karibasvaraja L. R., 2007. Species diversity of Odonata in the selected provenances of Sandal in Southern India. *Zoos' Print Journal*, 22(7): 2765–2767.

Simpson E. H., 1949. Measurement of diversity. *Nature*, 163: 688. http://dx.doi.org/10.1038/163688a0

Subramanian K. A., 2005. *India-A Lifescape, Dragonflies of India–A Field Guide*. Vigyan Prasar.

Subramanian A., Krishnan U. M. & Sethuraman S., 2009. Development of biomaterial scaffold for nerve tissue engineering: Biomaterial mediated neural regeneration. *Journal of biomedical science*, 16: 1–11. http://dx.doi.org/10.1186/1423-0127-16-108

Subramanian K. A. & Babu R., 2017. Checklist of Odonata (Insecta) of India. Version 3.0. *Records of the Zoological Survey of India, Kolkata.*

Summerville K. S., Metzler E. H. & Crist, T. O., 2001. Diversity of Lepidoptera in Ohio Forests at Local and Regional Scales: How Heterogeneous is the Fauna?. *Annals of the Entomological Society of America*, 94(4): 583–591. http://dx.doi.org/ 10.1603/0013-8746(2001)094

Syaripuddin K., Sing K. W., & Wilson J. J., 2015. Comparison of butterflies, bats and beetles as bioindicators based on four key

criteria and DNA barcodes. *Tropical Conservation Science*, 8(1): 138–149. http://dx.doi.org/10.1177/194008291500800112

Tiple A. D., Deshmukh V. P. & Dennis R. L., 2005. Factors influencing nectar plant resource visits by butterflies on a university campus: implications for conservation. *Nota lepidopterologica*, 28(3/4): 213–224.

Tiple A. D., Khurad A. M. & Dennis R. L., 2011. Butterfly larval host plant use in a tropical urban context: Life history associations, herbivory, and landscape factors. *Journal of Insect Science*, 11(1): 1–21. doi: 10.1673/031.011.6501

Tiple A. D., Padwad S. V., Dapporto L. & Dennis R. L., 2010. Male mate location behaviour and encounter sites in a community of tropical butterflies: taxonomic and site associations and distinctions. *Journal of biosciences*, 35: 629–646. http://dx.doi.org/10.1007/s12038-010-0071-x

Tiple A. D., Paunikar S. & Talmale S. S., 2012. Dragonflies and Damselflies (Odonata: Insecta) of Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, central India. *Journal of Threatened Taxa*, 4(4): 2529–2533. http://dx.doi.org/10.11609/JoTT.02657.2529-33

Tiple A. D., Sharma S. N. & Srivastava A.S., 2006. Psychiatric morbidity in geriatric people. *Indian Journal of Psychiatry*, 48(2): 88–94. http://dx.doi.org/10.4103/0019-5545.31596

Thomas J. A., 2005. Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. *Philosophical Transactions of the Royal Society B. Biological Sciences*, 360(1454): 339–357.2. http://dx.doi.org/10.1098/rstb.2004.1585

Varshney R. K. & Smetacek P. (eds.) 2015. A Synoptic Catalogue of the Butterflies of India. Butterfly Research Centre, Bhimtal and Indinov Publishing, New Delhi, ii + 261 pp., 8 pl. http://dx.doi.org/10.13140/RG.2.1.3966.2164

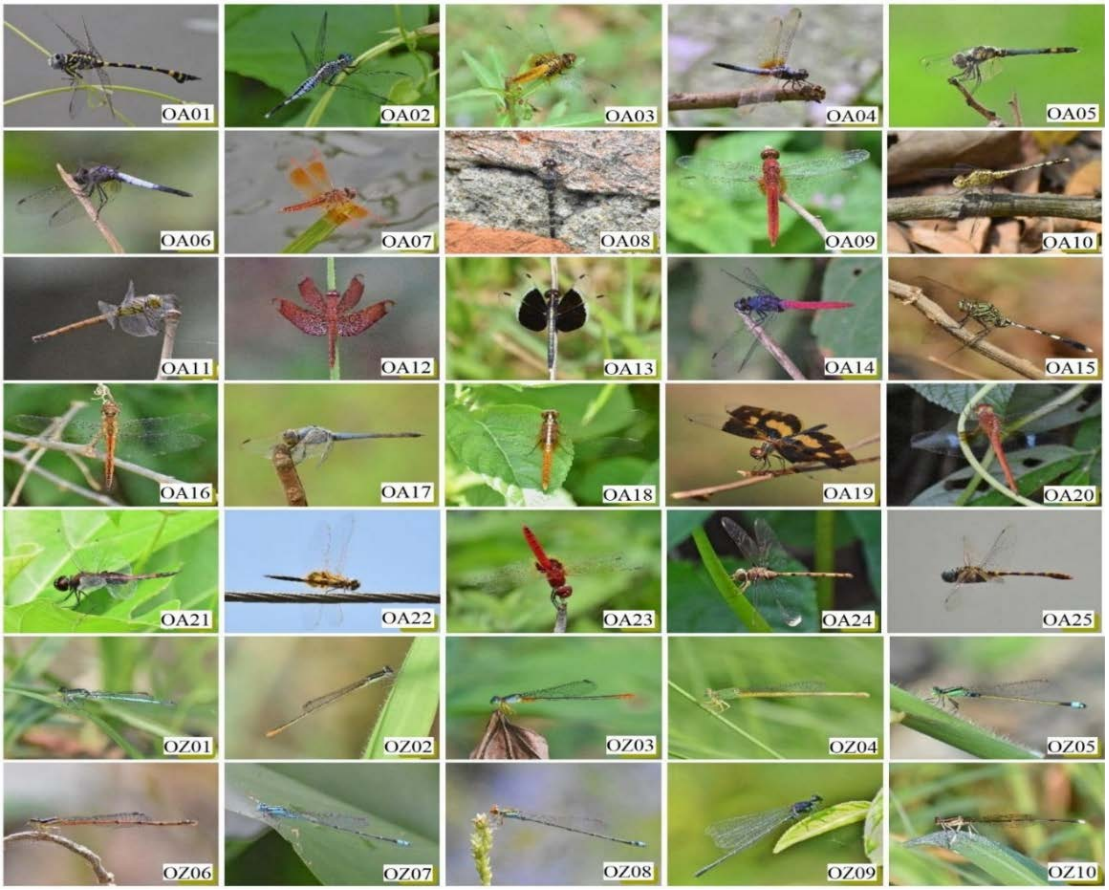
Verspagen N., Ikonen S., Saastamoinen M. & van Bergen E., 2020. Multidimensional plasticity in the Glanville fritillary butterfly: larval performance is temperature, host and family specific. *Proceedings of the Royal Society B*, 287(1941): 20202577. http://dx.doi.org/10.1098/rspb.2020.2577

Watson R., Baste I., Larigauderie A., Leadley, P., Pascual U., Baptiste B. ... & Mooney H., 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat: Bonn, Germany: 22–47.

Wright S. W., Jeffrey S. W., Mantoura R. F. C., Llewellyn C. A., Bjornland T., Repeta D. & Welschmeyer N., 1991. Improved HPLC method for the analysis of chlorophylls and carotenoids from marine phytoplankton. *Marine ecology progress series*, 183–196. http://dx.doi.org/10.3354/meps077183

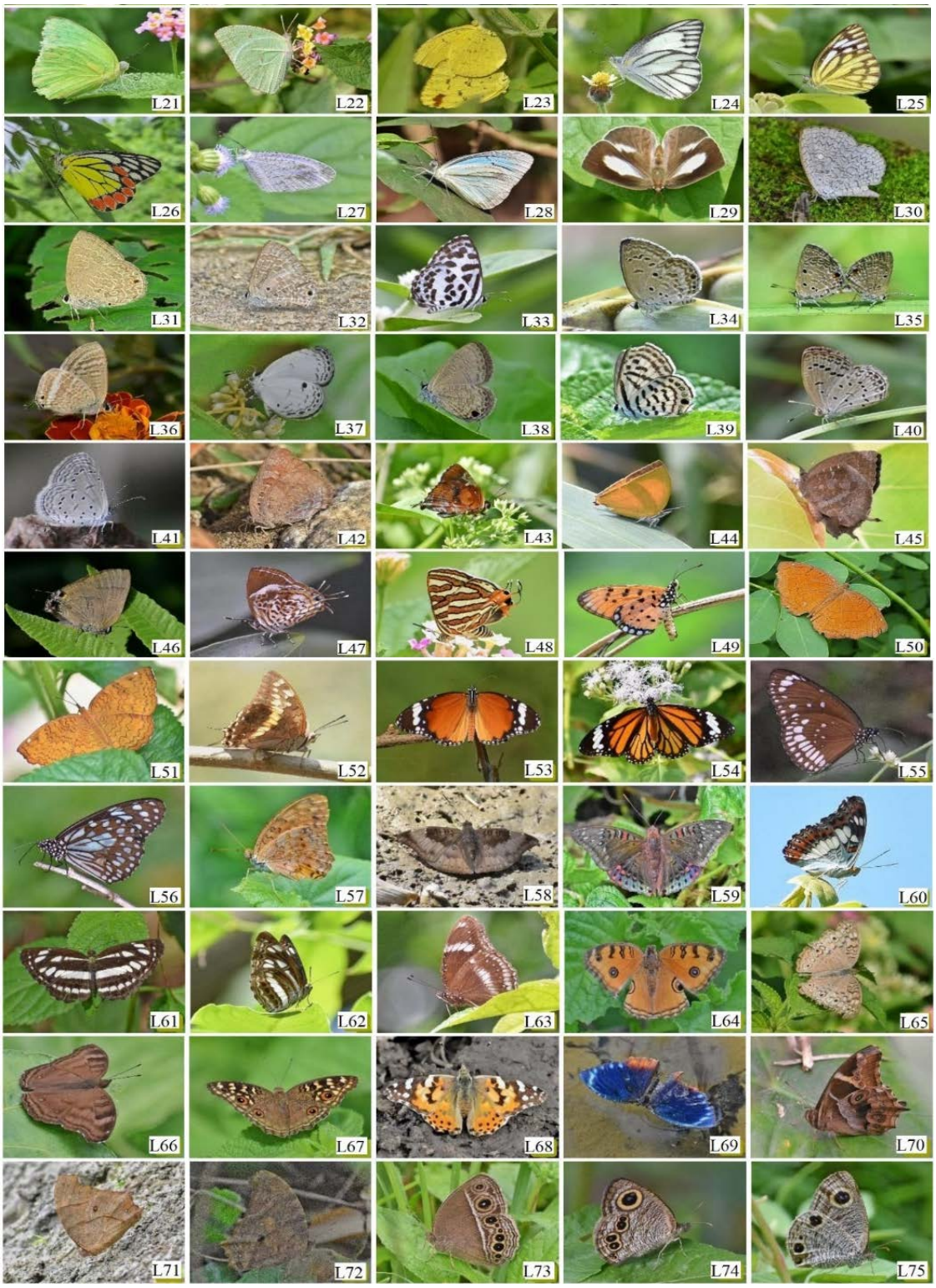
Wynter-Blyth M. A., 1957. Butterflies of the Indian region. CiNii Books.

Zaghloul A., Saber M., Gadow S. & Awad F., 2020. Biological indicators for pollution detection in terrestrial and aquatic ecosystems. *Bulletin of the National Research Centre*, *44*(1): 1–11. doi: 10.1186/s42269-020-00385-x



Appendix 1. The number to the left of each photograph corresponds to the odonate species number recorded in this study area in Table 1

Appendix 2. The number to the left of each photograph corresponds to the butterfly species number recorded in this study area in Table 2



Appendix 2. The number to the left of each photograph corresponds to the butterfly species number recorded in this study area in Table 2 (continue)