"ODONATE DIVERSITY

(Naduvile, Kottayam and Poyachira pond, Kakkanad, Ernakulam)

AND THEIR ROLE AS BIO – INDICATORS"

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CERTIFICATE

This is to certify that the project entitled **"ODONATE DIVERSITY (Naduvile, Kottayam and Poyachira pond, Kakkanad, Ernakulam) AND THEIR ROLE AS BIO – INDICATORS"** is a bonafide work done by **AFNITHA K H** with Register No: **180021043790** under the supervision of **DR. PRIYALAKSHMI G** during 2018-21 in partial fulfilment of the requirement for the award of the **Bachelor Degree of Science in Zoology** of Mahatma Gandhi University, Kottayam.

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DECLARATION

I do hereby declare that the work embodied in the dissertation entitled **"ODONATE DIVERSITY (Naduvile, Kottayam and Poyachira pond, Kakkanad, Ernakulam) AND THEIR ROLE AS BIO – INDICATORS"** submitted to Mahatma Gandhi University, Kottayam in partial fulfilment for the award of bachelor of science in Zoology is a bonafide dissertation done by me under the supervision of Dr. Priyalakshmi G, Department of Zoology, Bharata Mata College, Thrikkakara and that no part of this work has been submitted for the award of any other Degree /Diploma/Associate –ship /Fellow ship or any other similar title to any candidate of any university.

Place: Thrikkakara

Date:

Signature of the candidate

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SYNOPSIS

The order Odonata includes the dragonflies and damselflies, globally 5,952 species of Odonates under 652 genera have been reported (Schorr and Paulson, 2013). India harbours 474 species and 50 subspecies belonging to 142 genera in18 families (Subramanian, 2014). The Odonate fauna of the Western Ghats diverse with 176 species, 68 of which are endemic (Subramanian, 2009; Subramanian et al., 2008 and Kulkarni and Subramanian, 2013). Tsuda (1991) mentioned approximately 906 odonate species in his world list of Odonata from continental Asia, out of these 499 species belonged to 139 genera and 17 families are known from India (Prasad and Varshney, 1995). This project entitled "ODONATE DIVERSITY (Naduvile, Kottayam and Poyachira pond, Kakkanad, Ernakulam) AND THEIR ROLE AS BIO – INDICATORS" studies the odonate diversity of Naduvile in Kottayam district and Poyachira River and premises in Kakkanad, Ernakulam District of Kerala and the role of odonates as biological indicators. The present study enables to create a base line data of Odonates in the selected sites, a possibility to discover new or endangered species and monitor and evaluate the habitats of these odonates and thereby formulate strategies to conserve the water bodies and the environment. The study was conducted from January 2020 to January 2021.

In total 20 species of odonates were identified from the two sites. A total of 15 species of odonates were identified from Naduvile, including 12 species of Anisoptera (dragonflies) and 3 species of Zygoptera (damselflies). *Neurothemis tullia* (Plate 3, Fig. 15& 16), *Rhyothemis variegate* (Plate 1, Fig. 5), *Acisoma panorpoides* (Plate 1, Fig. 2&3), *Crocothemis servilia* (Plate 2, Fig. 7), *Orthetrum sabina* (Plate 3, Fig. 13), *Brachydiplax chalybea* (Plate 3, Fig. 17), *Agriocnemis pieris* (Plate 4, Fig. 22), *Diplacodes trivialis* (Plate 3, Fig. 14), *Brachythemis contaminate* (Plate 2, Fig. 9), *Pseudagrion microcephalum* (Plate 3, Fig. 18), *Hydrobasileus croceus* (Plate 1, Fig. 1), *Urothemis signata* (Plate 2, Fig. 12), *Rhodothemis rufa* (Plate 1, Fig. 6), *Pantala flavescens* (Plate 2, Fig. 10), *Ceriagrion cerinorubellum* (Plate 4, Fig. 20) were the species found at Naduvile. A total of 11 species of odonate including 8 Anisoptera- *Neurothemis tullia*, *Rhyothemis variegata*, *Acisoma panorpoides*, *Orthetrum sabina*, *Bradinopyga geminata* (Plate 2, Fig. 11), *Orthetrum pruinosum* (Plate 2, Fig. 8), *Orthetrum chrysis* (Plate 1, Fig. 4), *Brachythemis contaminate* and 3 Zygoptera - *Pseudagrion microcephalum*, *Ceriagrion coromandelianum* (Plate 4, Fig. 19), *Agriocnemis*

pygmaea (Plate 4, Fig. 21) was recorded from Kakkanad. Of the two sites Naduvile has greater diversity.

Based on the presence of certain species of odonate diversity, the quality of the water bodies was analysed. The abundance of species such as *Acisoma panorpoides, Brachythemis contaminate, Ceriagrion cerinorubellum* and *Agriocnemis pieris* which are found in contaminated water bodies, indicates the poor quality of water at Naduvile. The presence of *Acisoma panorpoides, Brachythemis contaminate* along with *Bradinopyga geminata* (an indicator of good water quality) in Kakkanad indicates that some water sources are polluted and unavailable for consumption while some are excellent sources of clean water.

INTRODUCTION

The Odonata are an order of flying insects that includes the dragonflies and damselflies that evolved in the early Mesozoic era [*Grimaldi et.al., 2005.*]. The order contains the dragonflies and damselflies and is one of the most popular insect groups. There are 5,952 species of odonates in the world. In India there are 474 species, 50 subspecies in 142 genera and 18 families (Subramanian, 2014). Their prototypes, the giant dragonflies of the Carboniferous, 325 million years ago, are no longer put in the Odonata. These are now called Protodonata or Meganisoptera. Odonates are active diurnal predatory insects found commonly flying over forests, fields, meadows, ponds and rivers (Subramanina, 2009). The larvae of Odonates are aquatic, while the adults arial. They have unique anatomical features of feeding, flight and reproductions (Moore, 1997). Among the class insecta, adult dragonflies exhibit the most conspicuous and highly developed morphological adaptations for arial foraging (Kakkassery, 2004). Some species fly over and around the water body and are called flyers. Some are often seen perching on vegetation in or around water bodies, they are called perchers.

Odonata was until recently composed of three suborders: Anisoptera, commonly known as dragonflies; Zygoptera, commonly known as damselflies; and Anisozyoptera, as the name denotes, a morphological composite of the previous two suborders. However, the suborder Anisozygoptera has been abandoned, as current research shows that Anisozygoptera is not a natural group, and is paraphyletic (Rehn 2003, Lohman 1996). Thus, the group has been combined with the suborder Anisoptera, which does form a natural group in a new suborder called Epiprocta (Bechly 1996).

SCIENTIFIC CLASSIFICATION:

Kingdom: Animalia

Class: Insecta

Subclass: Pterygota

Order: Odonata

Sub orders:

Zygoptera (damselflies) - front and hind wings are similar in shape

Anisoptera (dragonflies) - hind wings are broader near the base than the front wings

Major Families:

Dragonflies:

- Aeshnidae (Darners) -- These insects are notable for their large size and brilliant blue or green coloration. Includes the common green darner (*Anax junius*).
- Libellulidae (Common Skimmers) -- This is the largest family in the order. It contains many species with dark spots on the wings.
- Gomphidae (Clubtails) -- These dragonflies have the terminal abdominal segments swollen, hence the common name.

Damselflies:

- Calopterygidae (Broadwinged Damselflies) - The wings of these insects are shaped like the seeds of a maple tree.
- Coenagrionidae (Narrowwinged Damselflies) - Small, delicate insects. The body is usually black with blue markings. At rest, the wings are held together over the back.
- Lestidae (Spreadwinged Damselflies) -These damselflies rest with the body nearly vertical and the wings partly outspread.

ETYMOLOGY AND TERMINOLOGY:

Fabricius coined the term Odonata from the Ancient Greek ὀδών odṓn (Ionic form of ὀδούς odoús) 'tooth' apparently because they have teeth on their mandibles, even though most insects also have toothed mandibles [Mickel & Clarence, 1934]. The word dragonfly is also sometimes used to refer to all Odonata, but odonate is a more correct English name for the group as a whole. ["Odonate". Merriam - Webster Dictionary]. Odonata enthusiasts avoid ambiguity by using the term true dragonfly, [Field guide to lower aquarium animals. Cranbrook Institute of Science, 1939.] or simply Anisopteran, [Orr, A. G., 2005] when referring to just the Anisoptera. The term Warriorfly has also been proposed. [Philip S. Corbet & Stephen J. Brook, 2008.] Some 5,900 species have been described in this order [*Zhang, Z.-Q., 2011*.].

HABITATS OF ODONATES:

The odonates are closely associated with water bodies. Odonates breed in water and their larval stage are aquatic. They breed in both flowing and stagnant water bodies (Andrew *et al*., 2008) like rivers, streams etc., forested swamps, open marshes, freshwater lakes, freshwater ponds, and ditches and also seasonal ponds during monsoon. Agricultural fields and irrigation channels are also used as seasonal habitats by some of the dragonflies (Mitra *et al*., 2010). Among many factors that influence odonate assemblage around water bodies, physiochemical properties of water, surrounding vegetation and type of landscape around water bodies are some important factors (Balzan, 2012).

The vegetation around the water bodies plays an important role for the odonate community. It provides resting places and shelters from storm and rain (Andrew *et al*., 2008). Shade cover and presence of vascular plants in the vicinity of the water bodies is another factor.

DISTRIBUTION:

Odonates are found on every continent except for Antarctica. In particular, the majority of the families that comprise Anisoptera are broadly distributed throughout the world. In contrast, many families of damselflies are narrowly restricted and several families have an extremely limited distribution.

They can be seen near any body of water or running stream, often sitting in sunspots breaking through the forest canopy along a river or pond, or patrolling the water's edge. Some species can be found in open fields far away from water while searching for prey or while migrating.

DESCRIPTION:

These insects characteristically have large rounded heads covered mostly by well-developed, compound eyes, legs that facilitate catching prey (other insects) in flight, two pairs of long, transparent wings that move independently, and elongated abdomens. They have three ocelli and short antennae. The mouthparts are on the underside of the head and include simple chewing mandibles in the adult (Hoell. *et al*., 1998).

Flight in the Odonata is direct, with flight muscles attaching directly to the wings; rather than indirect, with flight muscles attaching to the thorax, as is found in the Neoptera. This allows active control of the amplitude, frequency, angle of attack, camber and twist of each of the four wings entirely independently (Richard. *et al.*, 2016)

In most families there is a structure on the leading edge near the tip of the wing called the pterostigma. This is a thickened, hemolymph–filled and often colourful area bounded by veins. The functions of the pterostigma are not fully known, but it most probably has an aerodynamic effect and may also have a visual function. More mass at the end of the wing may also reduce the energy needed to move the wings up and down. The right combination of wing stiffness and wing mass could reduce the energy consumption of flying. A pterostigma is also found among other insects, such as bees.

The nymphs have stockier, shorter, bodies than the adults. In addition to lacking wings, their eyes are smaller, their antennae longer, and their heads are less mobile than in the adult. Their mouthparts are modified, with the labium being adapted into a unique prehensile organ for grasping prey. Damselfly nymphs breathe through external gills on the abdomen, while dragonfly nymphs respire through an organ in their rectum.

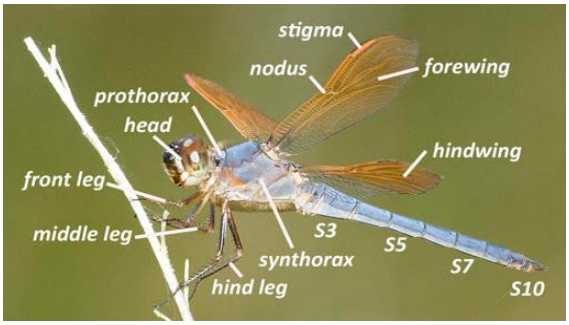

Fig 1a: Morphology of dragonfly

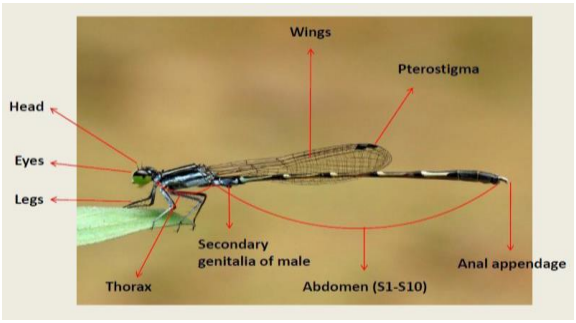

Fig 1b: Morphology of damselfly

Dragonflies (Anisoptera) make up the more specious of the two suborders and are much more easily observed than their dainty relatives, the damselflies. They have large eyes that take up nearly the entire head surface and when not contiguous are not as widely separated as within the damselflies. They also have a very robust body structure to support a massive musculature that propels their large, broad wings and at rest hold their wings either out to the side or out and downward (or even somewhat forward). Dragonflies are unmatched as fliers and have a very agile, deliberate flight. Males are often territorial, defending oviposition sites from other males. These insects are commonly found around ponds and open bodies of fresh water and large blacktop parking lots (perhaps parking lots resemble open bodies of water to odonates where they search for prey and mates). There are a number of species that disperse away from water for a time before returning with a mate to breed and deposit eggs.

Damselflies (Zygoptera) comprise the more morphologically diverse suborder of odonates. Eyes separated by more than the width of a single eye, abdomen much longer than wings, very slim body structure and a simple fluttering flight and when at rest most species hold their wings folded back over the abdomen in damselflies. Damselflies can often be quite spectacular in colour such as the ebony jewelwing damselfly.

Fig 2a: Eyes of dragonfly

Fig 2b: Eyes of damselfly

- Eggs: Odonate eggs display a large array of shapes, from those that resemble tiny rice grains to minute mangos. Odonates oviposit in three ways: endophytic (within a plant), epiphytic (on the surface of the plant), and exophytic (on water or land), (Corbet 1999). Generally, eggs oviposited endophytically are several times longer than wide while those laid epiphytically and exophytically are ellipsoidal to subspherical (Corbet 1999). Clutch sizes can be as large as 1500, with some females depositing several thousand eggs in a lifetime (Corbet 1999). Eggs hatch seven to eight days after oviposition but hatching can be postponed for up to 80 days (Miller 1992) and in one case 360 days (Sternberg 1990).
- Immature odonates (naiads): Immature odonates are sometimes referred to as larvae or nymphs, but here will be referred to as naiads because odonates are aquatic hemimetabolous (lacking a pupal stage) insects as immature. Naiads live in most aquatic habitats. Some can even survive in salt water (Corbet 1999). All naiads are voracious predators feeding on everything from small invertebrates such as mosquito larvae to smaller vertebrates such as fish and frogs. Naiads will moult nine to 17 times before becoming adults (Corbet 1999). The number of generations per year depends on the species of odonate. Species at higher altitudes or in dry environments usually have one generation per year while those in tropical habitats may undergo multiple generations per year depending on the availability of appropriate habitats.

When naiads are ready for their final moult they leave the water and crawl onto the bank or vegetation where they will moult into adults. Much like a caterpillar emerging from a chrysalis, they need to pump up their wings and allow their bodies to harden before they can be effective fliers. A newly emerged odonate is teneral (soft). A teneral dragonfly has glossy wings and the colours on the body are often pale. Several days after emerging and hardening completely, a dragonfly will have taken on the colours of an adult dragonfly.

- Adults: Identifying males and females is not difficult. Males will have what appears to be a pouch on the second and third abdominal segments that contains secondary genitalia. The actual male genitalia are found on the last abdominal segments along with a grasping structure used to hold the female while mating. The male produces sperm at the tip of the abdomen and transfers this sperm to the secondary genitalia where the female will have access to it. Females do not have secondary genitalia or grasping structures at the end of the abdomen but instead have a single genital opening and a small ovipositor at the end of the abdomen that will be used to oviposition her eggs normally; the male dragonfly is more colourful while the female will be a dull brown or grey. This is not true for all odonates. For example, both sexes of *Calopteryx maculata* are very similar in coloration with the exception of the female having a white pterostigma while the male does not.
- When odonates mate they form what is called a "mating wheel." The wheel is formed when the male grasps the female behind the head and the female raises the tip of her abdomen forward to come in contact with the secondary genitalia of the male. Odonates can often be seen flying in tandem in this fashion.

Fig 3: Life stages of dragonfly

ECONOMIC IMPORTANCE:

Most dragonflies and damselflies are regarded as beneficial insects because they feed on small flying insects such as mosquitoes, blackflies and other blood sucking flies and act as important bio-control agents of these harmful insects. They may also catch and eat honey bees -- then they are regarded as pests by the beekeepers.

In some parts of Europe, dragonflies are considered a threat to the poultry industry because they transmit *Prosthogoniums pellucidus* ,a parasitic flatworm. Dragonfly naiads become infected by ingesting cysts of the flatworm. These cysts survive into adulthood of the dragonfly and may spread to birds (particularly poultry) that catch and eat the adult dragonflies. The flatworm cysts dissolve in the bird's intestine and infection spreads into the cloaca and reproductive organs. The Dutch have a maxim: "Hide the hens, the dragonflies are coming."

ODONATES AS BIOLOGICAL INDICATORS:

Deterioration in the quality of hydrosphere, lithosphere and atmosphere may be attributed to the unhealthy anthropogenic practices and unplanned urbanization and industrialization (Arjun Shukla *et al*., 2016) in such situations, it is essential to have a base line data of fauna which are employed as indicators of ecosystem health. Odonata (Dragon flies and Damsel flies) is a good indicator of environmental changes as their larvae and adult both are sensitive to habitat degradation and climate changes. They can be used as environmental sentinels and as whistle-blowers for freshwater health, providing an effective tool for freshwater monitoring.

Odonates can act as bio - indicator of water quality in rivers because they rely on high quality water for proper development in early life. They are sensitive to disturbances at both small and large spatial scale. Since their diet consists entirely of insects, odonate density is directly proportional to the population of prey, and their abundance indicates the abundance of prey in the examined ecosystem [Golfieri *et al.,* 2016.].Species richness of vascular plants has also been positively correlated with the species richness of dragonflies in a given habitat. This means that in a location such as a lake, if one finds a wide variety of odonates, then a similarly wide variety of plants should also be present. This correlation is not common to all bio - indicator, as some may act as indicators for a different environmental factor, such as the pool frog acting as a bio - indicator of water quality due to its high quantity of time spent in and around water [Sahlén *et. al.,* 16 May 2000].

In addition, odonates are very sensitive to changes to average temperature because they have a tropical evolutionary origin and their distribution is temperature dependent. Many species have moved to higher elevations and latitudes as global temperature rises and habitats dry out. Changes to the life cycle have been recorded with increased development of the instar stages and smaller adult body size as the average temperature increases. As the territory of many species starts to overlap, the rate hybridization of species that normally do not come in contact is increasing [Bybee *et al.,* December (2016)]. Studies show that an increase in oxygen content of water increases both species diversity and abundance of both aquatic larvae and arial adults (Catling, 2005). If global climate change continues many members of Odonata will start to disappear. Because odonates are such an old order and have such a complete fossil record they are an ideal species to study insect evolution and adaptation. For example, they are one of the first insects to develop flight and it is likely that this trait only evolved once in insects, looking at how flight works in odonates, the rest of flight can be mapped out [Bybee *et.al.*, December 2016].

The dragonflies and damselflies, is unique to be used as an ecological indicator for water quality because of its close relationship with aquatic ecosystems and relative ease of observation and species-level identification. Odonata (dragonflies and damselflies) are used as bioindicators for wetland quality in Europe, Japan, the USA, and Australia [V. Clausnitzerand R. Jodicke, 2004.] and in South Africa [D.A.B, Stewart and M.J. Samways, 1998.].

TABLE 1: CERTAIN SPECIES OF ODONATES THAT HELP IN THE WATER QUALITY ANALYSIS:

SPECIES	**WATER QUALITY**
• *Bradinopyga geminate*	Excellent or good
• *Agriocnemis pieris*	Medium
• *Zyxomma petiolatum* • *Ceriagrion cerinorubellum* • *Vestalis apicalis* • *Trithemis aurora* • *Tetrathemis platyptera* • *Orthetrum taeniolatum* • *Orthetrum glaucum* • *Gynacantha bayadera* • *Gynacantha dravida* • *Brachythemis contaminate* • *Pseudagrion indicum* • *Pseudagrion rubriceps* • *Acisoma panorpoides*	Very bad or not suitable for consumption

AIM AND OBJECTIVE

AIM:

To study the diversity of odonates at two selected sites and to analyse the water quality by using odonates as indicator.

OBJECTIVE:

- Identification of Odonates (dragonflies and Damselflies) of the study area (Kakkanad, Ernakulam and Naduvile, Kottayam).
- Create a base line data of odonates of the study area.
- An analysis of odonate diversity of the area and comparison with water quality to identify its role as an ecological indicator.

REVIEW OF LITERATURE

Dragonflies and Damselflies satisfy most selection criteria for lentic bio- indicators of grazing impacts. Intensive cattle grazing affect most of the Canadian prairie pothole region but the effects of grazing on wetland are poorly understood. In 2005, the vegetation structure and invertebrate community composition of 27 prairie potholes in Canada were studied and compared to understand more about the use of odonates as biological indicators of grazing effects on Canadian prairie wetlands. Removal of emergent vegetation by cattle grazing decreased odonate abundance and reproductive effort. Shorter plant stems resulted in significantly fewer damselflies. Overall it was found that the diversity was affected by the height of key plant species, highlighting the importance of the vegetation structure of emergent vegetation for breeding and adjacent upland vegetation for nocturnal roosts. Wetland vegetation structure was more important than vegetation composition to the life history of odonates. It was also established that the larval odonate community can be an accurate bio- indicator of intactness and diversity of overall aquatic macro-invertebrate community in Canadian prairie wetlands.

Larvae of almost all of the 5680 species of the insect order odonate are dependent on freshwater habitats. A study was done in 2008 to understand the global diversity of dragonflies in freshwater. The paper discusses diversity, summarises the biogeography of dragonflies in the different bio geographical regions and gives the total number of species and genera per family per bio geographical regions. The highest diversity is found in flowing waters in rain forest of the tropics, the Oriental and Neotropical regions being the most specious. Examples are given of areas of particular diversity, in terms of areas of endemism, presence of ancient lineages or remarkable recent radiations etc.

Odonates are amongst the most reliable arthropod bio- indicators for monitoring riparian ecosystems. A study was conducted in 2017 to learn the use of odonate functional diversity in evaluating riparian conservation and restoration outcomes. 45 sites across six river- systems in north eastern South Africa was surveyed, to compare odonate FD and standardised effect size of odonate FD in riparian systems that had been invaded by alien plants, cleared of alien invasive and sites that had never been invaded (15 sites each). Odonate FD was found to be

lower in sites were invasion had occurred than those that had been cleared of alien riparian vegetation and those that had never been invaded.

Odonate diversity in buffer area of Similipal Biosphere reserve was observed, 58 species were recorded. Libellulidae was the richest family with 31 species and Orthetrum was the most common genera. The sub - order Zygoptera was represented by 23 species and 35 species represented sub - order Anisoptera. In the buffer area high anthropogenic disturbances were observed which creates high biotic pressure on forest and reduction in odonate diversity.

A study was conducted to understand the seasonal variation of dragonfly diversity in Muthupet Mangrove Forest, Tamil Nadu, India. The study was aimed at examining the diversity and dominance of dragonfly in Muthupet mangrove forest in Thiruvarur District, Tamil Nadu. It was carried out for a period of one year from January 2014 to December 2014. Combine technique sampler (Core and Sweeping net) were used for sampling of Odonata. Totally 8 species (*Rhyothemis variegata, Anax guttatus, Pantala flavescens, Brachythemis contaminata, Orthetrum sabina, Diplacodes trivialis, Crocothemis servilia and Tramea basilaris*) of Anisoptera (dragonflies) were recorded and all these species were grouped into two families. Libellulidae was the dominant family with 7 species followed by Aeshnidae family (1 species). Species diversity and abundance was highest in the months of monsoon and dropped to the minimum in the months of summer.

An inventory was carried out in 2016; to document the over looked odonate diversity in four habitat types (hill stream, river, reservoir and pond) of Koraput district, Southern Odisha, India. The study recorded 64 species representing 45 genera under 9 families. Maximum species were recorded along hill streams. 41 species were recorded from single habitat type, of which 37 species were confined to hill streams. A decreasing trend in species diversity was observed from the water bodies in forested area to human dominated landscapes indicating human impact on odonate species diversity. Ditch jewel (*Brachythemis contaminata*) was most frequently sighted in the water bodies near human habitations, indicating highly polluted water, whereas species like common Clubtail and common Hooktail were only recorded along hill streams, indicating unpolluted water.

Odonate diversity of Nalsarovar Bird Sanctuary, a Ramsar site in Gujarat, was studied between January 2015 and July 2017. A total of 46 species belonging to two suborders,

six families, and 27 genera were recorded, which included 14 species of Zygoptera (damselfly) and 32 species of Anisoptera (dragonfly). Out of the 46 species, 40 species were new records for the Nalsarovar Bird Sanctuary. As a result of the survey a need to monitor changes taking place in Odonata species composition after influx from Narmada canal at Nalsarovar was emphasized.

Odonata diversity of Salim Ali Bird Sanctuary and its adjacent areas in Thattekkad, Kerala, India were documented from 2010 to 2012. Opportunistic observations were carried out to record species diversity. Eighty-two species of Odonata, which included 51 species of Anisoptera (dragonflies) and 31 species of Zygoptera (damselflies), were recorded during the study. Of this 21 species are endemic to the Western Ghats. The presence of the IUCN categorized nearly threatened species like *Megalogomphus hannyngtoni* and vulnerable species like *Platysticta deccanensis* and *Protosticta sanguinostigma* was recorded.

A preliminary checklist of odonates in Kerala Agricultural University (KAU) campus, Thrissur District, Kerala, was prepared by C.K. Adarsh, K.S. Aneesh & P.O. Nameer. The Kerala Agricultural University (KAU) main campus is located at Vellanikkara, Thrissur District, Kerala. The area lies between 100 32'–100 33'N and 760 16'–760 17'E, with an average altitude of 50m. KAU campus is located very close to the Peechi - Vazhani Wildlife Sanctuary, Western Ghats. The odonates were studied for one year from February 2011 to March 2012. Surveys were conducted throughout the campus to cover all the habitats. Observations were done over three Seasons which are summer, monsoon and winter. All specimens were photo documented and these images were crosschecked with standard references and field guides. A total of 52 species of odonates, including 36 species of Anisoptera and 16 species of Zygoptera were recorded from the Kerala Agricultural University main campus. The relative abundance analysis showed that 21 species out of 52 found to be occasional, 13 were common, 10 very common, 7 rare and one very rare. The conclusion was that the odonate diversity did not vary much between the different Seasons at KAU campus during the study period.

A study was conducted at Chinnar Wildlife Sanctuary, Idukki District, Kerala, the southern Western Ghats, to assess the diversity of odonates. The odonates of the Chinnar wildlife sanctuary was surveyed by an all-out search method from September to December 2012. The study was conducted at five different sites within Chinnar wildlife sanctuary. At each study

site 5 to 10 days were spent searching for dragonflies and damselflies. Upon spotting them the odonates were photographed and identification was confirmed using taxonomic monographs and field guides. They reported 48 species of odonates, which include 31 species of Anisoptera (dragonflies) and 17 species of Zygoptera (damselflies). Among the dragonflies, the family Libellulidae dominated with 25 species, while Coenagrionidae with seven species was the dominant family among the damselflies. The odonate diversity of Chinnar WS accounted for 31.16 % of the odonates in Kerala and 27.58% of the odonates of the Western Ghats. Chinnar also recorded two species of odonates that are endemic to the Western Ghats, which are, the Pied Reed Tail *Protosticta gravelyi* and the Travancore Bamboo Tail *Esme mudiensi.*

Study on the diversity and abundance of odonates in three different geographical divisions in Kerala was carried out by Nitha Bose C and Francy K. Kakkassery from the Research and Postgraduate Department of Zoology, St. Thomas' College (Autonomous), Thrissur. The objective of their study was to analyse how different geographical features affect the distribution and diversity of odonates. For the survey, 12 different locations of Thrissur and Ernakulam districts were selected and they were categorised under three geographical divisions- the eastern highlands, the central midlands and the western coastal plains. The observation was carried out for 1 year from August 2017 to July 2018. As a result of the study, a total of 3392 individuals were recorded. Out of the 61 species found, 35 species belong to suborder Anisoptera, coming under 3 families and 26 genera. The remaining 26 species belong to suborder Zygoptera, coming under 8 families and 15 genera. Maximum species richness was observed in the eastern highlands, followed by central midlands and western coastal plains. Similarly, maximum values of diversity indices were recorded from eastern highlands, followed by central midlands and western coastal plains. Their observations indicate that Marotichal, Athirampilly, Vazhani and Malayatoor in the eastern highlands have a diverse odonate fauna.

In order to determine whether a relationship existed between water quality and odonate fauna, data were collected from four selected sites of Pala Municipality, Kottayam District, Kerala. The Water Quality Index, Simpson's diversity index and Species abundance values were calculated. The observation was that the area with highest water quality index shows highest species richness and the area with lowest water quality index shows lowest species richness. The abundance of Brachythemis contaminata sp. in the polluted area and Bradinopyga geminate sp. in the non-polluted area shows their indicator efficiency. A potential exists for

Odonata species diversity, numbers of individuals and occurrence of particular species to be used as a bio - indicator of water quality.

Kasargod district of Kerala has been rarely explored for Odonates. Odonate survey was done in Kidoor, located in Kumbla grama panchayath on 8th and 12th of July 2019. Covering two different habitats i.e., lateritic areas with natural ponds and paddy fields. A total of 18 species of Odonates, including 13 species from the sub- order Anisoptera and 5 species from sub-order Zygoptera were recorded. In the sub- order Anisoptera, Libullidae was the dominant family followed by Aeshnidae and Gomphidae, whereas in the sub- order Zygoptera, the dominant family was Coenagrionidae followed by Platycnemididae.

A study to prepare a checklist of Odonate of Wayanad district was done in 2020. Occasional surveys were conducted in 2009, 2013, 2014, 2015 and 2017 in three locations of Wayanad district of Kerala viz. Thiunelli, Kuruva Island and Kalpetta and the observations were tabulated. Fifty nine species in 40 genera and seven families are included of which Libellulidae included the most number of species followed by the Coenagrionidae.

A year-long study was conducted to study the dragonflies and damselflies of the Kole Wetlands, a Ramsar site in central Kerala and understand their seasonality. Checklist survey method was used to sample adult odonates in 30 randomly chosen locations. A total of 44 species (30 dragonflies and 14 damselflies) belonging to 33 genera and eight families were recorded in the study area. Species richness showed a peak in the post- monsoon season and a dip in the summer. The observations support the value of the Kole Wetlands in providing valuable resources for Odonates.

MATERIALS AND METHODS

STUDY AREA:

The study was done in two sites, the first site being Naduvile, near Vaikom in Kottayam district. The second site was Poyachira pond, adjacent water canals and premises in Kakkanad, Ernakulam district.

Naduvile village (Vaikom, Kottayam): Naduvile village is located in Vaikom Tehsil of Kottayam district in Kerala, India. It is situated 1km away from sub-district headquarter Vaikom and 34km away from district headquarter Kottayam. As per 2009 stats, Udayanapuram is the gram panchayat of Naduvile village. Naduvile is a beautiful, scenic place with paddy fields and water bodies covered with beautiful pink, and white water lilies. It is a peaceful, quiet spot and part of the Vembanad watershed area. The total geographical area of village is 908 hectares. Naduvile has a total population of 8,593 peoples. There are about 2,131 houses in Naduvile village. Vaikom is nearest town to Naduvile which is approximately 4km away. Location coordinates: 9.7581° N, 76.4187° E

Poyachira pond, adjacent water canals and premises (Kakkanad, Ernakulam): Poyachira is a big and beautiful pond in the heart of Kakkanad city. The locality is densely populated and has many uncultivated fields which might invite industrialists to set up huge projects in near future. The water from the adjacent canals drains into the Kadambrayar River. This place is highly affected by anthropogenic activities. Kakkanad is located near Thrikkakara, the capital of the mythical King Mahabali. In verse 273 of Na̲n̲n̲ūl, a 13th-century book on Tamil grammar, Sankara Namasivayar recites a venpa that describes the twelve districts of Tamil Nadu where Koduntamil is spoken, as Thenpandi Nadu, Kutta Nadu, Kuda Nadu, Karka Nadu, Venadu, Poozhi Nadu, Pandri Nadu, Aruva Nadu, Aruva Vadathalai, Seetha Nadu, Malai Nadu and Punal Nadu. "Karka Nadu" is believed to be a reference to Kakkanad. The old name of Kakkanad is karkanad-thrikakara. Location Coordinates: 10.017°N 76.344°E.

TWO SITES TAKEN FOR ODONATE IDENTIFICATION:

Fig 4a: Naduvile

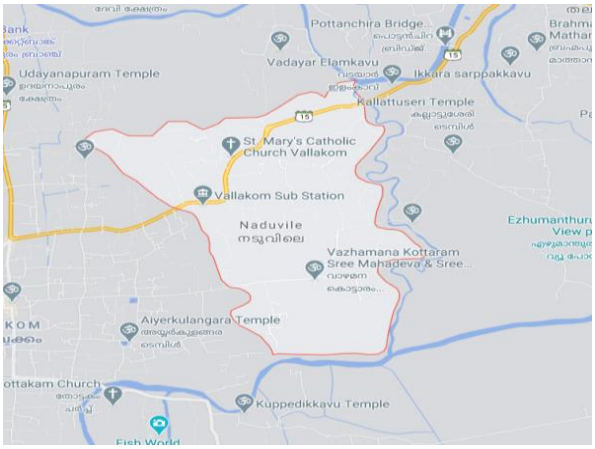

Fig 4b: Map showing Naduvile village

Fig 5a: Poyachira Pond

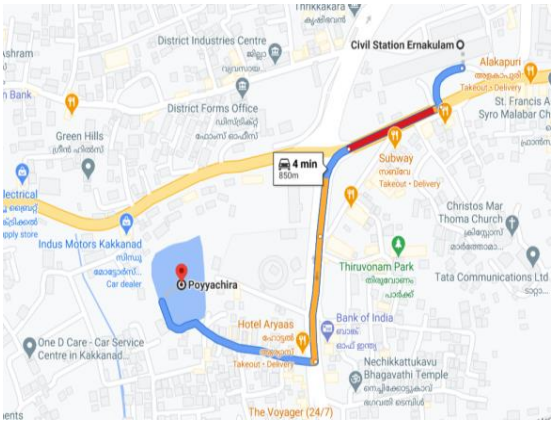

Fig 5b: Map showing Poyachira Pond

IDENTIFICATION OF ODONATES:

Procedure: Sampling of odonates from Naduvile, Vaikom was carried out from 2020, January 4-5 as part of the Vembanad Odonate Survey, Organised by the Department of Forests and Wildlife, Social Forestry Division, Govt. of Kerala and Tropical Institute of Ecological Sciences (TIES), Kottayam. Odonate sampling from Kakkanad was done from July 2020 to January 2021. The adult odonates were observed and photographs were taken using the Canon EOS1300D SLR camera and Realme C1 mobile camera. Sampling was conducted between 09:00 am and 01:00 pm when the insects were most active and on some sunny days between 04:30 pm and 05:30 pm. The preliminary identification of odonates were done using the Pocket Guide To Dragonflies And Damselflies Of Kerala – a guide put together by TIES and by uploading pictures in India biodiversity portal and later the proper identification was done by experts from TIES, Kottayam- Dr Abraham Samuel, Dr Punnen Kurian and using various visual keys – Dragonflies and Damselflies of Kerala (TIES, Kottayam). The diversity of species in each of the sites was tabulated. Based on the result obtained the quality of water in the sampling sites were analysed. Presence of species such as *Ceriagrion cerinorubellum, Brachythemis contaminata,* and *Acisoma panorpoides* indicates contamination in water bodies. Presence of species *Bradinopyga geminate* indicates that the water is of excellent quality.

RESULT

TABLE 2: Showing the identified species of odonates from the three sites.

NAME OF THE SPECIES	KAKKANAD	NADUVILE
DRAGONFLY		
Amber Winged Marsh Glider (*Hydrobasileus croceus)*	-	+
Asian Pin Tail, Trumpet Tail *(Acisoma panorpoides*)	+	+
Brown backed red marsh hawk (*Orthetrum chrysis*)	+	-
Common Picture Wing (*Rhyothemis variegate)*	+	+
Common redbolt (*Rhodothemis rufa*)	-	+
Common Scarlet (*Crocothemis servilia)*	-	+
Crimson tailed marsh hawk (*Orthetrum pruinosum*)	+	-
Ditch Jewel *(Brachythemis contaminata)*	+	+
Globe Skimmer(*Pantala flavescens*)	-	+
Granite Ghost(*Bradinopyga geminata*)	+	-
Greater crimson glider (*Urothemis signata*)	-	+
Green Marsh Hawk *(Orthetrum sabina*)	+	+
Ground Skimmer *(Diplacodes trivialis)*	-	+
Pied Paddy Skimmer (*Neurothemis tullia)*	+	+
Yellow Patched Lieutenant *(Brachydiplax chalybea)*	-	+
DAMSELFLY		
Blue River Damsel *(Pseudagrion microcephalum*)	+	+

Coromandel marsh dart, yellow wax tail *(Ceriagrion coromandelianum)*	+	-
Orange-Tailed Marsh Dart (*Ceriagrion cerinorubellum*)	-	+
Pygmy Dartlet *(Agriocnemis pygmaea)*	+	-
White Dartlet (*Agriocnemis pieris*)	-	+

(Red colour indicates the species that are seen in contaminated water) (+ indicates the presence of that species; - indicates the absence)

IDENTIFIED SPECIES:

1. Amber Winged Marsh Glider *(Hydrobasileus croceus*) (Plate1, Fig. 1): It is a large reddish-brown dragonfly with golden-amber tinted wings. Eyes are reddish-brown above, yellowish below. Its thorax is olivaceous suffused with golden reddish-brown, its base of hind-wings have a moderately broad dark reddish-brown mark. Abdomen is olivaceous, changing to ochreous towards anal end, marked with black. Segments 4 to 9 have apical and basal dorsal black wedge-shaped spots. It breeds in weedy ponds and lakes. The male is often seen patrolling over water, and rarely perches. When perched, they prefer to hang vertically on twigs inside dense shrubbery.

2. Asian Pin Tail, Trumpet Tail (*Acisoma panorpoides*) (Plate 2, Fig. 2&3): It is a small dragonfly with blue eyes. Its thorax is azure-blue marbled with black to form a beautiful pattern on the dorsum and the sides. Abdomen is azure-blue, marked with black. Segments 1 to 5 have sutures finely and ventral borders more broadly black. There is a dorsal stripe which broadens at the jugal sutures and apical borders of segments. There is a speckled stripe on sub-dorsum of segments 1 to 4. There is a large ventro-lateral spot on each of segments 3 to 5. Segments 6 and 7 are black with a large spot of blue on each side. Segments 8 to 10 are entirely black. Anal appendages are bluish-white. Female is similar to the male; but with greenish-yellow eyes, thorax and abdominal segments up to 5.The characteristic shape of the abdomen will serve to distinguish this species from other Libellulidae. It is found in subtropical or tropical swampy or marshy habitats. It has a very weak and short flight and keeps close to the herbage and reeds in the heavily weeded ponds and lakes where it breeds.

3. Brown backed red marsh hawk (*Orthetrum chrysis*) (Plate 1, Fig. 4): It is a medium sized dragonfly with dark thorax and blood-red abdomen. It looks very similar to *Orthetrum pruinosum* in shape and size; but can be distinguished by the colour of the abdomen. The abdomen of the female is ochreous brown. It breeds in pools and marshes.

4. Common Picture Wing (*Rhyothemis variegata*) (Plate 1, Fig. 5): It is a medium-sized dark bodied dragonfly with colourful wings tinted with pale yellow. There are a few black spots on the apices and nodes of the fore-wings. There is a large patch in the base of the hind-wings, marked with black and golden yellow. In females, the apical half of the fore-wings are transparent; basal half tinted with golden-yellow with black marks. The apical ends of the hind-wings are transparent; rest of wings marked with golden-yellow and black. It breeds in marshes, ponds and paddy fields. They appear to have weak flight and can easily be mistaken for butterflies

5. Common redbolt (*Rhodothemis rufa*) (Plate 1, Fig. 6): It is a medium sized dragonfly with red eyes, thorax and abdomen. But young males and females have a mid-dorsal citron-yellow stripe in the pro-thorax and a citron-yellow stripe on mid-dorsum of the abdominal segments. These marks get obscured by pruinescence in adult males. Colour of female is brown. It breeds in open ponds, marshes and lakes.

6. Common Scarlet (*Crocothemis servilia*) (Plate 2, Fig. 7): It is a medium sized blood-red dragonfly with a thin black line along the mid-dorsal abdomen. Its eyes are blood-red above, purple laterally. Thorax is bright ferruginous, often blood-red on dorsum. Abdomen is blood-red, with a narrow black mid-dorsal carina. Anal appendages are blood-red. Female is similar to the male; but with olivaceous-brown thorax and abdomen. The black mid-dorsal carina is rather broad. It breeds in ponds, ditches, marshes, open swamps and rice fields.

7. Crimson tailed marsh hawk (*Orthetrum pruinosum*) (Plate 2, Fig. 8): It is a medium-sized dragonfly with dark thorax with slight purple pruinescence and purple collared abdomen. Young males have red abdomen as in *Orthetrum chrysis*. Females of both species look similar. It breeds in ponds, lakes and sluggish streams

8. Ditch Jewel (*Brachythemis contaminata*) (Plate 2, Fig. 9): It is a small dragonfly with brown-capped yellowish-green eyes. Its thorax is olivaceous-brown, marked with a reddish-brown humeral stripe and two brownish stripes on each side. Wings are transparent; but with a broad bright orange fascia extending from base to within 2 to 3 cells of reddish pterostigma.

Abdomen is ochreous-red, marked with dorsal and sub-dorsal brown stripes. Anal appendages are in reddish-brown. Female is similar to the male; but in pale yellowish-green colour. Wings are transparent, tinted with yellow at extreme base; but the bright orange fascia seen in the male absent. It breeds in weedy ponds, lakes, and slowly moving streams; especially in sluggish waters. It is very common along sewage canals, tanks, ponds and ditches.

9. Globe Skimmer *(Pantala flavescens*) (Plate 2, Fig. 10): The front side of the head is yellowish to reddish. The thorax is usually yellow to golden coloured with a dark line and hairy. There were also specimens with a brown or olive thorax. The abdomen has a similar colour as the thorax. The wings are clear and very broad at the base. There, too, there are some specimens with olive, brown and yellow wings. On Easter Island there are wandering gliders with black wings. The pterostigma turns yellowish. The transparent wings may turn a yellowish shade towards the tip. The chestnut-red eyes take up most of the head, as is usual in the large dragonflies (Anisoptera).The above colours explain the many scientific descriptions of this species under different names. Females show some differences compared with males. The general rule is that the males have reddish yellow abdomen marked with black whereas the females lack the reddish wash in abdomen. The males have golden yellow patch on base of hind wings and narrow apical brown spot at the hind border of wings. The females lack apical brown patches in wings. In mainland males, the length of the femur, the longest leg section, varies; they also have longer front and shorter hind wings than the females. The island representatives, however, have the front and hind wings longer than the female and the femur is the same for both sexes. There are other differences between mainland and island specimens, particularly in terms of colouring. Island representatives are generally darker.

10. Granite Ghost (*Bradinopyga geminata*) (Plate 2, Fig. 11): It is a medium sized dragonfly with brown-capped grey eyes. Its thorax is cinereous, marbled and peppered with black in a very irregular manner. Wings are transparent with dual colour pterostigma, black at centre and pure white at distal and proximal ends. Abdomen is coloured very similarly to thorax; black marbled with yellow, but with a more definite plan. Segments 3 to 8 have pale basal annules interrupted on dorsum, and formed by two elongate parallel spots. There is a triangular apical sub-dorsal spot and a pale mid-dorsal spot. Anal appendages are creamy-white. Female is similar to the male. Taking advantage of its cryptic coloration, it always rests flat on slab rock or cement-plastered walls, where it almost invisible. Adults occupy habitat near water bodies, such as pools, irrigation channels, wells, and containers with

standing water. It breeds in rainy hollows in the rocks or in wells and small cemented tanks. The species has been studied as a predator of the disease-carrying yellow fever mosquito (*Aedes aegypti*). The larvae of the dragonfly consume the larvae of the mosquito in the standing-water habitat types that both occupy.

11. Greater crimson glider (*Urothemis signata*) (Plate 2, Fig. 12): It is a medium-sized dragonfly with red eyes, thorax and abdomen. Its wings are transparent with an amber collared spot surrounded by a dark-brown patch in the base of hind-wings. Its abdomen is blood-red, with some black marking on the dorsum of segments 8 and 9. Female is similar to the male; but yellowish in colour. The black spots on the dorsum are repeated on segments 3 to 7. Juvenile and sub-adult males also have these marks.[6]

This species breeds in ponds and slow flowing rivers, typically in lowland areas. The males often found perch on exposed twigs. This species has managed to colonise urban water bodies and park ponds.

12. Green Marsh Hawk (***Orthetrum sabina*) (Plate 3, Fig. 13):** It is a medium-sized dragonfly with a wingspan of 60-85mm. Adults are greyish to greenish yellow with black and pale markings and green eyes. Its abdomen is greenish-yellow, marked with black. Pale markings on segment four of the abdomen does not extend into the posterior section when viewed from above on Orthetrum sabina. Females are similar to males in shape, colour and size; differing only in sexual characteristics. This dragonfly perches motionless on shrubs and dry twigs for long periods. It voraciously preys on smaller butterflies and dragonflies.

13. Ground Skimmer (*Diplacodes trivialis*) (Plate 3, Fig. 14): It is a small dragonfly with bluish eyes and greenish-yellow or olivaceous thorax and abdomen with black marks. In very old adults, the whole thorax and abdomen become uniform pruinosed blue. Clear wings, without apical or basal markings, and the creamy white anal appendages and deep pruinescence in adults help to distinguish this species from others in its genus. It breeds in ponds, wet rice fields, shallow lakes, drainage ditches and similar habitats. It is one of the most common dragonflies in Asia, found in both the plains and hills and in dry and wet areas.

14. Pied Paddy Skimmer (*Neurothemis tullia*) (Plate 3, Fig. 15&16): It is a black dragonfly with a pale yellow mid-dorsal carina of thorax. Wings are hyaline for apical half and opaque steely blue-black for basal half which is bordered by a milky white patch towards the tip. Females differ remarkably from the males both in body-colouring and markings and in marking of the wings. Its body is greenish yellow with a bright yellow mid-dorsal carina of

thorax. Base of wings are amber yellow followed by a blackish brown patch. Apices of all wings are broadly opaque blackish brown and the reaming halves are pale yellow. It breeds in marshes, well vegetated ponds, lakes and rice fields. It perches very close to ground and its flight is very weak

15. Yellow Patched Lieutenant (*Brachydiplax chalybea*) (Plate 3, Fig. 17): The male of the species is 33 to 35 millimetres long and has a hind wing 24 to 27 millimetres long. It is powder blue with light brown sides and a dark tip to the abdomen. Wings are hyaline, with tinted burnt-brown base, fading to amber. The female is brownish yellow in colour with darker markings along the dorsal abdomen. Its wings lack the yellow tinge. This species can be easily distinguished from other species in this genus by its larger size, characteristic colour of the thorax, and bases of wings. This species is found in many types of wet habitat, including brackish and disturbed waters. The males are seen more often, due to their territorial behaviour. Females oviposit by "flicking" an egg mass out of the water into rocks and vegetation nearby.

16**. Blue River Damsel (*Pseudagrion microcephalum*) (Plate 3, Fig. 18):** It is a medium-sized damselfly with pale blue eyes, dark on top. They grow to 38mm in length. Its thorax is azure blue with black, broad dorsal stripes and narrow humeral stripes. Abdominal segments 1 and 2 are blue with black marks on the dorsum. Mark on segment 2 looks like a chalice or thistle-head. Segments 3 to 7 are black on dorsum and blue on the sides. Segments 8 and 9 are blue; 8 with a thick and 9 with a thin black apical annules. Segment 10 is black on dorsum and blue on the sides. Superior anal appendages are of the same length of segment 10; black and divided at the apices. Eyes and thorax of the female is bluish green, suffused with orange, marked as in the male; but black is replaced by orange. Colour of the abdomen is similar to the male; but paler. Segments 8 and 9 are also black with fine apical blue rings. Segment 10 is pale blue. *Pseudagrion microcephalum* looks similar to the common blue tail and the eastern billabong fly. The female is blue-grey to grey-green in colour. This species can easily be found near running water or still water. They usually rest on the plants either in the middle of ponds or at the water edges. It breeds in ponds, lakes and streams.

17. Coromandel marsh dart and **yellow wax tail (*Ceriagrion coromandelianum)* (Plate 4, Fig. 19):** It is a medium sized damselfly with yellowish green eyes. Its thorax is olive green above and yellowish green on the sides. Its abdomen is yellow. Its anal appendages are citron-yellow or ochreous, the inferiors tipped with black. The superiors are sub-quadrate as

seen from above, with the corners gently rounded. The inferiors are sloped strongly upwards, broad at base, then tapering rapidly to an acute point. Female is more robust and dull coloured. Its thorax is more greenish and abdomen is golden yellow to brown. It breeds in weedy ponds, ditches, and rice fields.

18. Orange-Tailed Marsh Dart (*Ceriagrion cerinorubellum*) (Plate 4, Fig. 20): It is a medium sized damselfly with greenish eyes, bluish above. Its thorax is yellowish green. Segments 1, 2 and basal half of three and apical half of 7 to 10 are in brick red colour. Other segments are black on dorsal half and pale blue on the ventral half. Female is similar to the male; but more robust and with dull colours. It breeds in weeded ponds, marshes and other Stillwater forms.

19.Wandering Midget (*Agriocnemis pygmaea*) (Plate 4, Fig. 21): It is a small damselfly with black capped green eyes, black thorax with apple green stripes on lateral sides. Segments 1 to 7 of its abdomen is black on dorsum and pale green on ventral half. The remaining segments are orange-red. Very old males may get pruinosed on the dorsum of the head and the thorax with snowy white, making all the markings beneath being quite obscured. Female is more robust and exhibits several colour morphs. The green colour of the male is replaced by red in the females in the red forms. In androchrome forms, the female has same green colours as in the male. It breeds in marshes and ponds.

20. White Dartlet (***Agriocnemis pieris*) (Plate 4, Fig. 22):** It is a slender, small damselfly but very conspicuous with its bluish white colour with dorsal black spots. Its eyes are pale blue with a black cap; thorax is black on dorsum and pale blue on the sides. Its abdomen is pale blue, deepening on the last four segments. They are marked with black on dorsum up to segment 8. *Agriocnemis lacteola* lacks these dorsal black marks on segments 4 to 10 of the abdomen. Female is similar to the male; but more robust and the blue is more dark. Its abdomen is marked with black up to segment 9. There is a narrow longitudinal lateral stripe of blue on segment 8. The females of this species exhibit sexual mimicry. One group mimics the males' colour (androchrome). Other groups will have their own female colouration (cytochromes). It breeds in marshes and wet grasslands.

IMAGES OF IDENTIFIED SPECIES:

Fig 1: *Hydrobasileus croceus*

Fig 2: *Acisoma panorpoides* (male)

Fig 3: *Acisoma panorpoides* (female)

Fig 4: *Orthetrum chrysis*

Fig 5: *Rhyothemis variegata*

Fig 6: *Rhodothemis rufa*

Plate 1: Fig. 1-6

Fig 7: *Crocothemis servilia*

Fig 8: *Orthetrum pruinosum*

Fig 9: *Brachythemis contaminata*

Fig 10: *Pantala flavescens*

Fig 11: *Bradinopyga geminata*

Fig 12: *Urothemis signata*

Plate 2: Fig. 7-12

Fig 13: *Orthetrum sabina*

Fig 14: *Diplacodes trivialis*

Fig 15: *Neurothemis tullia(male)*

Fig 16: *Neurothemis tullia(female)*

Fig 17: *Brachydiplax chalybea*

Fig 18: *Pseudagrion microcephalum*

Plate 3: Fig. 13-18

Fig 19: *Ceriagrion coromandelianum*

Fig 20: *Ceriagrion cerinorubellum*

Fig 21: *Agriocnemis pygmaea*

Fig 22: *Agriocnemis pieris*

Plate 4: Fig. 19-22

DISCUSSION

The Odonate diversity in Naduvile near Vaikom, Kottayam was studied as part of the Vembanad Odonate Survey organized by the Department Of Forests And Wildlife, Social Forestry Division, Govt. of Kerala and Tropical Institute of Ecological Sciences, Kottayam. The study area is a Vembanad watershed area and the survey was conducted on 2020 January 4 and 5. A total of 15 species of odonates were identified, including 12 species of Anisoptera (dragonflies) and 3 species of Zygoptera (damselflies). *Neurothemis tullia* (Plate 3, Fig. 15& 16), *Rhyothemis variegate* (Plate 1, Fig. 5), *Acisoma panorpoides* (Plate 1, Fig. 2&3), *Crocothemis servilia* (Plate 2, Fig. 7), *Orthetrum sabina* (Plate 3, Fig. 13), *Brachydiplax chalybea* (Plate 3, Fig. 17), *Agriocnemis pieris* (Plate 4, Fig. 22), *Diplacodes trivialis* (Plate 3, Fig. 14), *Brachythemis contaminate* (Plate 2, Fig. 9),*Pseudagrion microcephalum* (Plate 3, Fig. 18), *Hydrobasileus croceus* (Plate 1, Fig. 1), *Urothemis signata* (Plate 2, Fig. 12), *Rhodothemis rufa* (Plate 1, Fig. 6), *Pantala flavescens* (Plate 2, Fig. 10), *Ceriagrion cerinorubellum* (Plate 4, Fig. 20) were the species found at Naduvile. Species like *Neurothemis tullia, Rhyothemis variegate, Acisoma panorpoides, Brachythemis contaminate, Pseudagrion microcephalum, Rhodothemis rufa, Diplacodes trivialis* were seen in abundance represented by both males and females of the species. The abundance of species such as *Acisoma panorpoides, Brachythemis contaminate* and *Ceriagrion cerinorubellum,* which are exclusively found in contaminated water bodies, indicates the water quality of the area. The water in that area is highly polluted and is not suitable for consumption. The presence of *Agriocnemis pieris* indicates that the water is of medium quality. The study area had many paddy field and water bodies including rivers, ponds and canals, of which the canals mainly lying close to the paddy fields were polluted because the canal is like a sink for harmful pesticides and chemical fertilizers used in the fields. But the area has the most diversity of the two places studied because of greater sources of water and the peaceful, green and rich environment. Experts who participated in the survey agree that the diversity of the locality is less and suggests that the flood calamities that occurred in Kerala could be a possible cause of this.

The second study area was at Kakkanad in Ernakulam- Poyachira pond, adjacent water canals and premises at Thanapadam which ultimately join Kadambrayar River. The locality has many uncultivated lands and has many houses and buildings. The odonates were observed

from 2020 August to January 2021 at varying intervals. A total of 11 species of odonate including 8 Anisoptera- *Neurothemis tullia*, *Rhyothemis variegata*, *Acisoma panorpoides, Orthetrum sabina*, *Bradinopyga geminata* (Plate 2, Fig. 11), *Orthetrum pruinosum* (Plate 2, Fig. 8), *Orthetrum chrysis* (Plate 1, Fig. 4), *Brachythemis contaminate* and 3 Zygoptera - *Pseudagrion microcephalum, Ceriagrion coromandelianum* (Plate 4, Fig. 19), *Agriocnemis pygmaea* (Plate 4, Fig. 21). *Neurothemis tullia, A.panorpoides and C. coromandelianum* were seen in abundance. The presence of *Acisoma panorpoides, Brachythemis contaminate* shows the contaminated nature of water bodies in this locality and its unavailability for consumption. But the presence of species *Bradinopyga geminata,* which is seen only at sites of excellent water quality shows there are sources with clean unpolluted water. This site has lesser diversity as a result of anthropogenic activities. The water canals are dumping sites of household wastes and are highly polluted as it is evident from the dark coloured water flowing in the canals and the dense growth of water hyacinth (*Eicchornia crassipes*).

Of all the 20 species of odonates identified from the two sample sites, 7 species are common to both areas which are 35 km apart from each other, showing their cosmopolitan distribution. The insect order odonata (the dragonflies and damselflies), is unique to be used as an ecological indicator for water quality because of its close relationship with aquatic ecosystems and relative ease of observation and species-level identification. They are widespread and represent one of the historically most studied insect groups and are well dependent on the ecological conditions of the environment (Corbet, 2004). Odonates rely on high quality water for proper development in early life. The decrease in water quality due to the effects of anthropogenic activities and continuing global changes is leading to the disappearance of many members of odonates. They are also good indicators of environmental changes as they are sensitive to changes in the habits, atmospheric temperature and the weather conditions (Tiple, 2012).

CONCLUSION

15 species of odonates (12 Anisoptera and 3 Zygoptera) were recorded in Naduvile near Vaikom of Kottayam district; Kerala and a total of 11 species (8 Anisoptera and 3 Zygoptera) were recorded from Poyachira pond and premises at Kakkanad. Odonate diversity of Naduvile was better owing to its location, being a watershed area and away from city. The lesser diversity in Kakkanad indicates the loss of biodiversity in cities with the increasing level of pollution and anthropogenic activities. Based on this study, it is understood that there is better quality water sources in Kakkanad than in Naduvile. As odonates tend to be sensitive to environmental conditions, the presence of certain species and also their abundance, are indicators of the water quality. High abundance in an area indicates good water quality and presence of species such as *Brachythemis contaminata* indicates poor water quality. The present study enables to create a base line data of Odonates in Kakkanad and Naduvile, a possibility to discover new or endangered species and monitor and evaluate the habitats of these odonates and thereby formulate strategies to conserve the water bodies and the environment.

REFERENCES

1. 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.
2. A Lee Foote, Christine L Rice Hornung. (2005). Ecological Entomology 30(3): 273-283.
3. A. Vivek Chandran, Subin K Jose, Sujith V Gopalan. (2021). Journal of Threatened Taxa 13 (3): 17963-17971.
4. Andrew, R.J., Subramanian, K. A. and Tiple, A. D. 2009. A Handbook on Common Odonates of Central India. South Asian Council of Odonatology: 65.
5. Arjun Shukla, S. Rai and B. K. Ahirwar. 2016. International Journal of Advances in Scientific Research 2(4), 89-93.
6. Balzan M. V (2012)
7. Bechly, G. (2002): *Phylogenetic Systematics of Odonata*. Schorr, M. & Lindeboom, M., eds, (2003): Dragonfly Research 1.2003. Zerf – Tübingen. ISSN 1438-034X (CD-ROM)
8. Bybee, Seth; Córdoba-Aguilar, Alex; Duryea, M. Catherine; Futahashi, Ryo; Hansson, Bengt; Lorenzo- Carballa, M. Olalla; Schilder, Ruud; Stoks, Robby; Suvorov, Anton (December 2016). "Odonata (dragonflies and damselflies) as a bridge between ecology and evolutionary genomics". *Frontiers in Zoology*. 13 (1): 46. doi: 10.1186/s12983-016-0176-7. ISSN 1742-9994. PMC 5057408. PMID 27766110.
9. Catling, P. M., R. A. Cannings& P. M. Brunelle, (2005). An annotated checklist of the odonates of Canada. Bulletin of American Odonatology 9:1-20.
10. Clark, T.E. & M.J. Samways (1996). Dragonflies (Odonata) as indicators of biotope quality in the Kruger National Park, South Africa. *Journal of Applied Ecology* 33: 1001–1012.
11. Clausnitzerand, V. &. Jodicke (eds), 2004. Guardians of the watershed. Global status of dragonflies: critical species, threat and conservation. International Journal of Odonatology 7: 279-294.
12. Corbet, P. (1993). Are Odonata useful as bioindicators? Libellula 12(3-4): 91–102.

13. Corbet PS. 1999. Dragonflies: Behaviour and ecology of Odonata. Comstock Publishing Associates, Cornell University Press. Ithaca, New York.
14. Darshana M Rathod, B. M. Parasharya. (2018). Journal of Threatened Taxa 10(8): 12117-12122.
15. Emiliyamma, K.G. & C. Radhakrishnan (2000). Odonata (Insecta) of Parambikulam Wildlife Sanctuary, Kerala, India. *Records of Zoological Survey of India* 98(1): 157–167.
16. Emiliyamma, K.G. & C. Radhakrishnan (2002). Additions to the Odonata of (Insecta) of Thiruvananthapuram District, Kerala. *Zoo's Print Journal* 17(10): 914–917; http://dx.doi.org/10.11609/JoTT.ZPJ.17.10.914-7
17. Emiliyamma, K.G. (2005). On the Odonata (Insect) Fauna of Kottayam District, Kerala, India. *Zoo's print Journal* 20(12): 2108–2110; http://dx.doi.org/10.11609/JoTT.ZPJ.1338.2108-10
18. Emiliyamma, K.G., C. Radhakrishnan & M. J. Palot (2005). Pictorial Handbook on Common Dragonflies and Damselflies of Kerala. *Zoological Survey of India,* pp67.
19. Flenner, I. & G. Sahlén (2008). Dragonfly community re-organisation in boreal forest lakes: rapid species turnover driven by climate change? *Insect Conservation and Diversity* 1: 169–179.
20. Fraser, F.C. (1933). The Fauna of British-India including Ceylon and Burma, Odonata. *Vol. I. Taylor and Francis Ltd., London*, pp436.
21. Fraser, F.C. (1934). The Fauna of British-India including Ceylon and Burma, Odonata. *Vol. II. Taylor and Francis Ltd., London*, pp442.
22. Fraser, F.C. (1936). The Fauna of British-India including Ceylon and Burma, Odonata. *Vol. III. Taylor and Francis Ltd., London*, pp461.
23. Golfieri, B., Hardersen, S., Maiolini, B., & Surian, N. (2016). Odonates as indicators of the ecological integrity of the river corridor: Development and application of the Odonate River Index (ORI) in northern Italy. *Ecological Indicators,* 61, 234-247.
24. Grimaldi, David; Engel, Michael S. (2005). Evolution of the Insects. *Cambridge University Press.* pp. 175–187.
25. Hoell, H.V., Doyen, J.T. & Purcell, A.H. (1998). Introduction to Insect Biology and Diversity, *2nd ed. Oxford University Press.* pp. 355–358. ISBN 978-0-19-510033-4.
26. Kadoya, T., S. Suda & I. Washitani (2004). Dragonfly species richness on man-made ponds: effects on pond size and pond age on newly established assemblages.

Ecological Research 19(5): 461-467; http://dx.doi.org/10.1111/j.1440-1703.2004.00659.x

27. Kiran, C.G. & D.V. Raju (2011). Checklist of Odonata of Kerala with their Malayalam names. *Malabar Trogon* 9(3): 31-35.
28. Kiran, C.G. & D.V. Raju (2013). Dragonflies and Damselflies of Kerala (Keralathile Thumbikal). *Tropical Institute of Ecological Sciences*, pp. 156.
29. Lohmann H. 1996. Das phylogenetische system der Anisoptera (Odonata). Deutsche Entomologische Zeitschrift 106: 209-266.
30. Manoj V.Nair, 22 May 2011.*Dragonflies & Damselflies of Orissa and Eastern India*.
31. Martin Schorr; Dennis Paulson. "World Odonata List". University of Puget Sound. Retrieved 12 Oct 2018. Dijkstra, K-D. B., G. Bechly, S. M. Bybee, R. A. Dow, H. J. Dumont, G. Fleck, R. W. Garrison, M. Hämäläinen, V. J. Kalkman, H. Karube, M. L. May, A. G. Orr, D. R. Paulson, A. C. Rehn, G. Theischinger, J. W. H. Trueman, J. van Tol, N. von Ellenrieder, & J. Ware. 2013. The classification and diversity of dragonflies and damselflies (Odonata). *Zootaxa* 3703(1): 36-45.
32. Mathavan, S. & P.L. Miller (1989). A Collection of Dragonflies (Odonata) made in the Periyar National Park, Kerala, South India, in January 1988. *International Odonatological Society, Bilthoven* (Rapid communications (supplements), no. 10), pp10.
33. Mickel, Clarence E. (1934). "The significance of the dragonfly name "Odonata"". *Annals of the Entomological Society of America*. 27 (3): 411–414. doi:10.1093/aesa/27.3.411.
34. Miller PL. 1992. The effects of oxygen lack on egg hatching in an Indian dragonfly, *Potamarcha congene.* Physiological Entomology 17: 68-72.
35. Mitra T. R. 2006. Handbook of Common Indian Dragonflies (Insecta: Odonata). Zoological Survey of India: 124.
36. Moore, N. M. (1997) Dragonflies: Status Survey and Conservation Action Plan. IUCN/ SSC Odonata Specialist Group, 27 p.
37. Nameer, P.O., R.R. Nair, K.R. Anoop, S.G. Nair, R. Lekshmi & P. Radhakrishnan (2000). Birds of Kerala Agricultural University Campus, Thrissur. *Zoo's Print Journal* 15(4): 243–246.
38. Nitha Bose C. & Francy K Kakkassery. (2019). Biodiversity of Kerala after deluge – Concerns, Implications and Conservation Strategies. International Journal of Scientific Research and Reviews 8(1): 2373-2381.

39. "Odonate". Merriam-Webster Dictionary.
40. Prasad, M. (1987). A note on the odonata from south India. *Fraseria* 12: 50.
41. Prasad, M. & Varshney R. K. (1995). A checklist of the odonates of India including data on larval studies. Oriental Insects 29: 385-428
42. Radhakrishnan, C. & K.G. Emiliyamma (2003).Odonata (Insecta) of Kerala: A systematic Database, pp. 1-27. In: Gupta, R.K. (ed.). *Advancement in Insect Biodiversity, Jai Narain Vyas University, Jodhpur*.
43. Rao, R. & A.R. Lahiri (1982). First records of Odonates (Arthropoda: Insecta) from the Silent Valley and New Amarambalam Reserved Forests. *Journal of the Bombay Natural History Society* 79(3): 557–562.
44. Rehn A. C. 2003. Phylogenetic analysis of higher – level relationships of Odonata. Systematic Entomology 28: 181-240.
45. Richard J. Bomphrey, Toshiyuki Nakata, Per Henningsson, Huai-Ti Lin (2016) Flight of the dragonflies and damselflies, Phil. Trans. R. Soc. B 371 20150389; DOI: 10.1098/rstb.2015.0389.
46. Rifilwe V. M., Grant S. J., Colleen S, Paul Stefan. (2017). Biological Conservation 214: 46-54.
47. Rodrigues, M. (2018) A study on birds and Odonates of Puthige Paddyfields, Kasargod. *Piculet*. 1(4), 10-14.
48. Sahlén, Göran; Ekestubbe, Katarina (16 May 2000). "Identification of dragonflies (Odonata) as indicators of general species richness in boreal forest lakes". *Biodiversity and Conservation.* 10 (5): 673–690. doi:10.1023/A:1016681524097.
49. Sharat Kumar Palita, Sudheer Kumar Jena, Subrat Debata. (2016). Journal of Entomology and Zoology Studies 4(3):40-47.
50. Sharma, G., R. Sundararaj & L.R. Karibasvaraja (2007).Species diversity of Odonata in the selected provenances of Sandal in southern India. *Zoo's Print Journal* 22(7): 2765–2767; http://dx.doi.org/10.11609/ JoTT.ZPJ.1593.2765-7
51. Stenberg K. 1990. Autokologie von sechs Libellenarten der Moore and Hochmoore des Schwarzwaldes and Ursachenihrer Moorbindung. Dr T, Albert- Ludwigs-University, Freiburg Germany.
52. Subramanian, K.A. & K.G. Sivaramakrishnan (2002). Conservation of Odonate fauna in Western Ghats, pp. 11–22. In: Sanjayan, K.P., V. Mahalingam & M.C.

Muralirangan (eds.). *Vistas of Entomological Research for The New Millennium. G.S. Gill Research Institute, Chennai*

53. Subramanian, K.A. (2005). India-A Lifescape, Dragonflies of India – A Field Guide. Vigyan Prasar, India Offset Press, New Delhi, 118pp. Subramanian, K.A. (2007). Endemic odonates of the Western Ghats: Habitat distribution and Conservation, pp. 257–271. In: Tyagi, B.K. (ed.). Odonata-Biology of Dragonflies. *Scientific Publishers, Jodhpur, India.*
54. Subramanian, K.A. (2009). Dragonflies and Damselflies of Peninsular India - A Field Guide. Vigyan Prasar, Noida, India, 168pp. Subramanian, K.A. (2014). A Checklist of Odonata of India. *Zoological Survey of India, Kolkata*, pp31.
55. Subramanian, K.A., F. Kakkassery & M.V. Nair (2011). Chapter 5. The status and distribution of dragonflies and damselflies (Odonata) of the Western Ghats, pp. 63–86.
56. Sunit K R Das, Rahim Ahmed, S K Sajan, Nibedita Dash, Pradeep Sahoo, Pankajini Mohanta, H K Sahu, S D Rout, S K Dutta. (2012). Academic Journal of Entomology 5(1): 54-61.
57. Susanth C, Anooj S. S. (2020). Indian Journal of Entomology 82(2): 315-323.
58. Tiple, A. D., Paunikar, S. and 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.
59. Vincent J. K, Viola Clausnitzer, Klaas-Douwe B, Albert G. Orr, Dennis R. Paulson, Jan van Tol. (2008). *Hydrobiologia* 595: 351-363.