STUDIES ON DIVING BEETLES (COLEOPTERA: DYTISCIDAE) OF KERALA

Thesis submitted to the University of Calicut in partial fulfilment of the requirements for the Award of the Degree

of

Doctor of Philosophy in Zoology

By

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DEDICATION

This thesis is dedicated to the memory of Dr. Francy K. Kakkassery, who was my esteemed PhD supervisor at the beginning of my research journey. His guidance and wisdom illuminated every step of this research journey. His passion for knowledge and unwavering commitment to science served as the beacons that guided me through the challenges and complexities of this scholarly endeavor. In spite of his untimely demise, his spirit and teachings continue to inspire and shape every page of this work. This thesis stands as a testament to his enduring influence and the profound impact he had on my academic and personal growth.

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DECLARATION

I hereby declare that the work presented in the thesis entitled "**Studies on Diving Beetles (Coleoptera: Dytiscidae) of Kerala**" is based on the original work done by me under the guidance of **Dr. Joyce Jose** and has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis are undergone plagiarism check using **iThenticate** software at C.H.M.K. Library , University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI generated contents.

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Priyanka

Priyanka Prabhakaran

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List of abbreviations used

Abbreviation	Expansion
RGCB	Rajiv Gandhi Centre for Biotechnology, Trivandrum
NCBI	National Centre for Biotechnology Information, Bethesda, Maryland, USA
et al.	*et alia*
Coll.	Collected by
cf.	confer -- compare
sp.	species
mm	Millimetre
m	Metre
♂	Male
♀	Female

ABSTRACT

Diving beetles (Coleoptera: Dytiscidae) are the largest family of aquatic beetles. They inhabit almost all kinds of freshwater habitats but preferably lentic habitats. Their morphology is highly adapted to lead an aquatic life. They are holometabolous insects and are univoltine, semivoltine or multivoltine. They are consumed as food in various countries around the globe including India. They are also linked to different human cultures and mentioned in literature.

This study deals with the taxonomy, phylogeny and association of species presence and absence with different habitats based on the presence or absence of species and selected water parameters. Different freshwater habitats in the 14 districts were sampled. One hundred and sixty sites were involved in the study. The freshwater habitats were classified into 34 different types. Fifty-three species were observed and recorded. Subfamily Hydroporinae formed the largest subfamily and Colymbetinae formed the smallest subfamily. Two species are new reports to India. Eight species are reported first time from Southern India. One subfamily, four genera and 23 species are new records to Kerala state. Detailed descriptions, information on habitat and location data and distribution of the species in India are provided.

A checklist for the diving beetles of Kerala was prepared by compiling the species reports in previous studies and the current study. This has increased the number of diving beetles reported from Kerala from 51 species to 74 species.

The phylogenetic study of Dytiscidae involving 26 sequences from 24 species under five subfamilies and 10 genera reveals monophyly of genera *Leiodytes*, *Hydroglyphus*, *Clypeodytes*, *Hydrovatus* and *Sandracottus*. Meanwhile Genera *Copelatus*, *Laccophilus* and *Hydaticus* form paraphyletic groups. The higher-level phylogeny could not resolve indicating the need for further studies involving more species and gene sequences.

Similarity of different habitats based on the presence and absence of 36 species in different habitats and the effect of selected water parameters on species cooccurrence was examined based on data collected from 160 study sites. The results showed that there is similarity between smaller habitats, larger habitats and between smaller and larger habitats. Similarity between smaller habitats can be due to the presence of

specialists and also due to water depth. Similarly larger habitats shows similarity due to the specialists of that particular habitat. Similarity between smaller and larger habitats could be due to the dispersal of species from larger habitats to new temporary habitats for their survival. Congeneric species (e.g. *Copelatus boukali*, *C. davidi* and *C. sociennus*) as well as species in different genera were found to be coexisting (e.g. *Lacconectus regimbarti*, *Hydaticus ricinus* and *Hyphydrus renardii*).

This study presents pioneering and baseline data on diving beetles of Kerala from a taxonomical, phylogenetic and ecological perspective. Many species commonly distributed in Kerala as well as the neighbouring states have never been formally reported and this study thus becomes a pioneering document for the same. Many first reports from the study area indicate the lack of intensive studies on this group. Based on the experiences of this study it is recommended that intensive and repeated sampling in a smaller study area and phylogenetic examinations based on a multigene and morphometric approach could yield novel species to the fauna and insights in the systematics and evolution.

കേരളത്തിലെ ഊളിവണ്ടുകളെ (മുങ്ങാംകുഴിവണ്ടുകളെ) കുറിച്ചുള്ള പഠനങ്ങൾ

സംഗ്രഹം

സൂചകപദങ്ങൾ: ഊളിവണ്ടുകൾ, ശുദ്ധജലം, കേരളം, പരിതഃസ്ഥിതവിജ്ഞാനം, വിഭജന വിജ്ഞാനീയം

ജലത്തിൽ വസിക്കുന്ന വണ്ടുകളിലെ ഏറ്റവും വലിയ കുടുംബമാണ് ഡൈറ്റിസ്സിടെ (Dytiscidae). ഊളിവണ്ടുകൾ (Diving Beetles) എന്നാണിവ പൊതുവെ അറിയപ്പെട്ടുന്നത്. ഏറെക്കുറെ എല്ലാതരം ശുദ്ധജല ആവാസവ്യവസ്ഥകളിലും ഇവ കാണപ്പെടുന്നു. ലോകത്താകമാനം 4739 ഇനം (Species) ഊളിവണ്ടുകളെയാണ് ഇതുവരെ കണ്ടെത്തിയിട്ടുള്ളത്.

ഊളിവണ്ടുകളുടെ വർഗ വിഭജന വിജ്ഞാനീയം, വികാസാത്മക ബന്ധം, വിവിധ ഇനം ഊളിവണ്ടുകളുടെ സാന്നിധ്യത്തിൻറെയും അസാന്നിധ്യത്തിൻറെയും അടിസ്ഥാനത്തിൽ വിവിധ ശുദ്ധജല ആവാസവ്യവസ്ഥകൾ എങ്ങനെ സാമ്യപ്പെട്ടിരിക്കുന്നു, അതുപോലെ ജലത്തിൻറെ വിവിധ രാസ ഘടകങ്ങൾക്ക് ഊളിവണ്ടിനങ്ങളുടെ സഹവർത്തിത്വത്തിൽ ഉള്ള പങ്ക്, എന്നീ വിഷയങ്ങളാണ് ഈ പഠനം ഉൾക്കൊള്ളുന്നത്.

കേരളത്തിലെ 14 ജില്ലകളിലെ വിവിധ ശുദ്ധജല അവാസവ്യവസ്ഥകളിൽ നിന്നും ഊളിവണ്ടുകളെ കണ്ടെത്തുകയും പഠന വിധേയമാക്കുകയും ചെയ്തു. ആകെ 53 ഇനം ഊളിവണ്ടുകളെയാണ് ഈ പഠനത്തിൽ വിവരിച്ചിരിക്കുന്നത്. ഇന്ത്യയിൽ നിന്നും രണ്ട് ഇനം ഊളിവണ്ടുകൾ പുതിയതായി രേഖപ്പെടുത്തിയിരിക്കുന്നു. ദക്ഷിണേന്ത്യയിൽ നിന്നും കേരളത്തിൽ നിന്നുമായി യഥാക്രമം എട്ടും ഇരുപത്തിമൂന്നും ഇനങ്ങൾ ആദ്യമായി രേഖപ്പെടുത്തിയിട്ടുണ്ട്. ഒരു ഉപകുടുംബവും നാല് ജനുസ്സുകളും കേരളത്തിൽ നിന്നും ആദ്യമായാണ് രേഖപ്പെടുത്തപ്പെടുന്നത്. വിവിധ ഇനങ്ങളുടെ രൂപവിജ്ഞാനപരമായ വിവരണവും, അവ ശേഖരിക്കപ്പെട്ട ആവാസവ്യവസ്ഥയുമായി ബന്ധപ്പെട്ട വിവരങ്ങളും, ഇന്ത്യയിൽ അവ ഏതൊക്കെ സംസ്ഥാനങ്ങളിൽ കാണപ്പെടുന്നു എന്നുള്ള വിവരങ്ങളും ഈ പഠനത്തിൽ നൽകിയിരിക്കുന്നു. കേരളത്തിൽ ഇതുവരെ അറിയപ്പെടുന്ന ഊളിവണ്ടുകളുടെ പട്ടിക തയാറാക്കിയിരിക്കുന്നു. കേരളത്തിൽ നിന്ന് മുൻപ് 51 ഇനങ്ങളാണ് രേഖപ്പെടുത്തിയിട്ടുള്ളത്. ഈ പഠനത്തിലൂടെ അത് 75 ഇനമായി ഉയർത്താൻ സാധിച്ചു.

അഞ്ച് ഉപകുടുംബങ്ങളെയും പത്ത് ജനുസ്സുകളേയും ഉൾപ്പെടുത്തിക്കൊണ്ട് ഊളിവണ്ടുകളുടെ പരിണാമത്തെക്കുറിച്ച് നടത്തിയ പഠനത്തിൽ, ഡിറ്റിസ്സിടെ കുടുംബത്തിൻറെ

വംശവൃക്ഷം, ജനുസ്സുകളുടെ തലത്തിൽ ഇനങ്ങളുടെ വർഗ്ഗീകരണം കൃത്യമായി കാണിച്ചിരിക്കുന്നു (കോപ്പിലാറ്റസ്, ഹൈഡ്രോറ്റിക്കസ്, ലാക്കോഫിലസ് എന്നീ ജനുസ്സുകൾ ഒഴികെ). അതേ സമയം, ഉപകുടുംബങ്ങളുടെ തലത്തിലുള്ള ഇനങ്ങളുടെ ബന്ധത്തിൽ അവ്യക്തത നിലനിൽക്കുന്നു.

മുപ്പത്തിയാറ് ഇനങ്ങളേയും 160 ആവാസവ്യവസ്ഥയും ഉൾപ്പെടുത്തിക്കൊണ്ട് വ്യത്യസ്ത ആവാസവ്യവസ്ഥകൾ തമ്മിലുള്ള സാമ്യത കണ്ടെത്തുന്നതിനായുള്ള പഠനം നടത്തി. ഇതോടൊപ്പം ഓരോ അവാസവ്യവസ്ഥയിലുമുള്ള ഇനങ്ങളുടെ സഹവർത്തിത്വത്തിൽ ജലത്തിൻറെ തിരഞ്ഞെടുക്കപ്പെട്ട രാസ ഘടകങ്ങളുമായുള്ള ബന്ധം എപ്രകാരം ഉള്ളതാണെന്നും കണ്ടെത്തിയിരിക്കുന്നു. ജലത്തിൻറെ രാസഘടകങ്ങൾക്ക് ഇനങ്ങളുടെ സഹാവർത്തിത്വത്തിൽ കാര്യമാത്രയായ സ്വാധീനം ചെലുത്തുന്നില്ല എന്ന് കണ്ടെത്തിയിരിക്കുന്നു.

ഇരുപത്തിമൂന്ന് ഇനം ഊളിവണ്ടുകളുടെ ആദ്യ രേഖപ്പെടുത്തൽ,. ഊളിവണ്ടുകളെക്കുറിച്ച് കേരളത്തിൽ വേണ്ടത്ര പഠനങ്ങൾ നടന്നിട്ടില്ല എന്നതിനെയാണ് ഇതു സൂചിപ്പിക്കുന്നത്. കേരളത്തിലെ പഠന വിധേയമാകാത്ത പ്രദേശങ്ങളെക്കൂടി ഉൾപ്പെടുത്തിക്കൊണ്ട് ഭാവിയിൽ നടത്താവുന്ന സമഗ്ര പഠനങ്ങൾക്ക് കൂടുതൽ പുതിയ ഇനങ്ങളെ കണ്ടെത്താൻ കഴിയും എന്നതിൽ സംശയം ഇല്ല.

CHAPTER- 1

GENERAL INTRODUCTION

1. General Introduction

1.1 The Insects

Insects are the largest group among both animals and plants in the world (Scudder, 2017; Eggleton, 2020). They accounts for more than 80% of all arthropods and is estimated to have between six to ten million species. They are closely related to other arthropods like spiders, centipedes, millipedes, prawns and crabs. Insects are categorised into 39 distinct orders (Zhang, 2011). They are tracheate arthropods characterised by the presence of three distinct regions in their body, namely head, thorax and abdomen. Thorax bears two pairs of wings and three pairs of jointed legs. The head bears a pair of antennae and compound eyes. In many cases, simple eyes called ocelli are present in addition to the compound eyes. Insects exhibit different types of mouthparts such as biting and chewing, piercing and sucking, siphoning, sponging and chewing and lapping types. Their abdomens are segmented with the terminal segments modified to form part of the genitalia. Development may involve either complete or incomplete metamorphosis (Richards and Davies, 1977).

Insects first appeared around 480 million years ago during the Devonian period (Kumar *et al*., 2023) and have since become the most successful group of organisms on earth. Their success can be attributed to several factors such as their chitinous exoskeleton, exceptional reproductive potential, ability to maintain water balance, capacity for flight and dispersal and versatility in feeding on various materials. These adaptations enable insects to thrive in diverse environments, ranging from polar regions to tropical areas. India is home to a vast array of insect species. Even though India represents only 2% of the global space, it is one of the 17 megadiversity nations in the world (Sankarganesh, 2017). There are nearly 70,000 species known from India representing up to 10% of the world's insect fauna (Chapman, 2009).

Insects have both beneficial and harmful effects and humans cannot imagine an earth without them. Insects play diverse roles in nutrient recycling, maintaining plant and animal community structures, plant propagation and serving as food sources for many organisms (Verma *et al*., 2023). Therefore, their irreplaceable contributions to our ecosystems must not be underestimated. Insects are facing extinction due to habitat loss, over-exploitation, pollution, overpopulation, and the threat of global climate change. Since insect biodiversity plays a crucial role in maintaining ecosystems, there is an increasing need for taxonomic information, especially for biodiversity assessments aimed at achieving an environmentally sustainable future (Egambaram, 2017; Nayak *et al*., 2021).

1.2 Aquatic Insects

Insects dominate both terrestrial and aquatic environments. Almost all insect orders include at least a few aquatic representatives (Staniczek, 2011). Aquatic insects constitute only less than 1% of the total animal diversity (Pennak, 1978) and 3-5% of the total insect fauna, yet they are taxonomically diverse (Daly *et al*., 1978). They play crucial roles in the food chain and energy flow pathways within aquatic ecosystems, significantly contributing to biomass production (Pennak, 1978). Many of the aquatic insects are medically important as they feed on many insect vectors and control their population. Besides that, they are also well known as biological indicators of freshwater ecosystems (Lundkvist *et al*., 2003; Culler and Lamp, 2009).

Aquatic insects are a heterogeneous assemblage of various insect orders. Most of the aquatic insects are amphibiotic spending their initial life stages in association with water and adult stage on land. Many other insect families spend their entire life stages under the water or closely in association with the water. They have evolved various mechanisms to survive in aquatic habitats such as presence of gills, ability to exchange gas through the cuticle, ability to carry air bubble under elytra or between the hairs present on their body for respiration and flattened legs provided with natatory setae or hydrophobic legs to walk on water surface. These characters can help to distinguish aquatic insects from nonaquatic ones. However, these adaptations are not always identified, nor are they consistently visible (Yee and Kehl, 2015).

1.3 Aquatic Coleoptera

Order Coleoptera is the largest order in kingdom Animalia (Richards and Davies, 1977) consisting of more than 400,000 described species (Moodley *et al*., 2022). Order Coleoptera constitutes one-fourth of all known animal species (Gullan & Cranston, 2014) and are the most diverse group of animals on earth (Slipinski *et al*.,

2011) successfully thriving in both terrestrial and aquatic habitats. Aquatic Coleoptera is one of the major groups of aquatic insect fauna in freshwater ecosystems.

In a global assessment, it has been estimated that there are 12,600 species of obligatory water beetles (Jäch and Balke, 2008). In India, there are 776 species of aquatic beetles recorded under 137 genera, 17 families and 3 suborders (Chandra *et al*., 2017). Aquatic beetles have many adaptations that enable them to live in water. They often possess streamlined bodies to minimize water resistance and the presence of paddle-like legs fringed with long hairs (natatory setae) for swimming. Among the aquatic beetles, the family Dytiscidae is the largest and one of the most commonly encountered family in aquatic ecosystems.

1.4 Family: Dytiscidae

1.4.1 Introduction

Members of the family Dytiscidae are commonly known as diving beetles or predaceous diving beetles. The name is derived from the Greek word ‘*dytikos*’, meaning ‘able to dive’. This name aptly reflects their ability to submerge underwater. Initially, most of the beetles which live underwater were placed in Dytiscidae but later many were placed under other families. There are 4739 extant species in this family (Nilsson and Hájek, 2024). However, as with any other taxa on earth, the number of living species is likely to surpass the current total.

From lakes to phytotelmata, Dytiscids can be found in almost all kinds of freshwater habitats. Family Dytiscidae is a highly diverse and abundant group and possesses the perfect morphological features and respiratory mechanisms for an aquatic mode of life. Even though they are very unique among other aquatic Coleoptera, they possess some conspicuous morphological similarities with the family Noteridae, which recently originated from Dytiscidae (Yee, 2023). Both of the families are streamlined smooth and oval in shape.

Over the years, many beetle taxonomists have intensively studied this family, resulting in a natural and comprehensive classification of the group. Recently, there have been significant advancements in the biology, ecology, taxonomy and phylogenetics of this family. However, the continuous discovery of new species indicates that their diversity and importance in aquatic habitats are much greater than our current understanding.

1.4.2 Diving Beetles – a peep into the past

The first reference of family Dytiscidae is found in *Systema Naturae* (Linnaeus, 1758). Some of the diving beetles recorded therein remain in that original classification. The eminent biologist Charles R. Darwin also had a link with the family Dytiscidae. Diving beetles were present in the insect collection he made two years before his voyage on HMS Beagle. The records of his insect collections were published in several volumes of *British Insects* by James Francis Stephens in 1829. *Dyticus conformis*, *Hydaticus hybneri*, *Hygrotus scitulus*, *Hydroporus areolatus* and *Colymbetes agilis* are some of the dytiscids present in his collection. His insect collections made during the Beagle voyage also had dytiscids including *Colymbetes signatus* caught on board the ship (45 Miles from Cape St. Mary, Montevideo, Uruguay) and is considered as one of the first observations on the dispersal of diving beetles. In addition, Darwin also discovered several new species of dytiscids, which were later compiled and published by C. C Babbington in 1841. Darwin's research article about the dispersal of a bivalve (*Cyclas cornea*) with the help of *Dytiscus marginalis*, just 13 days before his death was his last living contribution to the scientific world. While looking at his life, one may feel that his scientific journey began and ended with diving beetles.

1.4.3 General Morphology

Adults of the family Dytiscidae are generally streamlined and dorso ventrally flattened. The shape and size of the adults show intra and inter-specific variation. The lateral outline of the body is continuous or interrupted between the pronotum and elytron.

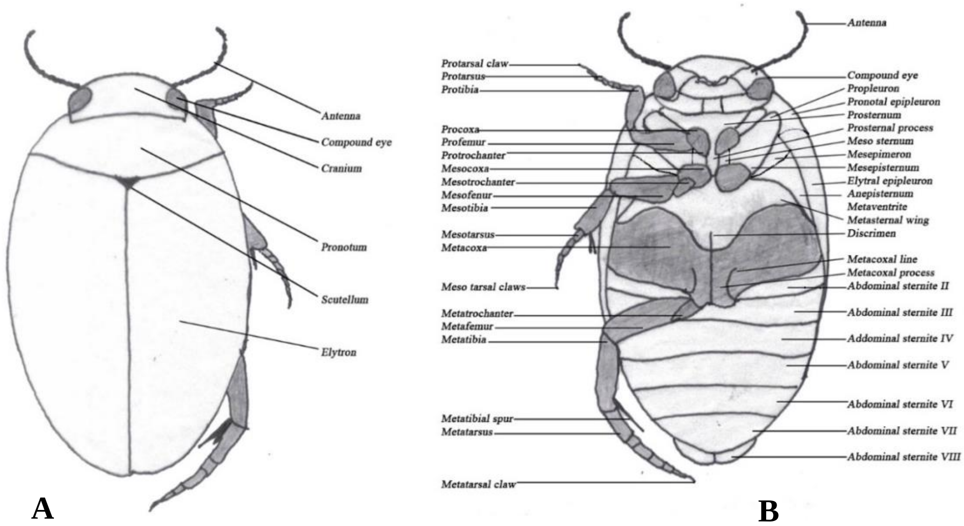


Figure. 1. Morphological characteristics of Dytiscidae: A) Dorsal view; B) Ventral view

(Diagram drawn by the scholar. Labels added in image editing software)

1.4.4 Aquatic Life

Both adults and larvae of diving beetles live underwater and have special adaptations for thriving in an aquatic environment. Generally, adults have a smooth, compact and streamlined body. The general morphology of an adult diving beetle is shown in Figure. **1**. There are intra and interspecific variations in the shape and size of the body. Certain species are narrow and elongated and others are short and compact. There is a pair of natatorial oar-like hind legs. The body shape and size are correlated to their habitat. Narrow and elongated species are found in open water and are better swimmers. Meanwhile, compact species are found in habitats with dense vegetation, where they spend most of the time associated with the plants and do little open-water swimming (Wolfe and Zimmerman, 1984; Ribera and Foster, 1997). Most of the species possess a very large meta coxa for the support of large muscles inserted into the meta trochanter, which in turn steer the large metathoracic swimming legs. Most of them have flattened or laterally expanded and paddle-like legs with fringes of long swimming hairs, mainly on the hind leg. The swimming hairs spread out to provide maximum surface area to push the water while swimming. The simultaneous leg movements during the swimming resemble the movements of the oars of a boat and this makes them unique from other families of water beetles.

Diving beetles possess a variety of surface sculptures such as punctures, setae, impressed micro reticulations and striae. These structures do not interfere with their ability to swim. Instead, these structures help to hold the boundary layer of water or make it thicker while swimming (Wolfe and Zimmerman, 1984). Dytiscids are positively buoyant, though, they can adjust the degree of buoyancy by regulating the amount of air under the elytra or by ingesting and storing water in the expandable region of the gut (Hicks and Larson, 1991). Larvae of diving beetle are negatively buoyant and sink in the water (except Dytiscinae). Depending on the taxa, larvae may burrow or live on the substrate, actively swim in the water or float. Most of the larvae usually crawl but some are strong swimmers and live in the open water (e.g. Dytiscinae). Abrupt contractions of the larval body or “shrimping movements” help in swimming. Some larvae swim with the help of their legs provided with natatorial setae.

Adults and larvae of almost all species are aquatic and breathe atmospheric oxygen. Adults carry air bubbles under their elytra, where they come in contact with the spiracles (tracheal openings). Once the air is used up, it comes to the surface of the water to refill the air. They collect the air by extending the tip of their abdomen out of the water surface. They can also extend the sub elytral bubble into the water column, while they are underwater. Here the bubble acts as a physical gill and exchanges gases with the water column. When threatened, the beetles expel the air bubble to reduce buoyancy and sink to the bottom. Species living in habitats with high levels of dissolved oxygen may exchange oxygen directly through the cuticle or specialized pores (Madsen, 2009).

Most larvae, especially the larger ones and late instars, may need to surface and collect atmospheric oxygen. Smaller species and the early instars can breathe through their cuticle. Larvae use the spiracles at the tip of the last abdominal segment (Urogomphus) to draw air from the atmosphere. Only the third instar has spiracles in the thorax and abdomen to help the late instars in respiration, when they leave the water body to pupate. Some larvae possess gills on either side of their abdomen in the form of lateral elongated extensions (Miller and Bergsten, 2016).

Studies on pupae and pupation of this group is very less with only a few dytiscid species being described so far. Pupae of diving beetles are exarate. The abdomen is nine-segmented and the last abdominal segment bears Urogomphus. Pupation takes place in the damp soil near the water body or a few meters away (Main, 1934; Holomuzki, 1988).

1.4.5 Habitats

Family Dytiscidae inhabit a variety of freshwater habitats. A few terrestrial species have been reported but these are very rare and there is no extensive diversification in terrestrial taxa. Nearly all species of diving beetles are closely associated with the water. The most commonly found species of diving beetles are eurytopic, occurring in different types of habitats. Some are stenotopic, occurring only in specialized habitats. Other species could be placed between stenotopic and eurytopic due to their response to environmental parameters. Several biotic and abiotic factors influence the distributional pattern of diving beetles, such as water temperature, exposure to the habitat, size of the water body, habitat stability, substrate type, water chemistry, water movement, type and amount of vegetation, presence of prey, predators or competitors. Though adults are able to disperse and are found in a wide range of habitats, larvae and adults generally occur in the same habitat (Gioria, 2014).

Diving beetles are found in both lentic and lotic freshwater habitats. Species diversity is much higher in lentic habitats possibly due to efficient partitioning and utilization of resources available in larger water body in different zones (regions with vegetation, margins, deeper reaches and wet substrate of extreme margins where there is no water at all). Certain species are specialized in mineral substrates and some others are highly tolerant to extreme salinity ranges (Timms and Hammer, 1988; Sanchez- Fernandez *et al.*, 2010; Cespedes *et al*., 2013; Pallares *et al*., 2015).

Dytiscids are less diverse in lotic habitats. Yet some dytiscid genera are entirely or nearly lotic specialists with some specialised in large rivers or in small streams. Certain species are confined to the interstices of margins of rivers and others survive in the pools along the rivers or the pools in drying rivers (Miller and Bergsten, 2016).

Phytotelmata is one of the unique habitats that harbour unique fauna. They are abundant in the tropical forests and are highly sensitive. Bromeliads, palm bracts and tree holes are some of these special habitats. Species diversity is very low in this type of habitats but a large number of specimens can be collected. *Laccophilus, Lacconectus* and *Copelatus* are very common to these sensitive habitats and most species of these temporary habitats exhibit a high tendency for dispersal (Balke *et al*, 2008; Campos and Fernandes, 2011).

Hygropetric habitat characterised by a thin layer of water flowing over longitudinal or vertical rock surfaces is another habitat utilized by diving beetles. Diving beetles swim in the water layer over the rock surface in small cracks and on exposed rock surfaces. These habitats are usually overlooked for dytiscids. There are considerable numbers of hygropetric species that have been recorded from different regions of the world, mainly from Venezuela, where there is the largest representation of this type of habitat. The diversity of hygropetric diving beetle fauna of Venezuela gives insight that other regions of the globe with similar habitats may be similarly productive (Miller and Spangler, 2008; Miller and Garcia, 2011).

Diving beetles of subterranean habitats (caves, wells, boreholes, wash out from springs etc.) are diverse and show distinct morphological features. The majority of the species come under the subfamily Hydroporinae and a few under the genus *Copelatus*.

Many taxa are able to live in nearly terrestrial habitats like muddy margins of streams and hygropetric habitats. Diving beetles are also able to overwinter dry seasons in terrestrial conditions. Most of them can survive in terrestrial habitats for at least some time during their migration. Five species have been recorded as terrestrial (Brancucci, 1979; Watts, 1982; Brancucci, 1985; Balke and Hendrich, 1996; Brancucci and Monteith, 1996; Brancucci and Hendrich, 2010) but it is difficult to establish whether they are exclusively terrestrial (Miller and Bergsten, 2015).

1.4.6 Feeding

Dytiscid larvae are fluid feeders and prey on a wide variety of invertebrates and small vertebrates. They use large sickle-shaped mandibles to capture and consume the prey. Digestive enzymes are released through the medial channel of the mandible and are injected into the captured prey to digest the tissues into a fluid form. The mandibles are again used to suck the fluid into the closed mouth. The presence of medially serrated mandibles without a medial channel and the presence of a well-developed crop in *Hydrotrupes* and *Copelatus* suggest solid feeding (Ruhnau and Brancucci, 1984; Beutel, 1994). Visual scanning and tactile and chemical cues are mainly used for prey detection. Vegetation influences the hunting strategy they choose. High plant density decreases the chances of cannibalism within the larvae leading to high species richness in those habitats (Yee, 2010).

Adult diving beetles are carnivorous, feeding on captured prey. If fresh prey is not available they are known to feed on recently dead animals. Hence, they are commonly called "predaceous diving beetles". Even though the adults occasionally feed on plant materials (Deding, 1988), its importance in their diet is not yet gauged. But experiments demonstrate that they can complete the developmental cycle in captivity feeding solely on animals. Diving beetles compete with conspecifics, other species and even between their life stages. They avoid competition by using different micro habitats, shifting the time of hunting and also by changing their preferences for prey (Holomuzki, 1985a; 1985b).

1.4.7 Development

Diving beetles are holometabolous insects (**Error! Reference source not found.**). They usually lay eggs underwater or in the splash zone of the water body. The type of oviposition is different across the family and the ovipositors are modified accordingly. Some groups glue their eggs on aquatic plants or objects under the water or lay randomly on the substrate. Females with this kind of egg-laying strategy as in the genus *Rhantus* have short ovipositors bearing numerous tactile setae. Members of *Aciliini* possess a long ovipositor for laying eggs in crevices or other hidden places (Miller, 2001). Others have a saw-like or knife-like ovipositor, which is used to cut the plant tissues, to lay the eggs (Jackson, 1960; Inoda, 2011). The time taken for the hatching of the eggs depends on factors like water temperature, species and time of the year. Usually, it will take 5-14 days to hatch the eggs. Some of them overwinter as eggs (Sueselbeck, 2002).

Dytiscids have three larval instars. Larvae are fully aquatic. They leave the water body only to pupate in the damp soil. Larval development depends on water temperature to a certain extent (Inoda, 2003). Other factors affecting larval development are not known. During the larval stage, most weight gain happens in the third instar (Kingsley, 1985). Only the third instar has functional spiracles on the abdominal segments I- VII. They use these spiracles for respiration when they crawl out of the water for pupation. Pupae and pupation are not well studied yet. Studies (Main, 1934; Holomuzki, 1988) on the pupae, pupation site and mortality rate of the *Dytiscus* species shows that pupation takes place near the water or a few meters away. It develops near or under an object. The pupal cell is constructed by the larval movements in the soil. But in some cases, larval mandibles are also involved in the construction of the cell (Matheson, 1914). The species of the Carabid genus *Brachinus* are known to parasitise Dytiscid pupae (Juliano, 1984).

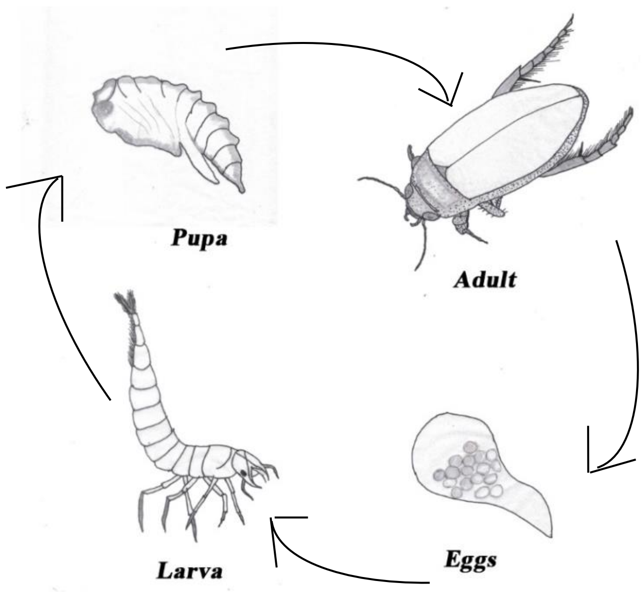


Figure. 2. Lifecycle of Diving beetles

(Diagram drawn by the scholar. Labels added in image editing software)

Most of the species studied so far, particularly temperate North American and European species are univoltine or semivoltine (Miller and Bergsten, 2015). Among the European diving beetles, there are five types of lifecycles, based on whether they are univoltine or semivoltine and how they diapause (Nilsson, 1986a). Some species overwinter as eggs, some as larvae and others as adults. Semivoltine species diapause as eggs or larvae in the first winter and as adults in the second winter. This kind of lifecycle can be visible in the eggs and larval development, with eggs hatching almost immediately or nearly one year after oviposition. Similarly, larvae may have a rapid or extended development. The timing of their reproductive maturity is influenced by their particular lifecycle strategy (Nilsson, 1986a). The phenology of developmental stages and lifecycle strategy varies with climate and the seasonal propensity of migration. Records show there are dytiscids which are moderately active under winter ice (Roughley, 2000). There are considerably fewer studies on the life cycle strategies of tropical species or species with a different type of seasonality. Dytiscids of these regions may be multivoltine or they may receive life history cues from the rain or other phenomena (Miller and Bergsten, 2015). Species in the areas experiencing seasonal drying may undergo terrestrial diapause as eggs or adults until the habitat has enough water (Garcia *et al.*, 1990). When habitats become dry dytiscids remain nearby or find new habitats. Especially larger water bodies with more permanency may form temporary habitats till new habitats are formed due to rain or snow melting. Species like those in the genus *Eretes* undergo mass migration from the drying habitats (Kingsley, 1985). In the tropics during extensive rain, a large number of diving beetles are attracted to the light, presumably dispersing to take advantage of the newly formed habitats . It is clear that tropical diving beetles exhibit greater seasonality than any other. For example, larvae are more common at certain times of the year.

1.4.8 Mating

Dytiscids are very peculiar in different aspects of their mating systems. They have unique sperm morphology, mating behaviour, genital morphology and secondary sexual characteristics. Among the animals, dytiscids have the most complex and diverse sperm morphology. In diving beetles, two or more sperms are found together forming sperm conjugates (Higginson and Pitnick, 2011; Higginson *et al.*, 2012a; 2012b). It may be a simple conjugate (two sperms attached at their head region), complex (numerous sperms attached) or rouleaux type (thousands of sperm are aligned in a string with their heads attached). Diving beetles show sperm heteromorphism where sperm of different sizes and shapes are in the same male ejaculate (Voïnov, 1902; Higginson *et al.*, 2012a; 2012b). In other cases, both fertile and infertile sperm can be present in the ejaculate (Mukherjee *et al.*, 1989).

Males possess stridulatory organs for sexual signalling. Females of the genus *Rhantus* rely on chemical signalling in mate-finding (Herbst *et al*, 2011). Extreme sexual antagonism is also visible in this family. Males hold females under the water during mating, a threatening behaviour which makes them unable to collect the atmospheric air. Larger species of *Cybistrinae* and *Dytiscinae* have modified forelegs for holding resisting females during mating. Few species show body shaking and male leg fluttering suggesting sexual selection happens before insemination (Miller and Bergsten, 2015). Meanwhile, Hydroporinae has a very complex and diverse female reproductive tract morphology, sperm conjugation and simple mating behaviour suggesting that sexual selection in this group happens after insemination (Miller and Bergsten, 2015).

1.4.9 Defence

Vertebrates like birds and fishes are the common predators of dytiscids. The evidence for the presence of dytiscids in the food of vertebrates also ascertains this. Sometimes, the vertebrate attack is visible as scratches on their cuticle (Peddle and Larson, 1999). Insects such as Hemiptera and Odonata also prey on dytiscids. Sometimes the larger species of dytiscids prey upon smaller dytiscid species. Adults and larvae of diving beetles employ different strategies such as cryptic colouration and rapid swimming to avoid their predators.

Adults and larvae can bite but only the larger species cause remarkable pain. Metathoracic legs which bear spine is also used for kicking. Larvae of certain groups remain still when a predator approaches. This special tactic is called “thanatosis”. Some larvae crawl and hide in the substrate when they get threatened.

Diving beetles possess two exocrine glands for the production of an array of defensive chemicals. The prothoracic gland, situated at the prothorax is considered the primary defensive gland and the products are released when an adult gets captured. The secretions have a characteristic odour and help to deter predators (Miller and Mumma 1976a;1976b; Gerhart *et al*., 1991). Other than the defensive role, the constituents of the secretions act like cannabimimetics and emulsifiers (Schaaf and Dettner, 2000). Pygidial glands, the second defensive gland in Dytiscidae, are located at the apex of the abdomen. The secretions are used for increasing wettability and as a defence against microorganisms (Schildknecht and Buhner, 1968; Schildnecht, 1971; Dettner, 1985).

Microsculptures and colouration in adults help to a great extent to hide themselves in their habitat. Colourful taxa and dark species are found in habitats with mineral and dark substrate or vegetation respectively. Bright colouration causes visual disruption in predators and is also used for aposematism.

1.4.10 Ecology

Diving beetles can form distinct communities according to particular habitats. Multiple species of similar or different sizes can be found coexisting and species of these communities have distinct but overlapping environmental tolerance. Species with similar dispersal tendencies and prey preferences co-exist. Some habitats are very low in species richness while high in species abundance.

Factors such as habitat size, degree of permanence, water movement, temperature, chemical factors of water, successional stage, exposure, vegetation and presence of predators and prey may affect diving beetle distribution. Competing species may have some effects on community structure (Larson, 1990). The extent to which these factors influence the dytiscid community is yet to be fully determined.

As with any of the organisms, diving beetles are also associated with other organisms. Many species of mites are known to have an association with diving beetles, of which the biology of a particular mite species, *Eylais* Latreille, on dytiscid, is well-studied (Aiken, 1985). Many of the fungi in the group Laboulbeniomycetes attack dytiscids (Majewski, 1988; Majewski and Sugiyama, 1989; Lee and Choi, 1992; Lee and Lim, 1998; Santamaria, 2001; Rossi and Bergonzo, 2008) and are transmitted through sexual contact (Goldmann and Weir, 2012). Dytiscids possess diverse microbial gut fauna (Schaaf and Dettner, 1997), of which many are involved in the production of steroid constituents in the prothoracic gland secretions (Schaaf and Dettner, 1998).

A bacterium in the group *Rickettsia* was isolated from a dytiscid in the genus *Deronectes* and is found to be vertically transmitted within generations. Microsporidia and gregarines have been isolated from the gut of *Eretes stiticus* and *Dytiscus* sp. respectively (Kalavati and Narasimhamurti, 1976; Baudoin, 1968; Kalavati and Prasada Rao, 1995). A species of ciliate parasite has been described from the oesophagus of several species of Dytiscidae (Stammer, 1948). Some wasp species of the family Mymaridae and Eulophidae are known to parasitise diving beetle eggs (Jackson, 1958a; 1958b; 1958c; Zerova and Fursov, 1995). Similarly, Myxobacteria has been reported from dytiscid eggs, but their role is unknown (Jackson, 1959). A fly in the family Anthomyiidae is also known to attack diving beetles (Chilcott and James, 1966) and the Carabid larvae in the genus *Brachinus* parasitise the pupal stage of diving beetles (Juliano, 1985; Saska and Honek, 2004).

1.4.11 Dispersal

Diving beetles are active during night and they fly long distances to disperse to new habitats. The degree of tendency for dispersal varies across the group. Species in habitats with recurring disturbance show frequent dispersal. For instance, members of the genus *Copelatus* have a high tendency for dispersal and they can be seen flying throughout the forest in the tropics during the rainy season. Species in permanent habitats show less dispersal tendency. They disperse only during the rainy season to find new habitats and return when the new habitat gets dried (Hilsenhoff, 1986).

In subterranean taxa, most of the species lost their ability to swim and fly since their habitats are not subjected to disturbances and there is no opportunity to find another habitat. Some species are dimorphic with respect to flight. Their dispersal tendency depends on the season, population size and other factors (Jackson, 1952, 1955, 1956a, 1956b; Spangler and Gordon, 1973; Bilton, 1994). The flight may be optional in certain cases so the flight muscles break down to form energy for various physiological purposes (Bilton, 1994).

Dytiscids use plain polarised light to find new habitats during their dispersal flights. They spend some time on emergent vegetation probably for drying, before they take their flight. Only a single species (*Coelambus salinarius*) is known to take flight directly from the water body (Miller, 2013). Entering a water body is difficult for small species, but it is overcome by the special movements of the body and also by the application of the pygidial gland secretions (Dettner, 1985). The factors which trigger dispersal may include water depth, the density of conspecifics, plants and prey. Different species respond to different types of cues (Yee, Taylor and Vamosi, 2009). The influencing factors for dispersal flight is poorly studied.

1.5 Significance of the Study

When compared to other groups of insects, there are only few studies on the diving beetles from Kerala and all of these are solely taxonomic. This include reports of 51 species from Kerala including the three new descriptions published recently (Ghosh and Nilsson, 2012; Wewalka, 2017, Sheth *et al*., 2021; Anand *et al*., 2023). Therefore, this study is the first comprehensive study on diving beetles from Kerala.

The current study can significantly increase our understanding of diving beetle fauna, especially regarding Kerala state. In order to simplify identification of the species recorded from this study, at the subfamily, genus and species levels, a taxonomic key has been created through this study. The findings of this study will benefit entomology enthusiasts, students and researchers who focus on this specific group of insects or aquatic beetles or aquatic insects.

In India, there are very few molecular phylogenetic studies on the family Dytiscidae (Sheth *et al*. 2021). The current study is a pioneering examination of molecular phylogenetics of this group from the study area. As a result of this study, it would be possible to contribute 26 COI gene sequences of dytiscids to the NCBI's GenBank database. Present and upcoming researchers around the globe working on the phylogeny of insects will have access to these sequences and can make use of them in their studies.

Family Dytiscidae is an ecologically important insect group and can be used as an indicator of water or wetland quality (Foster 1996; Painter 1999; Mebane *et al*, 2012). Numerous studies support their use as biodiversity indicators alongside of other insect groups and as a means of identifying regions deserving of conservation (Foster *et al*., 1990; Foster and Eyre, 1992; Ribera and Foster, 1992; Dong *et al*. 2014). As predators, they play a pivotal role in nutrient recycling. Moreover, they have an important role in freshwater macroinvertebrate community structure formation. Diving beetles are known to feed on smaller vertebrates and other invertebrates including immature life stages of insects like mosquitoes and blackflies. So, they can be used as biological control agents of disease-causing insects (Culler and Lamp 2009).

Furthermore, according to Pemberton (1999), diving beetles possess anti-diuretic properties and are consumed by people in many places in the world. Diving beetles' exocrine glands produce diverse chemicals of which some are known for their emulsifying and cannabimimetic properties. These could be beneficial to humans. Nevertheless, little is known about the chemistry of diving beetles (Dettner, 2014) and can be recognised as an important perspective for future research. Fundamental knowledge essential for such applied research is obtained from taxonomical studies.

1.6 Objectives of the Study

- To prepare a preliminary checklist of the diving beetles of Kerala.
- To conduct a taxonomic study of diving beetles collected during the study.
- To develop taxonomic keys for the identification of family Dytiscidae.
- To study the phylogeny of Dytiscidae based on COI gene sequences.
- To study the habitat similarity and the influence of selected water parameters on co-occurrence of dytiscid species.

CHAPTER- 2

A PRELIMINARY CHECKLIST OF DIVING BEETLES (COLEOPTERA: DYTISCIDAE) OF KERALA

2. A Preliminary Checklist of Diving Beetles (Coleoptera: Dytiscidae) of Kerala

2.1 Introduction

Beetles constitute 25% of the species described among all life forms and represent Earth's largest and most diverse group (Nielsen and Mound, 1999; Hunt *et al*., 2007; Powell *et al.*, 2009; Bouchard *et al*., 2017). Of all the described insect species 40% is constituted by the order Coleoptera (Hammond, 1992). It is estimated that the beetle species all over the world is around one million (Chapman, 2009). The actual number may exceed this estimate. Their diversity implies their ability to thrive in all possible habitats. Approximately 18,000 species of aquatic beetles are known to inhabit our freshwater ecosystems (Jäch and Balke, 2008).

Family Dytiscidae, the largest of all aquatic beetle families comprises 4739 species under 11 subfamilies and 181 genera (Nilsson and Hájek, 2024). The members in this family are very commonly encountered during freshwater insect sampling. In India, a substantial body of literature can be found, particularly among the faunal inventories of the Zoological Survey of India. Numerous researchers specializing in aquatic coleoptera have made significant contributions to the Indian diving beetle fauna. In India, 256 species are known from 36 genera and seven subfamilies (Chandra *et al.*, 2017).

2.2 Review of Literature

A global estimate of described species of diving beetles can be found in the world catalogue of Dytiscidae originally prepared by Nilsson (2001) and corrected and updated each year by Hájek. The latest version of this catalogue (Nilsson & Hájek, 2024) lists 4739 species from all around the globe.

The "Catalogue of Palearctic Dytiscidae (Coleoptera)" (Nilsson & Hájek, 2023) documents a total of 1200 species across 60 genera and five subfamilies of diving beetles.

Vazirani (1977) prepared a catalogue for the diving beetle fauna of the Oriental region which includes 371 species under 41 genera. In this catalogue, several species were reported from India including Kerala.

The "Catalogue of Diving Beetles in India and Adjacent Countries" (Ghosh & Nilsson, 2012), an updated version of Vazirani's catalogue (1977) on Oriental diving beetles, provided an estimate of the number of diving beetles in India, including Kerala. It documented the diving beetle fauna for each state in India and also for adjacent countries. It listed 254 species of diving beetles under 37 genera and 6 subfamilies from India.

From Kerala, Prabhakaran *et al*. (2024) listed 30 species from Kerala for the first time. This report also presented a checklist of 62 species known from the state. This publication originated from a part of this study.

Several studies on diving beetles have taken place in India as well as Kerala state (Vazirani, 1953, 1968, 1970a, 1970b, 1970c, 1970d, 1972a, 1972b, 1973; Biswas, Mukhopadhyay and Saha, 1995; Wewalka, 1997; Hendrich and Balke, 1998, 2000a; Mukhopadhyay *et al*., 2000; Sharma, 2002; Mukhopadhyay and Ghosh, 2004; Hájek and Šťastný, 2005; Brancucci, 2006a, 2006b; Mukhopadhyay and Ghosh, 2007; Chandra, 2008; Ghosh *et al*., 2011; Miller and Wewalka, 2010; Manivannan and Madani, 2011; Deb, 2017; Sheth *et al*., 2018; Wewalka, 2020; Ghosh, 2022; Wewalka, 2023).

But majority of these studies are based on museum specimens and insect collections which resulted from entomological expeditions years ago. Recently a study (Prabhakaran *et al*., 2024) showcased the surprising species richness and diversity of dytiscids from small aquatic habitat in Kerala.

2.3 Materials and Methods

The study area consists of all the 14 districts of Kerala state (Plate 3 (a- n)), excluding reserve forests and protected areas. Kerala, situated at the southern tip of Peninsular India (8°17'30" N and 12°47'40" N, 74°27'47" and 77°37'12" E), lies on the windward side of the Western Ghats. The state has an area of 38,863 km^2. It stretches for a maximum length of 560 km and varies in width from 11 to 124 km (Source: EiACP PC HUB; http://kerenvis.nic.in). Bordered by the Arabian Sea to the west and the Western Ghats to the east, part of Kerala lies in one of the world's biodiversity hotspots. The state experiences two monsoons— the Southwest and the Northeast monsoons— which contribute to its diverse freshwater bodies, including 44 rivers, seven inland lakes, the Kole wetland system, and numerous ponds and pools.

Kerala's geography is characterized by three distinct regions: the highlands, midlands, and lowlands. Land use features monoculture and mixed plantations, paddy fields, and natural forests interspersed with densely populated areas (Source: Official Web Portal-Government of Kerala;https://www.kerala.gov.in).

As part of the study, 268 randomly selected locations in the 14 districts were covered (Appendix A; Plate 3 (a-n)). The study locations represented the highland, midland and lowland regions of Kerala and lie between 12°42'N and 8°30'N latitude and 74°53'E and 77°10'E longitude. Geographical coordinates were obtained from Google Earth, and the study area map was prepared using QGIS.

2.3.1 Insect Collection and Preservation

Insects were collected between 6.00 AM and 6.00 PM. A D-frame pond net (mesh size: 500µm; diameter: 30 cm; depth: 15 cm) (Plate 1e) and plastic kitchen strainers (Plate 1a) of various sizes were used for sampling. For larger water bodies, the marginal zones were sampled by disturbing vegetation, substratum and objects like stones and small logs. In smaller habitats, the entire water body was sampled (Plate 2a-f). Larger specimens were handpicked. Smaller specimens were captured either using forceps or small brushes (Plate 1b).

The specimens were preserved in 70 % ethyl alcohol in sample bottles (Plate 1: Figure 3) at the collection sites and carried to the laboratory for further study.

2.3.2 Identification

Beetles were identified using keys, descriptions and illustrations from the literature (Vazirani, 1968, 1970 a, 1970b; Wewalka, 1975 & 1979; Brancucci, 1983 & 1986; Biström, 1997; Hendrich and Balke, 1998, 1999 & 2000a; Biström and Nilsson, 2003;

Brancucci, 2003; Hendrich and Wang, 2006; Miller and Wewalka, 2010; Biström and Bergsten, 2015; Wewalka, 2017; Sheth *et al*., 2018; Sheth *et al*., 2021), as well as expert opinion (Dr. Sayali D. Sheth, Maharashtra; Dr. Gunther Wewalka, Austria; Dr. Jiri Hájek, Czech Republic and Zhuoyin Jiang, China; Olof Biström, Finland). For all species, male characteristics such as genitalia, colouration, markings on the dorsal surface and microsculptures were used for identification (details given in Chapter 3). Where males were not available, females were used to describe the species.

2.3.3 Preparation of Checklist

The checklist was prepared by compiling the species recorded in both the previous and current study.

2.4 Results

A total of 53 species were identified based on adult characteristics. These species belong to six subfamilies and 16 genera. Two species are first reports from India, eight are first reports from South India, and 23 are first reports from Kerala. A comprehensive overview of the collected species is provided in Table 1.

Table 1. Taxonomic classification and overview of the diving Beetles (Coleoptera: Dytiscidae) collected during the study

Subfamily	Genus	Total Number of species in the study area
Colymbetinae	*Rhantus*	1
Copelatinae	*Copelatus*	6
	Lacconectus	3
Cybistrinae	*Cybister*	5
Dytiscinae	*Hydaticus*	5

Subfamily	**Genus**	**Total Number of species in the study area**
	Sandracottus	1
Hydroporinae	*Clypeodytes*	2
	Hydroglyphus	2
	Hydrovatus	5
	Hyphydrus	2
	Leiodytes	1
	Microdytes	1
	Peschetius	6
	Yola	1
Laccophilinae	*Laccophilus*	9
	Neptosternus	4

Table 2. A preliminary checklist of diving beetles (Coleoptera: Dytiscidae) of Kerala

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
1.	**Subfamily: Colymbetinae Tribe: Colymbetini** ***Genus: *Rhantus* Dejean, 1833**	****Rhantus taprobanicus* cf. Sharp, 1890	CR
2.	**Subfamily: Copelatinae** **Tribe: Copelatini** **Genus: *Copelatus* Erichson, 1832**	*Copelatus biswasi* Mukherjee & Sengupta, 1986	PR; EN
3.		*Copelatus boukali* Hendrich & Balke, 1998	PR; CR; EN

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
4.		*Copelatus cryptarchoides* Régimbart, 1899	PR; CR
5.		*Copelatus davidi* Wewalka, 2017	PR; CR; EN
6.		***Copelatus neelumae* Vazirani, 1973	CR
7.		***Copelatus oblitus* Sharp, 1882	CR
8.		***Copelatus sociennus* J. Balfour-Browne, 1952	CR
9.		*Copelatus wayanadensis* Manivannan & Madani, 2011	PR; EN
10.	**Genus: *Lacconectus* Motschulsky, 1856**	*Lacconectus blandulus* Brancucci, 2003	PR; CR; EN

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
11.		*Lacconectus freyi* Guéorguiev, 1968	PR
12.		*Lacconectus munnarensis* Brancucci, 2003	PR; EN
13.		*Lacconectus pacholatkoi* Brancucci, 2003	PR
14.		*Lacconectus regimbarti* Brancucci, 1986	PR; CR
15.		*Lacconectus satoi* Brancucci, 2003	PR; CR
16.	**Subfamily: Cybistrinae** **Tribe: Cybistrini** **Genus: *Cybister* Curtis, 1827**	****Cybister confusus* Sharp, 1882	CR
17.		*Cybister cardoni* Severin, 1890	CR

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
18.		Cybister dejeanii Aubé, 1838	PR; EN
19.		*Cybister javanus* Aubé, 1838	PR
20.		*Cybister limbatus* (Fabricius, 1775)	PR
21.		***Cybister posticus* Aubé, 1838	CR
22.		****Cybister sugillatus* Erichson, 1834	CR
23.		****Cybister tripunctatus lateralis* (Fabricius, 1798)	CR
24.	**Subfamily: Dytiscinae** **Tribe: Hydatiscini** **Genus: *Hydaticus* Leach, 1817**	*Hydaticus bipunctatus* Wewalka, 1975	PR

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
25.		****Hydaticus discindens* Walker, 1858	CR
26.		*Hydaticus histrio* Clark, 1864	PR
27.		***Hydaticus incertus* Régimbart, 1888	CR
28.		*Hydaticus luczonicus* Aubé, 1838	CR
29.		*Hydaticus ricinus* Wewalka, 1979	PR; CR
30.		*Hydaticus vittatus* (Fabricius, 1775)	PR; CR
31.	**Tribe: Aciliini** **Genus: *Sandracottus* Sharp, 1882**	*Sandracottus dejeanii* (Aubé, 1838)	PR
32.		****Sandracottus festivus* (Illiger, 1801)	CR

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
33.		*Sandracottus mixtus* (Blanchard, 1843)	PR
34.		*Sandracottus vijayakumari* Anand, Ashiq, Smitha, Adhithya, Tibin & Suresh, 2021	PR; EN
35.	**Subfamily: Hydroporinae** **Tribe: Bidessini** ***Genus: *Clypeodytes* Régimbart, 1894**	****Clypeodytes bufo* Sharp, 1890	CR
36.		**Clypeodytes* cf. *feryi* Hendrich & Wang, 2006	CR
37.	**Genus: *Geodessus* Brancucci, 1979**	*Geodessus kejvali* Balke & Hendrich, 1996	PR; EN

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
38.	**Genus: Hydroglyphus Motschulsky, 1853**	*Hydroglyphus crassifrons* (Régimbart, 1903)	PR; EN
39.		*Hydroglyphus flammulatus* Sharp, 1882	PR: CN
40.		****Hydroglyphus pendjabensis* Gugnot, 1954	CR
41.	***Genus: *Leiodytes* Guignot, 1936**	***Leiodytes orissaensis* (Vazirani, 1969)	CR
42.	**Genus: *Peschetius* Guignot, 1942**	*Peschetius bistroemi* Sheth, Ghate, Dahanukar & Hájek, 2021	PR; CR; EN
43.		*Peschetius quadricostatus* (Aubé, 1838)	PR; CR
44.		*Peschetius toxophorus* Guignot, 1942	PR; CR
45.		**Peschetius taprobanicus* cf. Biström &	CR

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
		Bergsten, 2015	
46.		*Peschetius sp.*	CR
47.	***Genus: *Yola* Gozis, 1886**	****Yola consanguinea* (Régimbart, 1892)	CR
48.	***Genus: Hydrovatus Motschulsky, 1853***	*Hydrovatus acuminatus* Motschulsky, 1859	PR
49.		*Hydrovatus cardoni* Severin, 1890	PR; CR
50.		*Hydrovatus castaneus* Motschulsky, 1855	PR
51.		*Hydrovatus confertus* Sharp, 1882	PR; CR
52.		***Hydrovatus picipennis* Motschulsky, 1860	CR

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
53.		*Hydrovatus rufescens* Motschulsky, 1859	PR
54.		***Hydrovatus rufoniger* (Clark, 1863)	CR
55.		*Hydrovatus seminarius* Motschulsky, 1860	PR; CR
56.	**Tribe: Hygrotini** ***Genus: Hygrotus (Hyphoporus)*** **Stephens, 1828**	*Hyphoporus pugnator* Sharp, 1890	PR; EN
57.	**Tribe: Hyphydrini** **Genus: *Hyphydrus* Illiger, 1802**	*Hyphydrus intermixtus* (Walker, 1858)	PR; CR
58.		*Hyphydrus renardi* Severin, 1890	PR; CR

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
59.	**Genus: *Microdytes* J. Balfour-Browne, 1946**	****Microdytes cameroni* cf. Miller & Wewalka, 2010	CR
60.		*Microdytes belli* J. Balfour-Browne, 1946	PR
61.		*Microdytes boukali* Wewalka, 1997	PR; EN
62.		*Microdytes svensoni* Miller & Wewalka, 2010	PR
63.	**Subfamily: Laccophilinae Tribe: Laccophilini Genus:**	*Laccophilus anticatus anticatus* Sharp, 1890	PR; CR
64.		*Laccophilus aurofasciatus* Vazirani, 1972	PR
65.		****Laccophilus auropictus* cf. Régimbart, 1899	CR

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
66.		****Laccophilus elegans* Sharp, 1882	CR
67.		*Laccophilus ellipticus* Régimbart, 1889	PR; CR
68.		*Laccophilus flexuosus* Aubé, 1838	PR; CR
69.		*Laccophilus inefficiens* Walker, 1859	PR; CR
70.		*Laccophilus parvulus parvulus* Aubé, 1838	PR; CR
71.		*Laccophilus parvulus obtusus* Sharp, 1882	PR; CR
72.		*Laccophilus sharpi* Régimbart, 1889	PR; CR
73.	**Genus: *Neptosternus* Sharp, 1882**	*Neptosternus annettae* Hendrich & Balke, 2000	PR; CR; EN

No.	Subfamily, Tribe and Genus	Species Name	Status
	*** First record in India; ** First record in South India; *** First record in Kerala** **CR: Found during the current study** **PR: Already reported by other authors but not seen in this study** **EN: Endemic species**		
74.		*Neptosternus boukali* Hendrich & Balke, 1999	PR; CR; EN
75.		Neptosternus kerala Hendrich & Balke, 1999	PR; CR; EN
76.		*Neptosternus leyi* Hendrich & Balke, 2000	PR; CR; EN

2.5 Discussion

Fifty-one species of diving beetles have been previously reported from Kerala (Miller and Wewalka, 2010; Ghosh and Nilsson, 2012; Wewalka, 2017; Anand *et al*., 2021; Deb and Subramanian, 2023). Of these 30 species were observed during this study. A total of 53 species could be identified till species level in this study. In addition, one species which were clearly distinct from all others but could not identified were also observed. This adds up the number of diving beetles from Kerala to 76 till date (Table 2).

Subfamily Hydroporinae is the largest subfamily of diving beetles (Miller and Bergsten, 2016). On examining the 53 species documented during this study, Hydroporinae was the most dominant with 20 species under eight genera, *Clypeodytes*, *Hydroglyphus*, *Hydrovatus*, *Hyphydrus*, *Leiodytes*, *Microdytes*, *Peschetius* and *Yola*. Among this, four genera (*Rhantus*, *Clypeodytes*, *Leiodytes* & *Yola*) are being reported for the first time from Kerala. *Clypeodytes* (*C. bufo* & *C.* cf. *feryi*) has two species and *Rhantus, Leiodytes* and *Yola* has one species each (*R. taprobanicus, L. orissaensis* & *Y. consanguinea*). *Clypeodytes* cf. *feryi* is a first report from India. Some species from genera *Hydroglyphus*, *Hydrovatus*, *Microdytes* and *Peschetius* are first reports, *Hydroglyphus pendjabensis*, *Hydrovatus picipennis*, *Hydrovatus rufoniger*, *Microdytes cameroni* and *P. taprobanicus*. *H. picipennis* and *H. rufoniger* are first reports from South India and P. *taprobanicus* is a first report from India.

In this study Laccophilinae was the second largest subfamily with 13 species under two genera, *Laccophilus* and *Neptosternus*. *L. auropictus* and *L. elegans* are first reports. Genus *Copelatus* contains six species, of which *C. oblitus* and *C. sociennus* are first reports from South India.

Dytiscinae had two genera, *Hydaticus* and *Sandracottus*. *Hydaticus incertus* is a first report for South India. Whereas *Hydaticus discindens* and *Hydaticus luczonicus* are first reports from Kerala. Only one species, *Sandracottus festivus* is recorded under genus *Sandracottus*, which is also a first report from Kerala.

Subfamily Cybistrinae is represented by only a single genus, *Cybister*. *Cybister posticus* is first report from South India. *C. confusus*, *C. sugillatus* and *C. tripunctatus lateralis* are first reports from Kerala. Subfamily Colymbetinae is recorded from Kerala for the first time and has a single species *Rhantus* cf *taprobanicus.*

In the recent times, entomological expeditions have become a rare phenomenon. The focus of biological research has shifted from taxonomy and diversity to molecular and clinical biology with immediate applications and profits. Taxonomy is often referred to as dying science (Lisa, 2011; Löbl, 2023). Even though, new equipments and techniques can enable better species identification, classification and phylogeny. Lack of interest and funding in taxonomy and loss of habitats have led to many gaps in taxonomy and systematic knowledge. Twenty-three first reports during this study is a clear indication that intensive and extensive studies could significantly increase the number of dytiscids recorded in the study area and elsewhere.

2.6 Conclusion

Fifty-three species of diving beetles were identified under 16 genera and six subfamilies. One species under the genus *Peschetius* was identified up to the genus level. One subfamily, four genera and twenty-three species were recorded for the first time from Kerala. A checklist of diving beetles was compiled, incorporating 23 new records obtained from this study along with the 51 species reported in previous studies.

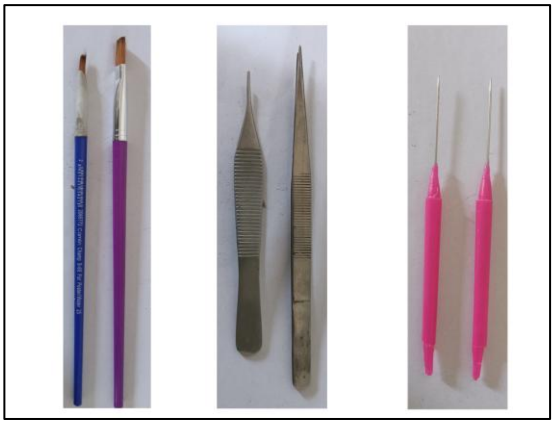
Several specimens of diving beetles collected in this study remains unidentified and were excluded from this study due to taxonomic uncertainties. Additional faunistic studies on dytiscids are crucial to resolve these ambiguities and to describe new species to the scientific world.

PLATE 1

MATERIALS USED

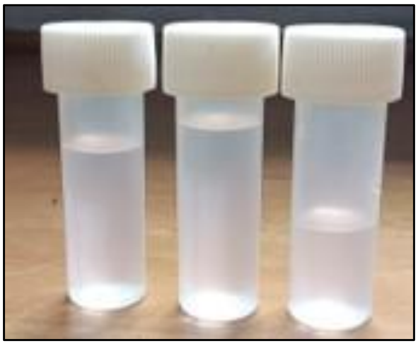
PLATE-1
Materials Used

1a. Plastic kitchen sieves of various size



1b. Brushes, Forceps & Needles

1c. Sample bottles



1d. Specimen tubes

1e. D-frame pond net

PLATE 2

INSECT COLLECTION

PLATE- 2
Insect Collection

2a. Vellachal (Thrissur)

2b. Urulanthanni(Ernakulam)

2c. Thalikkode (Thrissur)

2d. Azhinjillam(Kozhikode)

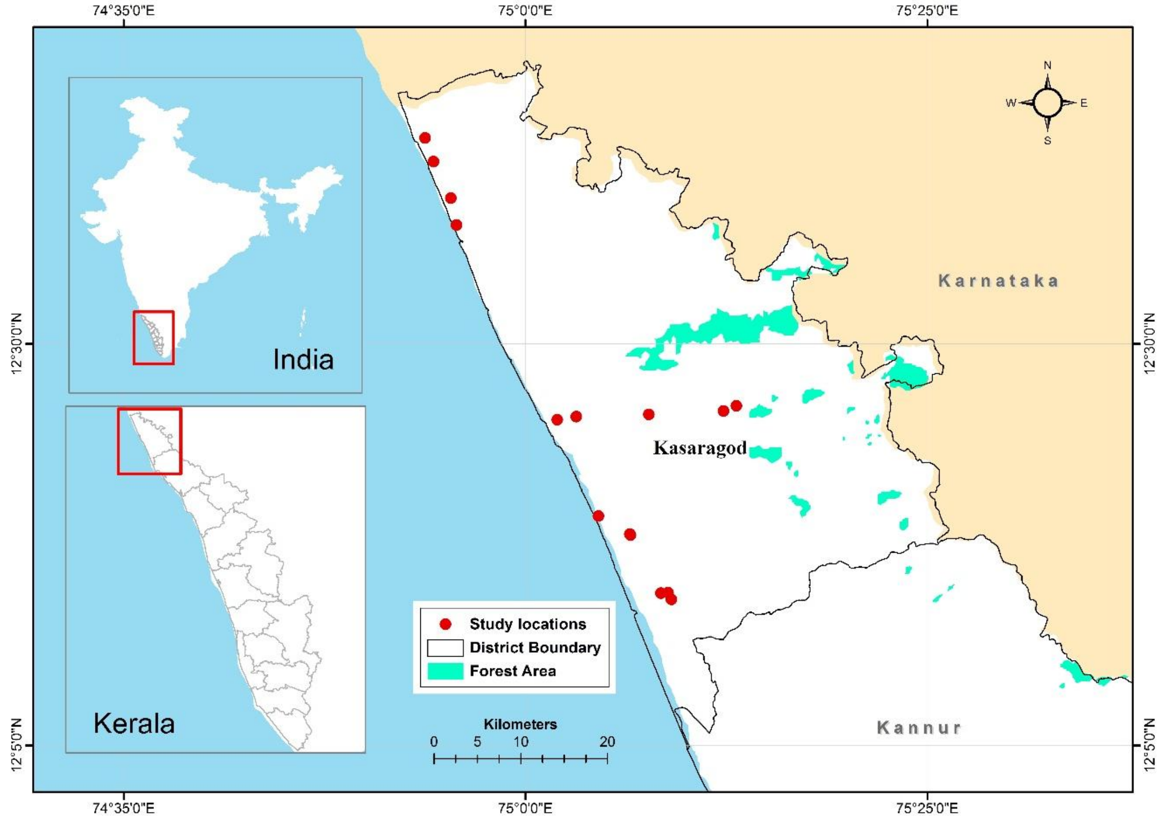
2e. Chembuthra (Thrissur)

2f. Karingachira (Ernakulam)

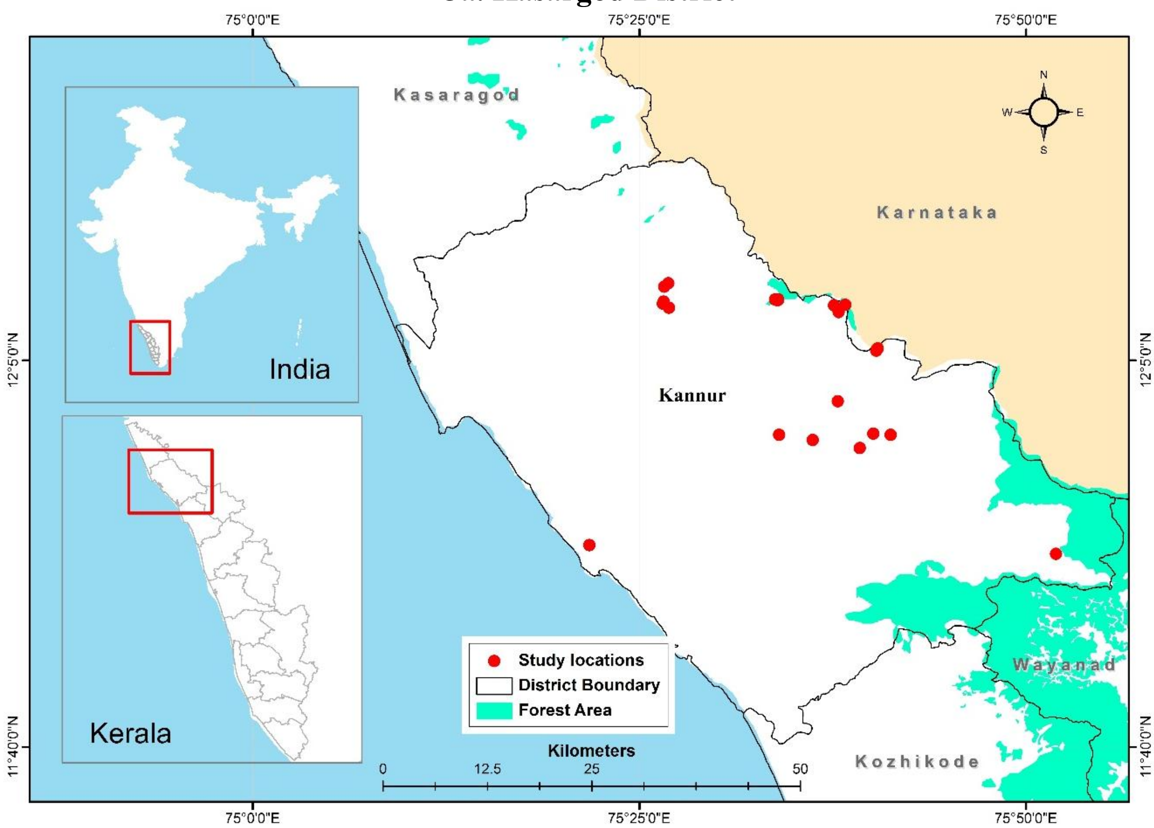
PLATE 3

STUDY SITES IN DIFFERENT DISTRICTS IN KERALA

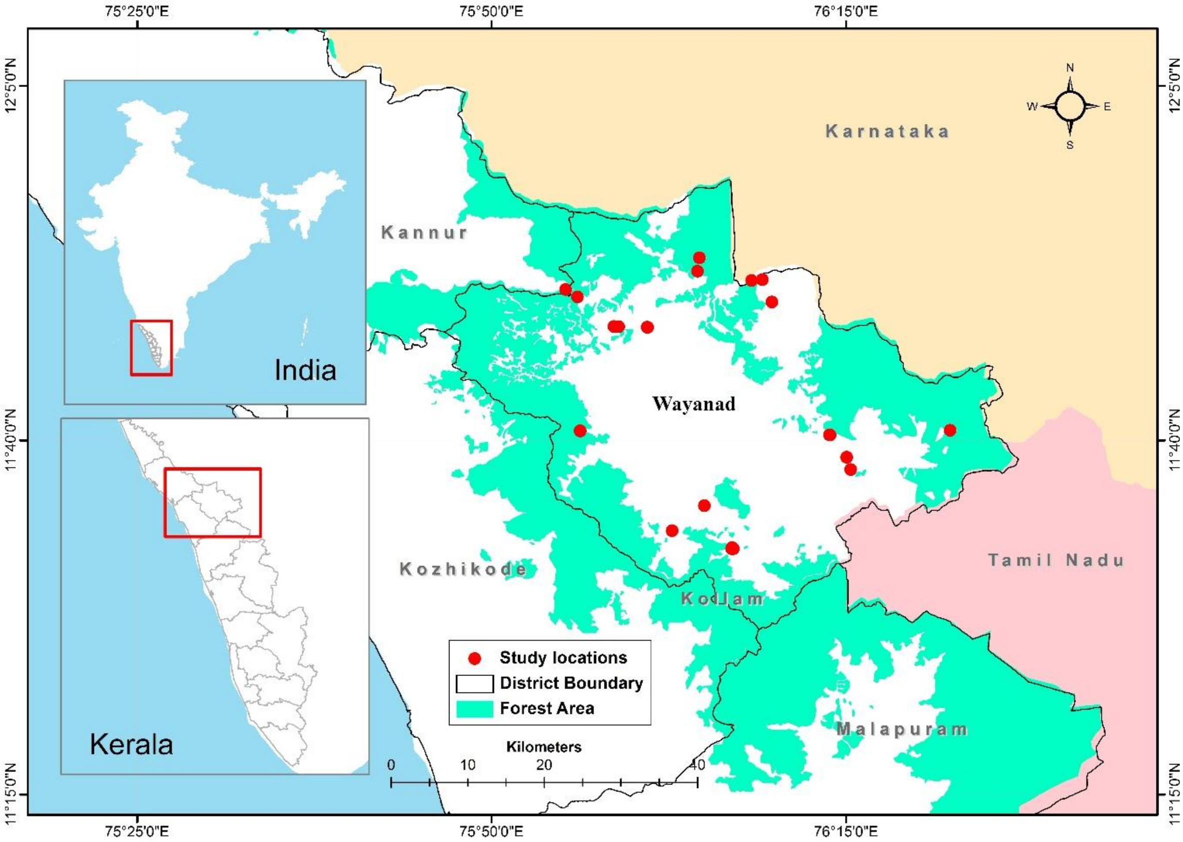
Plate 3- Study Sites in Different Districts in Kerala*



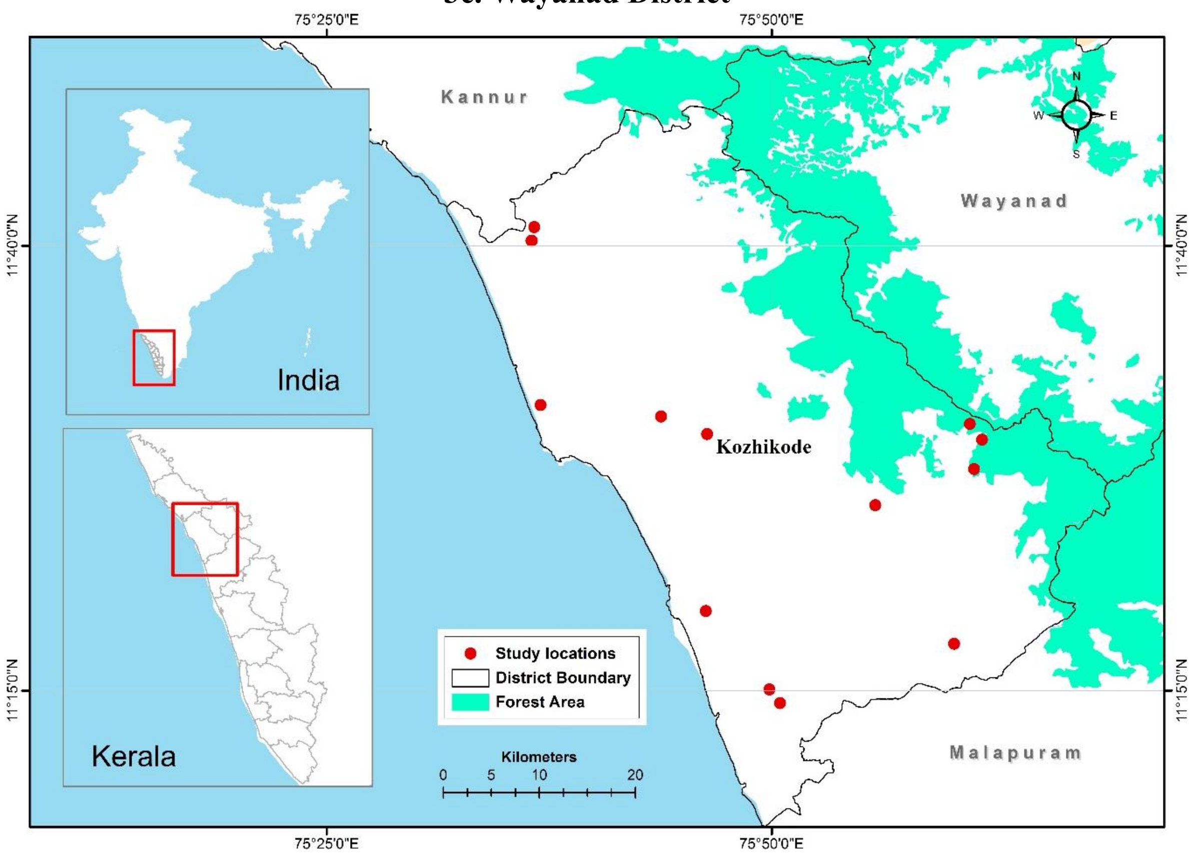
3a. Kasargod District



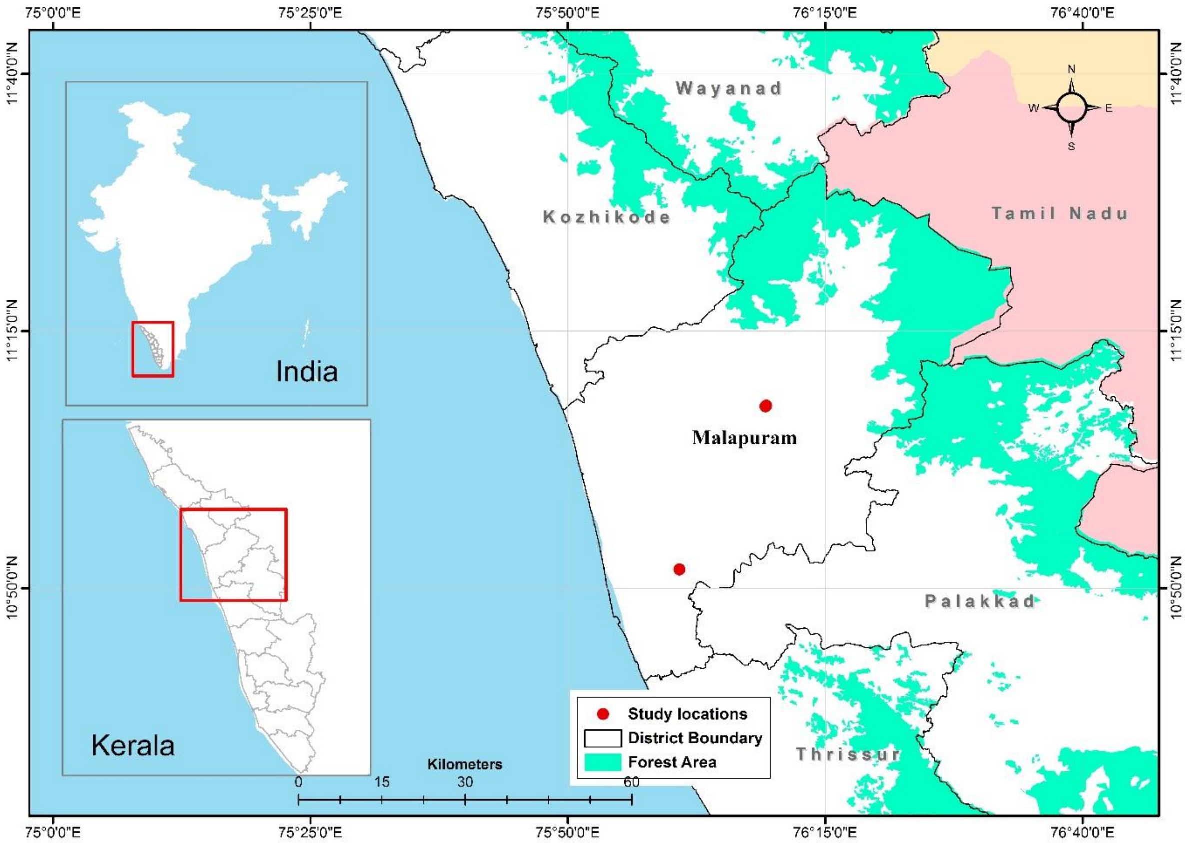
3b. Kannur District



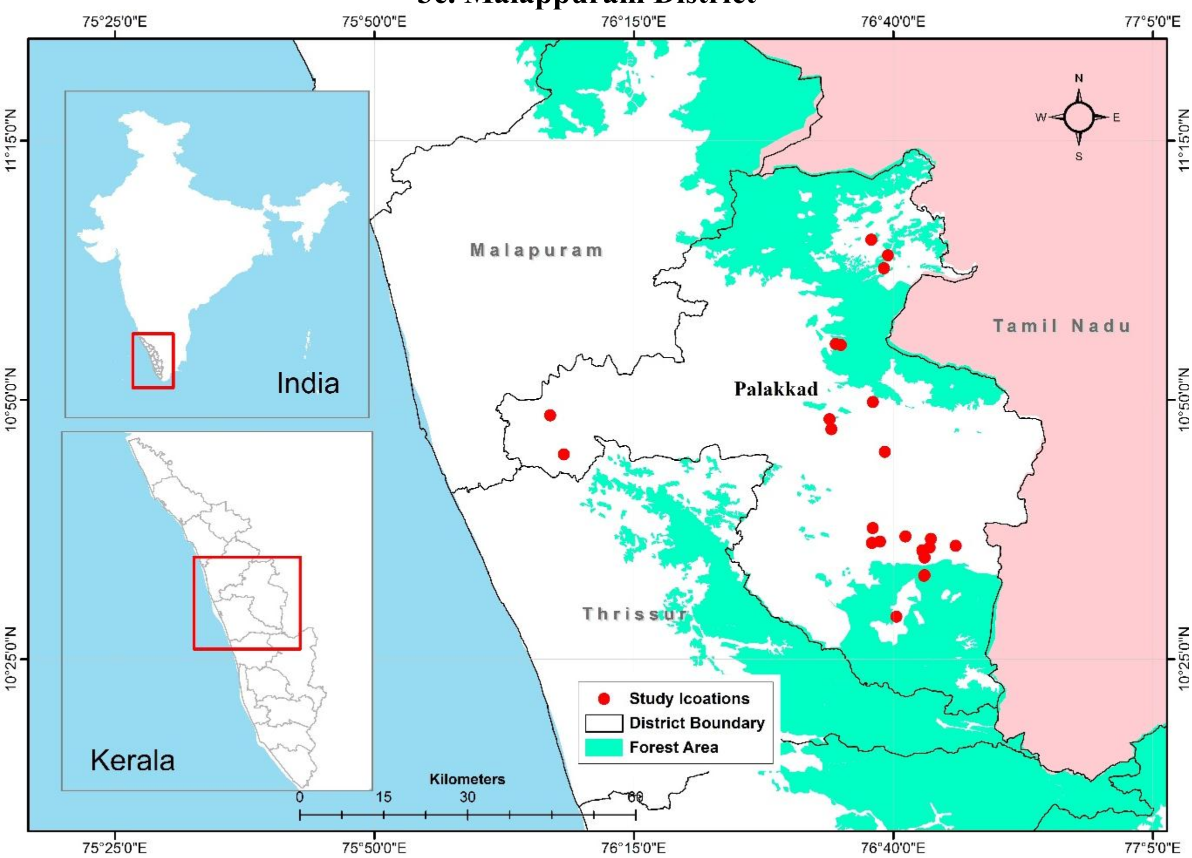
3c. Wayanad District



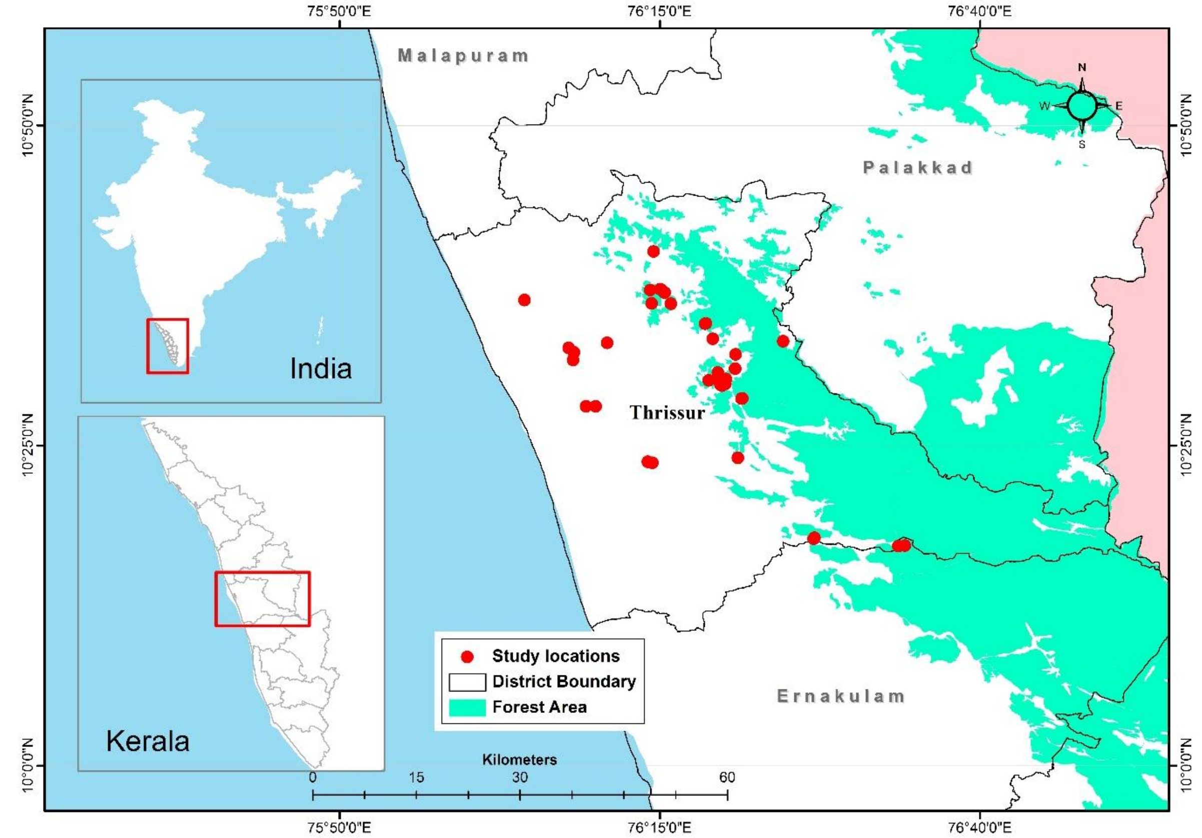
3d. Kozhikode District



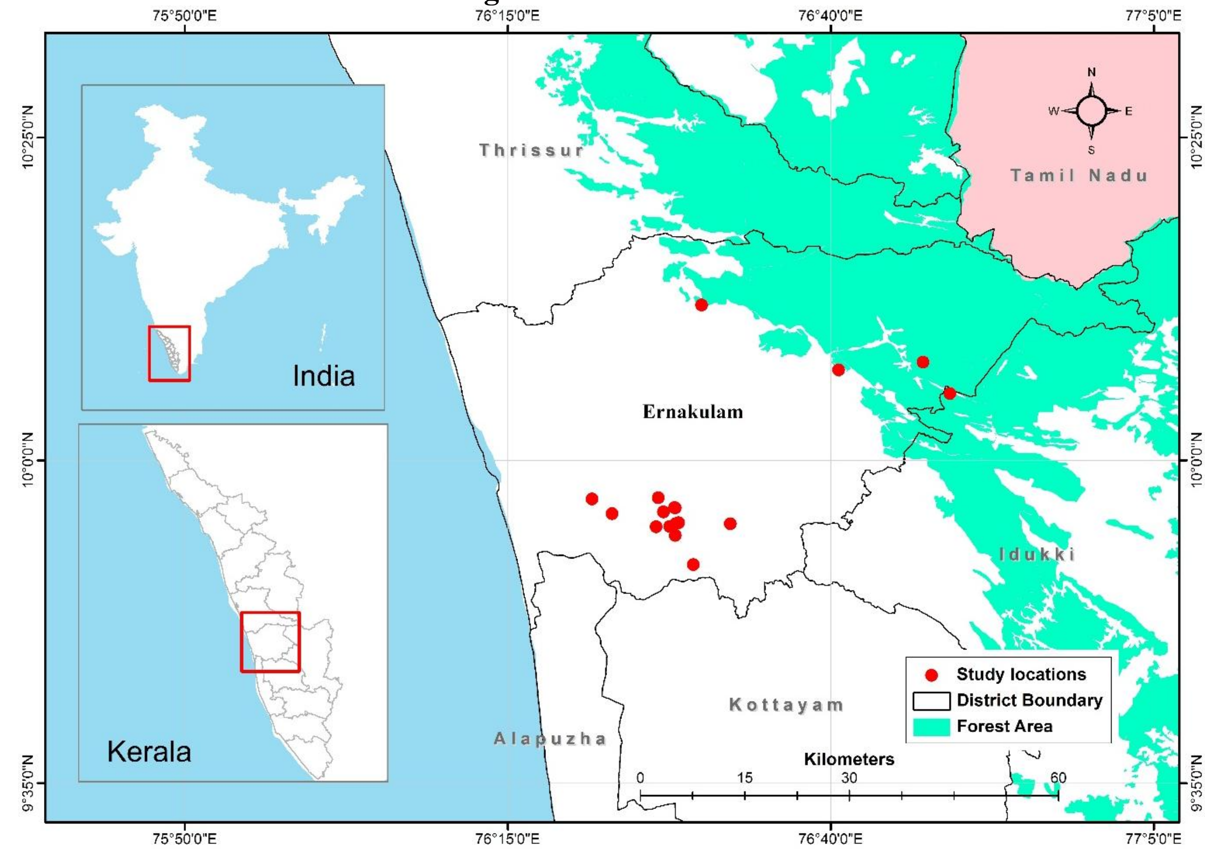
3e. Malappuram District



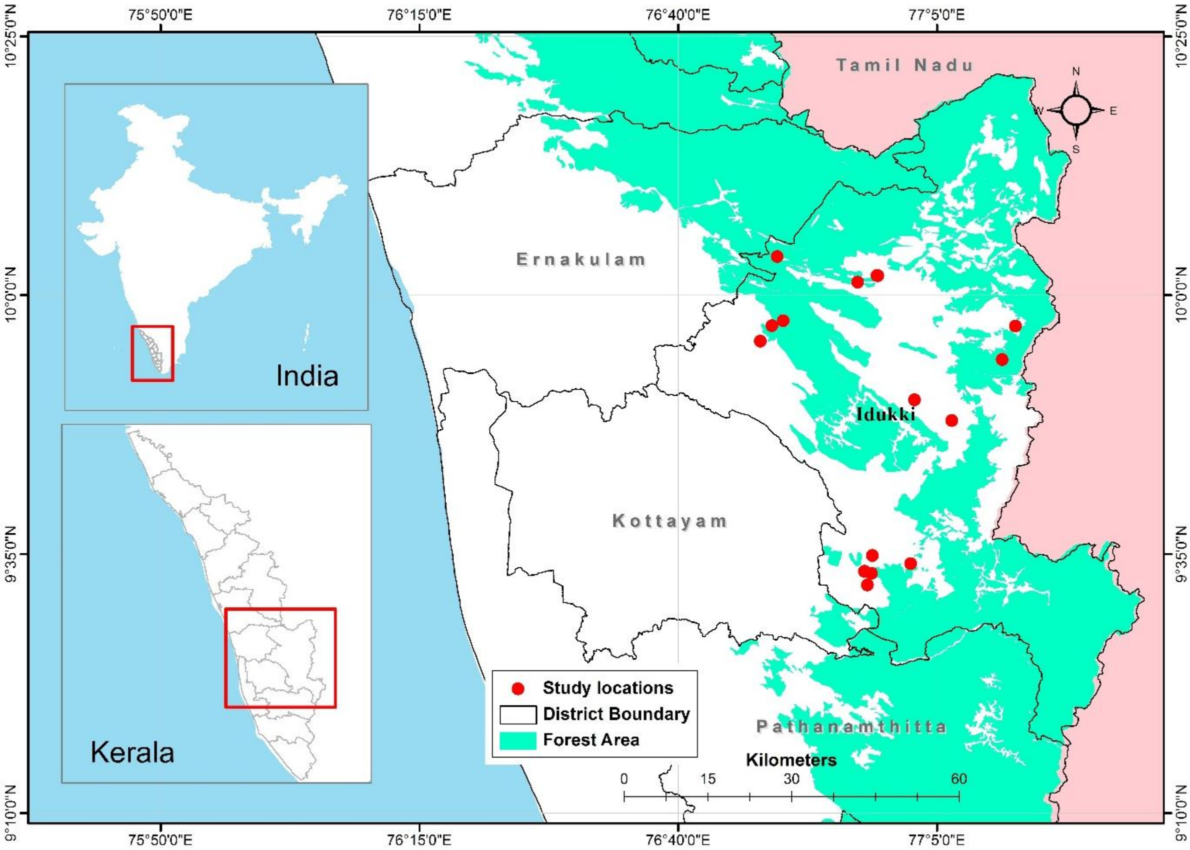
3f. Palakkad District



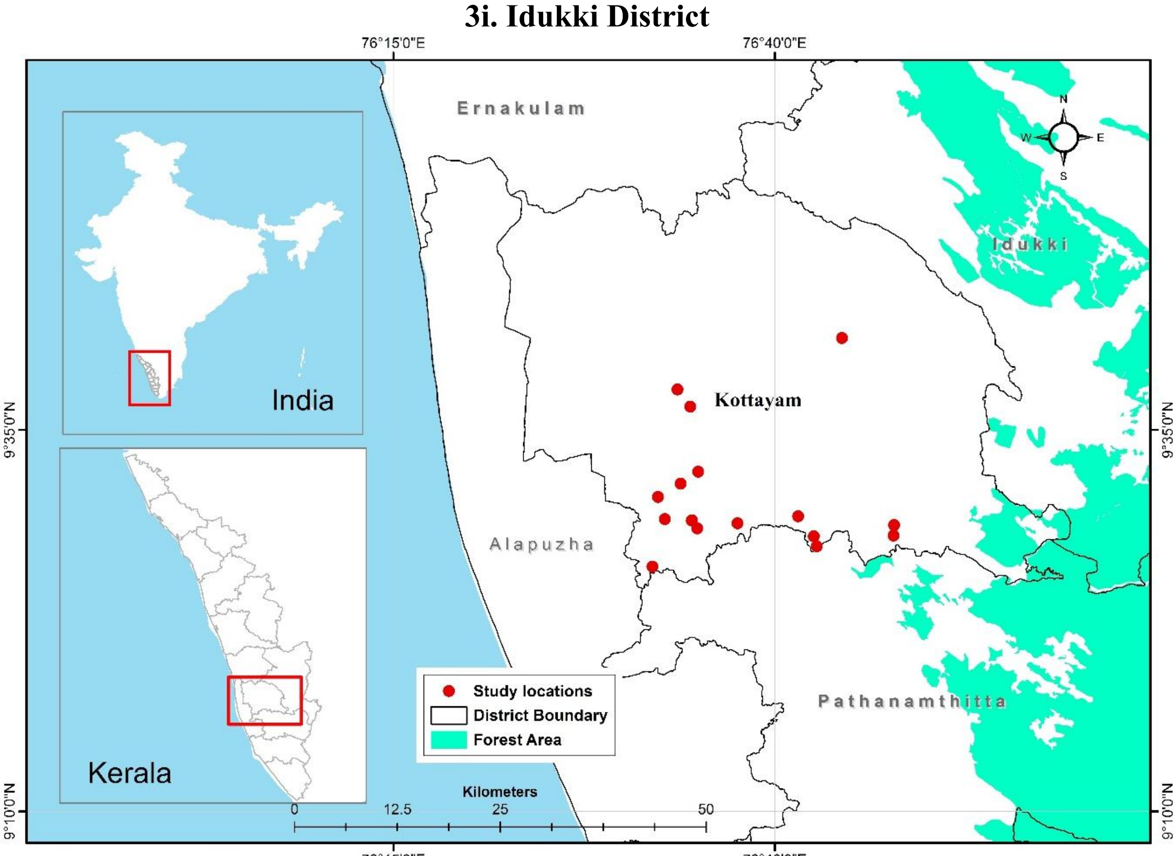
3g. Thrissur District



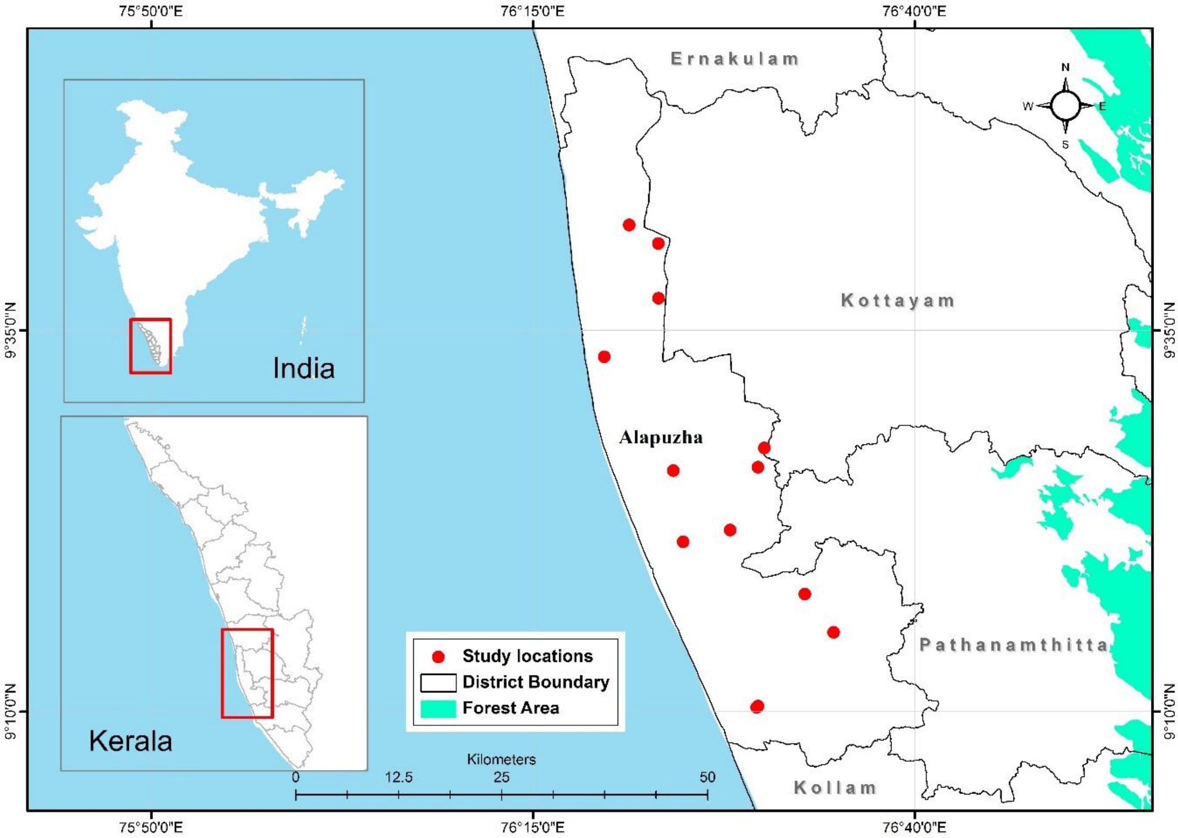
3h. Ernakulam District



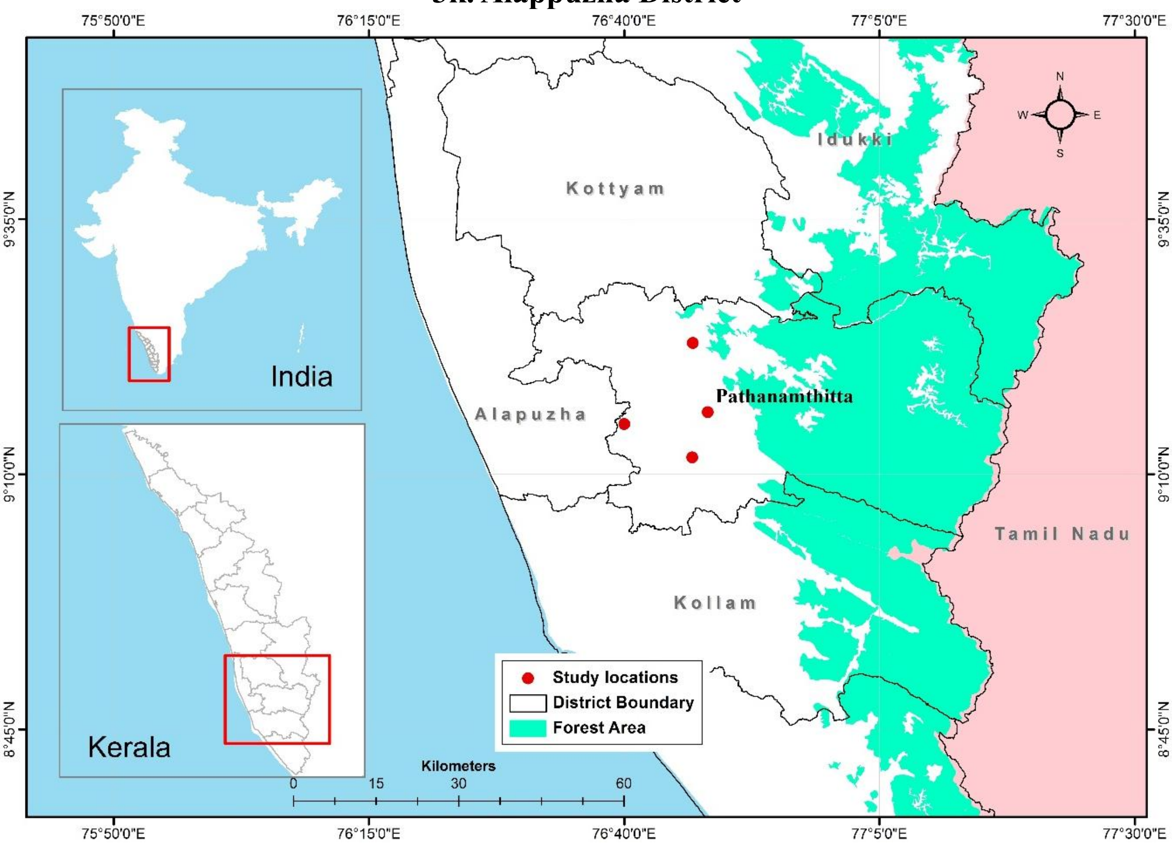
3i. Idukki District



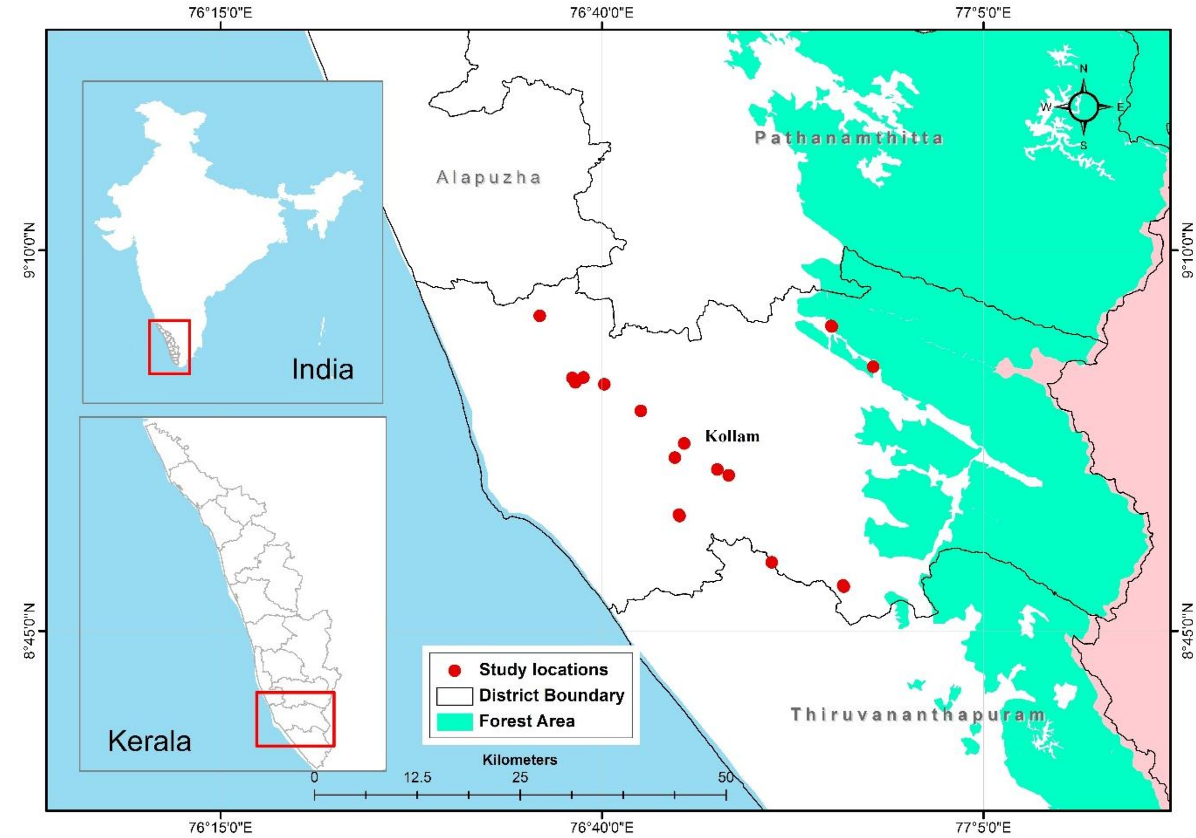
3j. Kottayam District



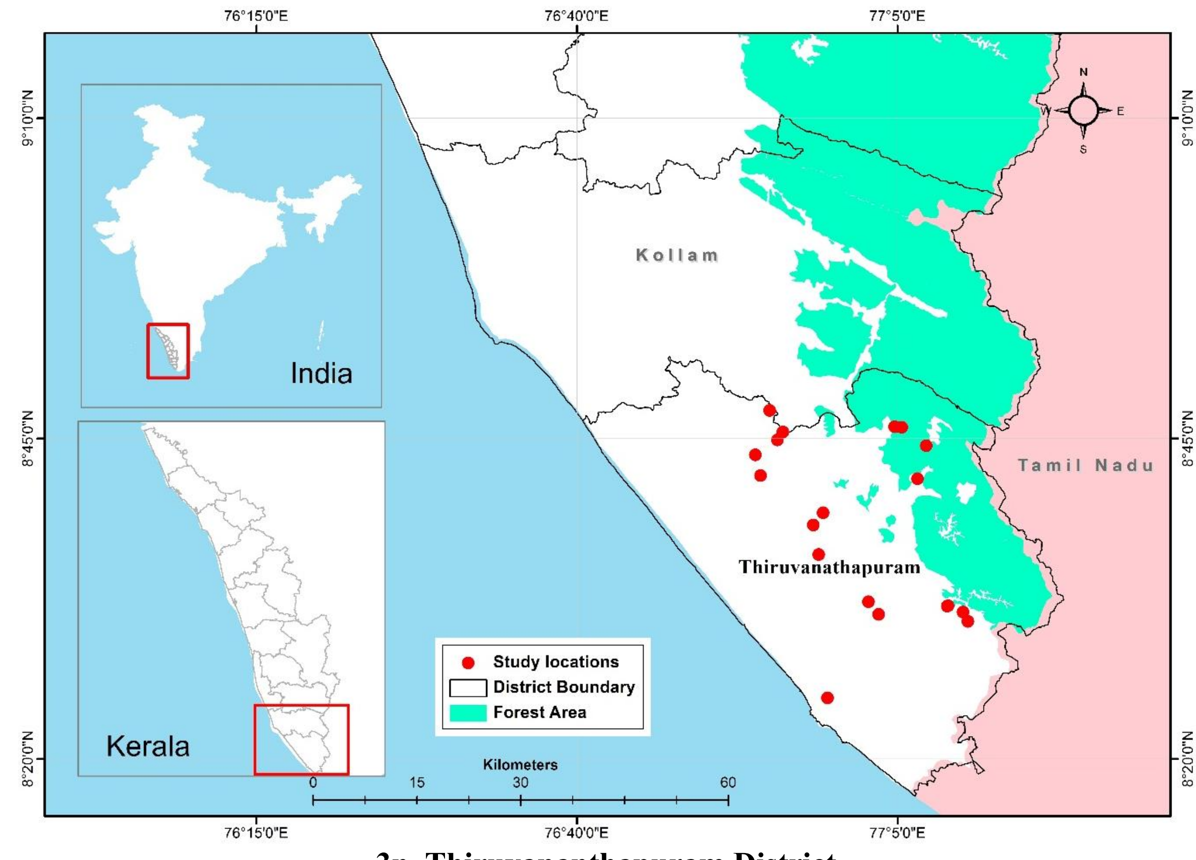
3k. Alappuzha District



3l. Pathanamthitta District



3m. Kollam District



3n. Thiruvananthapuram District

*Collection sites which lie very close to each other are not represented as distinct dots in the maps as the maps are scaled

CHAPTER- 3

A TAXONOMIC STUDY OF DIVING BEETLES (COLEOPTERA: DYTISCIDAE) OF KERALA

3. A Taxonomic Study of Diving Beetles (Coleoptera: Dytiscidae) of Kerala

3.1 Introduction

Diving beetles are one of the most successful groups of aquatic insects in freshwater ecosystems. They have been the subject of extensive taxonomic study since the early days of entomology. The history of diving beetles' taxonomy can be traced back to the 17th century when diving beetles appeared in *Systema Naturae* (Linnaeus, 1758). In the 18th century many taxonomic studies on this family were published (Boheman, 1852; Perris, 1862; Sharp, 1882). These were followed by the studies exploring different aspects of Dytiscidae. Currently, there are 4739 described species in this largest aquatic beetle family (Nilsson & Hájek, 2024).

Initially, the classification of Dytiscidae was mainly based on the pioneering work of Carl Linnaeus, which led to the inclusion of family in S*ystema Naturae*.

The classification of diving beetles has undergone significant refinement and revision, as researchers have applied increasingly sophisticated analytical techniques, including morphological, anatomical and molecular approaches to unravel the complex evolutionary relationships within the group.

3.2 Review of Literature

3.2.1 Taxonomical studies on the family Dytiscidae (Diving Beetles) outside India

Many extensive taxonomic studies have taken place in different regions in the world, to understand the diversity, distribution and evolutionary relationships within the family Dytiscidae. Studies especially from the Neotropical regions have increased the knowledge of this group. Recent taxonomical studies focussing on particular geographical areas such as North America, South America, Africa, Europe, Southeast Asia and Australia has also contributed a lot to the understanding of the diversity and distribution of this group and led to the description of numerous species and systematic revisions.

Libonatti *et al*. (2011) published a taxonomic key for the identification of 73 species under eight subfamilies, 16 tribes and 31 genera from Argentina. Miller (2013) reviewed the genus *Cybister* in North America and recognised three species under the genus. Miller and Montano (2014), described four species (*F. microphthalmos, F. bettae, F. christineae* and *F. aquarupe*) under the genus *Fontidessus*, which is peculiar to hygropetric habitats of northern part of South America. They reviewed the genus containing seven species including the three previously known species. Miller (2017) reviewed the Neotropical genus *Bidessodes* and added four new species into this genus (*B. chlorus*, *B. erythros*, *B. leukus* and *B. melas*). A couple of years later Megna *et al.* (2019) reviewed the genus *Hydaticus*, of Peru and described a new species, *Hydaticus (Prodaticus) panguana* and provided notes on the 11 Neotropical species of that genus.

A new species, *Agabus picotee* was described under *Agabus guttatus*- group from Portugal (Foster and Bilton, 1997). Millán and Ribera (2001) studied the *Agabus* (gaurodytes) *brunneus* group, with description of a new species from the Western Mediterranean. Four species were recognised under this group with a description of a new species (*A. ramblae*).

Biström *et al.* (2015) described 22 species from Africa under the genus *Laccophilus*. They recognised 105 species under the genus and revised the Afrotropical *Laccophilus*. Hjalmarsson *et al.* (2013) reviewed the genus *Rhantus* of Madagascar and recognised three species under this genus based on morphological and molecular data which are endemic to the highlands of the island. Five years later Ranarilalatiana *et al*. (2019) reviewed the genus *Copelatus* Erichson 1832, of Madagascar by an integrative taxonomical approach. Thirteen species were considered under this genus of which five species were new to science (*Copelatus ankaratra*, *C. kely*, *C. pseudostriatus* and *C. safiotra*).

Nilsson (1994) revised the *Ilybius crassus*-complex of Palearctic region. He has described *Ilybius nakanei* as a new species from south Sakhalin and Hokkaido. A new species *Laccosternus krausi* was described by Brancucci and Vongsana (2013) from Sumatra. Hájek (2006a) reviewed the family Dytiscidae of Baluchistan and recognised 23 species under this family. *Neptosternus circumductus* was reported as a westernmost record among the oriental member of the genus *Neptosternus*.

Twenty-one new species (Microdytes akitai, M. balkei, M. bistroemi, M. boukali, M. dimorphus, M. gabrielae, M. hainanensis, M. hendrichi, M. jaechi, M. mariannae, M. menopausis, M. nilssoni, M. sarawakensis, M. satoi, M. schoedli, M. schoenmanni, M. schuhi, M. schwendingeri, M. sinensis, M. shepardi and M. zetteli) were described by Wewalka (1997) in a revision of the genus Microdytes.

Hendrich and Yang (1999) described two *Lacconectus* species from the Peninsular Malaysia. Fifty-two species of dytiscids were recorded by Hájek and Reiter (2014) from Oman. *Hyphydrus dioscoridis* was described as new species from the Socotra Island. Eighteen species were new reports from Yemen. The adult and larval instars of a new hygropetric species, *Platynectes* (*Gueorguievtes*) *davidorum* was described by Hájek *et al*. (2019) from Eastern China.

Wewalka and Biström (1987) described a new species *Clypeodytes jaechi* from Nepal. Hájek *et al*. (2010) described a new species *Copelatus sibelaemontis* from Indonesia. Fourteen new species (*Deronectes balkei*, *D. bilioni*, *D. brancuccii*, *D. elmii*, *D. hendrichi*, *D. youngi*, *D. danielssoni*, *D. roberti*, *D. evelynae*, *D. hebaueri*, *D. riberai*, *D. kinzelbachi*, *D. palaestinus* and *D. bameuli*) were described from Afghanistan, Türkiye, Iraq, Syria and Pakistan by Fery and Hosseinie (1999) in a revisional study on the genus *Deronectes* Sharp 1882.

Vazirani contributed a major part of the studies in Oriental region especially in India. He (1977a) listed 371 species under 41 genera from the Oriental region.

There are many studies on the diving beetles of the Australian region, the majority of which are listed below. *Eretes explicitus* was described by Miller (2002) in a revisional study of the genus *Eretes* Laporte, 1833. Hendrich and Balke (2009) described *Kakadudessus tomweiri*, a new genus and species from Northern Australia. Leys *et al*. (2010) described a new subterranean species, *Paroster extraordinarius* from the Southern Australia. A new species *Copelatus martinbaehri* was described by

Hendrich *et al.* (2019) in a revisional study on the Australian species of genus *Copelatus*. Six new species of diving beetles were described by Hendrich *et al.* (2020) in the revision of genus *Gibbidessus*. *Neobidessodes mjobergi* was first reported from Australia by Surbakti *et al*. (2021).

There are several taxonomical studies on diving beetles around the globe including checklists, reports, revisions and reviews of particular genera with descriptions of new species (Young, 1977 & 1980; Nilsson, 1985 & 1986; Nilsson, 1995a; b; Mazzoldi and Toledo, 1998; Nilsson, 1998; Rocchi, 2000; Zalat *et al.*, 2000; Fery, 2003; Jäch and Balke, 2003; Rocchi and Terzani, 2003; Hajek and Šťastný, 2005; Rocchi, 2005; Hájek, 2006b; Deler-Hernández and Megna, 2007; Rocchi, 2007; Fikáček *et al.*, 2008; Miller and Wheeler, 2008; Hájek and Wewalka., 2009; Rochhi, 2009; Ortmen and Nilsson, 2010, Toledo *et al.*, 2011; Megna and Epler, 2012; Pederzani and Rocchi, 2012; Hájek *et al.*, 2013; Rocchi and Terzani, 2012; Rocchi, 2013; Miller, 2013; Terzani *et al.*, 2013; Miller, 2014; Miller and Montano, 2014; Rocchi and Terzani, 2015; Darilmaz and Ahmed, 2016; Rocchi and Terzani, 2016; Toledo and Rocchi, 2017; Manuel *et al.*, 2018; Megna and Sánchez-Fernández, 2014; Rocchi, *et al.*, 2018; Alarie *et al*., 2019; Balke *et al*., 2019; Heino and Alahuhta, 2019; Hendrich *et al.*, 2019; Megna *et al.*, 2019; Soesbergen and Hakkaart, 2021; Hendrich *et al.*, 2022; Megna *et al*., 2021; Bergsten and Biström, 2022; Bergsten *et al*., 2022; Watanabe and Biström, 2022).

3.2.2 Studies on Family Dytiscidae from India

Researchers have conducted studies in various regions of India shedding light on the taxonomy of diving beetles in India. The Zoological Survey of India has played a significant role in the exploration and study of diving beetles in India. Pioneering taxonomic studies on diving beetles of India were conducted by the late Mr. T. G. Vazirani.

Vazirani has published a series of publications on aquatic beetles in India. A great majority of the species described were diving beetles. In a study conducted in the Salem district of Tamil Nadu, Vazirani (1953) recorded six species under five genera. In 1968, he recorded 26 species of aquatic beetles for the first time from the Western

Ghats of India, of which *Microdytes sabitae* and *Clypeodytes hemani* were described as new.

In the following year, Vazirani (1969) reviewed four subfamilies of aquatic beetles from India (Odisha, Rajastan, Chotanagpur, Southern India and Western Ghats). Eight species of diving beetles were described as new such as *Laccophilus sindensis*, *Hyphydrus assamensis*, *Guignotus pradhani*, *Clypeodytes orissaensis*, *C. horai*, *C. minutus*, *Hydaticus sharpi* and *Sandracottus manipurensis*. *Canthydrus ritsemai*, *C. morsbachi*. *Laccophilus basalis*, *Uvarus genitilis*, *Hydaticus litigiosus* and *Cybister dehaani* were the first reports from India and nine species were transferred to other genera.

Three years later (1970a) he reviewed 31 species of diving beetles under 8 genera of the subfamily Hydroporinae. He described *Hydroporus kasmirensis*, *Potamonectes manii* and *Potamonectes* (s. str.) *balli* as new species. Also, several were redescribed. *Hydrovatus rufoniger*, *Hydrovatus picipennis*, *Hydrovatus acuminatus* and *Potamonectes* (S. str.) *kashmirensis* were recorded for the first time from India.

In the same year Vazirani (1970b) revised the Subfamily Colymbetinae. He considered 52 species under nine genera from India. Seven new species (*Copelatus bangalorewnsis*, *C. assamensis*, *C. mysorensis*, *Agraphis kempi*, *Hydronebrius guignoti*, *Rhantus birmanicus*, *R. punjabensis*) and three new subgenera (*Paralacconectus*, *Paraplatynectus* and *Neoplatynectus*) were reported. He also proposed four synonymies. Several lectotypes were designated and redescribed.

The same year (1970c), he published a paper on the family Dytiscidae based on the species collected from Goa. He considered 15 species in his paper all of which were new records from Goa. Two species under *Canthydrus* were later transferred to the family Noteridae.

A couple of years later Vazirani (1972a) described a new species *Copelatus neelumae*, from the Tiruchirappalli district of Tamil Nadu state. In the same year, Vazirani(1972b) recorded 22 species under 14 genera from Junagadh, Jamnagar and Surendra Nagar districts of Gujrat. After five years Vazirani (1977a), prepared a catalogue of the family Dytiscidae occurring all over India. He listed 371 species under 41 genera.

Holmen and Vazirani (1990) described a new species from Karnataka, *Copelatus karnatakus* along with three new species of the genera *Neptosternus* and *Copelatus* from Sri Lanka. Based on the specimens collected from different wetlands in Calcutta, De and Sengupta (1993) reported 13 species of diving beetles. Vazirani (1977b) recorded 23 species under eight genera from Maharashtra.

In 1997, Wewalka revised the genus *Microdytes*. He described 21 new species which include *Microdytes boukali* and *M. schoenmanni* from Kerala and West Bengal respectively. The following year, Hendrich and Balke (1998) described *Copelatus schuhi* from the Maharashtra state which was the first species described under the group *Nigrolineatus*. Ghosh *et al*. (2000) recorded 20 species under nine genera from Tripura. In the same year, Mukhopadhyay *et al*. (2000) recorded 33 species under 12 genera from Meghalaya. Thirty-one species of diving beetles were recorded under 13 genera from Manipur by Mukhopadhyay and Ghosh (2004). Brancucci (2006a) described a new species *Platambus (s. str.) dembickyi* from Meghalaya and recorded *P. nepalensis* first time from Arunachal Pradesh.

Nahar (2004) recorded 34 species under 14 genera from Bihar (Including Jharkhand). Later, Mukhopadhyay and Ghosh (2007) recorded 31 species under 15 genera from Andhra Pradesh. In the following year, 24 species were reported from the Jabalpur district of Madhya Pradesh (Chandra, 2008). Three new species of *Microdytes*, *M. svensoni* and *M. cameroni* from Karnataka and *M. whittingi* from Maharashtra and the other seven known species from India were described by Miller and Wewalka (2010). A key for the identification of the 10 species of *Microdytes* known from India is also provided by their study.

Manivannan and Madani (2011) described *Hydrovatus sringeriensis* from Karnataka. In 2015, Wewalka revised the species under the *Hydaticus (Prodaticus) sexguttatus* group and resembling species from the Pacific, Palaearctic, Oriental and Australian regions. He recorded *Hydaticus sexguttatus*, *H. laetabilis* and *H. bengalensis* from Tamil Nadu, Assam and West Bengal respectively. Ghosh and Sinha (2016) recorded

Cybister (*s. str.*) *tripunctatus lateralis* and *Cybister* (*Melanectus*) *sugillatus* from Arunachal Pradesh. Deb (2017) recorded *Hydaticus conjungens* under the name *Hydaticus* (*Prodaticus*) *bipunctatus bipunctatus* from Meghalaya.

Sheth *et al*. (2018) reviewed the diving beetle species of Maharashtra state coming under the genus *Copelatus*. They recorded nine species of which three were described as new (*Copelatus deccanensis*, *C. maushomi* and *C. bezdeki*). In this study, several species were documented for the first time in Maharashtra.

Wewalka (2020) revised the species under *Hydaticus (Prodaticus) vittatus* and *H. (Prodaticus) daemeli* groups of the Pacific, Asian and Australian regions. He reported *Hydaticus vittatus*, *H. conjungens* and *H. histrio* from India.

In the following year, Sheth *et al.* (2021) described a new species, *Peschetius nilssoni* from Maharashtra. In 2022, Ghosh described a new species *Hyphydrus biswasi* from Arunachal Pradesh.

Wewalka (2023) reviewed diving beetle species of *Hydaticus fabricii* and *H. grammicus* groups. Eighteen species including two new species, *H. geiseri* and *H. mazzoldii* were considered under the *fabricii* group. Subspecies of *Hydaticus fabricii* were also included in the study. *Grammicus* group was established and six species were considered under this group including two new species (*H. schoenleithneri* and *H. shaverdoae*). Besides this new species *H. borneensis* was described which had similarity with both groups but had distinctly different male genitalia.

There are several records of diving beetles in India (Biswas *et al*., 1995; Sharma, 2002; Hájek and Šťastný, 2005; Ghosh, 2010).

Most recently, Deb and Subramanian (2023) reported *Sandracottus mixtus* as a new record for Maharashtra, Karnataka and Tamil Nadu. Additionally, another species of the same genus, *Sandracottus dejeanii*, was documented for the first time in Karnataka.

3.2.3 Studies on Family Dytiscidae from Kerala

Various researchers have conducted entomological expeditions in Kerala. Specimens of those collections are deposited in ZSI, Kolkata as well as the other museums outside India. Publications based on these studies started to appear in the early 18th century, which includes first records and new species discoveries. Diving beetle fauna of Kerala has been studied from the unidentified specimens in the museum collections also. Before this study, Kerala had a record of 51 species of diving beetles based of previous studies (Miller and Wewalka, 2010; Manivannan and Madani 2011; Ghosh and Nilsson, 2012; Wewalka, 2017; Anand *et al*. 2021; Sheth *et al*. 2021; Deb and Subramanian 2023; Wewalka, 2023). The first ever report of a diving beetle from Kerala was made by Aubé (1838). He described a new species *Cybister dejeanii* from the Malabar region of Kerala state.

Régimbart (1903) described a new species, *Hydroglyphus crassifrons* from Mahe of Kerala state. In 1986, Brancucci revised the genus *Lacconectus*. He recognised 38 species under the genus. In his work, he described 24 new species as new to the science. *Lacconectus andrewesi*, *L. freyi*, *L. regimbarti* and *L. scholzi* were the new species described from Southern India, of which, *L. regimbarti* was described from Kerala state.

The same year Mukherjee and Sengupta (1986) described a new species *Copelatus biswasi* from Silent Valley. They also recorded *Sandracottus dejeanii*, *Hydaticus vittatus*, *H. histrio* and *H. leechi* from the same area.

Balke and Hendrich (1996) described a new species of terrestrial water beetle *Geodessus kejvali*, collected in leaf litter near the edge of a stream in Idukki district of Kerala. After a couple of years, Hendrich and Balke (1998) described two new species of diving beetles, *Copelatus boukali* and *C. schuhi* from Kerala and Maharashtra respectively.

In 2003, Brancucci reviewed the genus *Lacconectus* from the Indian subcontinent. He recognised 21 species under this genus and described five new species from Meghalaya, Karnataka and Kerala. *Lacconectus munnarensis*, *L. blandulus* and *L. satoi* were the new species from Kerala state.

In 2010, Miller and Wewalka recorded three species of *Microdytes* (*M. svensoni*, *M. belli* and *M. boukali*) from Kerala. A key for the identification of the 10 species of *Microdytes* known from India was also provided by their study.

Manivannan and Madani (2011) described *Copelatus wayanadensis* from Panamaram in the Wayanad district.

A new species was added to the genus *Copelatus* by Wewalka (2017). He described *Copelatus davidi*, a new species similar to *Copelatus boukali,* from the Trivandrum district of Kerala. Additional locality data for the species *Copelatus boukali* is also provided in the study.

In the following year Prabhakaran and Kakkassery (2018) recorded *Hydaticus ricinus* under the name *Hydaticus fabricii* from Thrissur district in Kerala.

Wewalka (2020) revised the Asian and Australian/Pacific species of *Hydaticus (Prodaticus) vittatus* and *H. (P.) daemeli* species groups considering three species (*Hydaticus bipunctatus*, *H. histrio* and *H. vittatus*) from Kerala.

Sheth *et al*. (2021) conducted a review of the genus *Peschetius* using an integrative taxonomic approach, identifying four species in India. Among these, *Peschetius bistroemi* was newly described from Kerala. The study also provided descriptions of other species within the genus and included a key for identifying the species known in India.

The same year, Anand *et al.* (2021) described a new species, *Sandracottus vijayakumari* from the Palakkad district which is a part of the Nelliyampathy forest range of Southern Western Ghats of Kerala. A comparative key of closely related species *Sandracottus dejeanii* was also provided.

The *Hydaticus fabricii* group and *Hydaticus grammicus* group were reviewed by Wewalka (2023), based on the median lobe aedeagus and the elytral colouration. Eighteen species and a subspecies under *H. grammicus* were studied. *Hydaticus geiseri* and *Hydaticus mazzoldii* were described as new species. *Hydaticus ricinus* was documented first time in Kerala.

Deb and Subramanian (2023) recorded *Sandracottus mixtus* for the first time from Kerala. The record was based on a study in various locations in the Western Ghats of India between 2019 and 2023. Seventy-seven samples of the genus *Sandracottus* Sharp, 1882 were collected and studied.

Recently, Prabhakaran *et al*. (2024) reported 11 species of diving beetles from Kerala for the first time, along with a checklist of the known species in the region which brings the total number of diving beetles of Kerala 62 (This work was part of this study).

3.3 Materials and Methods

3.3.1 Study Area

Study area has been described in chapter 2. Particulars of field sampling has also been described in chapter 2.

3.3.2 Insect Collection and Preservation

See 2.3.1 of chapter 2

3.3.3 Examination of Specimens and Identification

The specimens were studied under a Stereozoom research microscope (Leica S8APO) connected to the camera (LEICA MC170 HD). Morphological features were studied and measurements were taken. Subsequently, genitalia were dissected following literature (Gurney *et al.*, 1964; Miller and Bergsten, 2016). The tip of the abdomen was removed, placed in 10% KOH solution and warmed near boiling. Then the preparation was washed 2-3 times with water. Genitalia was observed under the microscope in a drop or a few drops of water. Genitalia and habitus were imaged with the aid of LAS software. Habitus of large specimens were taken using a Canon 60D camera with a 105 mm macro lens. Genitalia of smaller specimens were slide mounted using DPX as mountant. Genitalia of larger species were kept in glycerine in small vials. Literature used for identification are mentioned in 2.3.2 of chapter 2. Body shape and size, colouration, microsculptures on cuticle, specific characters of head, thorax, elytra, legs, abdomen, male genitalia are highly important in the identification of this group. The specimens were stored in 70% ethyl alcohol and initially deposited in the insect collection of the Research Laboratory of the Department of Zoology, St. Thomas College (Autonomous), Thrissur. The preservative of larger specimens was changed from time- to time to prevent the decaying of the specimens. After writing the thesis the specimens were submitted at Zoological Survey of India (ZSI), Western Ghats Regional Centre (WGRC), Calicut, Kerala (Appendix B).

3.3.4 Preparation of Taxonomic Key

There are different kinds of taxonomic keys- dichotomous keys and polytomous keys. Dichotomous key consists of couplets of statements which are mutually exclusive and leads to the next set of statements until the organism get identified. In this study dichotomous keys for the 53 species of diving beetles observed directly are presented. The keys were prepared by observing and recording the characters of the beetle and also by referring previous literature. Keys are presented at subfamily, genus and species level.

3.4 Results

3.4.1 Systematic Account of Family Dytiscidae with Detailed Description of Recorded Species

During the study, a total of 53 species of diving beetles were observed, collected and studied. They belong to six subfamilies and 16 genera. The following are the key identification features of various taxonomic groups, beginning with class Insecta.

Class: Insecta

Insects are characterised by the presence of a chitinous exoskeleton, body divided into three distinct regions (head, thorax and abdomen), three pairs of legs attached to the thorax, one or two pairs of wings (wingless are also present) and a pair of antennae and compound eyes on the head (Richards and Davies, 1977).

Order: Coleoptera (Fig. 3)

The most important morphological features of Coleoptera (Fig. 3) are the presence of modified first pair of wings into horny or leathery structure called elytra that almost always meet to form a straight mid-dorsal suture. The hind wings are membranous, folded beneath the elytra, or often reduced or absent. The mouthparts are adapted for biting (Richards and Davies, 1977).

Suborder: Adephaga (Fig. 4)

The key distinguishing characters of suborder adephaga can be found in Fig. 4. Adults have notopleural sutures visible on the prothorax and the first visible abdominal sternum divided by the hind coxae (Almeida and Mise, 2009; Abdulla and Azmir, 2021).

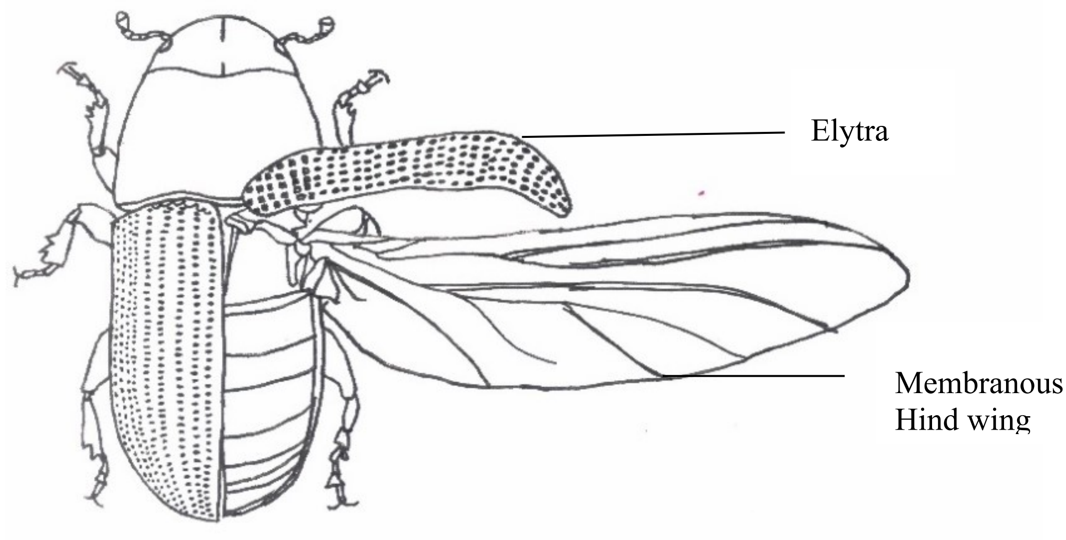


Figure 3. Characteristic features of order Coleoptera.

(Diagram drawn by the scholar)

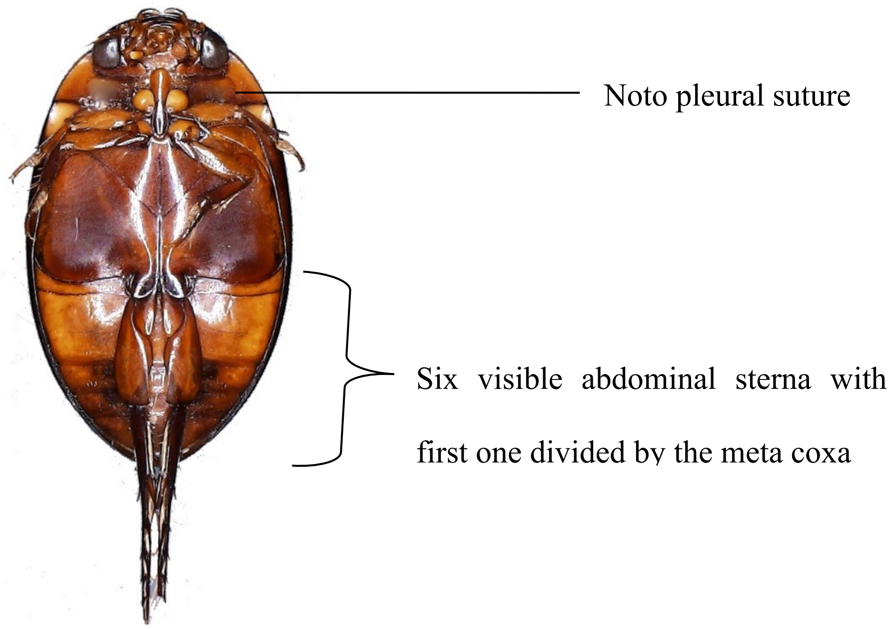


Figure 4. Characteristic features of suborder Adephaga

Family: Dytiscidae Leach, 1815

Dytiscids typically have a streamlined body. The meta sternum features distinctive lateral 'wings.' The metacoxae are large and have a paired posterior metacoxal process posteriorly (Chapter 1, Fig. 1). Their size ranges from 1 to 50 mm (Balke *et al.*, 2004a).

I. Subfamily: Colymbetinae

Members of the subfamily Colymbetinae have eyes that are emarginated anteriorly. In many species, the median lobe of the aedeagus is bilaterally asymmetrical, while the lateral lobes are bilaterally symmetrical. Females have gonocoxae that are apically rounded and flat (Miller and Bergsten, 2016). The prosternum and prosternal process lie in the same plane. The metacoxal lines are distinct but not closely approximated. The elytral apices are evenly rounded and the metatarsal claws are unequal. There are distinct transverse rugae on the second abdominal pleurite. There are 142 species under 11 genera under a single tribe. During this study, only one genus (*Rhantus*) was recorded in this subfamily.

Genus: *Rhantus* Dejean, 1833

The members of this genus have a body length between 5.70 mm – 17.80 mm. The species are brown or yellowish-brown. The head and pronotum usually have various black markings. Some species are entirely black. Others are marked with maculae on elytra. Lateral outline nearly continuous between the pronotum and elytra in most of the species. Apical margins of metatarsomeres I-IV apically sinuate and lobed. The prosternal process medially rounded. Marginal pronotal beads narrow. The anterior surface of the metatibia with few setiferous punctures arranged as a linear series. Only one species of this genus was recorded during the present study.

1. *Rhantus* cf *taprobanicus* Sharp,1890 (Plate 4 (1))

1890. *Rhantus taprobanicus* Sharp, 346.
1970. *Rhantus taprobanicus* Vazirani, 356.

Material examined: Idukki district: Shantharuvi, 1♀, 9°59'43"N 77°11'22"E, 1319 m, 23.II.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 13.80 mm; Maximum width: 7.60 mm.

Form elongated oval; lateral outline continuous between pronotum and elytra. Head black; anteriorly yellowish; posterior yellow spot on vertex; punctures not distinct. Pronotum yellow with indistinct black patterns; posterior border black; lateral margins broadly rebordered. Scutellum yellow. Elytra yellow with dense black irrotations; punctation fine; longitudinal rows of punctures on disc; punctures in median row sparse. Ventral surface reddish black; pro and meso legs, posterior border of abdominal sternites 3-5 and posterior region of apical sternite yellowish; punctures fine.

Habitat: Remnant pool in the rocky bed of a river (Plate 5 (1)).

Distribution: The species is distributed in the Oriental and Palaearctic regions. India (Assam, Delhi, Gujrat, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala (New record), Maharashtra, Manipur, Meghalaya, Panjab, Pondicherry, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal)

II. Subfamily: Copelatinae

The subfamily Copelatinae is characterised by the visible scutellum when the elytra is closed, metacoxal lines closely approximate medially or absent, metatarsal claws approximately equal in length in both male and female.

The subfamily is divided into eight genera under the single tribe *Copelatini.* In Kerala, there are two genera (*Copelatus* & *Lacconectus*) present. Species of both genera were collected during the study.

Genus: *Copelatus* Erichson, 1832

Members of this genus are with the metacoxal lines distinctly visible or very rarely obscured or absent, metacoxae with short strioles, dorsal surface vary, many species with longitudinal striae or short strioles, others with a smooth surface, without any reticulations or striae.

Previously, four species were known from Kerala. This study has recorded six species within the genus.

2. *Copelatus boukali* Hendrich & Balke, 1998 (Plate 4 (2))

1998. *Copelatus boukali* Hendrich & Balke, 357.

Material examined: Kozhikode district: Adivaram, 6♂12♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll. Priyanka Prabhakaran. Ernakulam district: Mamalakandam, 1♂1♀, 10°05'11"N 76°49'14"E, 454 m, 02.I.2021, Coll. Priyanka Prabhakaran. Idukki district: Kallar, 1♂2♀, 10°01'54"N 76°59'13"E, 873 m, 23.II.2020, Coll. Priyanka Prabhakaran; Kallar, 11♂18♀, 10°01'53"N 76°59'18"E, 849 m, 23.II.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 4. 90 mm- 5.18 mm, Maximum width: 2.24 mm- 2.45 mm.

Form oblong oval and nearly flattened. Head dark brown and paler towards anterior; punctures fine dense; surface microreticulated with longitudinal strioles in the posterior margin of the clypeus and near the eyes. Pronotum brownish black with longitudinal strioles except in the lateral sides; anterior border with coarse and irregular punctures; posterior border with a row of well-impressed punctures in the middle; surface microreticulated. Elytra brownish black with well impressed 11 longitudinal striae and 1 submarginal stria; 10th stria is slightly abridged anteriorly; the remaining elytral striae almost reach the base; submarginal stria extends up to the middle of the elytra; striae 1,3,5 and 7 not reaching elytral apex; 6th stria less abridged at the apex; 9th stria greatly shortened; surface microreticulated (Plate 4 (2) a). Ventral surface, appendages and epipleura reddish brown; meta sternum and meta coxae micro reticulated. Median lobe narrow and tapering towards the apex (Plate 4 (2) b). Parameres bi-segmented, apical segment with a club shaped projection with a series of long hairs along the ventral margin of apical segment. (Plate 4 (2) c).

Habitats: Rock pools in river beds (Plate 5 (2; 4), remnant pool in a ditch (Plate 5 (3)).

Distribution: The species is distributed in the Oriental region. India (Kerala).

3. *Copelatus cryptarchoides* Régimbart, 1899 (Plate 4 (3))

1899. *Copelatus cryptarchoides* Régimbart, 293.
1939. *Copelatus nilgiricus* J. Balfour-Browne, 74; 1970. Vazirani, 318, Synonymy.
1970. *Copelatus cryptarchoides* Vazirani, 318.
2018. *Copelatus cryptarchoides* Sheth et al., 250.

Material examined: Thrissur district: Ayyampuzha, 1♂, 10°17'50"N 76°27'11" E, 66 m, 18.VII.2019, Coll. Priyanka Prabhakaran; Darbha, 2♂, 10°31'00"N 76°20'54"E, 106 m, 11.VI.2023, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.80 mm- 4.00 mm; Maximum width: 2.40 mm- 2.60 mm.

Form oblong oval. Head ferruginous, paler anteriorly and posteriorly; punctures fine and sparse; surface microreticulated; clypeus darker. Pronotum ferruginous and paler on lateral sides; lateral sides moderately curved; posterolateral angles right-angled; punctures and micro reticulations more impressed than head; anterior margin with a row of irregular punctures; posterior margin with a row of less impressed punctures; few strioles present from the posterolateral angle up to nearly half the length of the lateral margin. Elytra dark brown; 6 dorsal striae present; submarginal stria absent;

basal margin with yellow band that extend posteriorly between the 3rd and 4th striae and between 6th and lateral margin; between the elytral suture and 3rd stria and between 4th stria and the 6th stria are dark brown with predominantly yellow colouration to some extent; apical region of elytra yellowish except near the suture; stria 1 abridged at base; striae 2 and 3 slightly abridged at the apical region; 6th stria abridged at the apical one- fourth (Plate 4 (3) a). Ventral surface and appendages ferruginous; epipleura and lateral sides of metacoxal plate slightly darker; metacoxae reticulated; strioles absent. Median lobe sickle-shaped in lateral view; evenly curved except the base; gradually narrows towards the pointed apex (Plate 4 (3) b). Parameres “C” shaped; moderately broad; apical region broad and short; club-shaped long apical lobe (Plate 4 (3) c).

Habitats: The specimens were collected in small muddy puddles in a garden and in a dirt road (Plate 5 (5)).

Distribution: This species is distributed in the Oriental region. India (Karnataka, Kerala, Maharashtra, Tamil Nadu).

4. *Copelatus davidi* Wewalka, 2017 (Plate 4 (4))

2017. *Copelatus davidi* Wewalka, 9.

Material examined: Kannur district: Manikkadavu, 3♂1♀, 12°05'47"N 75°40'26"E, 83 m, 12.II.2022, Coll. Priyanka Prabhakaran; Edumbapalam, 2♂, 11°53'55"N 75°39'15"E, 602 m, 16.II.2022, Coll. Priyanka Prabhakaran; Vayathur, 1♂, 12°05'40"N 75°40'21"E, 69 m, 12.II.2022, Coll. Priyanka Prabhakaran; Vayathur, 1♂1♀, 12°05'38"N 75°40'20"E, 70 m, 12.II.2022, Coll. Priyanka Prabhakaran; Vellad, 15♂24♀, 11°59'20"N 75°39'16"E, 528 m, 14.II.2022, Coll. Priyanka Prabhakaran; Kanjirakolli, 1♂4♀, 12°08'07"N 75°37'54"E, 368 m, 12.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Puthukkad, 3♂2♀, 11°32'21"N 76°06'57"E, 1007 m, 14.II.2022, Coll. Priyanka Prabhakaran; Puthukkad, 1♂5♀, 11°32'21" N 76°07'03" E, 976 m, 14.II.2022, Coll. Priyanka Prabhakaran; Puthukkad, 1♂1♀, 11°32'25"N 76°06'58"E, 995 m, 14.II.2022, Coll. Priyanka Prabhakaran; Padinjarathara, 1♂, 11°40'39"N 75°56'16"E, 876 m, 13.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Adivaram, 6♂12♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll.

Priyanka Prabhakaran; Kodenjery, 1♂7♀, 11°29'06"N 76°01'49"E, 783 m, 16.II.2022, Coll. Priyanka Prabhakaran; Chembukadavu, 2♂3♀, 11°27'27"N 76°01'22"E, 598 m, 16.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Moonnekkar, 10♂16♀, 10°55'24"N 76°34'27"E 120 m, 24.II.2022, Coll. Priyanka Prabhakaran; Padagiri, 1♂1♀, 10°29'06"N 76°40'18"E, 973 m, 07.I.2021; Puthuppariyaram, 1♂2♀, 10°55'18"N 76°34'57"E, 155 m, 24.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Marottichal, 2♂5♀, 10°28'40"N 76°21'24"E, 51 m, 04.I.2022, Coll. Priyanka Prabhakaran. Ernakulam district: Kothamangalam, 1♂1♀, 10°07'00"N 76°40'37"E, 68 m, 02.I.2021, Coll. Priyanka Prabhakaran; Mamalakandam, 1♂1♀, 10°05'11"N 76°49'14"E, 454 m, 02.I.2021, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 4.52 mm- 5.10 mm; Maximum width: 2.19 mm- 2.48 mm.

Form oblong oval, wider in the middle, nearly convex. Head dark brown; surface with dense, fine reticulation; punctation fine and sparse; short strioles on posterior region; a row of well-impressed punctures along the inner margin of eyes; an oblique row of four well-impressed punctures at the anterior region; clypeus paler, truncate without beads. Pronotum dark brown; slightly paler on lateral sides; lateral margins evenly curved and rimmed which is absent at the anterolateral angles; pronotum broadest at posterolateral angle; reticulation fine regular and dense; punctation fine and sparse; row of well-impressed punctures at the anterior and lateral margins; longitudinal strioles present throughout. Elytra dark brown; lateral margins with a fine rim that is absent at the apex; reticulation fine; punctation fine and sparse; 11 well impressed dorsal striae and a submarginal stria present; all striae almost reach the base except 10^{th} stria; striae 1,3,5,6 and 10 moderately abridged at the apex of these 6^{th} stria more abridged; 7^{th} and 9^{th} striae slightly abridged at the apex (Plate 4 (4) a). Ventral surface dark brown; prosternum, meta sternal wings, meta coxae, abdominal segments I-III and appendages are reddish brown; metacoxae and meta ventrites reticulated; metacoxae with short strioles; distinct metacoxal lines; prosternal process smooth, broadly lanceolate, bluntly pointed, convex with distinct beads. Metasternal wings narrow and curved; well impressed short groove on the posterior margin of the metacoxal process. Abdominal sternites with fine reticulation; abdominal sternites 4^{th} to 6^{th} sparsely punctated; oblique strioles on abdominal ventrites 1-4. Pro and meso tarsomeres 1-3 of males dilated. Median lobe curved at the apical fourth; narrowed at the apical region with a denticle at the tip (Plate 4 (4) b). Parameres bi-segmented; apical segment with a club shaped projection with a tuft of long hairs basally (Plate 4 (4) c).

Habitat: Remnant rock pools in river/stream beds (Plate 5 (6-12; 15-16; 20-22), remnant pool in a river bed (Plate 5 (13)) and remnant pools in waterfalls (Plate 5: (14) & (17-19).

Distribution: The species is distributed in the Oriental region. India (Kerala(Current study)).

5. *Copelatus neelumae* Vazirani, 1973 (Plate 4 (5))

1972.*Copelatus neelumae* Vazirani, 224.
2018.*Copelatus neelumae* Sheth *et al*., 248.

Material examined: Thrissur district: Cheppara, 2♀, 10°37'04"N 76°15'15"E, 141 m, 19.X.2021, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 5.60 mm- 5.62 mm; Maximum width 2.82 mm- 2.91 mm.

Form oblong oval. Head brownish black; yellowish at the anterior; distinct micro reticulations present; punctation dense but sparse at the anterior and lateral region. Pronotum brownish black; yellowish at the anterior, posterior and lateral margins; punctation fine, regular and less dense; reticulation as of head. Elytra brownish-black with yellow colouration at elytral base, space between the 3rd and 4th striae, laterally from the 5th stria and apex of the elytra. Elytral striae well impressed; stria 1 starts sub-basally; striae 2,3 and 5 shorter than 1 and 4 and not reaching the apex of the elytra; stria 6 reaches only the apical fifth of the elytral length; the sublateral stria starts from the base and extends up to the fifth of the elytral length; short strioles between the 4th and 6th striae at middle of the elytra (Plate 4 (5) a). Ventral surface dark brown with appendages more or less brown. Posterior border of the 4th and 5th abdominal segments yellowish (Plate 4 (5) b).

Habitat: Ephemeral pool (Plate 5 (23)).

Distribution: This species is distributed in the Oriental region. India (Goa, Karnataka, Kerala (New report), Maharashtra, Tamil Nadu).

6. *Copelatus oblitus* Sharp, 1882 (Plate 4 (6))

1882. *Copelatus oblitus* Sharp, 582.
1899. *Copelatus andamanicus* Régimbart, 302; 2004. Hendrich *et al*., 118, Synonymy
1990. *Copelatus karnatakus* Holmen & Vazirani, 27; 2018. Sheth *et al*., 255, Synonymy
2022. Copelatus oblitus Jiang et al., 265.

Material examined: Thrissur district: Assarikkadu, 1♂1♀, 10°29'57"N 76°19'43"E 83m, 10.IX.2018, Coll. Priyanka Prabhakaran; Assarikkadu, 1♂, 10°29'57"N 76°19'43"E 83m, 01.VII.2019, Coll. Priyanka Prabhakaran; Assarikkadu, 1♂, 10°29'57"N 76°19'43"E 83m, 23.X.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 4.40 mm- 4.80 mm; Maximum width: 2.50 mm- 2.90 mm.

Form oblong oval, posteriorly attenuated, dorsally moderately convex. Head dark brown between the eyes and at posterior border of eyes; anterior region and posterior border yellowish; surface micro reticulated; punctation fine. Pronotum dark brown; laterally yellowish; reticulation and punctation same as on head; distinct strioles at the posterolateral angles; distinct row of punctures near the anterior border. Elytra dark brown with a yellow band at the base that reaches the lateral margin; reticulation as on head and pronotum; punctures well impressed, fine; dorsal striae 6 and submarginal stria 1 abridged at the base; stria 7 starts at the middle length of elytra; all the other striae start close to the base; at the apical region striae 2,3, and 5 shorter than striae 1 and 4; stria 6 shorter than 5; stria 6 nearly equal to the submarginal stria (Plate 4 (6) a). Ventral surface reddish brown; appendages yellowish. Median lobe curved apically; anterior half straight up to the finger like projection produced ventrally at the base of curved apex (Plate 4 (6) b). Parameres “D” shaped apical lobe elongate and club shaped (Plate 4 (6) c)

Habitat: Rainwater-fed plastic containers (Plate 5 (24)).

Distribution: This species is distributed in the Oriental and Palaearctic region. India (Andaman & Nicobar, Karnataka, Kerala (New report))

7. *Copelatus sociennus* J. Balfour-Browne, 1952 (Plate 4 (7))

1970. *Copelatus bangalorensis*, Vazirani, 311; 2018. Sheth *et al*., 255, Synonymy
2018. *Copelatus sociennus* Sheth *et al*., 255.
2022. *Copelatus sociennus* Jiang *et al*., 271

Material examined: Kasargod district: Nileswaram (Mundemmad Road), 1♂5♀, 12°14'28"N 75°08'28"E, 503 m, 08.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Assarikkadu, 1♂, 10°29'57"N 76°19'43"E, 83 m, 26.V.2022, Coll. Priyanka Prabhakaran; Assarikkadu, 1♂, 10°29'57"N 76°19'43"E, 83 m, 14.VII.2019, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 4.70 mm- 5.30 mm; Maximum width: 2.60 mm- 2.80 mm.

Form oval, attenuated posteriorly, moderately convex. Head ferruginous; dark between and along the posterior border of the eyes; surface micro reticulated; punctation dense. Pronotum brownish black with the anterior border and the lateral margins ferruginous; lateral sides moderately curved; row of irregular puncture near the anterior border; row of short strioles near the lateral borders; punctation fine, dense. Elytra brownish black; surface micro reticulated; punctation fine, dense; yellow band near the base which reaches the lateral margins and extend between the stria 2 and 3 up to the two-third of its length; six well impressed dorsal striae and a submarginal stria present; submarginal stria starts from the middle of the elytra and extend up to the length of the 6th stria; 1st stria slightly abridged at the base and extend up to the apex; striae 2 and 3 are shorter than 5; striae 2, 3, 4 and 5 terminates at the same point; stria 6 terminates just before stria 5 (Plate 4 (7) a). Ventral surface brown with appendages light brown except hindleg, epipleura brown; abdominal segments with indistinct paler spots; metacoxae with distinct reticulation and oblique strioles; males with protibiae enlarged at the apex and incurved; dilated meso and meta tarsi. Median lobe curved at the middle at an angle with a spoon-like ventral projection, slender at the apical half (Plate 4 (7) b). Parameres "D" shaped, apex short and wide, apical lobe elongate and club- shaped (Plate 4 (7) c).

Habitats: Muddy puddle (Plate 5 (26)), rainwater-fed plastic container (Plate 5 (24)) and remnant pool in an abandoned ditch (Plate 5 (25))

Distribution: The species is distributed in the Oriental and Palaearctic region. India (Karnataka, Kerala (Current study), Uttarakhand).

Genus: *Lacconectus* Motschulsky, 1856

Members of this genus are variable. But they are generally oval, flattened and dorsally marked with maculae. Body length ranges between 3.50 mm- 7.10 mm. They are characterised by the absence of the metacoxal lines and metafemur with rounded apical margin. In most cases dorsal surface of elytra smooth with distinct microreticulation.

There are 80 described species under this genus. Six species are so far known from Kerala. Current study recorded three species under this genus.

8. *Lacconectus blandulus* Brancucci, 2003 (Plate 4 (8))

2003. *Lacconectus blandulus* Brancucci, 31.

Material examined: Kottayam district: Murinjapuzha, 4♂2♀, 9°32'00"N 76°58'18"E, 893 m, 21.VI.2022, Coll. Priyanka Prabhakaran. Idukki district: Thommankuthu, 2♂, 9°57'32"N 76°50'10"E, 216 m, 21.II.2020, Coll. Priyanka Prabhakaran; Kallar, 6♂5♀, 10°01'57"N 76°59'14"E, 860 m, 23.II.2020, Coll. Priyanka Prabhakaran; Kamakshi, 2♂4♀, 9°49'43"N 77°04'54"E, 997 m, 24.II.2020, Coll. Priyanka Prabhakaran; Pazhampyllichal, 2♂, 10°03'43"N 76°49'35"E, 517 m, 02.I.2021, Coll. Priyanka Prabhakaran. Ernakulam district: Urulanthanni, 2♂2♀, 10°07'37"N 76°47'09"E, 119 m, 02.I.2021, Coll. Priyanka Prabhakaran; Palakkad district: Kollengode South, 2♂, 10°33'06"N 76°43'00"E, 1057 m, 07.I.2021, Coll. Priyanka Prabhakaran; Moonnekkar, 10♂16♀, 10°55'24"N 76°34'27"E, 120 m, 24.02.2022, Coll. Priyanka Prabhakaran; Puthuppariyaram, 5♂4♀, 10°55'17"N 76°34'57"E, 155 m, 24.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Adivaram, 5♂8♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll. Priyanka Prabhakaran; Kodenjery, 3♂1♀, 11°29'06"N 76°01'49"E, 783 m, 16.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Kanjirakolli, 8♂11♀, 12°08'07"N 75°37'54"E, 368 m, 12.II.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total Length: 4.70 mm- 5.00 mm; Maximum width: 2.30 mm- 2.50 mm.

Form oval, glossy. Head reddish brown; darker along the margins of eyes; surface micro reticulated with minute meshes; punctures fine and dense on disc; a row of less impressed punctures along the inner margin of the eyes. Pronotum reddish brown; darker at the centre; micro sculpture consists of minute round meshes; punctures minute, well-impressed; anterior border with a row of punctures; lateral margins finely rebordered and with a row of punctures; lateral furrow interrupted at the anterolateral angles. Elytra dark brown; testaceous sub basal band present; apical region testaceous; remaining part with indistinct testaceous pattern; darker near the suture; punctures small and regular; sutural row of puncture consists of few punctures at the apical third and 2 or 3 punctures at the basal two- thirds; discal row of punctures consists of spaced groups of medium sized punctures at the basal two-thirds; sublateral row consists of more spaced groups of punctures towards the apical region; few large punctures in the space between the discal and sublateral rows (Plate 4 (8) a). Ventral surface reddish brown; prosternal process elongate oval, margin rebordered, widely rounded at the tip; metacoxal line represented by a short, impressed stria at the mid- length; meta coxae, abdominal sternites microreticulate; few medium- sized and minute punctures at the middle of abdominal sternites; last abdominal segment smooth only with an oblique row of coalescent puncture mediolaterally; apex rounded and rebordered. Median lobe (Plate 4 (8) b) strongly curved; broadened at the middle and gradually tapering towards the triangular apical region; apex rounded. Parameres broad "D" shaped; apical region narrow, elongate; apical lobe slender elongate and club-shaped (Plate 4 (8) c).

Habitat: The specimens were collected in a remnant pool in a roadside drain (Plate 5 (27)), remnant rock pools in river and stream beds (Plate 5 (6; 7; 8; 21; 30; 31), remnant rock pools downstream of waterfalls Plate 5 (18; 28; 33), remnant pool in a ditch Plate 4 (3) and small hillside pool (Plate 5 (29)).

Distribution: The species is found only in Kerala in India.

9. *Lacconectus satoi* Brancucci, 2003 (Plate 4 (9))

2003. *Lacconectus satoi* Brancucci, 33.

Material examined: Kasargod district: Nileswaram (Mundemmad Road), 2♂, 12°14'28"N 75°08'28"E, 503 m, 08.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Edumbapalam, 3♂, 11°53'55"N 75°39'15"E, 602 m, 16.II.2022, Coll. Priyanka Prabhakaran; Vellad, 5♂11♀, 12°08'57"N 75°33'59"E, 400 m, 10.II.2022, Coll. Priyanka Prabhakaran; Vellad, 1♂2♀, 12°08'54"N 75°33'59"E, 397 m, 10.II.2022, Coll. Priyanka Prabhakaran; Vayathur, 1♀, 12°05'40"N 75°40'21"E, 637 m, 12.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Adivaram, 5♂6♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll. Priyanka Prabhakaran; Chembukadavu, 2♂1♀, 11°27'27"N 76°01'22"E, 598 m, 16.II.2022, Coll. Priyanka Prabhakaran; Kodenjery, 3♂, 11°29'06"N 76°01'49"E, 783 m, 16.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Chittor (Streamlet), 1♂2♀, 11°03'46"N 76°39'14"E, 586 m, 16.IX.2021, Coll. Priyanka Prabhakaran; Moonnekkar, 15♂9♀, 10°55'23.7"N 76°34'27"E, 120 m, 24.II.2022, Coll. Priyanka Prabhakaran; Puthuppariyaram, 1♂1♀, 10°55'18"N 76°34'57"E, 155 m, 24.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Assarikkadu, 6♂4♀, 10°29'57"N 76°19'43"E 83 m, 10.IX.2018, Coll. Priyanka Prabhakaran; Vellachal, 1♂4♀, 10°30'12"N 76°20'11"E, 95 m, 24.XII.2021, Coll. Priyanka Prabhakaran. Idukki District: Kuttikkanam, 18♂11♀, 9°34'52"N 76°58'46"E, 1550 m, 21.VI.2022, Coll. Priyanka Prabhakaran; Thommankuthu, 1♂, 9°57'32"N 76°50'10"E 216 m, 21.II.2020, Coll. Priyanka Prabhakaran; Kamakshi, 2♂, 9°49'41"N 77°04'56"E 983 m, 22.II.2020, Coll. Priyanka Prabhakaran; Kallar, 1♀, 10°01'52"N 76°59'17"E 824 m, 23.II.2020, Coll. Priyanka Prabhakaran. Kottayam district: Murinjapuzha, 4♂4♀, 9°32'00"N 76°58'18"E, 893 m, 21.VI.2022, Coll. Priyanka Prabhakaran. Kollam district: Punnala, 4♀, 9°05'00"N 76°55'03"E, 53 m, 13.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Mankayam (Brimore), 2♀2♂, 8°45'55"N 77°04'47"E, 168 m, 14.VI.2022, Coll. Priyanka Prabhakaran; Pazhayakunnummel (Meenmutti), 3♂1♀, 8°47'11"N 76°55'03"E, 116 m, 17.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total Length: 5.10 mm- 6.00 mm: Maximum width: 3.00 mm- 3.60 mm.

Form oval, broad, glossy. Head reddish- brown; clypeus paler; micro sculpture consists of well impressed rounded meshes; large well impressed punctures sparse on the anterior region; clypeal groove present; row of punctures along the margin of the eyes. Pronotum reddish brown; lateral sides paler, finely bordered; microsculpture consists of well impressed polygonal meshes, punctures minute, well impressed short longitudinal stria medially; row of coarse punctures at the anterior and posterior border. Elytra dark brown; micro reticulated with polygonal meshes; punctures minute; sutural row of punctures consists of large well-spaced punctures especially before the middle; discal and sublateral row of punctures starts from the base; punctures large, irregularly distributed apically, close, in straight line at the anterior region (Plate 4 (9) a). Ventral surface reddish- brown; prosternal process short broad and rounded at the tip, sides bordered; metacoxal lines represented only by a short well impressed strioles at its mid-length. Punctures on abdominal sternite 3- 4 sparse, medium sized; anal sternite microreticulate, small depressions mediolaterally. Median lobe (Plate 4 (9) b) evenly curved in lateral view, constant in width, bit tapering suddenly at the middle, apex rounded. Paramere broad (Plate 4 (9) c)

Habitat: Specimens were collected in remnant pools in waterfalls (Plate 5 (6; 8; 14; 17; 28; 33)), remnant pools in river and stream beds (Plate 5 (6; 8; 15; 4; 21; 22; 35)), rainwater fed plastic container (Plate 5 (24)), remnant pool in an abandoned ditch (Plate 5 (25)), remnant pool in a streamlet (Plate 5 (34)), road-side drains (Plate 5 (27; 38)), remnant pool in a ditch (Plate 5 (3)), rock pools (Plate 5 (36; 39)), muddy puddle (Plate 5 (37)) and a small hillside pool (Plate 5 (29)).

Distribution: The species is distributed in the Oriental region. India (Karnataka, Kerala)

10. *Lacconectus regimbarti* Brancucci, 1986 (Plate 4 (10))

1986. *Lacconectus regimbarti* Brancucci, 160.

Material examined: Thrissur district: Thalikkode, 2♂, 10°34'32"N 76°18'37"E, 141 m, 15.1.2021, Coll. Priyanka Prabhakaran. Idukki district: Peermade, 9♂13♀, 9°34'15"N 77°03'54"E, 1490 m, 21. VI.2022, Coll. Priyanka Prabhakaran; Kuttikkanam, 10♂19♀, 9°34'51"N 76°58'30"E, 1550 m, 21.VI.2022, Coll. Priyanka

Prabhakaran; Murinjapuzha, 5♂4♀, 9°32'00"N 76°58'18"E, 893 m, 21.VI.2022, Coll. Priyanka Prabhakaran; Peerumade, 2♂, 9°33'09"N 76°58'41"E, 718 m, 21.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Length: 5.90 mm- 6.70 mm; Maximum width: 3.40 mm- 3.70 mm.

Form oval, large, slightly glossy. Head ferruginous brown; dark along the posterior region and margin of eyes; well impressed small rounded meshes; punctures minute, well impressed, numerous and irregular at sides; clypeal groove present; short row of coalescent punctures alongside the eyes. Pronotum ferruginous brown; dark along the anterior and posterior margins; lateral sides bordered and the furrow disappears near the anterior border; micro sculpture consists of well impressed small rounded meshes, punctation dense, well impressed; medial longitudinal stria well impressed; row of coarse punctures along the anterior and lateral margins, punctures large either coalescent or separate, well-spaced punctures near the anterolateral angles. Elytra brownish–black with a testaceous band near the base; a median transverse patch and a subapical patches, which neither reach the suture nor lateral margins; micro sculpture consists of small round meshes; punctures minute, well- impressed, dense; sutural row of punctures represented by some punctures near the apical third; discal and sublateral rows interrupted before the base; punctures medium- sized in well-spaced groups especially at the anterior region; some punctures in the space between the discal and the sublateral rows (Plate 4 (10) a). Ventral surface reddish- brown; appendages testaceous, hindleg darker; epipleura testaceous at the base; prosternal process microreticulated, elongate, rounded at the apex, sides bordered; metacoxal lines are represented by long furrows; abdominal sternites 3,4 and 5 with transverse row of punctures medio laterally; anal sternite striolate anteriorly rest microreticulated; punctures minute; depressions of 3-4 coalescent punctures on each sides of the middle. Median lobe strongly curved, broadened after the middle and just before the apical region, apex narrowly rounded, apex is triangular in dorsal view (Plate 4 (10) b). Parameres elongate, more or less "D" shaped, apical region narrow and elongate, apical lobe club- shaped (Plate 4 (10) c).

Habitat: The species was collected in remnant pool in a streamlet (Plate 5 (40)),spring-fed rock pools (Plate 5 (36; 41)), spring-fed pool (Plate 5 (42)) and remnant pool in roadside drain (Plate 5 (27)).

Distribution: The species has an Oriental distribution. India (Kerala, Tamil Nadu)

III. Subfamily: Cybistrinae

The members of the subfamily are larger, body length ranging between 13 mm- 47 mm. The colouration is dark green to black. Many species have a yellow lateral line on the pronotum and/or elytra. Presence of small apicoventral elytral setal patch. Posteroapical surface of metatibia with a large cluster of bifid setae. Metatibial spurs are different in size and shape. Tibial spur on the anteroapical surface are acuminate and broader than the posteroapical spur. Males with protarsomeres I-III broadly expanded laterally and were provided with adhesive setae. One hundred and thirty species are known under seven genera under the tribe *Cybistrini* of this subfamily.

Genus: *Cybister* Curtis, 1827

Members of this group measures between 13 mm- 43 mm in length. Medium to large-sized species. Some species are uniformly darker dorsally. Others with a yellowish lateral margin on both pronotum and elytra. Posteroventral apical margin of mesotarsomeres of males and of pro and meso tarsomeres in females with a series of setae. Males have only single metatarsal claw. Females have either one or two metatarsal claws, if two, the posterior claw will be small. The medial margin of the abdominal sternum VIII is emarginated. Five species were recorded under this genus during the study.

11. *Cybister cardoni* Severin, 1890 (Plate 4 (11))

1969. *Cybister cardoni* Vazirani, 288.

Material examined: Thrissur district: Marottichal, 1♂, 10°28'40"N 76°21'24"E, 51 m, 28.I.2018, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 21.00 mm; Maximum width: 16.00 mm.

Form oblong oval, attenuated anteriorly, slightly convex. Head greenish-brown; clypeus and labrum yellow. Pronotum dark brown with yellow lateral margins; punctation fine and dense; median longitudinal stria present; two sub basal short transverse striae separated by a distance of their length. Elytra dark-brown with yellow lateral and submarginal stripes uniform in width and reach up to the apex connecting to the suture; punctation fine and dense; two longitudinal rows of large punctures; punctures of 2nd stria widely spaced and disappears after the middle (Plate 4 (11) a). Ventral surface reddish-brown; male with basal 3 segments of protarsi dilated with a round shape; basal 3 segments of midtarsi provided with a brush-like hairs of rusty appearance (Plate 4 (11) b).

Habitats: The species was collected in the shallow, sandy margin of the plunge pool down the waterfall (Plate 5 (43)).

Distribution: The species is distributed in the Palaearctic and Oriental regions. India (Bihar, Jharkhand, Kerala (Current study).

12. *Cybister confusus* Sharp, 1882 (Plate 4 (12))

1882. *Cybister confusus* Sharp, 739.
1969. *Cybister confusus* Vazirani, 295.

Material examined: Thrissur district: Assarikkadu, 1♂, 10°29'57"N 76°19'43"E, 83 m, 01.IX.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 37.00 mm; Maximum width:10.90 mm.

Form oval, broad, slightly attenuated posteriorly, convex, broadest after the middle of elytra. Head brownish-black; clypeus and labrum reddish-yellow. Pronotum brownish-black; lateral margin yellow; surface smooth; Elytra brownish-black; yellow marginal and submarginal stripes that gradually narrows towards the apex not touching suture. Punctures large, shallow. Two longitudinal rows of short striae (Plate 4 (12) a). Ventral surface reddish-brown; prosternal process brownish-green, broadly lanceolate, tip pointed. Males with the basal 3 segments of protarsi dilated and triangular in shape; basal 2 segments of the midtarsi broad and covered with pubescence. Median lobe with apical two-third curved in lateral view (Plate 4 (12) c), apex broader in ventral view with a deep notch (Plate 4 (12) b). Parameres Broader, narrowed towards the apical region with series of long setae at the ventral margin (Plate 4 (12) d)

Habitats: The specimen was collected at light.

Distribution: The species is distributed in the Oriental and Palaearctic region. India (Bihar, Jharkhand, Karnataka, Kerala (Current study), Madhya Pradesh, Maharashtra, Manipur, Orissa, Tamil Nadu, Tripura, West Bengal)

13. *Cybister sugillatus* Erichson, 1834 (Plate 4 (13))

1969. *Cybister sugillatus* Vazirani, 281.
2023. Cybister sugillatus Jiang et al., 97.

Material examined: Kasargod district: Kodom, 1♂1♀, 12°25'49"N 75°12'19"E, 546 m, 06.II.2022, Coll. Priyanka Prabhakaran; Kolathur, 1♂1♀, 12°25'36"N 75°07'40"E, 528 m, 07.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Kanjirakolli (Valapattanam River), 1♂, 12°08'22"N 75°37'51"E, 366 m, 12.II.2022, Coll. Priyanka Prabhakaran; Manikkadavu, 2♀, 12°05'47"N 75°40'26"E, 83 m, 12.II.2022, Coll. Priyanka Prabhakaran; Vellad, 1♂1♀, 12°08'57"N 75°33'59"E, 1001 m, 10.II.2022, Coll. Priyanka Prabhakaran; Vellad, 4♂2♀, 12°08'54"N 75°33'59"E, 397 m, 10.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Malavayal, 3♂2♀, 11°37'56"N 76°15'20"E, 909 m, 30.V.2016, Coll. Priyanka Prabhakaran; Malayilpedika, 2♂3♀, 11°47'58"N 76°00'59"E, 764 m, 13.II.2018, Coll. Priyanka Prabhakaran; Perikkallur (Kabini River), 2♂1♀, 11°51'35"N 76°08'26"E, 735 m, 12.II.2022, Coll. Priyanka Prabhakaran; Poomala, 1♂, 11°38'48"N 76°15'03"E, 910 m, 30.V.2016, Coll. Priyanka Prabhakaran. Kozhikode district: Naduvannur, 1♂, 11°29'25"N 75°46'22"E, 508 m, 16.II.2022, Coll. Priyanka Prabhakaran; Palazhi, 1♂1♀, 11°19'28"N 75°46'18"E, 30 m, 18.II.2024, Coll. Priyanka Prabhakaran. Thrissur district: Cheppara, 2♂, 10°36'56"N 76°15'24"E, 113 m, 11.I.2021, Coll. Priyanka Prabhakaran. Kottayam district: Santhipuram, 1♂, 9°28'52"N 76°37'33"E, 75 m, 26.II.2021, Coll. Priyanka Prabhakaran. Kollam district, Ezhukone, 1♂2♀, 8°59'27"N 76°42'33"E, 1006 m, Coll. Priyanka Prabhakaran; Maruthimala (Muttara), 2♂2♀, 8°57'19"N 76°45'24"E, 562 m, 18.VI.2022, Coll. Priyanka Prabhakaran;

Vilappilsala, 2♂1♀, 8°32'15"N 77°02'45"E, 107 m, 15.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 18.00 mm- 23.00 mm; Maximum width: 12.00 mm– 17.00 mm.

Form oblong oval. Head dark green. Pronotum dark green with reddish brown lateral sides. Elytra dark green with apical reddish-brown spot; males with indistinct tubercles (Plate 4 (13) a). Ventral surface black; abdominal sternites with indistinct reddish-brown spots laterally; labrum brown; maxillary palp and antennae reddish-brown; pro legs black; meso and meta legs black with femora brownish; males with basal three segments of pro tarsi dilated. Median lobe uniformly wide at base, narrows towards the apex, at the apical one-fourth narrow abruptly forming a tubular spine; apex rounded, medially broad in ventral view (Plate 4 (13) b). Lateral lobes moderately broad (Plate 4 (13) c).

Habitats: The species is collected in the margin of a remnant pool downstream of a waterfall (Plate 5 (44)), leaf-choked river margin (Plate 5 (45)), remnant pool in a river bed (Plate 5 (46)), temporary pools in abandoned paddy fields (Plate 5 (47; 50; 51), leaf choked margins of a pond in the floodplains of a river (Plate 5 (48)), pond with rocky bottom (Plate 5 (52)), vegetated margin of a slow-moving stream (Plate 5 (49)), vegetated margin of a quarry pond (Plate 5 (55)), remnant pool in a river bed (Plate 5 (13)), remnant pool in a waterfall (Plate 5 (17)), rock pools (Plate 5 (33; 54)) and an ephemeral pool on roadside (Plate 5 (53)).

Distribution: This species is distributed in the Oriental and Palaearctic region. India (Assam, Bihar, Himachal Pradesh, Kerala (Current study), Madhya Pradesh, Maharashtra, Manipur, Orissa, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal)s

14. *Cybister tripunctatus lateralis* (Fabricius, 1798) (Plate 4 (14))

1899. *Cybister similis* Régimbart, 352.

1931. *Cybister tripunctatus orientalis* Gschwendtner, 99.

1936. *Cybister szechwanensis* Falkenström, 238.

2001. *Cybister tripunctatus orientalis* Nilsson, 90.

2010. *Cybister szechwanensis* Jia *et al*., 258.

Material examined: Thrissur district: Cheppara, 1♂, 10°37'04"N 76°15'15"E, 141 m, 19.X.2021, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 23.00 mm; Maximum width: 12.00 mm

Form oblong oval. Head olive green; clypeus yellow. Pronotum olive green with yellow lateral margins. Elytra olive green, laterally with distinct yellow margins; posterior end of yellow margin crochet shaped (Plate 4 (14) a). Ventral surface brown; meta sternite and metacoxae yellowish; abdominal sternites are yellowish laterally; meta legs are reddish brown with apical segments black; prosternal process lanceolate, surface flat with distinct beads on lateral sides, apex pointed; the lateral part of meta ventrites tongue-shaped, not reaching lateral margins; metacoxal lines well impressed and with a row of punctures along with it; males with protarsomeres 1-3 broadly expanded into a palette with 4 rows of adhesive setae at the ventral side; metatarsal claw single. Median lobe of aedeagus moderately curved, “C” shaped in lateral view (Plate 4 (14) b), apex slightly narrowed in ventral view, apex furcate with a deep acute- angled notch medially, lateral margins of apex convex Plate 4 (14) c). Parameres moderately broad, tapering apically (Plate 4 (14) d).

Habitat: The specimen is collected in an ephemeral pool (Plate 5 (23)).

Distribution: The species is distributed in the Oriental and Palaearctic region. India (Andaman & Nicobar Islands, Andhra Pradesh, Assam, Delhi, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala (Current study), Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal)

15. *Cybister posticus* Aubé, 1838 (Plate 4 (15))

1838. *Cybister posticus* Aubé, 87.

2023. *Cybister posticus* Jiang et al., 95.

Material examined: Kozhikode district: Iringal, 1♂, 11°19'28"N 75°46'18"E, 30 m, 18.II.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 23.00 mm; Maximum width:13.00 mm.

Form oblong oval. Head, pronotum and elytra brown. Pronotum with series of punctures along the base of anterior border; two foveae laterally on the middle of the anterior border; lateral and posterior borders with feebly impressed strioles; lateral margins paler. Elytra with large, well-impressed, sparse punctures (Plate 4 (15) a). Ventral surface dark brown; prosternal process lanceolate apically narrowed with pointed tip. Median lobe more or less uniform in width from base to just after midlength; apical 1⁄3 narrowed to form tubular spine (Plate 4 (15) b). Lateral lobe "C" shaped; gradually narrowing towards a pointed tip; numerous long hairs from the middle towards the apex (Plate 4 (15) c).

Habitat: The specimen is collected in an abandoned paddy field (Plate 5 (56)).

Distribution: The species is distributed in the Oriental and Palaearctic region. India (Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Kerala (Current study), Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Sikkim, Uttarakhand, Uttar Pradesh, West Bengal)

IV. Subfamily: Dytiscinae

The members are medium to large sized. Scutellum is visible when the elytra is closed. In males protarsomeres I- III are broadly expanded to form a rounded palette provided with adhesive setae ventrally. Metatibial spurs are similar in size and shape. A few species bear two metatarsal claws and with metatarsomeres lobed at the posteroapical margin. There are 263 species under five tribes and 12 genera.

Genus: *Hydaticus* Leach, 1817

The is the only genus under the tribe *Hydatiscini* and includes 158 species. Members of the genus are quite large and often have attractive markings. There are two subgenera under this genus such as *Hydaticus s. str.* and *Hydaticus (Prodaticus)*. Species of the subgenus *Hydaticus* (*Prodaticus*) were only observed and collected during the study. The are characterized by the absence of fine punctation on the anterior surfaces of the metafemur and metatibia. The posterior surface of the metatibia with the bifid setae proximally curved towards the ventral side. Male mesotarsomere I with small and linear basal brush of setae. The anterior margin of metaventrite is straight or only slightly concave.

Previously, three species have been reported from Kerala state. Additionally, four more species have been recorded, making a total of seven species under the genus.

16. *Hydaticus bipunctatus* Wehncke, 1876 (Plate 4 (16))

1876. *Hydaticus bipunctatus* Wehncke, 196
1975. *Hydaticus satoi* Wewalka, 91; 2020.Wewalka, 38, Synonymy
2003. *Hydaticus satoi dhofarensis* Pederzani, 105; 2021. Hájek *et al*., 146, Synonymy.
2020. *Hydaticus bipunctatus* Wewalka, 38.

Material examined: Wayanad district: Puthukkad, 3♂1♀, 11°32'21"N 76°07'03"E, 976 m 14.II.2022, Coll. Priyanka Prabhakaran. Malappuram district: Thottuppoyil, 1♂, 11°07'40"N 76°09'12"E, 130 m, 18.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Murukkumpara, 1♂, 10°29'46"N 76°19'46"E, 116 m, 31.V.2016, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂, 10°29'46"N 76°19'46"E, 116 m, 29.IX.2017, Coll. Priyanka Prabhakaran. Idukki district: Adimali, 1♂2♀, 10°01'16"N 76°57'21"E 769 m, 1.II.2020, Coll. Priyanka Prabhakaran; Cheriyar (S- Valavu), 1♂, 9°56'35"N 77°13'04"E, 1240 m, 23.2.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 9.00 mm- 15.00 mm; Maximum width: 4.00 mm- 8. 00 mm.

Form oval, moderately convex. Head black with posterior margin yellowish. Pronotum black with lateral sides yellow. Elytra black, smooth and with golden-yellow humeral and submarginal longitudinal stripes that do not merge; humeral stripe extends up to the elytral apex ending in a crochet shape; submarginal stripe wider than humeral stripe and ends before the mid-length of elytra (Plate 4 (16) a). Ventral surface dark brown; males with basal three segments of protarsi dilated and provided with sucker palettes; meso tarsi with sessile palettes. Median lobe moderately curved, uniformly broad towards the apical region, apex blunt (Plate 4 (16) b).

Habitat: The specimens were collected in an abandoned ditch (Plate 5 (57)), rock pool (Plate 5 (11)), small pools (Plate 5(58; 59)) and remnant pool in a river bed (Plate 5 (60)).

Distribution: India (Andhra Pradesh, Assam, Arunachal Pradesh, Dadra & Nagar Haveli, Delhi, Goa, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Manipur, Maharashtra, Meghalaya, Odisha, Rajasthan, Sikkim, Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal).

17. *Hydaticus discindens* Walker, 1858 (Plate 4 (17))

1858. *Hydaticus discindens* Walker, 204.
1935. *Hydaticus pacificus* var. *ceylonicus* Guignot, 130; 2016. Wewalka, 22, Synonymy.
1969. *Hydaticus sharpi* Vazirani, 264; 2016. Wewalka, 22, Synonymy.
1999. *Hydaticus orissanensis* Nilsson, 20; 2016. Wewalka, 22, Synonymy.

Material examined: Kasargod district: Nileswaram (Mundemmad Road), 1♂, 12°14'28"N 75°08'28"E, 503 m, 08.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Edumbapalam, 1♂2♀, 11°53'55"N 75°39'15"E, 602 m, 16.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Pazhupathur, 1♀, 11°40'22"N 76°13'53"E, 834 m, 15.II.2022, Coll. Priyanka Prabhakaran; Thenmavinkadavu, 1♂, 11°51'35"N 76°08'26"E, 735 m, 12.II.2022, Coll. Priyanka Prabhakaran; Panavally, 5♀3♀, 11°40'42"N 76°22'21"E, 879 m, 15.II.2022, Coll. Priyanka Prabhakaran; Vythiri, 2♀, 11°33'37"N 76°02'44"E, 793 m, 16.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Chittur (Streamlet), 2♂1♀, 11°03'46"N 76°39'14"E, 586 m, 16.IX.2021, Coll. Priyanka Prabhakaran; Moonnekkar, 2♂, 10°55'23.7"N 76°34'27"E, 120 m, 24.02.2022, Coll. Priyanka Prabhakaran. Thrissur district: Assarikkadu, 1♂, 10°29'57"N 76°19'42.6"E, 83 m, 17.XI.2018, Coll. Priyanka Prabhakaran; Assarikkadu, 1♂, 10°29'57"N 76°19'43"E 83 m, 15.IV.2019, Coll. Priyanka Prabhakaran; Assarikkadu, 1♀, 10°29'57"N 76°19'423"E 83 m, 29.IV.2023, Coll. Priyanka Prabhakaran; Punnachuvadu, 1♂, 10°30'43"N 76°19'33"E, 120 m, 24.X.2021, Coll. Priyanka Prabhakaran; Thalikkode, 13♂6♀, 10°34'32"N 76°18'37"E, 141 m, 15.1.2021, Coll. Priyanka Prabhakaran; Thalikkode, 1♂1♀, 10°34'32"N 76°18'37"E, 141 m, 04.I.2022, Coll. Priyanka Prabhakaran. Alappuzha district: Pavumba, 1♂1♀, 9°05'41"N 76°35'56"E, 24 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Kollam district: Ezhukone, 1♀, 8°59'35"N 76°42'45"E, 56 m, 19.VI.2022, Coll. Priyanka Prabhakaran; Ezhukone, 3♂3♀, 8°59'27"N 76°42'33"E, 47 m, 19.VI.2022, Coll. Priyanka Prabhakaran; Punnala, 1♂, 9°05'00"N 76°55'03"E, 53 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Sasthamkotta, 1♂3♀, 9°01'50"N 76°38'09"E, 24 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Venkode, 2♀, 8°35'20"N 76°58'39"E, 121 m, 16.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 12.00 mm- 14.00 mm; Maximum width 6.00 mm- 7.10 mm.

Form elongated oval, widest after mid-length and nearly convex. Head reddish-orange; blackish on vertex and along the eyes and between eyes; pronotum reddish orange, broad black band at the middle, which widens towards the posterior; posterior border finely bordered with black colouration. Elytra black with reddish-orange markings consisting of a humeral mark; a transverse band not reaching suture but joined with the humeral mark; irregular band along the lateral side; a postmedian mark joined to lateral band; a subapical mark joined to lateral mark (Plate 4 (17) a). Ventral surface dark brown; antennae, mouthparts, forelegs, midlegs and epipleura brown; abdominal sternites 4-6 with irregular orange markings. Median lobe slender, broader at the apical region (Plate 4 (17) b & c).

Habitat: The specimens were collected in a remnant pool in an abandoned ditch (Plate 5 (25)), remnant rock pool in a waterfall (Plate 5 (14)), ditch in an agricultural field (Plate 5 (61)), leaf- choked margins of a pool in the floodplains of a river (Plate 5 (48)), remnant pool in a ditch (Plate 5 (63)), remnant pool in a streamlet (Plate 5 (34)), remnant pool in a well (Plate 5 (64)), water tank, rainwater-fed plastic container (Plate 5 (24)), remnant pools in streamlets (Plate 5 (40; 65)), ephemeral pool on a dirt road (Plate 5 (66)), small pools (Plate 5 (67; 69)), ephemeral roadside pool (Plate 5 (53)), muddy puddle (Plate 5 (37)), rock pools (Plate 5 (6; 70)) and ditch in an abandoned paddy field (Plate 5 (71)).

Distribution: The species is distributed in the Oriental and Palaearctic region. India (Andhra Pradesh, Karnataka, Kerala (Current study), Tamil Nadu).

18. *Hydaticus incertus* Régimbart, 1888 (Plate 4 (18))

1888. *Hydaticus incertus* Régimbart, 617.

1972. *Hydaticus martensi* Wewalka, 115; 1979. Wewalka, 130, Synonymy.

2023. *Hydaticus incertus* Wewalka, 23.

Material examined: Kasargod district: Kolathur, 1♂, 12°25'36"N 75°07'40"E, 528 m, 07.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Vayathur, 1♂2♀, 12°05'47"N 75°40'26"E, 83 m, 12.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Panavally, 4♂3♀, 11°51'55"N 76°04'32"E, 747 m, 15.II.2022, Coll. Priyanka Prabhakaran; Panavally, 4♂3♀, 11°40'42"N 76°22'21"E, 879 m, 15.II.2022, Coll. Priyanka Prabhakaran; Thavinhal, 4♂4♀, 11°50'05.9"N 75°56'33.9"E, 769 m, 13.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Murukkumpara, 2♂, 10°29'46"N 76°19'46"E, 116 m, 29.IX.2017, Coll. Priyanka Prabhakaran; Murukkumpara, 2♂, 10°29'46"N 76°19'46"E, 116 m, 10.VI.2019, Coll. Priyanka Prabhakaran. Idukki district: Cheriyar, 1♂, 9°56′35"N 77°13′04"E, 1139 m, 23.II.2020, Coll. Priyanka Prabhakaran; Thommankuthu, 2♂1♀, 9°57'32"N 76°50'10"E, 216 m, 21.II.2020, Coll. Priyanka Prabhakaran. Kottayam district: Poovanthode, 1♂, 9°40'59.9"N 76°44'24"E, 53 m, 98.VII.2019, Coll. Priyanka Prabhakaran. Alappuzha district: Varanad, 6♂6♀, 9°41'54"N 76°21'19"E, 20 m, 20.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 10.30 mm- 11.00 mm; Maximum width 5.40 mm- 5.80 mm.

Form oval and wide. Head reddish brown and anteriorly slightly darker; black band at the posterior margin. Pronotum reddish brown; medially black; lateral sides paler and rebordered; a short longitudinal stria medially. Elytra reddish-brown with slightly confluent black speckles (Plate 4 (18) a). Ventral surface brown. Penis slightly curved with a small bristle plate at the tip (Plate 4 (18) b & c).

Habitat: Leaf-choked margin of a river (Plate 5 (45)), rock pools (Plate 5 (15; 28; 62; 70; 96), remnant pool in a river bed (Plate 5 (60)), small pool (Plate 5 (59)), ditch in an abandoned paddy field (Plate 5 (71)), ephemeral pool on a dirt road and the margin of a pool (Plate 5 (177)).

Distribution: The species is distributed in the Oriental and Palaearctic regions. India (Assam, Delhi, Gujarat, Himachal Pradesh, Jharkhand, Kerala (Current study), Madhya Pradesh, Maharashtra, Meghalaya, Uttarakhand, Uttar Pradesh).

19. *Hydaticus* cf *luczonicus* Aubé, 1838 (Plate 4 (19))

1838. *Hydaticus luczonicus* Aubé,179.
1969. *Hydaticus luczonicus* Vazirani, 262.

Material examined: Thrissur district: Assarikkadu, 1♀, 10°29'57"N 76°19'43"E 83 m, 17.XI.2018, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 13.50 mm; Maximum width: 06.80 mm.

Form elongate oval, moderately convex. Head reddish yellow; black colouration along the inner margin of eyes and the posterior margin, black colouration merges at the middle leaving two yellow spots on vertex; reticulation not well developed; punctation double, smaller one dense and fine, larger ones sparse and moderate; anterior margin of clypeus truncate and emarginated. Pronotum reddish- brown, broad black longitudinal streak between anterior and posterior margin which dilated at the posterior margin; reticulation more distinct; punctation as on head. Elytra black with broad golden-yellow lateral lines with sub basal transverse elongations; punctation fine dense, larger punctures sparse (Plate 4 (19) a). Ventral surface black and shiny; epipleurite and appendages except hindlegs are reddish; abdominal sternite dark brown with obscured reddish spots on lateral sides of abdominal sternites 4-6; basal three segments of fore tarsi largely dilated and provided with 'sucker pallettes' underneath; the basal two pallettes largest; mesotarsi with four rows of 'sessile pallettes' on the basal three segments. Penis slightly curved, moderately broadened at apical one-fourth (Plate 4 (19) b).

Habitat: Remnant pool in a well (Plate 5 (64)).

Distribution: The species is distributed in the Oriental and Palaearctic region. India (Bihar, Delhi, Gujarat, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal).

20. *Hydaticus ricinus* Wewalka, 1979 (Plate 4 (20))

1979. *Hydaticus ricinus* Wewalka, 128.

2023. *Hydaticus ricinus* Wewalka, 23.

Material examined: Kannur district: Kanjirakolli (Valapattanam River), 4♂3♀, 12°08'22"N 75°37'51"E, 366 m, 12.II.2022, Coll. Priyanka Prabhakaran; Kudiyanmala, 2♀, 12°08'56"N 75°33'47"E, 363 m, 10.II.2022, Coll. Priyanka Prabhakaran; Kudiyanmala, 1♀, 12°08'54"N 75°33'54"E, 391 m, 10.II.2022, Coll. Priyanka Prabhakaran; Kudiyanmala, 1♂3♀, 12°08'53"N 75°33'56"E, 402 m, 10.II.2022, Coll. Priyanka Prabhakaran; New Naduvil, 1♂, 12°09'46"N 75°26'37"E, 50 m, 10.II.2022, Coll. Priyanka Prabhakaran; New Naduvil, 1♂, 12°08'40"N 75°26'32"E, 68 m, 10.II.2022, Coll. Priyanka Prabhakaran; New Naduvil, 1♂1♀, 12°09'59"N 75°26'53"E, 54 m, 10.II.2022, Coll. Priyanka Prabhakaran; Puthussery, 1♂, 12°00'16"N 75°40'09"E, 56 m, 12.II.2022, Coll. Priyanka Prabhakaran; Vayathur, 2♂1♀, 12°05'40"N 75°40'21"E, 68 m, 12.II.2022, Coll. Priyanka Prabhakaran; Vellad, 1♂4♀, 12°08'54"N 75°33'59"E, 397 m, 10.II.2022, Coll. Priyanka Prabhakaran; Vellad, 1♀, 12°08'57"N 75°33'59"E, 401 m, 10.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Puthukkad, 1♂4♀, 11°32'21"N 76°07'03"E, 976 m 14.II.2022, Coll. Priyanka Prabhakaran; Padinjarathara, 1♀, 11°40'39"N 75°56'16"E, 876 m, 13.II.2022, Coll. Priyanka Prabhakaran; Palchuram, 1♂, 11°50'51"N 75°55'01"E, 545 m, 13.II.2022, Coll. Priyanka Prabhakaran; Panavally, 1♂4♀, 11°52'52"N 76°04'40"E, 765 m, 15.II.2022, Coll. Priyanka Prabhakaran; Thenmavinkadavu, 4♂3♀, 11°51'56"N 76°08'41"E, 734 m, 12.II.2022, Coll. Priyanka Prabhakaran. Malappuram district: Thottuppoyil, 1♂, 11°07'44"N 76°09'16"E, 77 m, 18.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Purameri, 2♂, 11°41'00"N 75°36'38"E, 26 m, 16.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Agali (Narathumkolli), 1♂1♀, 11°02'40"N 76°39'06"E, 698 m, 02.II.2021, Coll. Priyanka Prabhakaran; Chittur (Siruvani river), 1♂, 10°04'10"N 76°39'16"E, 68 m, 02.II.2021, Coll. Priyanka Prabhakaran; Pappadi, 2♂1♀, 10°49'48"N 76°38'02"E, 105 m, 24.II.2022, Coll. Priyanka Prabhakaran; Puthuppariyaram, 1♀, 10°55'18"N 76°34'57"E, 155 m, 24.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Murukkumpara, 2♂, 10°29'46"N 76°19'46"E, 116 m, 29.IX.2017, Coll. Priyanka Prabhakaran. Ernakulam district: Aikkaranadu, 1♂, 9°57'07"N 76°26'39"E, 44 m, 20.II.2022, Coll. Priyanka Prabhakaran. Idukki district: Manjumala, 1♂, 9°34'15"N 77°03'54"E, 1490 m, 21.VI.2022, Coll. Priyanka Prabhakaran; Pazhampyllichal, 1♂, 10°03'43"N 76°49'35"E, 517 m, 02.I.2021, Coll. Priyanka Prabhakaran. Alappuzha district: Thanneermukkom, 2♂1♀, 9°05'41"N 76°35'56"E, 26 m, 20.VI.2022, Coll. Priyanka Prabhakaran. Kottayam district: Mukkada, 3♂2♀, 9°28'45"N 76°47'49"E, 82 m, 27.II.2021, Coll. Priyanka Prabhakaran; Mukkada, 7♂6♀, 9°28'04"N 76°47'47"E, 96 m, 27.II.2021, Coll. Priyanka Prabhakaran. Kollam district: Chepra (Mukkavalappara), 1♂, 8°55'13"N 76°48'19"E, 129 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Kizhakkekallada, 1♂1♀, 9°01'12"N 76°40'10"E, 25 m, 19.VI.2022, Coll. Priyanka Prabhakaran; Maruthimala (Muttara), 1♂, 8°57'19"N 76°45'24"E, 562 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Valiyode, 1♂1♀, 8°55'36"N 76°47'34"E, 73 m, 18.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Cheenikkala, 3♂4♀, 8°30'43"N 77°10'30"E, 192 m, 15.VI.2022, Coll. Priyanka Prabhakaran; Kuttimoodu, 1♂, 8°44'53"N 76°55'39"E, 17.VI.2022, Coll. Priyanka Prabhakaran; Neyyar, 4♂, 8°31'55"N 77°08'54"E, 103 m, 15.II.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 9.50 mm-10.70 mm; Maximum width: 4.80 mm- 5.50 mm.

Form elongate oval. Head yellow with posterior border black. Pronotum yellow with a short black band in the middle of the posterior boarder. Elytra yellowish with black speckles which is confluent (Plate 4 (20) a). Ventral surface brown; appendages testaceous, meta legs brown; elytral epipleura testaceous; abdominal sternites with indistinct yellow spots on lateral sides; males with basal 3 segments of protarsi enlarged and provided with sucker palettes; meso legs with sessile palettes in the basal 3 segments. Median lobe straight, slender, with two tufts of bristles, tip knob-shaped (Plate 4 (20) b & c).

Habitat: The species is collected in a remnant rock pools in waterfalls (Plate 5 (72; 73; 74), ephemeral pool (Plate 5 (76)), remnant pool in a waterfall (Plate 5 (17)), rock pools (Plate 5 (10; 12; 16; 33; 62; 87; 89), margin of a pond in the floodplains of a river (Plate 5 (48)), abandoned ditch (Plate 5 (57)), pool in abandoned paddy fields (Plate 5 (80; 82)), margins of streams and a river (Plate 5 (77; 78; 81)), remnant pools in streamlets, streams and rivers (Plate 5 (8; 46; 75; 79; 85; 86)), Ephemeral pool

(Plate 5 (88)), vegetated margin of a pond (Plate 5 (93)), Pools on mud roads (Plate 5 (84; 90)) and ditches (Plate 5 (83; 91; 92)).

Distribution: The species is distributed in the Oriental and Palaearctic regions. India (Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Himachal Pradesh, Jharkhand, Karnataka, Kerala (Current study), Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Sikkim, Tamil Nadu (incl. Puducherry), Telangana, Uttarakhand, West Bengal)

21. *Hydaticus vittatus* (Fabricius, 1775) Plate 4 (21))

1880. *Hydaticus sesquivittatus* Fairmaire, 164; 1975. Wewalka, 87, Synonymy.
1890. *Graphoderus vittatus* var. *lenzi* Schönfeldt, 170; 1975. Wewalka, 87, Synonymy.
1899. *Hydaticus vittatus* var. *angustulus* Régimbart, 329; 2020. Wewalka, 29, Synonymy.
1961. *Hydaticus lenzi nepalensis* Satô, 60; 1975. Wewalka, 87, Synonymy
1975. *Hydaticus vittatus* Wewalka, 88.

Material examined: Kasargod district: Kolathur, 1♂, 12°25'36"N 75°07'40"E, 528 m, 07.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Edumbapalam, 1♀, 11°53'55"N 75°39'15"E, 602 m, 16.II.2022, Coll. Priyanka Prabhakaran; Oduvallithattu, 2♂1♀, 12°08'24"N 75°26'56"E, 54 m, 10.XII.2022, Coll. Priyanka Prabhakaran; Kanjirakolli (Valapattanam River), 2♂1♀, 12°08'21.8"N 75°37'50.9"E, 366 m, 12.II.2022, Coll. Priyanka Prabhakaran; New Naduvil, 1♂, 12°08'40"N 75°26'32"E, 65 m, 10.II.2022, Coll. Priyanka Prabhakaran. Vellad, 1♂, 12°08'57"N 75°33'59"E, 400 m, 10.II.2022, Coll. Priyanka Prabhakaran; Vellad, 12♂11♀, 12°08'54"N 75°33'59"E, 397 m, 10.II.2022, Coll. Priyanka Prabhakaran; Vayathur, 2♂, 12°05'40"N 75°40'21"E, 68 m, 12.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Puthukkad, 2♂1♀, 11°32'21"N 76°07'03"E, 976 m, 14.II.2022, Coll. Priyanka Prabhakaran; Padinjarathara, 2♀, 11°40'39"N 75°56'16"E, 876 m, 13.II.2022, Coll. Priyanka Prabhakaran; Padinjarathara, 1♂2♀, 11°40'40"N 75°56'15"E, 877 m, 13.II.2022, Coll. Priyanka Prabhakaran; Vythiri, 1♂, 11°33'37"N 76°02'44"E, 793m, 16.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Chembukadavu, 3♂, 11°27'27"N 76°01'22"E, 598m, 16.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Chittur (Siruvani river), 1♂1♀, 10°04'10"N 76°39'16"E, 68 m, 02.II.2021, Coll. Priyanka Prabhakaran; Puthuppariyaram, 1♀, 10°55'17"N 76°34'57"E, 155 m, 24.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Ayyampuzha, 2♂3♀, 10°17'43"N 76°27'02"E, 45 m, 18.VII.2019, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂, 10°29'46"N 76°19'46"E, 116 m, 29.IX.2017, Coll. Priyanka Prabhakaran; Murukkumpara, 2♂,s 10°29'46"N 76°19'46"E, 116 m, 29.V.2018, Coll. Priyanka Prabhakaran; Ayyampuzha, 1♂, 10°17'48"N 76°27'06"E, 54 m, 02.II.2019, Coll. Priyanka Prabhakaran. Idukki district: Manjumala, 1♂, 9°34'15"N 77°03'54"E 1490 m, 21. VI.2022, Coll. Priyanka Prabhakaran. Kottayam district: Mukkada, 1♂2♀, 9°28'45"N 76°47'49"E, 82 m, 27.II.2021, Coll. Priyanka Prabhakaran; Mukkada, 2♂4♀, 9°28'04"N 76°47'47"E, 96 m, 27.II.2021, Coll. Priyanka Prabhakaran; Santhipuram, 2♂3♀, 9°28'52"N 76°37'33"E, 75 m, 26.II.2021, Coll. Priyanka Prabhakaran. Kollam district: Kizhakkekallada, 2♂1♀, 9°01'12"N

76°40'10"E, 25 m, 19.VI.2022, Coll. Priyanka Prabhakaran; Maruthimala (Muttara), 5♂, 8°57'19"N 76°45'24"E, 562 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Valiyode, 1♂, 8°55'36"N 76°47'34"E, 73 m, 18.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Cheenikkala, 1♂, 8°30'43"N 77°10'30"E, 192 m, 15.VI.2022, Coll. Priyanka Prabhakaran; Karette, 1♀, 8°43'43"N 76°53'55"E, 40 m, 17.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 11.00 mm- 12.00 mm; Maximum width: 5.10 mm- 6.00 mm.

Form oval, slightly wider after the middle, convex. Head black, anteriorly yellow. Pronotum black with narrow yellow stripe at the lateral sides. Elytra black with a longitudinal humeral and submarginal stripes that join after the mid length of the elytra and extend up to the elytral apex; stripes curved slightly inward, ends crochet-shape (Plate 4 (21) a). Ventral surface brown; appendages testaceous; tibiae of meso legs brown; meta legs entirely brown; abdominal sternites with indistinct yellow spots on lateral sides; males with basal three segments of prolegs enlarged and provided with sucker palettes; basal three segments of meso legs with two rows of sessile palettes. Median lobe moderately curved and broadest at the middle; apical half almost uniform (Plate 4 (21) b).

Habitat: The specimens were collected from leaf-choked river margin (Plate 5 (45)), rock pools (Plates 5 (11; 14; 16; 22; 33; 86; 89; 94; 95; 96; 97; 99), remnant pool in a waterfall (Plate 5 (17)), remnant pool in rivers and streamlet (Plate 5 (8; 46; 85), remnant pool in a ditch (Plate 5 (63)), road-side ditch (Plate 5 (83)), puddle in dirt roads (Plate 5 (84; 90), ditch in an agricultural field (Plate 5 (98)) and a road-side ditch (Plate 5 (91)).

Distribution: This species is distributed in the Oriental and Palaearctic region. India (Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nicobar Islands, Odisha, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, West Bengal)

Genus: *Sandracottus* Sharp, 1882

Species of this genus are moderately large and dorsally attractively marked with complex maculae and fasciae. The size of the members of this group ranges between 11.00 mm- 15.50 mm. They can be easily recognised by the absence of metacoxal lines. Ventral setae of mesofemur that is longer than half the width of mesofemur. The anterior surface of metaventrite concave.

Currently, there are 17 species in this genus. Two species are known from Kerala. In the present study, one species was recorded.

22. *Sandracottus festivus* (Illiger, 1801) (Plate 4 (22))

1801. *Dyticus festivus* Illiger, 166.
1882. *Sandracottus festivus* Sharp, 686.
1968. *Sandracottus festivus* Vazirani, 273.

Material examined: Thrissur district: Assarikkadu, 1♂, 10°29'57"N 76°19'43"E, 94 m, 15.IV.2019, Coll. Priyanka Prabhakaran; Darbha, 1♂1♀, 10°31'00"N 76°20'54"E, 123 m, 11.VI.2023, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 11.78 mm- 11.80 mm; Maximum width 6.90 mm- 7.00 mm.

Form oval, wider after the middle. Head reddish-yellow; posterior border black extending anteriorly along the inner margin of the eyes; two oval spots between the eyes. Pronotum reddish-yellow, anterior border with a black band in the middle; posterior border with broader band in the middle, narrowly extending to the lateral sides; a longitudinal black band on the disc which is connected to the anterior and posterior bands. Elytra with two rows of punctures; elytral markings consist of a black colouration along the suture with a transverse dilation near the apex forming a subapical mark; median and postmedian transverse bands; median transverse band extend anteriorly parallel to the suture forming a longitudinal yellow spot; second anterior extension of median band irregular and form another yellow spot around it; inner side of the median and postmedian transverse bands are connected by two black spots placed one behind the other. Two or three comparatively small black spots arranged one behind the other in the space between the two transverse bands; postmedian band connects to the subapical marks by means of one or two black spots (Plate 4 (22) a). Ventral surface dark brown; legs brown; tibia, tarsus of meta legs dark brown; first and second abdominal sternites brown; posterior border of abdominal sternites darker; epipleura paler; protarsi in males enlarged and provided with sucker palettes underneath; meso tarsi with two rows of sessile palettes underneath. Penis nearly rectangular at apical two third, narrowed at base, apex bifurcate with a 'V' shaped notch (Plate 4 (22) b)

Habitat: The species was collected in a remnant pool in a well (Plate 5 (64)) as well as a muddy puddle in a dirt road (Plate 5 (100)).

Distribution: This species has an Oriental and Palaearctic distribution. India (Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Jharkhand, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamil Nadu)

V. Subfamily: Hydroporinae

This is the most diverse diving beetle subfamily with more than half of the total species of the family dytiscidae. The size of the beetles in this subfamily ranges between 0.90 mm- 7.80 mm. They are distinguished by the anteromedial portion of the prosternal process distinctly declivitous with respect to the prosternum. They possess pseudo tetramerous pro and mesotarsi. Scutellum is absent when the elytra are closed. There are 132 genera under 11 tribes.

Eighteen species across seven genera have been previously documented from Kerala. The present study has recorded eighteen species across eight genera from the state.

Genus: *Clypeodytes* Régimbart, 1894

Members of this subfamily are usually short and robust. The beetle's length varies between 1.50 mm- 2.50 mm. They can be identified by a group of characteristics, the presence of a transverse occipital line, anterior clypeal margin distinctly flattened, the presence of basal pronotal stria, the presence of basal elytral stria, absence of sutural stria on the elytra, presence of a low carina laterally on the elytra, presence of transverse carina at the humeral angle of epipleuron, presence of two segmented lateral lobes of aedeagus, line of punctures on each side of the metaventrite.

Forty species are known to exist within three subgenera under this genus. This study documented two species from this genus, which is being recorded in Kerala state for the first time.

23. *Clypeodytes bufo* Sharp, 1890 (Plate 4 (23))

1890. *Bidessus bufo* Sharp, 344.
1899. *Clypeodytes bufo* Régimbart, 217.
1969. *Guignotus pendjabensis* Vazirani, 325.

Material examined: Wayanad district: Perikkallur, 1♂, 11°51'35"N 76°08'26"E, 735 m, 12.II.2022, Coll. Priyanka Prabhakaran. Ernakulam district: Maneed, 1♂, 9°54'52"N 76°26'29"E, 37 m, 20.II.2022, Coll. Priyanka Prabhakaran; Maneed, 1♂, 9°54'54"N 76°27'33"E, 59 m, 01.II.2020, Coll. Priyanka Prabhakaran. Idukki district: Kottakkavala, 2♂3♀, 9°55'33"N 76°47'57"E, 66 m, 21.II.2020, Coll. Priyanka Prabhakaran; Mulappuram, 1♂, 9°57'03"N 76°49'04"E, 60 m, 21.II.2022, Coll. Priyanka Prabhakaran. Kollam district, Chenkulam, 1♂, 8°52'38"N 76°45'03"E, 51 m, 18.VI.2022, Coll. Priyanka Prabhakaran. Kudavattoor, 1♂, 8°56'23"N 76°44'47"E, 75 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Kaithode (Nilamel), 1♂, 8°49'30"N 76°51'08"E, 89 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Chepra

(Mukkavalappara), 1♀, 8°55'13"N 76°48'19"E, 129 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Chaliyakkara, 1♂, 9°02'21"N 76°57'47"E, 70 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Ezhukone, 1♂, 8°59'27"N 76°42'33"E, 47 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Panayara, 2♂4♀, 8°45'35"N 76°45'02"E, 36 m, 18.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 1.50 mm- 1.70 mm; Maximum width 0.92 mm- 0.95 mm

Form oval, slightly enlarged at the pronotum, posterior region attenuated. Head brownish yellow; darker on the posterior margin. Pronotum brownish yellow; darker in the middle of the posterior border; anterior half of lateral sides rounded; posterior half straight; latero- basal plica oblique and incurved; punctation fine, dense. Elytra testaceous with indistinct black markings; punctation large, well impressed, dense (Plate 4 (23) a). Ventral side testaceous; punctation on meta sternum and meta coxae large, shallow, dense; punctation on abdominal sternites small. Median lobe moderately curved, sides subparallel, narrowed near the apex, tip rounded (Plate 4 (23) b). Parameres slightly curved, apical region narrowed, apex rounded (Plate 4 (23) c)

Habitats: The species were collected in the margin of a river and irrigation canal (Plate 5 (101; 102)), muddy puddles (Plate 5 (103; 104)), shallow and muddy edges of a river (Plate 5 (105)), ditch in an abandoned paddy field (Plate 5 (106)), spring-fed pool (Plate 5 (107)), pools in abandoned paddy fields (Plates 5 (108; 109)), rock pool (Plate 5 (87)) and rain-fed ephemeral pool on road-side (Plate 5 (53)).

Distribution: The species is distributed in the Oriental as well as Palaearctic regions. India (Assam, Goa, Jharkhand, Maharashtra, Meghalaya, Orissa, Tamil Nadu, West Bengal).

24. *Clypeodytes* cf *feryi* Hendrich & Wang, 2006 (Plate 4 (24))

1922. *Bidessus bifasciatus* Zimmermann, 3.
2006. *Clypeodytes feryi* Hendrich & Wang, 2.

Material examined: Kasargod district: Cheruvathur, 1♂, 12°14'05"N 75°09'03"E, 35 m, 05.II.2022, Coll. Priyanka Prabhakaran; Shiriya, 1♂, 12°37'23"N 74°55'42"E, 30 m, 08.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Chiranellur, 1♂, 10°38'01"N 76°07'16"E, 24 m, 20.IV.2018, Coll. Priyanka Prabhakaran. Ernakulam district: Vettithara, 1♂, 9°55'07"N 76°28'01"E, 45 m, 05.XII.2022, Coll. Priyanka Prabhakaran. Idukki district: Kottakkavala, 1♂, 9°55'33"N 76°47'57"E, 66 m, 21.II.2020, Coll. Priyanka Prabhakaran. Alappuzha district: Kalavoor, 1♂, 9°33'16"N 76°19'41"E, 27 m, 20.VI.2022, Coll. Priyanka Prabhakaran; Kunnumma, 1♀, 9°21'08"N 76°24'51"E, 20 m, 20.VI.2022, Coll. Priyanka Prabhakaran. Kollam district: Sasthamkotta, 1♂2♀, 9°01'46"N 76°38'08"E, 24 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Kallikkad (Neyyar Dam), 1♀, 8°31'56"N 77°08'57"E, 107 m, 15.VI.2022, Coll. Priyanka Prabhakaran; Panayara, 4♂5♀, 8°45'35"N 76°45'02"E, 36 m, 18.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 1.58 mm- 1.68 mm; Maximum width:1.00 mm- 1.10 mm.

Form small, oval, discontinuous between pronotum and elytra. Head ferruginous with vague pale brown colouration anteriorly and between the eyes; punctures fine, regular. Pronotum ferruginous with a black band at the middle of posterior border; latero-basal plica slightly oblique; punctation small dense, row of larger punctures at the anterior border; lateral sides finely bordered. Elytra ferruginous with a longitudinal black marking along the suture up to the apex; longitudinal band expands laterally i) at the base of the elytra with a bisinuate posterior border ii) medially with sinuate anterior and posterior border, extend anteriorly and posteriorly iii) subapically with anterior and posterior extensions; anterior extension confluent with the posterior extension of median band. v) small apical transverse band. Sub basal and median transverse bands touching lateral margins. Punctures dense, well-impressed (Plate 4 (24) a). Ventral surface pale brown; appendages and abdominal segments testaceous; meta ventrites with dense and well-impressed punctures; punctures on the abdominal segments less impressed and less dense than the meta ventrites. Median lobe slightly curved with a basal process; apex pointed (Plate 4 (24) c). Lateral lobes narrower from the middle towards the apex; broader up to the mid length, anterior border straight, posterior border distinct invagination near the base, apex slightly hooked and rounded (Plate 4 (24) b).

Habitats: The species is collected in the margin of a pond (Plate 5.(110)), Pool in an abandoned paddy field (Plate 5 (111)), paddy fields (Plate 5 (112; 115; 118), muddy puddles (Plate 5 (104; 113)), rain-fed ephemeral pool (Plate 5 (114)), margin of a reservoir (Plate 5 (117)) and water-logged paddy field (Plate 5 (118)).

Distribution: This species is so far only found in Australia. India (Kerala (current study)).

Genus: *Hydroglyphus* Motschulsky, 1853

This is a large and species-rich genus. Members are elongated with lateral lines nearly continuous between the pronotum and elytra. Beetles are dorsally marked with fasciae and maculae. They have a body length ranging between 1.40 mm- 3.40 mm. The distinguishing characteristics include the absence of a transverse occipital line on the head, unmodified anterior clypeal margin, a pair of basal striae on pronotum, basal stria and sutural stria on the elytra, absence of transverse carina at the humeral angle of the epipleuron lateral lobes of aedeagus three-segmented.

Ninety-two species are known to occur globally under this genus. In Kerala, two species have been documented. This study recorded two species, including one that is new to the state.

25. *Hydroglyphus flammulatus* (Sharp, 1882) (Plate 4 (25))

1882. *Bidessus flammulatus*, Sharp, 359.
1892. *Bidessus antennatus* Régimbart, 118.
1969. *Bidessus flammulatus*, Vazirani, 315.
1988. *Bidessus flammulatus*, Biström, 12.

Material examined: Kasargod district: Arai Bridge, 1♂, 12°18'05"N 75°06'29"E, 41 m, 06.II.2022, Coll. Priyanka Prabhakaran; Arai Kadavu, 2♀3♀, 12°18'09"N 75°06'29"E, 44 m, 06.II.2022, Coll. Priyanka Prabhakaran; Cheruvathur, 6♂2♀, 12°14'05"N 75°09'03"E, 35 m, 05.II.2022, Coll. Priyanka Prabhakaran; Kariyamkode (Manjeswaram), 3♂5♀, 12°14'30"N 75°08'56"E, 39m, 08.II.2022, Coll. Priyanka Prabhakaran; Kolathur, 1♂2♀, 12°25'36"N 75°07'40"E, 528 m, 07.II.2022, Coll. Priyanka Prabhakaran; Kottody, 1♂, 12°26'07"N 75°13'06"E, 67 m, 07.II.2022, Coll.

Priyanka Prabhakaran; Majibial, 1♂1♀, 12°41'20"N 74°54'16"E, 23 m, 07.II.2022, Coll. Priyanka Prabhakaran; Manjeswaram, 1♂, 12°42'49"N 74°53'45"E, 29 m, 08.II.2022, Coll. Priyanka Prabhakaran; Nileswaram (Mundemmad Road), 1♂1♀, 12°14'28"N 75°08'28"E, 503 m, 08.II.2022, Coll. Priyanka Prabhakaran; Pallikkara-II, 1♂, 12°25'26"N 75°01'58"E, 32m, 07.II.2022, Coll. Priyanka Prabhakaran; Panayal, 1♂, 12°25'28"N 75°03'09"E, 62 m, 07.II.2022, Coll. Priyanka Prabhakaran; Puthiyavalapu, 2♂2♀, 12°19'39"N 75°05'26"E, 32 m, 06.II.2022, Coll. Priyanka Prabhakaran; Vavadukkam, 1♂, 12°26'08"N 75°13'07"E, 69 m, 06.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Kalliad (Pattakkal falls), 1♂, 12°00'11"N 75°34'03"E, 156 m, 11.II.2022, Coll. Priyanka Prabhakaran; Madathil, 2♂, 12°00'11"N 75°41'16"E, 57 m, 12.II.2022, Coll. Priyanka Prabhakaran; Puthussery, 24♂34♀, 12°00'16"N 75°40'09"E, 56 m, 12.II.2022, Coll. Priyanka Prabhakaran; Vallyad, 3♂1♀, 11°59'20"N 75°39'16"E, 59 m, 11.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Panavally, 1♂1♀, 11°52'52"N 76°04'40"E, 766 m, 15.II.2022, Coll. Priyanka Prabhakaran; Kalpetta, 2♂, 11°35'23"N 76°05'01"E, 770 m, 14.II.2024, Coll. Priyanka Prabhakaran; Kottiyur, 1♂1♀, 11°52'27"N

75°52'04"E, 165 m, 13.II.2024, Coll. Priyanka Prabhakaran; Mananthavady (Kabini River), 1♂, 11°48'00"N 75°58'48"E, 755 m, 13.II.2022, Coll. Priyanka Prabhakaran; Padichira, 3♂, 11°50'00"N 76°09'22"E, 754 m, 15.II.2022, Coll. Priyanka Prabhakaran; Pazhupathur, 2♂2♀, 11°40'23"N 76°13'51"E, 824 m, 15.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Purameri, 1♂, 11°41'00"N 75°36'38"E, 26 m, 16.II.2022, Coll. Priyanka Prabhakaran; Thamarassery, 3♂2♀, 11°25'25"N 75°55'49"E, 51 m, 16.II.2024, Coll. Priyanka Prabhakaran. Malappuram district: Chembikkal, 15♂13♀, 10°51'54"N 76°00'35"E, 18 m, 20.IV.2018, Coll. Priyanka Prabhakaran; Thottuppoyil, 1♂, 11°07'44"N 76°09'16"E, 77 m, 18.II.2022, Coll. Priyanka Prabhakaran; Thottuppoyil, 10♂6♀, 11°07'40"N 76°09'12"E, 130 m, 18.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Manchira, 2♀, 10°36'35"N 76°43'37"E, 127 m, 12.II.2021, Coll. Priyanka Prabhakaran; Neerakkode, 1♂, 10°37'38"N 76°38'01"E, 75m, 09.XII.2020, Coll. Priyanka Prabhakaran; Pappadi, 4♂2♀, 10°49'48"N 76°38'02"E, 105 m, 24.II.2022, Coll. Priyanka Prabhakaran; Parali, 1♂2♀, 10°48'08"N 76°33'51"E 77 m, 13.I.2017, Coll. Priyanka Prabhakaran; Parali, 5♂6♀, 10°47'11"N 76°34'00"E, 92 m, 30.III.2017, Coll. Priyanka Prabhakaran; Parudur (Bharathappuzha), 1♀, 10°48'31"N

76°06'56"E, 26 m, 15.II.2021, Coll. Priyanka Prabhakaran; Thalur, 2♂2♀, 10°37'38"N 76°38'01"E 75 m, 9.XII.2020, Coll. Priyanka Prabhakaran. Viruthi, 1♂, 10°35'18"N 76°42'52"E, 140 m, 09.XII.2020, Coll. Priyanka Prabhakaran; Yakkara, 10°44'59"N 76°39'11"E, 107 m, 14.II.2017, Coll. Priyanka Prabhakaran. Thrissur district: Adat, 1♂, 10°32'17"N 76°08'19"E 20m, 10.XII.2019, Coll. Priyanka Prabhakaran; Adat, 1♂, 10°31'41"N 76°08'15"E, 17m, 10.XII.2019, Coll. Priyanka Prabhakaran; Adat, 48♂22♀, 10°31'41"N 76°08'15"E, 17m, 17.I.2020, Coll. Priyanka Prabhakaran. Chembuthra, 1♂2♀, 10°33'20"N 76°19'09"E, 40m, 08.III.2017, Coll. Priyanka Prabhakaran; Cheppara, 1♂, 10°36'56"N 76°15'24"E, 113 m, 11.I.2021, Coll. Priyanka Prabhakaran; Cheppara, 1♂, 10°37'04"N 76°15'15"E, 19.X.2021, Coll. Priyanka Prabhakaran; Darbha, 1♂1♀, 10°29'49"N 76°20'08"E, 82 m, 23.III.2019, Coll. Priyanka Prabhakaran; Kannamkuzhy, 9♂7♀, 10°17'09"N 76°33'38"E, 101m, 03.I.2022, Coll. Priyanka Prabhakaran; Mullur, 2♀, 10° 32'38"N 76°07'54"E, 17 m, 20.X.2018, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂, 10°29'46"N 76°19'46"E, 116 m, 29.V.2018, Coll. Priyanka Prabhakaran; Nandhikkara, 22♂20♀, 10°23'39"N 76°14'26"E, 29.1.2020, Coll. Priyanka Prabhakara; Pariyaram, 1♂, 10°17'11"N 76°34'09"E, 122m, 03.I.2022, Coll. Priyanka Prabhakaran; Peechi, 2♂1♀, 10°33'08"N 76°24'39"E, 101m, 12.II.2021, Coll. Priyanka Prabhakaran; Peechi, 1♂, 10°32'07"N 76°20'56"E, 49 m, 18.XII.2020, Coll. Priyanka Prabhakaran; Pullu, 3♂4♀, 10°28'04"N 76°10'00"E, 15 m, 26.12.2021, Coll. Priyanka Prabhakaran; Pullu, 2♂3♀, 10°28'04"N 76°09'16"E, 13 m, 26.12.2021, Coll. Priyanka Prabhakaran; Puzhakkal, 18♂11♀, 10°32'24"N 76°10'44"E, 18 m, Coll. Priyanka Prabhakaran. Ernakulam district: Aikkaranadu, 3♂3♀, 9°57'07"N 76°26'39"E, 44 m, 20.II.2022, Coll. Priyanka Prabhakaran; Elanji (Koorumala), 2♂2♀, 9°51'01"N 76°33'12"E, 140 m, 05.XII.2022, Coll. Priyanka Prabhakaran; Karikkattupadi, 1♂2♀, 9°56'00"N 76°27'03"E, 56 m, 20.II.222, Coll. Priyanka Prabhakaran; Karingachira, 2♂, 9°57'00"N 76°21'32"E, 24 m, 02.VII.2019, Coll. Priyanka Prabhakaran; Malayatur, 2♂, 10°12'02"N 76°30'0"E, 45 m, 28.III.2021, Coll. Priyanka Prabhakaran; Memury, 1♂, 9°56'49"N 76°32'20"E, 90 m, 05.XII.2022, Coll. Priyanka Prabhakaran; Nechoor, 9♂6♀, 9°54'12"N 76°27'58"E, 41 m, 20.II.222, Coll. Priyanka Prabhakaran; Piravom, 2♂, 9°51'56"N 76°29'22"E, 40 m, 05.III.2020, Coll. Priyanka Prabhakaran. Vettithara, 2♂3♀, 9°55'07"N 76°28'01"E, 45 m, 05.XII.2022, Coll. Priyanka Prabhakaran. Idukki district: Kottakkavala, 2♂2♀, 9°55'33"N 76°47'57"E, 66 m, 21.II.2020, Coll.

Priyanka Prabhakaran; Mulappuram, 1♂1♀, 9°57'03"N 76°49'04"E, 60 m, 21.II.2022, Coll. Priyanka Prabhakaran; Erattayar, 1♀, 9°48'02"N 77°06'24"E, 767 m, 22.2.2020, Coll. Priyanka Prabhakaran; Kamakshi, 6♂4♀, 9°49'43"N 77°04'54"E, 997 m, 24.II.2020, Coll. Priyanka Prabhakaran; Shantharuvi, 1♂, 9°59'43"N 77°11'22"E, 1318 m, 23.II.2020, Coll. Priyanka Prabhakaran; Chillithodu, 7♂2♀, 10°01'40"N 76°52'49"E, 561 m, 23.II.2020, Coll. Priyanka Prabhakaran. Alappuzha district: Edathua, 1♂, 9°21'54"N 76°27'56"E, 21 m, 08.VII.2019, Coll. Priyanka Prabhakaran; Kalavoor, 2♂1♀, 9°33'16"N 76°19'41"E, 27 m, 20.VI.2022, Coll. Priyanka Prabhakaran; Govindamuttom, 1♂2♀, 9°10'16"N 76°29'40"E, 26 m, 19.VI.2022, Coll. Priyanka Prabhakaran; Kayamkulam, 1♂3♀, 9°10'21"N 76°29'45"E, 23 m, 19.VI.2022, Coll. Priyanka Prabhakaran; Kidangara, 2♂4♀, 9°26'00"N 76°29'45"E, 28.II.2021, 22 m, Coll. Priyanka Prabhakaran; Kunnumma, 1♀, 9°21'08"N 76°24'51"E, 20 m, 20.VI.2022, Coll. Priyanka Prabhakaran; Valady, 2♂, 9°27'17"N 76°30'10"E, 21 m, 28.II.2021, Coll. Priyanka Prabhakaran; Varanad, 5♂4♀, 9°41'54"N 76°21'19"E, 20 m, 20.VI.2022, Coll. Priyanka Prabhakaran. Kottayam district: Kadamuri, 2♂2♀, 9°32'15"N76°34'58"E, 29 m, 25.II.2021, Coll. Priyanka Prabhakaran; Kangazha, 1♂, 9°29'20"N 76°41'32"E, 54 m, 27.II.2021, Coll. Priyanka Prabhakaran; Kulathurmuzhy, 1♂, 9°27'22" N 76°42'45"E, 36 m, 27.II.2021, Coll. Priyanka Prabhakaran; Peroor, 1♂, 9°37'39"N 76°33'37"E, 22 m, 10.II.2021, Coll. Priyanka Prabhakaran; Perumpanachy, 1♂1♀, 9°29'03"N 76°34'33"E, 27 m, 26.II.2021, Coll. Priyanka Prabhakaran; Thiruvanchoor, 1♂1♀, 9°36'31"N 76°34'27"E, 23 m, 10.II.2021, Coll. Priyanka Prabhakaran; Vellavoor, 1♂1♀, 9°28'00"N 76°42'33"E, 33 m, 27.II.2021, Coll. Priyanka Prabhakaran. Pathanamthitta district: Angadickal, 3♂1♀, 9°11'39"N 76°46'40"E, 45 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Manthuka, 2♂, 9°14'55"N 76°40'01"E, 29 m, 13.VI.2022, , Coll. Priyanka Prabhakaran. Kollam district: Chaliyakkara, 3♂, 9°02'21"N 76°57'47"E, 70 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Chenkulam, 1♂, 8°52'33"N 76°45'06"E, 31 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Ezhukone, 3♂1♀, 8°59'35"N 76°42'45"E, 56 m, 19.VI.2022, Coll. Priyanka Prabhakaran; Chepra (Mukkavalappara), 2♀, 8°55'13"N 76°48'19"E, 129 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Kummil, 2♂1♀, 8°47'59"N 76°55'49"E, 133 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Malackal, 2♀, 8°48'16"N 76°50'56"E, 106 m, 17.VI.2022, Coll. Priyanka Prabhakaran.

Thiruvananthapuram district: Mankayam (Brimore), 2♀2♂, 8°45'55"N 77°04'47"E, 168 m, 14.VI.2022, Coll. Priyanka Prabhakaran; Mylakkara, 2♂1♀, 8°31'19"N 77°07'57"E, 100 m, 15.VI.2022, Coll. Priyanka Prabhakaran; Neyyar, 2♂3♀, 8°31'55"N 77°08'54"E, 103 m, 15.II.2022, Coll. Priyanka Prabhakaran; Palai, 2♂2♀, 8°44'26"N 77°07'15"E, 459 m, 14.VI.2022, Coll. Priyanka Prabhakaran; Pantha, 4♂1♀, 8°31'27"N 77°10'07"E, 122 m, 15.VI.2022, Coll. Priyanka Prabhakaran; Venkode, 6♂7♀, 8°35'56"N 76°58'52"E, 77 m, 16.VI.2022, Coll. Priyanka Prabhakaran; Vithura, 1♀, 8°41'51"N 77°06'34"E, 136 m, 14.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 2.30 mm- 2.50 mm; Maximum width: 0.90 mm- 0.98 mm.

Form oval, elongate, slightly convex, densely pubescent. Head testaceous; posterior margin black. Pronotum testaceous; punctation fine; narrowly black at the anterior margin; latero-basal plica short, oblique and not continued on elytra; half the length of pronotum. Elytra testaceous with dark brown to black markings as follows: i) irregular broad basal transverse mark not touching the suture ii) broad mark along the suture that variably extend laterally; punctation moderately impressed, dense (Plate 4 (25) a). Ventral surface dark brown to black; abdominal sternites darker. Median lobe moderately curved, narrowed at the apical region, apex pointed (Plate 4 (25) b).

Habitats: The species is collected in a pools and ditches in an abandoned paddy fields (Plate 5 (109; 119; 126; 131; 139; 164; 167; 177; 182; 184; 191)), ditches in agricultural fields (Plate 5 (120; 138)), paddy fields (Plate 5 (115; 121; 136; 137; 142; 147; 150; 151; 152; 153; 156; 163; 169; 171; 175)), margins of rivers (Plate 5 (78; 123; 134; 146; 149; 180)), muddy puddles (Plate 5 (113; 124; 125; 143; 155; 168; 187; 190)), remnant rock pool in a waterfall (Plate 5 (72)), pools (Plate 5 (173; 183; 192)), abandoned ditches (Plate 5 (25; 132; 57)), remnant pool in a pond (Plate 5 (127)), pool in irrigation canal (Plate 5 (128)), pool in the flood plain of a river (Plate 5 (129)), remnant pool downstream of a waterfall (Plate 5 (130)), ephemeral pools (Plate 5 (23; 140; 157; 159; 172; 174; 53), rock pools (Plate 5 (62; 87; 135; 160), remnant pools in rivers, irrigation canals and streams (Plate 5 (133; 144; 145; 154), small puddle (Plate 5 (141)), margins of streams (Plate 5 (81; 162; 170; 178; 179)), remnant pool in paddy field (Plate 5 (158)), margin of ponds (Plate 5 (93; 110; 166;

185)), margins of reservoirs (Plate 5 (161; 189)), rock puddles (Plate 5 148; 165)), Ditches (Plate 5 (176; 186; 188)), roadside drainage (Plate 5 (38)) and pool in floodplains of river (Plate 5 (181)).

Distribution: The species is distributed in the Oriental and Palaearctic regions. India (Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal).

26. *Hydroglyphus pendjabensis* Gugnot, 1954 (Plate 4 (26))

1954. *Guignotus pendjabensis* Guignot, 221.
1969. *Guignotus pendjabensis* Vazirani, 320.
1988. *Hydroglyphus pendjabensis* Biström, 14.

Material examined: Kasargod district: Arai Bridge, 1♀, 12°18'05"N 75°06'32"E, 41 m, 06.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Nandhikkara, 2♂, 10°23'39"N 76°14'26"E, 18 m, 29.1.2020, Coll. Priyanka Prabhakaran. Idukki district: Erattayar, 1♂1♀, 9°48'02"N 77°06'24"E, 767 m, 22.2.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 1.80 mm- 1.82 mm; Maximum width 0.85 mm- 0.87 mm.

Form elongate oval, slightly convex. Head testaceous; punctation fine and sparse. Pronotum testaceous, punctation well impressed, dense; lateral margins of the pronotum nearly convex; latero-basal striae about one-third of the length of the pronotum, well impressed, little incurved. Elytra testaceous with brownish black markings: i) along basal and sutural margins ii) two longitudinal markings not touching the base or the apex of the elytra, outer one half the length of the inner one, end of both lines crochet shaped and nearly touches the lateral margins; punctation well impressed; distinctly pubescent; discal striae half the length of the pronotal plica (Plate 4 (26) a). Ventral side brownish; appendages and epipleura paler; punctation on meta sternum, meta coxae and abdominal sternite fine; pubescence less. Median lobe gradually tapered from the base to the apical region, apex pointed (Plate 4 (26) b).

Habitats: The species is collected in a pool in an abandoned paddy field (Plate 5 (119)), remnant pool in a paddy field (Plate 5 (158)) and in a muddy puddle (Plate 5 (193)).

Distribution: The species has an Oriental as well as Palaearctic distribution. India (Andhra Pradesh, Delhi, Goa, Gujarat, Jharkhand, Kerala (current study), Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal).

Genus: *Leiodytes* Guignot, 1936

This genus was a subgenus of C*lypeodytes* earlier. They look very similar to *Clypeodytes*. Body size ranges between 1.40 mm- 2.20 mm. They can be distinguished by the presence of a transverse occipital line, modified or unmodified anterior clypeal margin, pair of basal pronotal striae, absence of sutural stria and presence of basal stria on elytron, lack of carina on elytra, absence of transverse carina at the humeral angle of epipleuron, two segmented lateral lobes in male aedeagus and a line of punctures on lateral sides of metaventrite.

There are 31 described species under this genus. The present study recorded one species under this genus. The genus and the species are first records for the state.

27. *Leiodytes orissaensis* (Vazirani, 1969) (Plate 4 (27))

1969. *Clypeodytes orissaensis* Vazirani, 328.
1982. *Clypeodytes orissaensis* Wewalka,125.
1988. *Clypeodytes orissaensis* Biström, 27.

Material examined: Kasargod district: Panayal, 1♂, 12°25'28"N 75°03'09"E, 62 m, 07.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Padichira, 1♂, 11°50'00"N 76°09'22"E, 754 m, 15.II.2022, Coll. Priyanka Prabhakaran; Pazhupathur, 1♂2♀, 11°40'23"N 76°13'51"E, 824 m, 15.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Kollengode south, 1♂, 10°33'02"N 76°42'58"E, 60 m, 07.I.2021, Coll. Priyanka Prabhakaran; Yakkara, 1♂, 10°44'59"N 76°39'11"E, 107 m, 14.II.2017, Coll. Priyanka Prabhakaran. Thrissur district: Puzhakkal, 1♂, 10°33'01"N 76°10'54"E, 23 m, 25.V.2019, Coll. Priyanka Prabhakaran. Ernakulam district: Vettithara, 1♂1♀, 9°55'07"N 76°28'01"E, 45 m, 05.XII.2022, Coll. Priyanka Prabhakaran. Alappuzha district: Edathua, 1♂, 9°21'54"N 76°27'56"E, 21 m, 08.VII.2019, Coll. Priyanka Prabhakaran; Kunnam, 18♂7♀, 9°15'12"N 76°34'42"E, 24 m, 15.VII.2019, Coll. Priyanka Prabhakaran; Varanad, 5♂4♀, 9°41'54"N 76°21'19"E, 20 m, 20.VI.2022, Coll. Priyanka Prabhakaran. Idukki district: Kottakkavala, 2♂2♀, 9°55'33"N 76°47'57"E, 66 m, 21.II.2020, Coll. Priyanka Prabhakaran; Mulappuram, 1♂, 9°57'03"N 76°49'04"E, 60 m, 21.II.2022, Coll. Priyanka Prabhakaran. Kottayam district: Ithithanam, 2♂2♀, 9°29'09"N 76°32'47"E, 26 m, 26.II.2021, Coll. Priyanka Prabhakaran. Kollam district: Chaliyakkara, 2♂3♀, 9°02'21"N 76°57'47"E, 70 m, 13.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Kallara, 1♂, 8°45'30"N 76°56'04"E, 105 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Kallikkad, 2♂1♀, 8°31'56"N 77°08'57"E, 107 m, 15.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 2.22 mm- 2.30 mm; Maximum width: 1.21 mm- 1.29 mm.

Form oval, attenuated anteriorly, lateral outline discontinuous between pronotum and elytra. Head testaceous; anterior margin of clypeus rebordered; punctures less impressed, dense; posterior border impunctate. Pronotum testaceous, laterally enlarged, lateral margins narrowly rebordered; median transverse depression present; lateral row of punctures curved look like a stria; punctures large, well impressed than head. Elytra testaceous, vague dark spots; punctures large, well-impressed (Plate 4 (27) a). Ventral surface brown; appendages brown; pro and meso sternum testaceous; antennae testaceous; well-impressed large punctures on meta sternum that reduced in numbers towards the abdominal segments; apical three abdominal sternites impunctate, slightly pubescent. Median lobe more or less straight, slightly curved, tip blunt Plate 4 (27) b). Lateral lobes evenly broad up to the $^{3}/_{4}$ of the length then abruptly broaden at the apical region, tip rounded (Plate 4 (27) c).

Habitats: The species is collected in a remnant pool in a pond (Plate 5 (127)), paddy fields (Plate 5 (136; 137; 171)), rock puddle (Plate 5 (194)), margin of rivers and streams (Plate 5 (105; 149; 196)), muddy puddles (Plate 5 (104; 113)), ephemeral pools (Plate 5 (195; 197)), pool in abandoned paddy field (Plate 5 (177; 208)) and margin of a reservoir (Plate 5 (189)).

Distribution: This species has an Oriental as well as Palaearctic distribution. India (Gujarat, kerala (current study), Orissa, West Bengal).

Genus: *Peschetius* Guignot, 1942

Members of this genus are larger and distinct than the other members of the tribe *Bidessini*. Most of them are robust and dorsally marked with maculae. Size ranges between 2.90 mm- 4.40 mm. They are characterised by a set of characteristics such as the tectiform abdomen, a deeply foveate region between the metacoxal lines, broad epipleuron of elytra, basal abdominal punctation conspicuous, and the surface of the elytra strongly bicarinate.

There are 12 described species under this genus. Two species have been recorded from Kerala before. The present study recorded 4 species under this genus including one new to India.

28. *Peschetius bistroemi* Sheth, Ghate, Dahanukar & Hájek, 2021 (Plate 4 (28))

2021. *Peschetius bistroemi* Sheth, Ghate, Dahanukar & Hájek, 541.

Material examined: Kasargod district: Vavadukkam, 4♂6♀, 12°25'49"N 75°12'19"E, 69 m, 06.II.2022, Coll. Priyanka Prabhakaran. Kolathur, 1♂1♀, 12°25'36"N 75°07'40"E, 528 m, 07.II.2022, Coll. Priyanka Prabhakaran. Majibial, 2♂6♀, 12°41'20"N 74°54'16"E, 23 m, 07.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Kanjirakolli, 1♂, 12°08'07"N 75°37'54"E, 368 m, 12.II.2022, Coll. Priyanka Prabhakaran. Idukki district: Thommankuthu, 1♂, 9°57'32"N 76°50'10"E 216 m, 21.II.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 2.30 mm- 3.15 mm: Maximum width: 1.70 mm- 1.80 mm.

Form elongate oval, discontinuous between elytra and pronotum. Head ferruginous, transverse; punctation dense; setiferous punctures present along the inner margin of eyes. Pronotum ferruginous with a bilobed black band near the posterior margin; anterior boarder straight; lateral boarders paler, curved; posterior margin sinuate; a short transverse depression on the disc near the posterior boarder; distinct depression between the disc and the lateral margin; punctures setiferous, fine on disc but coarser towards the margins. Elytra black with testaceous markings as follows: i) two sub basal spots ii) Pre-median and post-median transverse bands iii) preapical spot; elytral keels prominent; elytra widest before mid-length; punctation dense, coarser but fine along the suture, costae and the lateral margins (Plate 4 (28) a). Ventral surface and appendages testaceous; prosternal process darker marginally; coxae reddish brown; posterior border of abdominal ventrites darker; prosternal process raised, broad anteriorly narrow posteriorly; punctures on meta ventrite coarse; anterior border of meta ventrite with distinct depression below meso coxae; first abdominal ventrite with two rows of 6-10 macro punctures on either sides; second abdominal ventrite with two rows of 2-5 macro punctures; punctures on ventral surface setiferous. Median lobe moderately curved, broad at base, narrowed towards the apex, apical half slender apex pointed (Plate 4 (28) b). Parameres broad at base narrowed towards apical region, apex club-shaped, apical half with uniformly distributed long setae (Plate 4 (28) c)

Habitat: The species is collected in a pool in the flood plains of a river (Plate 5 (129)), margin of river (Plate 5 (123)), muddy puddles (Plate 5 (124; 198)) and a leaf-choked rockpool (Plate 5 (28)).

Distribution: The species is endemic to Kerala. India (Kerala).

29. *Peschetius quadricostatus* (Aubé, 1838) (Plate 4 (29))

1838. *Hydroporus quadricostatus* Aubé, 487.

2003. *Hydroporus quadricostatus* Biström & Nilsson, 140.

1942. *Peschetius quadricostatus* Guignot, 21.

Material examined: Kasargod district: Panayal, 1♂2♀, 12°25'28"N 75°03'09"E, 62 m, 07.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Valiya paramba, 34♂18♀, 11°17'38"N 76°00'15"E, 56 m, 20.IV.2018, Coll. Priyanka Prabhakaran. Palakkad district: Agali, 1♂1♀, 11°02'40"N 76°39'06"E, 698 m, 02.II.2021, Coll. Priyanka Prabhakaran; Chittur, 2♂, 10°35'30"N 76°42'48"E, 142 m, 12.II.2021, Coll. Priyanka Prabhakaran; Pappadi, 2♂2♀, 10°49'48"N 76°38'02"E, 105 m, 24.II.2022, Coll. Priyanka Prabhakaran; Parali, 1♂, 10°48'08"N 76°33'51"E 77m, 13.I.2017, Coll. Priyanka Prabhakaran. Thrissur district: Cheppara, 5♂2♀, 10°36'59"N 76°15'09"E, 128 m, 22.I.2021, Coll. Priyanka Prabhakaran; Cheppara (Quarry pond), 12♂10♀, 10°37'12"N 76°15'03"E, 143 m, 22.I.2021, Coll. Priyanka Prabhakaran; Darbha, 2♂, 10°29'49"N 76°20'08"E, 82 m, 23.III.2019, Coll. Priyanka Prabhakaran; Punnachuvadu, 2♂2♀, 10°30'06"N 76°18'50"E, 103 m, 03.II.2018, Coll. Priyanka Prabhakaran; Thalikkode, 5♂6♀, 10°34'30"N 76°18'33"E, 118 m, 15.I.2021, Coll. Priyanka Prabhakaran; Thekkumkara (Pathazhakundu Dam), 10♂15♀, 10°37'08"N 76°14'16"E, 153 m, 22.I.2021+, Coll. Priyanka Prabhakaran. Ernakulam district: Pampakkuda, 1♂, 9°55'06"N 76°32'14"E, 73 m, 06.VII.2019, Coll. Priyanka Prabhakaran. Kottayam district: Kadamuri, 1♂3♀, 9°32'15"N 76°34'58"E, 29 m, 25.II.2021, Coll. Priyanka Prabhakaran; Kuzhimattom, 1♂, 9°30'36"N 76°32'20"E, 31 m, 28.II.2021, Coll. Priyanka Prabhakaran; Peroor, 2♂, 9°37'39"N 76°33'37"E, 22 m, 10.II.2021, Coll. Priyanka Prabhakaran; Santhipuram, 1♂4♀, 9°28'52"N 76°37'33"E, 75 m, 26.II.2021, Coll. Priyanka Prabhakaran. Kollam district: Kudavattoor, 6♂7♀, 8°56'23"N 76°44'47"E, 75 m, 18.VI.2022, Coll. Priyanka Prabhakaran

Diagnosis: Total length: 3.15 mm-3.40 mm; Maximum width: 1.60 mm-1.80 mm.

Form elongate, oval, discontinuous between pronotum and elytra. Head reddish-brown with two black anterolateral lobes near the anterior margin of eyes; punctures dense, posterior border impunctate; a row of setiferous punctures along the inner margin of eyes. Pronotum reddish-brown with a narrow median black band at the anterior border and bilobed black band at the posterior border; pronotal disc with distinct posterior depression; punctation dense, setiferous punctures on disc become coarser towards the margins. Elytra black with testaceous markings as follows: i) two sub basal spots ii) pre-median and post-median transverse bands iii) sub-apical band, elytral keel prominent; punctures dense, coarser at disc but finer along suture, costae and lateral margin; elytra widest at mid-length (Plate 4 (29) a). Ventral surface reddish-brown; prosternal process lanceolate, broader at base, narrowed at apex; First abdominal sternite with 6-9 macro punctures in one row and second sternite with 3-5 macro punctures in two rows on both sides; punctures on abdominal sternite 2-5 setiferous; abdominal sternite 3 and 5 with distinct lateral depression. Median lobe curved, gradually narrowing towards the apex, apex pointed (Plate 4 (29) b). Parameres with short setae at the apical half, apex bunt (Plate 4 (29) c).

Habitats: This species is collected in spring fed pool (Plate 5 (107)), remnant pool in a pond (Plate 5 (127)), margin of a stream (Plate 5 (81; 178; 199)), quarry pond (Plate 5 (201; 220)), remnant pool in an irrigation canal (Plate 5 (154)), margin of pond (Plate 5 (52)), remnant pool in a river (Plate 5 (145)), margin of a pool (Plate 5 (202)), remnant pool in a stream (Plate 5 (204)), pool in the floodplain of a river (Plate 5 (181)), muddy margin of a reservoir, and remnant pool downstream of a waterfall (Plate 5 (203)).

Distribution: This species is distributed in the Oriental and Palaearctic regions. India (Bihar, Delhi, Goa, Gujarat, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh, West Bengal).

30. *Peschetius toxophorus* Guignot, 1942 (Plate 4 (30))

1942. *Peschetius toxophorus* Guignot, 20.
1946. *Peschetius andrewesi* J. Balfour-Browne, 104; 1970. Vazirani, 113, Synonymy.
2003. *Peschetius toxophorus* Biström & Nilsson, 132.

Material examined: Palakkad district: Puthuppariyaram, 4♂1♀, 10°55'17"N 76°34'57"E, 155 m, 24.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Darbha, 2♂, 10°30'19"N 76°20'00"E, 92 m, 21.I.2020, Coll. Priyanka Prabhakaran; Thalikkode, 3♂, 10°30'49"N 76°20'09"E, 123 m, 15.I2021, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 2.65 mm- 2.95 mm; Maximum width: 1.60 mm- 1.80 mm.

Form elongate, oval, discontinuous between the pronotum and elytra. Head black with posterior border testaceous; punctation dense; posterior margin impunctate; setiferous punctures in a row along the inner margin of eyes. Pronotum testaceous with bilobed black band in the middle of the posterior margin extending narrowly to the posterior angles; pronotal disc with less prominent posterior depression; punctation dense, setiferous and finer on disc and gradually become coarser towards the margins and the lateral sides. Elytra black with testaceous markings consisting of two sub basal spots, pre median and post median bands and sub-apical spot; elytra broadest at mid length; keels prominent; punctures dense, coarser on disc, finer along the suture, costae and lateral margins (Plate 4 (30) a). Ventral surface testaceous, punctures large and setiferous, prosternal process elongate, narrowed and keeled at apex, tuberculated in males. First abdominal ventrite with a row of 7-9 macro punctures on either sides; second abdominal ventrite with two rows of 4-7 macro punctures randomly arranged on both sides; second and fifth abdominal ventrites with setiferous punctures; third and fifth abdominal sternite with distinct lateral depression. Median lobe strongly curved with a basal process, narrowed apically, apex pointed (Plate 4 (30) b). Parameres with long hairs at the apical region, apex rounded, inner margin bisinuate (Plate 4 (30) c).

Habitats: The species is collected in remnant rock pool in river bed (Plate 5 (8)), remnant pool in irrigation canal (Plate 5 (154)) and margin of a pool (Plate 5 (202)).

Distribution: The species are only found in the Oriental region. India (Andhra Pradesh, Bihar, Gujarat, Jharkhand, Karnataka, Kerala, Maharashtra, Orissa, Rajasthan, Tamil Nadu).

31. *Peschetius taprobanicus* Biström & Bergsten, 2015 (Plate 4 (31))

2015. *Peschetius taprobanicus* Biström & Bergsten, 57.

Material examined: Kozhikode district: Purameri, 4♂2♀, 11°40'16"N 75°36'31"E, 27 m, 16.II.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.51 mm- 3.67 mm; Maximum width: 1.89 mm- 2.02 mm.

Form oval with distinct angle between pronotum and elytra. Head yellowish-brown; punctures dense, well-impressed; posterior region impunctate. Pronotum dark with anterior and lateral margins testaceous; pronotal disc with shallow but distinct posterior depression; punctures dense, well-impressed. Elytra dark with testaceous markings consists of i) two small sub basal spots ii) two pre-median bands iii) post median transverse band and iv) apical spots; punctures larger, dense and well-impressed; elytral keels prominent (Plate 4 (31) a). Ventral surface dark brown; antennae and palpi slightly paler; first and second abdominal segments with a row of

6-7 and 2-3 macro punctures respectively; apical abdominal segments slightly pubescent. Median lobe moderately curved and "C" shaped, broader at the base, gradually narrowing towards the mid-length, very slender from the mid-length towards the apex, tip sharply pointed (Plate 4 (31) b). Lateral margins of lateral lobe subparallel at base, hairs dense at apex and sparse from midlength towards apical region (Plate 4 (31) c).

Habitats: The species is collected in a ditch in an agricultural field (Plate 5 (138)).

Distribution: The species is only known from Sri Lanka. India (Kerala (current study)).

32. *Peschetius* sp. (Plate 4 (32))

Material examined: Kozhikode district: Purameri, 1♀, 11°40'16"N 75°36'31"E, 27 m, 12.II.2023, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.60 mm; Maximum width: 1.90 mm.

Form oval with distinct angle between the pronotum and elytra. Head testaceous; punctation small, dense, posterior region impunctate. Pronotum testaceous with a bilobed black band at the middle of the posterior border; punctation small, dense. Elytra black with testaceous markings consists of i) one sub basal spot ii) pre median vertical and transverse bands iii) post- median transverse band and a sub apical band iv) an apical band, all bands except the sub- basal spot touches with the other by their lateral extensions; elytra with maximum width at the mid-length; elytral keels prominent; punctation larger than pronotum, well-impressed and dense (Plate 4 (32) a). Ventral surface testaceous; pro and meso coxae and trochanters slightly darker; meta legs darker; first and second abdominal segments with a row of shallow macro punctures; apical two segments with a black spot at the lateral sides of the anterior border; punctures larger, well-impressed and dense in meta sternum, punctures on abdominal segments dense, smaller (Plate 4 (32) b).

Habitats: The species is collected in a ditch in agricultural field (Plate 5 (205)).

Distribution: India (Kerala (current study))

Genus: *Hydrovatus* Motschulsky, 1853

Species of this genus are robust and globular with an acuminate posterior apex of the body. The colour of species varies between concolorous to distinctly marked with maculae or fasciae. The size of the species ranges between 1.60 mm- 5.30 mm. The species can be identified easily by the deeply incised metacoxal process having metacoxal lobes long and slender, anterior clypeal margin rounded or straight and unbordered or weakly narrowly bordered.

With 217 species, this genus is one of the largest in the family Dytiscidae. In Kerala, six species of this genus are known. This study recorded five species, including two that are reported for the first time.

33. *Hydrovatus cardoni* Severin, 1890 (Plate 4 (33))

1890. *Hydrovatus cardoni* Severin, 179.
1997. *Hydrovatus cardoni* Biström, 134.

Material examined: Idukki district: Kottakkavala, 1♂, 9°55'33"N 76°47'57"E, 66 m, 21.II.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 2.80 mm- 3.00 mm; Maximum width: 1.80 mm- 1.98 mm.

Form oval, rounded anteriorly. Head reddish yellow; punctation fine irregular, sparse, dense along the inner margin of eyes. Pronotum reddish-yellow with black colouration at the middle of the anterior and posterior boarders; punctation less impressed, larger than that on head. Elytra black with reddish-yellow irregular sub basal band and post medial band, which are confluent with the lateral reddish-yellow band but not reaching the suture; punctation dense, less impressed; apex acuminate (Plate 4 (33) a). Ventral surface reddish-brown; appendages testaceous; elytral epipleura paler anteriorly; metacoxal plate sparsely punctate. Median lobe rather narrow, moderately curved and more curved apically (Plate 4 (33) b)

Habitats: The species is collected in a muddy puddle (Fig. 104).

Distribution: This species is distributed only in the Oriental region. India (Jharkhand, Karnataka, Kerala, Orissa, Tamil Nadu, West Bengal).

34. ***Hydrovatus confertus*** **Sharp, 1882 (Plate 4 (34))**

1882. *Hydrovatus confertus* Sharp, 329.

1970. *Hydrovatus confertus* Vazirani, 102.

1997. *Hydrovatus confertus* Biström, 524.

Material examined: Kasargod district: Mangalpady, 1♂, 12°39'04"N 74°55'21"E, 27 m, 8.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Puthussery, 1♂, 12°00'16"N 75°40'09"E, 56 m, 12.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Adivaram, 6♂12♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll. Priyanka Prabhakaran; Palazhi, 2♂, 11°15'05"N 75°49'54"E, 28 m, 18.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Padichira, 1♀, 11°50'00"N 76°09'22"E, 754 m, 15.II.2022, Coll. Priyanka Prabhakaran. Thrissur District: Kumaranellur, 1♂3♀, 10°40'09"N 76°14'32"E, 48 m, 8.X.2021, Coll. Priyanka Prabhakaran; Kundukad, 3♂3♀, 10°36'04"N 76°15'53"E, 40 m, 8.X.2021, Coll. Priyanka Prabhakaran. Alappuzha district: Pathiramanal (Vembanad Lake), 2♂, 9°37'06"N 76°23'14"E, 17 m, 20.VI.2022, Coll. Priyanka Prabhakaran. Kottayam district: Kadamuri, 1♀, 9°32'15"N 76°34'58"E, 29 m, 25.II.2021, Coll. Priyanka Prabhakaran; Perumpanachy, 2♂1♀, 9°29'03"N 76°34'33"E, 27 m, 26.II.2021, Coll. Priyanka Prabhakaran; Santhipuram, 1♂2♀, 9°28'52"N 76°37'33"E, 75 m, 26.II.2021, Coll. Priyanka Prabhakaran; Vellavoor, 1♂, 9°28'00"N 76°42'33"E, 33 m, 27.II.2021, Coll. Priyanka Prabhakaran. Pathanamthitta district: Chuttippara, 15♂8♀, 9°17'08"N 76°47'55"E, 72 m, 12.XI.2022, Coll. Priyanka Prabhakaran. Kollam district: Chepra (Mukkavalappara), 1♂1♀, 8°55'13"N 76°48'19"E, 129 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Malackal, 1♂3♀, 8°48'16"N 76°50'56"E, 106 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Maruthimala (Muttara), 2♂4♀, 8°57'19"N 76°45'24"E, 562 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Sasthamkotta, 1♂, 9°01'46"N 76°38'08"E, 24 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Elappuram, 2♂2♀, 8°41'44"N 76°47'07"E, 29 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Elappuram, 5♂6♀, 8°41'41"N 76°47'03"E, 35 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Irinchayam, 16♂10♀, 8°38'14"N 76°58'27"E, 139 m, 16.VI.2022, Coll. Priyanka Prabhakaran; Kallara, 5♂, 8°45'30"N 76°56'04"E, 105 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Karette, 6♂1♀, 8°43'43"N 76°53'55"E, 40 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Panayara, 8♂5♀, 8°45'35"N 76°45'02"E, 36 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Ponganadu (Vennichira Pond), 2♂2♀, 8°46'47"N 76°50'49"E, 70 m, 17.VI. 2022, Coll. Priyanka Prabhakaran; Venkode, 6♂7♀, 8°35'56"N 76°58'52"E, 77m, 16.VI.2022, Coll. Priyanka Prabhakaran; Vilappil (Kudumbu Para), 1♂, 8°31'16"N 77°03'32"E, 167 m, 15.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 2.30 mm- 2.50 mm; Maximum width: 1.55 mm- 1.60 mm.

Form oval, acuminate posteriorly. Head reddish-brown; punctation fine. Pronotum reddish-brown; punctation fine, dense at anterior and posterior boarder; pronotum laterally rebordered. Elytra reddish-brown; punctation well impressed and dense (Plate 4 (34) a). Ventral surface testaceous; meta sternum and meta coxal plates with large well impressed punctures; median segments of antennae in males enlarged. Median lobe uniformly broad, apical $^{1}/_{3}$ bend inward in ventral view, narrowed into a claw-shaped apex (Plate 4 (34) b).

Habitats: The species is collected in the shallow margins of streams and a river (Plate 5 (78; 178; 206; 210)), rock pools (Plate 5 (4; 54; 87; 207; 215)), pools in abandoned paddy fields(Plate 5 (51; 208)), paddy fields (Plate 5 (118; 136)), ephemeral pools (Plate 5 (197; 209)), ditches in agricultural fields (Plate 5 (98; 211; 212)), ditch (Plate 5 (68; 188; 230)), pools (Plate 5 (69; 183)) and abandoned ponds (Plate 5 (213; 214)).

Distribution: This species is distributed in the Oriental as well as Palaearctic regions. India (Andaman & Nicobar Islands, Assam, Delhi, Jharkhand, Kerala, Manipur, Pondicherry, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal)

35. *Hydrovatus picipennis* Motschulsky, 1860 (Fig. 53)

1860. *Hydrovatus picipennis* Motschulsky, 40.
1997. *Hydrovatus picipennis* Biström, 395.

Material examined: Kasargod district: Arai Bridge, 1♂1♀, 12°18'05"N 75°06'29"E, 41 m, 06.II.2022, Coll. Priyanka Prabhakaran; Arai Kadavu, 1♀, 12°18'09"N 75°06'29"E, 44 m, 06.II.2022, Coll. Priyanka Prabhakaran; Kanhangad, 1♂, 12°19'15"N 75°04'31"E, 29 m, 06.II.2022, Coll. Priyanka Prabhakaran; Pallikkara-II, 1♂, 12°25'26"N 75°01'58"E, 32 m, 07.II.2022, Coll. Priyanka Prabhakaran;

Puthiyavalapu, 1♂, 12°19'39"N 75°05'26"E, 32 m, 06.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Padichira, 1♀, 11°50'00"N 76°09'22"E, 754 m, 15.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Adivaram, 2♂4♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll. Priyanka Prabhakaran; Iringal, 2♂, 11°19'28"N 75°46'18"E, 30 m, 18.II.2022, Coll. Priyanka Prabhakaran; Kozhukkallur, 1♂4♀, 11°30'24"N 75°43'47"E, 30 m, 16.II.2022, Coll. Priyanka Prabhakaran; Purameri, 2♂, 11°41'00"N 75°36'38"E, 26 m, 12.II.2023, Coll. Priyanka Prabhakaran. Thrissur district: Cheppara, 2♂3♀, 10°36'59"N 76°15'09"E, 128 m, 22.I.2021, Coll. Priyanka Prabhakaran; Kumaranellur, 3♂1♀, 10°40'09"N 76°14'32"E, 48 m, 8.X.2021, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂4♀, 10°29'41"N 76°19'53"E, 87 m, 11.X.2021, Coll. Priyanka Prabhakaran; Nandhikkara, 1♂, 10°23'39"N 76°14'26"E, 29.1.2020, Coll. Priyanka Prabhakara. Pathanamthitta district: Chuttippara, 1♂6♀, 9°17'08"N 76°47'55"E, 72 m, 12.XI.2022, Coll. Priyanka Prabhakaran. Kottayam district: Perumpanachy, 1♂, 9°29'03"N 76°34'33"E, 27 m, 26.II.2021, Coll. Priyanka Prabhakaran. Kollam district: Chepra (Mukkavalappara), 2♂, 8°55'13"N 76°48'19"E, 129 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Chuttippara, 1♂2♀, 9°17'08"N 76°47'55"E, 72 m, 12.XI.2022, Coll. Priyanka Prabhakaran; Ezhukone, 1♂, 8°59'27"N 76°42'33"E, 1006 m, Coll. Priyanka Prabhakaran; Kaithode (Nilamel), 3♂1♀, 8°49'30"N 76°51'08"E, 89 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Sasthamkotta, 3♂2♀, 9°01'46"N 76°38'08"E, 24 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Elappuram, 1♂1♀, 8°41'44"N 76°47'07"E, 29 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Karette, 1♂, 8°43'43"N 76°53'55"E, 40 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Panayara, 1♂, 8°45'35"N 76°45'02"E, 36 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Ponganadu (Vennichira Pond), 2♂, 8°46'47"N 76°50'49"E, 70 m, 17.VI. 2022, Coll. Priyanka Prabhakaran; Venkode, 1♂, 8°35'56"N 76°58'52"E, 77 m, 16.VI.2022, Coll. Priyanka Prabhakaran; Vilappil (Kudumbu Para), 1♂1♀, 8°31'16"N 77°03'32"E, 167 m, 15.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 3.60 mm- 3.70 mm; Maximum width 2.30 mm- 2.42 mm.

Form oval, convex and slightly pointed posteriorly. Head ferruginous; punctations fine, sparse, irregular; clypeus is densely punctate and rebordered. Pronotum ferruginous; punctation dense, less impressed. Elytra ferruginous with distinct lines of punctures; punctation fine, well-impressed, and less dense than pronotum (Fig. 53 a). Ventral side is ferruginous; fine, sparse punctures on the meta sternum and meta coxal plate; first abdominal segment with a few punctures, other segments impunctate. Median lobe "C" shaped, ventral margin of median lobe evenly curved up to the tip in lateral view (Fig. 53 b).

Habitats: The species is collected in a pool in an abandoned paddy field (Plate 5 (108; 119; 126; 182; 208; 217; 218)), ditches in agricultural fields (Plate 5 (98; 120; 138; 211)), muddy puddle (Plate 5 (216)), pools in an irrigation canal (Plate 5 (128)), rock pools (Plate 5 (4; 87; 215)), ephemeral pools (Plate 5 (219; 53)), paddy fields (Plate 5 (118; 136), Ditch (Plate 5 (116)), abandoned pond Plate 5 (214)) and a small pool (Plate 5 (69)).

Distribution: The species has an Oriental and Palaearctic distribution. India (Kerala (current study), West Bengal).

36. *Hydrovatus rufoniger* (Clark, 1863) (Plate 4 (36))

1863. *Hyphydrus rufoniger* Clark, 423.
1970. *Hyphydrus rufoniger* Vazirani, 97.
1997. *Hyphydrus rufoniger* Biström, 388.
1882. *Hydrovatus rufoniger* Sharp, 334.
1880. *Hydrovatus atricolor* Régimbart, 212; 1899. Régimbart, 240, Synonymy.

Material examined: Palakkad district: Manchira, 1♂1♀, 10°36'35"N 76°43'37"E, 127 m, 12.II.2021, Coll. Priyanka Prabhakaran. Thrissur district: Chembuthra, 1♂1♀, 10°33'20"N 76°19'09"E, 40 m, 08.III.2017, Coll. Priyanka Prabhakaran; Chiranellur, 1♂, 10°38'01"N 76°07'16"E, 24 m, 20.IV.2018, Coll. Priyanka Prabhakaran. Ernakulam district: Karingachira, 1♂, 9°57'00"N 76°21'32"E, 24 m, 02.VII.2019, Coll. Priyanka Prabhakaran; Vettithara, 1♂2♀, 9°55'07"N 76°28'01"E, 45 m, 05.XII.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.50 mm- 3.60 mm; Maximum width: 2.15 mm- 2.20 mm.

Form oval and slightly attenuated posteriorly. Head testaceous to ferruginous; punctation fine; clypeus anteriorly rebordered; post clypeal pit profound. Pronotum testaceous to ferruginous; punctation strong and dense. Elytra ferruginous; punctation, fine, less impressed less dense than pronotum, distinct lines of punctures (Plate 4 (36) a). Ventral surface pale brown, coxae and trochanter of pro and meso legs, elytral epi pleuron, lateral sides of pronotum brown; punctation on meta coxae dense, less impressed; punctation on abdominal ventrites sparse. Median lobe curved, “C” shaped, ventral margin of median lobe straight at the tip in lateral view (Plate 4 (36) b).

Habitats: The species is collected in paddy fields (Plate 5 (112; 142; 153)), ditch in an abandoned paddy field (Plate 5 (167)), muddy puddle (Plate 5 (113)).

Distribution: India (Bihar, Kerala (current study))

37. *Hydrovatus seminarius* Motschulsky, 1860 (Plate 4 (37))

1860. *Hydrovatus seminarius* Motschulsky, 42.
1882. *Hydrovatus fusculus* Sharp, 326.; 1997. Biström, 368, Synonymy
1882. *Hydrovatus tinctus* Sharp, 328; 1997. Biström, 369, Synonymy
1990. *Hydrovatus matsuii* Nakane, 198; 1997. Biström,369, Synonymy
1997. *Hydrovatus seminarius* Biström, 368.

Material examined: Kasargod district: Arai Bridge, 1♂2♀, 12°18'05"N 75°06'29"E, 41 m, 06.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Padichira, 3♂3♀, 11°50'00"N 76°09'22"E, 754 m, 15.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Adivaram, 1♂1♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll. Priyanka Prabhakaran; Palazhi, 1♂2♀, 11°15'05"N 75°49'54"E, 28 m, 18.II.2022, Coll. Priyanka Prabhakaran; Purameri, 3♂7♀, 11°40'16"N 75°36'31"E, 27 m, 16.II.2022, Coll. Priyanka Prabhakaran; Purameri, 4♂6♀, 11°41'00"N 75°36'38"E, 26 m, 16.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Thalur, 2♂, 10°36'50"N 76°41'10"E, 94 m, 9.XII.2020, Coll. Priyanka Prabhakaran. Thrissur district: Cheppara, 1♂, 10°36'59"N 76°15'09"E, 128 m, 22.I.2021, Coll. Priyanka Prabhakaran; Cheppara (Quarry Pond), 1♂, 10°37'12"N 76°15'03"E, 143 m, 22.I.2021, Coll. Priyanka Prabhakaran; Kumaranellur, 1♂1♀, 10°40'09"N

76°14'32"E, 48 m, 8.X.2021, Coll. Priyanka Prabhakaran; Kundukad, 1♂, 10°36'04"N 76°15'53"E, 40 m, 8.X.2021, Coll. Priyanka Prabhakaran; Murukkumpara, 2♀, 10°29'41"N 76°19'53"E, 87 m, 11.X.2021, Coll. Priyanka Prabhakaran; Poomala, 1♂1♀, 11°38'48"N 76°15'03"E, 910 m, 30.V.2016, Coll. Priyanka Prabhakaran; Pullu, 1♂2♀, 10°28'04"N 76°09'16"E, 13 m, 26.12.2021, Coll. Priyanka Prabhakaran. Kottayam district: Perumpanachy, 1♂2♀, 9°29'03"N 76°34'33"E, 27 m, 26.II.2021, Coll. Priyanka Prabhakaran. Pathanamthitta district: Chuttippara, 1♂1♀, 9°17'08"N 76°47'55"E, 72 m, 12.XI.2022, Coll. Priyanka Prabhakaran. Kollam district: Chepra (Mukkavalappara), 7♂6♀, 8°55'13"N 76°48'19"E, 129 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Sasthamkotta, 1♂1♀, 9°01'46"N 76°38'08"E, 24 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Elappuram, 1♂2♀, 8°41'44"N 76°47'07"E, 29 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Elappuram, 1♂, 8°41'41"N 76°47'03"E, 35 m, 18.VI.2022, Coll. Priyanka Prabhakaran; Kallara, 1♂, 8°45'30"N 76°56'04"E, 105 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Karette, 2♂2♀, 8°43'43"N 76°53'55"E, 40 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Vellayani Lake (Venganoor), 3♂3♀, 8°24'45"N 76°59'33"E, 26 m, 25.II.2017, Coll. Priyanka Prabhakaran; Vilappil (Kudumbu Para), 4♂1♀, 8°31'16"N 77°03'32"E, 167 m, 15.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 2.30 mm- 2.50 mm; Maximum width: 1.50- 1.59 mm.

Form oval anteriorly rounded, slightly acuminate posteriorly. Head reddish- brown; punctation fine and sparse, denser near the eyes. Pronotum dark reddish brown, laterally with pale reddish-brown colouration; punctation fine and sparse; lateral sides round-shape. Elytra dark reddish-brown; punctation fine sparse; epipleura paler (Plate 4 (37) a). Ventral surface ferruginous brown; punctation coarse, sparse; abdominal ventrites impunctate; prosternal process finely margined laterally, medially slightly convex; appendages paler; pro and meso tarsi enlarged. Median lobe evenly curved, abruptly narrowed in to a hook-shape at the apical region, apex curved inward in ventral view (Plate 4 (37) b).

Habitats: The species is collected in a pools in abandoned paddy fields (Plate 5 (51; 80; 119; 182)), rock pools (Plate 5 (4; 87; 207; 215), paddy fields (Plate 5 (136; 147; 163)), ditches in an agricultural fields (Plate 5 (138; 211; 212), muddy puddle (Plate 5

(198)), ephemeral pools (Plate 5 (23; 197; 209)), quarry pond (Plate 5 (220)), ditch in an abandoned paddy field (Plate 5 (116)) and shallow margin of a lake (Plate 5 (221)).

Distribution: This species is distributed in the Oriental and Palaearctic region. India (Andaman & Nicobar Islands, Assam, Gujarat, Jharkhand, Kerala, Orissa, Rajasthan, Tamil Nadu, West Bengal).

Genus: *Hyphydrus* Illiger, 1802

This is the largest genus of the tribe *Hyphydrini*. Members are small to medium-sized and typically globular in form. Most are dorsally attractively marked with maculae or fasciae. Their body length ranges between 2.50 mm- 6.80 mm. They can be identified by the presence of a prosternal process without any prominence and reaches the anterior margin of the metaventrite, absence of posteriorly acutely projected posterolateral angles of the pronotum, lack of any elytral carina, exposed base of metatrochanter, lack of lobes of any kind in the metacoxal process, presence of distinct anterior marginal bead on the clypeus in most cases.

One hundred and forty-one species are known under 20 groups. Two species are already known from Kerala state and both were recorded in this study.

38. *Hyphydrus intermixtus* (Walker, 1858) (Plate 4 (38))

1858. *Hydroporus intermixtus* Walker, 204.
1882. *Hyphydrus indicus* Sharp, 382; 1936. J. Balfour-Browne, 130, Synonymy.
1982. *Hydroporus intermixtus* Biström, 97; 1936. J. Balfour-Browne, 129.

Material examined: Thrissur district: Assarikkadu, 1♀, 10°29'57"N 76°19'43"E, 94 m, 15.IV.2019, Coll. Priyanka Prabhakaran; Assarikkadu, 1♀, 10°29'57"N 76°19'43"E, 94 m, 12.VI.2019, Coll. Priyanka Prabhakaran; Assarikkadu, 1♀, 10°29'57"N 76°19'43"E, 94 m, 24.XI.2022, Coll. Priyanka Prabhakaran; Assarikkadu, 2♀, 10°29'57"N 76°19'43"E, 94 m, 26.V.2020, Coll. Priyanka Prabhakaran; Assarikkadu, 1♀, 10°29'57"N 76°19'43 "E, 94 m, 23.IV.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.95 mm- 4.05 mm; Maximum width: 2.55 mm- 2.65 mm.

Form oval, ventral surface moderately convex. Head testaceous; clypeus narrowly rebordered; punctures moderate, more or less well impressed, distinctly reticulated with rounded areoles. Pronotum medially black; laterally testaceous; punctation irregular, strong and dense; lateral margins rebordered. Elytra testaceous with a black band along the suture ii) two longitudinal black bands, abridges at the base and apical region, inner margin of inner band confluent with the sutural band, outer longitudinal band broad and more irregular in shape; punctation less-impressed, dense (Plate 4 (38) a). Ventral surface reddish-brown; pro, meso and meta legs paler at the posterior end; apical segments of fore and mid tarsi black; basal three segments of fore tarsi slightly dilated (Plate 4 (38) b).

Habitat: The species is collected in a remnant pool in a well (Plate 5 (64)), rainwater-fed plastic containers and a garden pool (Plate 5 (222)).

Distribution: The species is distributed only in the Oriental region. India (Gujarat, Kerala, Maharashtra, Rajasthan, Tamil Nadu),

39. *Hyphydrus renardi* Severin, 1890 (Plate 4 (39))

1890. *Hyphydrus renardi* Severin, 191.
1968. *Hyphydrus renardi* Vazirani, 308.
1982. *Hyphydrus renardi* Biström, 99.

Material examined: Kasargod district: Manjeswaram, 2♂3♀, 12°42'49"N 74°53'45"E, 29 m, 08.II.2022, Coll. Priyanka Prabhakaran; Puthiyavalapu, 1♂, 12°19'39"N 75°05'26"E, 32 m, 06.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Puthussery, 1♂, 12°00'16"N 75°40'09"E, 56 m, 12.II.2022, Coll. Priyanka Prabhakaran; Talap, 1♂, 11°53'04"N 75°21'47"E, 29 m, 09.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Payyoli, 1♂1♀, 11°31'23"N 75°37'03"E, 33 m, 18.II.2022, Coll. Priyanka Prabhakaran. Idukki district: Manjumala, 2♂3♀, 9°34'15"N 77°03'54"E 1490 m, 21.VI.2022, Coll. Priyanka Prabhakaran. Alappuzha district: Pavumba, 1♂, 9°05'41"N 76°35'56"E, 24 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Kollam district: Ezhukone, 1♀, 8°59'35"N 76°42'45"E, 56 m, 19.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Irinchayam, 1♂7♀, 8°38'14"N 76°58'27"E, 139 m, 16.VI.2022, Coll. Priyanka Prabhakaran;

Nellanad, 2♂3♀, 8°42'06"N 76°54'20"E, 95 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Ponganadu (Vennichira Pond), 2♂, 8°46'47"N 76°50'49"E, 70 m, 17.VI. 2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.30 mm- 3.75 mm; Maximum width: 2.25 mm- 2.55 mm.

Form oval, ventrally convex. Head testaceous; posteriorly reddish-brown; micro reticulated with rounded areoles; punctures moderately strong, dense on vertex, irregular on other parts. Pronotum testaceous; black bands on anterior and posterior border which are confluent at the middle; lateral sides oblique, slightly convex and narrowly rebordered; punctation dense on disc, irregular on other sides. Elytra testaceous with black markings: i) a black longitudinal band extending along the suture which extend externally medially and post medially ii) a humeral spot iii) a median sub lateral black spot confluent with sutural dilation at its inner margin; punctation double, smaller punctures numerous, irregular, large punctures lesser in number, punctation confluent at base (Plate 4 (39) a). Ventral surface reddish- brown; epipleura paler; meta sternum and meta coxae with numerous large shallow punctures; abdominal sternites with similar but sparse punctures; males with basal three segments of pro tarsi slightly enlarged. Median lobe broad, slightly narrowed at apex and notched at the middle of the apex (Plate 4 (39) b). Parameres triangular with small hairs apically on inner side..

Habitats: The species is collected in muddy puddles (Plate 5 (66; 125; 224)), pool in an irrigation canal (Plate 5 (128)), muddy margin of a river (Plate 5 (78)), abandoned paddy field (Plate 5 (223)), roadside drainage channel (Plate 5 (225)), small pool (Plate 5 (67; 226)) and abandoned ponds (Plate 5 (213; 214)).

Distribution: The species has Oriental and Palaearctic distribution. India (Bihar, Gujarat, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal),

Genus: *Microdytes* J. Balfour-Browne, 1946

Members of the genus are small to extremely small, short, broadly rounded and globular. Some are nearly elongated and flattened. Size ranges between 1.20 mm-

2.30 mm. The beetles can be identified by the presence of a medially prominent prosternal process that extends to the metaventrite, postero lateral angles of the pronotum not extending posteriorly, the base of the metatrochanter nearly obscured by a small triangular lobe.

There are 52 described species under this genus. From Kerala, one species is known so far. The current study recorded a single species which is a new record for the state.

40. *Microdytes cameroni* Miller & Wewalka, 2010 (Plate 4 (40))

2010. *Microdytes cameroni* K. B. Miller & Wewalka, 29.

Material examined: Idukki District: Kallar, 1♂1♀, 10°01'52"N 76°59'17"E, 23.2.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 1.21 mm-1.23 mm; Maximum width: 0.86 mm- 0.87 mm.

Form nearly spherical, moderately convex, lateral outline continuous between pronotum and elytra, lateral sides of the elytra moderately curved. Head dark brown; punctation fine; clypeus paler, slightly truncate; Pronotum dark brown with lateral sides yellow-brown; punctation fine. Elytra reddish brown with yellowish maculae: one at the base, along lateral sides and subapically; elytra near the suture darker; punctation fine (Plate 4 (40)a). Ventral surface dark brown; meso and meta coxae, abdominal ventrites and elytral epipleura dark brown; posterior margin of abdominal segments yellowish; palpi, antennae and legs (except meso and metacoxae) yellowish brown; metaventrite and abdominal ventrites with fine, irregular punctation (Plate 4 (40) b).

Habitat: The species is collected in a remnant rock pool in a river bed (Plate 5.(2)).

Distribution: The species is only distributed in the Oriental region. India (Karnataka, Kerala)

Genus: *Yola* Gozis, 1886

Members of this genus are robust with distinct colour patterns. The body size ranges between 1.50 mm- 3.00 mm. They are characterised by the presence of a transverse occipital line, unmodified anterior clypeal margin, presence of basal pronotal stria and basal stria on elytra, absence of sutural stria on elytra, absence of transverse carina across elytral epipleuron at the humeral angle, presence of prominent longitudinal carina on the disc of the elytra, basal pronotal stria not connected by the transverse furrow, absence of linear series of punctures on elytra and two-segmented lateral lobe of male aedeagus.

There are 50 known species in this genus. The current study recorded one species under *Yola.* The genus is a first report for the state.

41. *Yola consanguinea* (Régimbart, 1892) (Plate 4 (41))

1892. *Bidessus consanguineus* Régimbart, 118.
1899. *Yola consanguinea* Régimbart, 221.
1983. *Bidessus consanguineus* Biström, 31.

Material examined: Palakkad district, Viruthi, 1♂, 10°35'18"N 76°42'52"E, 140 m, 09.XII.2020, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 1.80 mm; Maximum width: 0.93 mm.

Form small oval, widest at the mid-length of elytra. Head black; punctation moderate, closer on vertex. Pronotum testaceous with black colouration at anterior and posterior border; punctation indistinct; latero-basal carinae oblique, hardly extend up to middle. Elytra testaceous with black colouration along the suture; black transverse band consists of basal, median and subapical bands; punctation large and dense; longitudinal carinae sub laterally and near the suture extend from base to the three fourth of the length of the elytra; slightly pubescent (Plate 4 (41) a). Ventral surface reddish brown; appendages testaceous; metasternum and metacoxae with large dense punctation; basal three segments of protarsi slightly enlarged in males (Plate 4 (41) b). Median lobe moderately curved, broadest at the middle. Parameres broadest at the middle, gradually narrowing towards the apex, apical one-third tubular, tip blunt.

Habitats: The species is collected in a rock puddle (Plate 5 (148)).

Distribution: This species is distributed only in the Oriental region. India (Andhra Pradesh, Gujarat, Jharkhand, Kerala (current study), Maharashtra, Orissa).

VI. Subfamily: Laccophilinae

Laccophilinae is one of the largest subfamilies in the family dytiscidae. Majority of the species in this subfamily come under the tribe *Laccophilini*. Most of them have a characteristic shape, anteriorly broad and posteriorly attenuated. They have distinct markings with maculae, fasciae or other patterns dorsally. The body size ranges between 1.50 mm- 8.60 mm. Natatory setae is present on the posteroventral margin of meta tarsomeres in both males and females. Posteroventral natatory setae is absent on metatibia. Metatarsus bears only a single claw. Anteroapical margin of metatarsomeres I-IV are distinctly lobed.

A total of 469 described species are present in this subfamily. The current study documented 13 species under the subfamily.

Genus: *Laccophilus* Leach, 1815

This is the largest genus in the subfamily. Members are quite variable in colouration and markings. The body size range is 1.80 mm- 8.60 mm. Their distinguishing characteristics are two apically bifid metatibial spurs, the presence of the stridulatory device in the form of a series of closely placed ridges in both males and females or only in males of many species.

There are 295 described species under this genus. Eight species have been recorded under this genus from Kerala. Current study reports nine species including two new records to the state.

42. *Laccophilus anticatus anticatus* Sharp, 1890 (Plate 4 (41))

1890. *Laccophilus anticatus* Sharp, 341.
1975. *Laccophilus wewalki* Vazirani, 487.
1983. *Laccophilus anticatus* Brancucci, 302.
1999. *Laccophilus wewalkai* Nilsson, 20.

Material examined: Kasargod district: Manjeswaram, 8♂12♀, 12°42'49"N 74°53'45"E, 29 m, 08.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Kanjirakolli, 1♂, 12°08'07"N 75°37'54"E, 368 m, 12.II.2022, Coll. Priyanka Prabhakaran; Vayathur, 2♂, 12°05'40"N 75°40'21"E, 637 m, 12.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Mananthavady (Kabini River), 1♂, 11°48'00"N 75°58'48"E, 755 m, 13.II.2022, Coll. Priyanka Prabhakaran; Padinjarathara, 1♂, 11°40'39"N 75°56'16"E, 876 m, 13.II.2022, Coll. Priyanka Prabhakaran; Padinjarathara, 1♂1♀, 11°40'40"N 75°56'15"E, 877 m, 13.II.2022, Coll. Priyanka Prabhakaran; Palchuram, 1♂, 11°50'51"N 75°55'01"E, 545 m, 13.II.2022, Coll. Priyanka Prabhakaran; Pazhupathur, 1♀, 11°40'22"N 76°13'53"E, 834 m, 15.II.2022, Coll. Priyanka Prabhakaran; Perikkallur (Kabini River), 1♂3♀, 11°51'35"N 76°08'26"E, 735 m, 12.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Payyoli, 3♀, 11°31'23"N 75°37'03"E, 33 m, 18.II.2022, Coll. Priyanka Prabhakaran.; Purameri, 1♂2♀, 11°40'16"N 75°36'31"E, 27 m, 16.II.2022, Coll. Priyanka Prabhakaran; Purameri (Chalode bridge), 1♀, 11°41'30"N 75°36'39"E, 26 m, 12.II.2023, Coll. Priyanka Prabhakaran. Palakkad district: Kumbalakkode, 2♂, 10°36'12"N 76°37'56"E, 100 m, 12.II.2021, Coll. Priyanka Prabhakaran. Alappuzha district: Varanad, 9♂4♀, 9°41'54"N 76°21'19"E, 20 m, 20.VI.2022, Coll. Priyanka Prabhakaran. Kottayam district: Kurumbanadam, 1♂1♀, 9°28'32"N 76°34'55"E, 27 m, 26.II.2021, Coll. Priyanka Prabhakaran; Peroor, 2♂2♀, 9°37'39"N 76°33'37"E, 22 m, 10.II.2021, Coll. Priyanka Prabhakaran; Perumpanachy, 2♂, 9°29'03"N 76°34'33"E, 27 m, 26.II.2021, Coll. Priyanka Prabhakaran; Perumpanachy, 2♂2♀, 9°29'04"N 76°34'34"E, 28 m, 26.II.2021, Coll. Priyanka Prabhakaran; Vakathanam, 1♂2♀, 9°31'28"N 76°33'49"E, 24 m, 28.II.2021, Coll. Priyanka Prabhakaran. Kollam district: Chenkulam, 2♂2♀, 8°52'33"N 76°45'06"E, 31 m, 18.II.2022, Coll. Priyanka Prabhakaran; Maruthimala (Muttara), 3♂1♀, 8°57'19"N 76°45'24"E, 562 m, 18.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length 3.30 mm- 3.50 mm; Maximum width 1.70 mm-1.80 mm.

Form elongate oval. Head testaceous. Pronotum testaceous with brown indistinct colour patterns at the middle. Elytra brown with testaceous transverse bands: i) sub basal transverse band ii) medio-lateral spot iii) post median transverse band iv) apical spot, all these testaceous markings confluent with lateral testaceous margin; reticulation double, large polygonal meshes well impressed, smaller one less impressed; punctures large and irregular (Plate 4 (41) a). Ventral surface and appendages testaceous; prosternal process elongated, narrowed towards the apex, tip pointed; apical ventrites densely punctate medially and laterally; males with basal three segments of protarsi slightly enlarged; basal three segments of mesotarsi provided with four rows of adhesive cups. Median lobe narrow, elongated, arched in lateral view, with a ventral process; apex truncate; apical half of ventral process cylindrical Plate 4 (41) b). Parameres strongly sclerotised, right paramere broad narrowed at the apical region, apex blunt (Plate 4 (41) c).

Habitats: The species is collected in a muddy puddle (Plate 5 (125; 198; 228)), remnant pool in a river (Plate 5 (227)), rock pools (Plate 5 (12; 54; 99; 35)), remnant pool in a streamlet (Plate 5 (79)), a pool in the flood plain of a river (Plate 5 (181)), paddy field (Plate 5 (137)), margins of rivers (Plate 5 (101; 229)), abandoned ditch (Plate 5 (224)), ditch in agricultural field (Plate 5 (138)), pool in an abandoned paddy field (Plate 5 (177; 182)), ditch (Plate 5 (186)), and small pools (Plate 5 (230; 231; 232)).

Distribution: This species is distributed in the Oriental and Palaearctic regions. India (Andhra Pradesh, Assam, Bihar, Delhi, Goa, Gujarat, Karnataka, Kerala, Maharashtra, Manipur, Orissa, Pondicherry, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal).

43. *Laccophilus auropictus* Régimbart, 1899 (Plate 4 (43))

1899. *Laccophilus auropictus* Régimbart, 253.
1972. *Laccophilus auropictus* Vazirani, 120.
1983. *Laccophilus auropictus* Brancucci, 259.

Material examined: Palakkad district: Choondakulam, 2♀, 11°03'55"N 76°39'29"E 663 m, 02.II.2021, Coll. Priyanka Prabhakaran.

Diagnosis: Total Length 4.00 mm- 4.20 mm, Maximum width 2.30 mm- 2.50 mm.

Form oval, broad, slightly attenuated posteriorly, moderately convex. Head yellowish orange. Pronotum yellowish-orange with anterior and posterior borders slightly darker. Elytra dark brown with yellow markings: i) sub basal transverse fascia consisting of three confluent spots, external spot confluent with the lateral border, innermost spot not reaching the suture. ii) posterior sub lateral spot iii) small apical spot not touching the elytral margins; reticulation double with distinct larger areoles with fine margins, smaller areoles fine and less impressed (Plate 4 (49) a). Ventral surface is reddish-brown; meta legs darker; prosternal process short and lanceolate (Plate 4 (49) b).

Habitats: The species is collected in a small pool with a muddy substratum (Plate 5 (233)).

Distribution: India (Karnataka, Kerala (current study), Tamil Nadu).

44. *Laccophilus elegans* Sharp, 1882 (Plate 4 (44))

1882. *Laccophilus elegans* Sharp, 302.
1983. *Laccophilus elegans* Brancucci, 257.

Material examined: Kasargod district: Nileswaram (Mundemmad Road), 1♀, 12°14'28"N 75°08'28"E, 503 m, 08.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Edumbapalam, 1♀, 11°53'55"N 75°39'15"E, 602 m, 16.II.2022, Coll. Priyanka Prabhakaran; Kanjirakolli, 9♂61♀, 12°08'07"N 75°37'54"E, 368 m, 12.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Palchuram, 4♂,6♂ 11°50'51"N 75°55'01"E, 545 m, 13.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Adivaram, 2♀, 11°29'59"N 76°01'08"E, 699 m, 16.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Padagiri, 2♂, 10°29'05.9"N 76°40'18.2"E, 973 m, 07. I.2021, Coll. Priyanka Prabhakaran. Thrissur district: Thalikkode, 6♂4♀, 10°34'32"N 76°18'37"E, 141 m, 15.1.2021, Coll. Priyanka Prabhakaran. Idukki District: Kallar, 12♂4♀, 10°01'53"N 76°59'18"E, 849 m, 23.II.2020, Coll. Priyanka Prabhakaran: Peermade, 1♂2♀, 9°34'52"N 76°58'46"E, 1550 m, 21.VI.2022, Coll. Priyanka Prabhakaran; Peermade, 2♂2♀, 9°33'21"N 76°57'60"E, 690 m, 21.VI.2022, Coll. Priyanka Prabhakaran; Manjumala, 3♂3♀, 9°32'00"N 76°58'18"E, 893 m, 21.VI.2022, Coll. Priyanka Prabhakaran; Thommankuthu, 1♂♀, 9°57'32"N 76°50'10"E 216 m, 21. II.2020, Coll. Priyanka Prabhakaran. Kottayam district: Murinjapuzha, 4♂3♀, 9°32'00"N 76°58'18"E, 893m, 21.VI.2022, Coll. Priyanka

Prabhakaran. Thiruvananthapuram district: Brimore, 3♀, 8°45'52"N 77°05'21"E, 663 m, 14.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total Length 3.70 mm- 4.00 mm; Maximum width 1.80 mm- 2.10 mm.

Form elliptical, relatively broader and nearly convex. Head reddish orange; less impressed large polygonal meshes; Medium-sized punctures along the inner margin of eyes. Pronotum yellowish-orange; micro reticulation as of head. Elytra black, shiny with three orangish-yellow fasciae: sub basal transverse fascia, postmedian transverse fascia and apical band; fine and well impressed large polygonal meshes (Plate 4 (44) a). Ventral surface testaceous; meta sternum, meta tibiae, meta tarsi slightly darker; prosternal process comparatively flat. Median lobe slightly curved, slightly narrowed anteriorly, tip blunt (Plate 4 (44) b).

Habitats: The species is collected in remnant pool in an abandoned ditch (Plate 5 (25)), remnant pools in waterfalls (Plate 5 (14), remnant pool in a streamlet (Plate 5 (79)), rock pools (Plate 5 (4; 18)), remnant pool in a stream bed (Plate 5 (7)), spring-fed pools (Plate 5 (41; 234), and remnant pool in a roadside drain (Plate 5 (27)).

Distribution: India (Andaman & Nicobar Islands, Andhra Pradesh, Bihar, Karnataka, Kerala (current study), Nagaland, Orissa, West Bengal).

45. *Laccophilus ellipticus* Régimbart, 1889 (Plate 4 (44))

1860. *Laccophilus flavescens* Motschulsky, 45;1983. Brancucci, 375: Synonymy.
1889. *Laccophilus ellipticus* Régimbart, 152.
1983. *Laccophilus ellipticus* Brancucci, 312.

Material examined: Kasargod district: Arai Bridge, 1♀, 12°18'05"N 75°06'29"E, 41 m, 06.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Nagalassery, 1♂1♀, 10°44'43"N 76°08'14"E, 40 m, 15.II.2021, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.20 mm- 3.65 mm; Maximum width: 1.50 mm- 1.90 mm.

Form elongated oval, elliptical, slightly convex. Head brownish yellow; reticulation double, well impressed large polygonal meshes, feebly impressed small meshes at the posterior region. Pronotum brownish yellow; darker on posterior half; reticulation double; large polygonal meshes especially large on disc; small meshes obsolete; series of large punctures at the anterior, lateral boarders and posterior angles. Elytra reddish brown; testaceous on lateral sides; reticulation double; large polygonal meshes irregular in size; smaller ones more visible towards posterior region; sutural row of punctures medium sized and extend up to the apex (Plate 4 (44) a). Ventral surface light reddish- brown; appendages testaceous; prosternal process laterally compressed and apex long sharply pointed; posterior abdominal segments with large punctures; males with basal three segments of pro and meso tarsi slightly enlarged and provided with suction palettes. Median lobe curved ventrally near the base, dorsally with a process arising from the base, apex rounded (Plate 4 (44) b).

Habitats: The species was collected in a pool in an abandoned paddy field (Plate 5 (119)) and in the margin of a pond (Plate 5 (236)).

Distribution: This species is distributed in the Oriental and Palaearctic region. India (Andhra Pradesh, Assam, Bihar, Goa, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Meghalaya, Orissa, Pondicherry, Tamil Nadu, West Bengal).

46. *Laccophilus flexuosus* Aubé, 1838 (Plate 4 (46))

1838. *Laccophilus flexuosus*, Aubé, 430

1882. *Laccophilus cognatus* Sharp, 316; 1890. Severin, 188, Synonymy.

1882. *Laccophilus solutus* Sharp, 315; 1890. Severin, 188, Synonymy.

1887. *Laccophilus chloroticus*, Régimbart, 267; J. 1938. Balfour-Browne, 103, Synonymy.

1932. *Laccophilus formosanus* Takizawa, 22; 1983. Brancucci, 318, Synonymy.

1983. *Laccophilus flexuosus* Brancucci, 318.

Material examined: Kasargod district: Manjeswaram, 1♀, 12°42'49"N 74°53'45"E, 29 m, 08.II.2022, Coll. Priyanka Prabhakaran; Shiriya, 1♂, 12°37'23"N 74°55'42"E, 30 m, 08.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Chinganchira, 1♀., 10°34'48"N 76°43'01"E 107 m, 12.2.2021, Coll. Priyanka Prabhakaran. Malappuram district: Chembikkal, 1 ♀, 10°51'54"N 76°00'35"E, 18 m, 20.IV.2018, Coll. Priyanka Prabhakaran. Thrissur district: Chiranellur, 2♀, 10°38'01"N 76°07'16"E, 24 m, 20.IV.2018, Coll. Priyanka Prabhakaran; Chowallur, 1♂, 10°36'21"N 76°04'27"E, 20 m, 05.VII.2018, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Panayara, 2♀, 8°45'35"N 76°45'02"E, 36 m, 18.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.00 mm- 4.10 mm; Maximum width: 1.90 mm- 2.10 mm.

Form oval, moderately elongated, anteriorly and posteriorly attenuated. Head testaceous to pale reddish. Pronotum light reddish brown with fine traces of black lines at the anterior and posterior border occasionally. Elytra light reddish-yellow with irregular traces of fine black lines; posterior half darker; moderately impressed microreticulation (Plate 4 (46) a). Ventral surface fawn coloured; meta legs and elytral epipleuron darker (Plate 4 (46) b).

Habitat: This species is collected in a muddy puddle (Plate 5 (125)), pool in an abandoned paddy field (Plate 5 (111)), margin of a pond (Plate 5 (237)), ephemeral pool (Plate 5 (140)) and paddy fields (Plate 5 (112; 118; 238).

Distribution: The species is distributed in the Oriental and Palaearctic regions. India (Andaman & Nicobar Islands, Andhra Pradesh, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Orissa, Pondicherry, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal),

47. *Laccophilus inefficiens* (Walker, 1859) (Plate 4 (47))

1859. *Hydroporus inefficiens* Walker, 51.
1860. *Laccophilus basalis* Motschulsky, 45; 1983. Brancucci, 375, Synonymy.
1882. *Laccophilus inefficiens* Sharp, 287.
1983. *Hydroporus inefficiens* Brancucci, 332.

Material examined: Kannur district: Kalliad (Kokkoli falls), 3♂, 11°59'51"N 75°36'14"E, 159 m, 11.II.2022, Coll. Priyanka Prabhakaran; Kanjirakolli (Valapattanam River), 3♂, 12°08'22"N 75°37'51"E, 366 m, 12.II.2022, Coll. Priyanka Prabhakaran; New Naduvil, 2♂, 12°09'46"N 75°26'37"E, 50 m, 10.II.2022, Coll. Priyanka Prabhakaran; New Naduvil, 1♀, 12°08'40"N 75°26'32"E, 68 m, 10.II.2022, Coll. Priyanka Prabhakaran; New Naduvil, 1♂2♀, 12°09'59"N 75°26'53"E, 54 m, 10.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Perikkallur (Kabini River), 1♂, 11°51'35"N 76°08'26"E, 735 m, 12.II.2022, Coll. Priyanka Prabhakaran. Kozhikode district: Purameri (Chalode bridge), 2♂, 11°41'30"N 75°36'39"E, 26 m, 12.II.2023, Coll. Priyanka Prabhakaran. Palakkad district: Chittur, 2♀, 11°03'46"N 76°39'14"E, 586 m, 16.IX.2021, Coll. Priyanka Prabhakaran. Thrissur district: Cheppara, 1♂, 10°36'59"N 76°15'09"E, 128 m, 22.I.2021, Coll. Priyanka Prabhakaran; Cheppara (Quarry pond), 4♂6♀, 10°37'12"N 76°15'03"E, 143 m, 22.I.2021, Coll. Priyanka Prabhakaran; ; Cheppara (Quarry pond), 4♂6♀, 10°37'12"N 76°15'03"E, 143 m, 08.XI.2022, Coll. Priyanka Prabhakaran; Murukkumpara, 2♂2♀, 10°29'46"N 76°19'46"E, 116 m, 29.IX.2017, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂3♀, 10°29'46"N 76°19'46"E, 116 m, 26.VII.2019, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Chaliyakkara, 1♀, 9°02'21"N 76°57'47"E, 70 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Nellanad, 1♂6♀, 8°42'06"N 76°54'20"E, 95 m, 17.VI.2022, Coll. Priyanka Prabhakaran;

Diagnosis: Total length 3.30 mm- 3.60 mm; Maximum width 1.60 mm- 1.70 mm.

Form elongate oval. Head testaceous; large punctures on clypeal groove and along the margin of the eyes. Pronotum testaceous with dark colouration at the middle of the anterior and posterior margins; reticulation double large polygonal meshes well impressed, smaller ones feebly impressed; large irregularly arranged punctures at the anterior, posterior and lateral boarders and at the posterior angles. Elytra testaceous with brown regular irrotations which is free forming a sub basal testaceous band with sharp tooths on margins; vague testaceous subapical band and an apical spot; lateral sides testaceous; reticulation double, large polygonal meshes on disc well impressed, smaller round meshes less impressed but strongly impressed towards anterior, punctation irregular (Plate 4 (47) a). Ventral surface and appendages pale brown, prosternal process laterally compressed tip pointed; apical sternites with large punctures. Males with basal three segments of pro and meso tarsi slightly enlarged and provided with sucker palettes. Median lobe narrow, slightly curved from the middle towards the apical region, apex pointed (Plate 4 (40) b).

Habitats: The species is collected in a remnant pool in a waterfall (Plate 5 (130)), muddy puddles (Plate 5 (198; 228)), remnant pool in a stream (Plate 5 (75)), ephemeral pools (Plate 5 (23; 76), margin of rivers (Plate 5 (77; 101)), margin of a quarry pond (Plate 5 (220)), pond (Plate 5 (52)), rock pool (Plate 5 (96)), pool in an abandoned paddy field (Plate 5 (109)) and a small pools (Plate 5 (59; 226)).

Distribution: The species is distributed in the Oriental and Palaearctic region. India (Andaman & Nicobar Islands, Andhra Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Punjab, Rajasthan, Sikkim, Tripura, Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal),

48. *Laccophilus parvulus parvulus* Aubé, 1838 (Plate 4 (48))

1838. *Laccophilus parvulus* Aubé, 429.
1838. *Laccophilus orientalis* Aubé, 431; 1888. Régimbart, 611: Synonymy.
1983. *Laccophilus parvulus* Brancucci, 355.
1877. *Laccophilus proteus* Régimbart, 110; 1892. Régimbart, 118: Synonymy.
1860. *Laccophilus undulifer* Motschulsky, 44;1899. Régimbart, 259: Synonymy.

Material examined: Kasargod district: Arai Bridge, 1♀, 12°18'05"N 75°06'32"E, 41 m, 06.II.2022, Coll. Priyanka Prabhakaran; Shiriya, 1♂, 12°37'23"N 74°55'42"E, 30 m, 08.II.2022, Coll. Priyanka Prabhakaran. Kannur district: Vayathur, 1♀, 12°05'40"N 75°40'21"E, 637 m, 12.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Panavally, 1♂, 11°52'52"N 76°04'40"E, 765 m, 15.II.2022, Coll. Priyanka Prabhakaran; Malappuram district: Chembikkal, 2♂3♀, 10°51'54"N 76°00'35"E, 18 m, 20.IV.2018, Coll. Priyanka Prabhakaran. Palakkad district: Chittur (Siruvani river), 2♂, 10°04'10"N 76°39'16"E, 68 m, 02.II.2021, Coll. Priyanka Prabhakaran; Kumbalakkode, 2♂3♀, 10°36'12"N 76°37'56"E, 100 m, 12.II.2021, Coll. Priyanka Prabhakaran Pappadi, 4♀, 10°49'47.8"N 76°38'01.9"E, 105 m, 24.II.2022, Coll. Priyanka Prabhakaran; Yakkara, 10♂7♀, 10°44'59"N 76°39'11"E, 107 m, 14.II.2017, Coll. Priyanka Prabhakaran. Thrissur district: Adat, 2♂4♀, 10°32'17"N 76°08'19"E 20 m, 10.XII.2019, Coll. Priyanka Prabhakaran; Chembuthra, 2♂, 10°33'20"N 76°19'09"E, 40 m, 08.III.2017, Coll. Priyanka Prabhakaran; Cheppara, 1♂1♀, 10°36'59"N 76°15'09"E, 128 m, 22.I.2021, Coll. Priyanka Prabhakaran; Cheppara (Quarry pond), 6♂4♀, 10°37'12"N 76°15'03"E, 143 m, 22.I.2021, Coll. Priyanka Prabhakaran; Kodali, 3♂1♀, 10°24'02"N 76°21'07"E, 34 m, 03.I.2022, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂, 10°29'46"N 76°19'46"E, 116 m, 29.IX.2017, Coll. Priyanka Prabhakaran; Puzhakkal, 4♂5♀, 10°33'01"N 76°10'54"E, 23 m, 25.V.2019, Coll. Priyanka Prabhakaran; Thalikkode, 2♂1♀, 10°34'32"N 76°18'37"E, 141 m, 15.1.2021, Coll. Priyanka Prabhakaran; Ernakulam district: Malayatur, 3♂1♀, 10°12'02"N 76°30'0"E, 45 m, 28.III.2021, Coll. Priyanka Prabhakaran; Vettithara (OC Road), 2♂, 9°56'15"N 76°28'11"E, 37 m, 05.XII.2022, Coll. Priyanka Prabhakaran. Idukki district: Chillithodu, 2♂4♀, 10°01'40"N 76°52'49"E, 561 m, 23.II.2020, Coll. Priyanka Prabhakaran; Erattayar, 1♂1♀, 9°48'02"N 77°06'24"E, 767 m, 22.2.2020, Coll. Priyanka Prabhakaran; Kamakshi, 1♂, 9°49'43"N 77°04'54"E, 997 m, 24.II.2020, Coll. Priyanka Prabhakaran; Kottakkavala, 2♂1♀, 9°55'33"N 76°47'57"E, 66 m, 21.II.2020, Coll. Priyanka Prabhakaran; Shantharuvi, 2♂, 9°59'43"N 77°11'22"E, 1318 m, 23.II.2020, Coll. Priyanka Prabhakaran. Alappuzha district: Kalavoor, 2♂1♀, 9°33'16"N 76°19'41"E, 27 m, 20.VI.2022, Coll. Priyanka Prabhakaran; Aryad South, 1♂, 9°33'16"N 76°19'41"E, 27 m, 20.VI.2022, Coll. Priyanka Prabhakaran; Nedumudi, 9°25'48"N 76°24'12"E, 17 m, 20.VI.2022, Coll. Priyanka Prabhakaran. Kottayam district: Vallavoor, 2♂1♀, 9°28'00"N 76°42'33"E, 33 m, 27.II.2021, Coll. Priyanka Prabhakaran. Kollam district: Kummil, 3♂5♀, 8°47'54"N 76°55'52"E, 130 m, 17.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 2.70- 3. 60 mm; Maximum width: 1.50 mm- 1.90 mm.

Form elongate oval, slightly attenuated posteriorly. Head testaceous; reticulation double small meshes well impressed on anterior, posterior and lateral sides. Pronotum testaceous; slightly darkened at the middle of the posterior border; anterior margin, lateral margins and posterior angles with series of punctures. Elytra testaceous with black double, irregular, flexuous lines which often confluent; these are absent at sub basally, post medially and apically; well-spaced punctures on disc (Plate 4 (48) a). Ventral surface brown; appendages, prosternal process, metacoxae and the first two abdominal segments testaceous; prosternal process laterally compressed, apically narrowed, apex pointed; anterior border of meta sternum sinuate and with small scattered punctures; apical sternites with strioles and small scattered punctures; males with basal three segments of pro and meso tarsi dilated and equipped with suction palettes. Median lobe elongated nearly equal in width throughout, strongly bent at middle, obliquely truncates, apex slightly indented (Plate 4 (48) b).

Habitats: This species is collected in a pool in abandoned paddy field (Plate 5 (111; 119)), remnant pool in a streamlet and a river (Plate 5 (40; 227)), rock pools (Plate 5 (62; 96; 241)), ephemeral pools (Plate 5 (23; 114; 140; 172; 240), margin of a stream (Plate 5 (81)), margin of rivers (Plate 5 (229; 149), paddy field (Plate 5 (153)), margin of a quarry pond (Plate 5 (220)), ditch (Plate 5 (239)) and a pool (Plate 5 (183)).

Distribution: This species has an Oriental and Palaearctic distribution. India (Goa, Kerala, Manipur, Pondicherry, Tripura, Uttarakhand, Uttar Pradesh, West Bengal).

49. *Laccophilus parvulus obtusus* Sharp, 1882 (Plate 4 (49))

1882. *Laccophilus obtusus* Sharp, 311.

1882. *Laccophilus derasus* Sharp, 311; 1983. Brancucci, 360, Synonymy.

1882. *Laccophilus dispersus* Sharp, 312; 1983. Brancucci, 361: Synonymy.

1983. *Laccophilus obtusus* Brancucci, 360.

Material examined: Wayanad district: Malayilpedika, 1♂, 11°47'57"N 76°01'01"E, 755 m, 13.II.2018, Coll. Priyanka Prabhakaran. Palakkad district: Chittur (Siruvani river), 1♂2♀, 10°04'10"N 76°39'16"E, 68 m, 02.II.2021, Coll. Priyanka Prabhakaran; Elavanjery (Karimkulam), 1♂, 10°36'20"N 76°38'43"E, 105 m,12.II.2021, Coll. Priyanka Prabhakaran; Kumbalakkode, 1♀, 10°36'12"N 76°37'56"E, 100 m, 12.II.2021, Coll. Priyanka Prabhakaran; Parali, 5♂7♀, 10°48'08"N 76°33'51"E 77 m, 13.I.2017, Coll. Priyanka Prabhakaran. Thrissur district: Adat, 3♂3♀, 10°32'17"N 76°08'19"E 20 m, 10.XII.2019, Coll. Priyanka Prabhakaran; Cheppara, 2♂2♀, 10°36'59"N 76°15'09"E, 128 m, 22.I.2021, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂, 10°29'46"N 76°19'46"E, 116 m, 26.VII.2019, Coll. Priyanka Prabhakaran; Ayyampuzha, 3♂5♀, 10°17'43"N 76°27'02"E, 44 m, 11.IV.2019, Coll. Priyanka Prabhakaran. Idukki district: Shantharuvi, 2♂, 9°59'43"N 77°11'22"E, 1318 m, 23.II.2020, Coll. Priyanka Prabhakaran. Kottayam district: Kurumbanadam, 1♂1♀, 9°28'32"N 76°34'55"E, 27 m, 26.II.2021, Coll. Priyanka Prabhakaran; Santhipuram, 6♂2♀, 9°28'52"N 76°37'33"E, 75 m, 26.II.2021, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 2.90 mm- 3.40 mm; Maximum width: 1.55 mm- 1.80 mm.

Form elongate oval, slightly attenuated posteriorly. Head testaceous, irregular brownish yellow margins; reticulation double. Pronotum testaceous; slightly darkened at the middle of the posterior border; distinct black band at the middle of anterior border; series of punctures at the anterior margin, lateral margins and posterior angles. Elytra testaceous with black double, irregular, flexuous lines which often confluent; well-spaced punctures on disc (Plate 4 (49) a). Ventral surface light brown; appendages, prosternal process, metacoxae and the first two abdominal segments testaceous; prosternal process laterally compressed, apically narrowed, apex pointed; anterior border of meta sternum with small scattered punctures; apical sternites with strioles and small scattered punctures; males with basal three segments of pro and meso tarsi dilated and equipped with suction palettes. Median lobe is narrowed at the apical region in lateral view (Plate 4 (49) b).

Habitat: The species is collected in a paddy field Plate 5 (152)), rock pools (Plate 5 (1; 96; 97)), abandoned pond (Plate 5 (242)), margin of a river (Plate 5 (229)), remnant pool in a river (Plate 5 (144)), abandoned paddy field (Plate 5 (182)) and the margin of a quarry pond (Plate 5 (220)).

Distribution: This species is distributed in the Oriental as well as Palaearctic region. India (Goa, Kerala, Manipur, Pondicherry, Tripura, Uttarakhand, Uttar Pradesh, West Bengal),

50. ***Laccophilus sharpi*** **Régimbart, 1889 (Plate 4 (50))**

1889. *Laccophilus sharpi* Régimbart,151.
1889. *Laccophilus similis* Régimbart,150; 1899. Régimbart, 257: Synonymy.
1938. *Laccophilus samosir* Csiki, 125; 1983. Brancucci, 347: Synonymy.
1983. *Laccophilus sharpi* Brancucci, 348.

Material examined: Kannur district: Kanjirakolli, 1♂2♀, 12°08'07"N 75°37'54"E, 368 m, 12.II.2022, Coll. Priyanka Prabhakaran; Kanjirakolli (Valapattanam River), 1♂2♀, 12°08'22"N 75°37'51"E, 366 m, 12.II.2022, Coll. Priyanka Prabhakaran. Wayanad district: Panavally, 5♂4♀, 11°52'52"N 76°04'40"E, 765 m, 15.II.2022, Coll.

Priyanka Prabhakaran; Perikkallur (Kabini River), 1♂, 11°51'35"N 76°08'26"E, 735 m, 12.II.2022, Coll. Priyanka Prabhakaran. Palakkad district: Pappadi, 1♂6♀, 10°49'48"N 76°38'02"E, 105 m, 24.II.2022, Coll. Priyanka Prabhakaran. Thrissur district: Adat, 2♂, 10°32'17"N 76°08'19"E 20m, 10.XII.2019, Coll. Priyanka Prabhakaran; Cheppara (Quarry Pond), 1♂, 10°37'12"N 76°15'03"E, 143 m, 22.I.2021, Coll. Priyanka Prabhakaran; Murukkumpara, 1♂1♀, 10°29'46"N 76°19'46"E, 116 m, 31.V.2016, Coll. Priyanka Prabhakaran; Nandhikkara, 4♂6♀, 10°23'39"N 76°14'26"E, 29.1.2020, Coll. Priyanka Prabhakara; Poomala, 2♀, 11°38'48"N 76°15'03"E, 910 m, 30.V.2016, Coll. Priyanka Prabhakaran; Pullu, 2♂3♀, 10°28'04"N 76°10'00"E, 15 m, 26.12.2021, Coll. Priyanka Prabhakaran; Pullu, 2♂3♀, 10°28'04"N 76°09'16"E, 13 m, 26.12.2021, Coll. Priyanka Prabhakaran. Ernakulam district: Karikkattupadi, 1♂, 9°56'00"N 76°27'03"E, 56 m, 20.II.222, Coll. Priyanka Prabhakaran; Vettithara, 1♂1♀, 9°55'07"N 76°28'01"E, 45 m, 05.XII.2022, Coll. Priyanka Prabhakaran. Kollam district: Kummil, 1♂, 8°55'06"N 76°51'46"E, 81 m, 17.VI.2022, Coll. Priyanka Prabhakaran; Ezhukone, 7♂1♀, 8°59'27"N 76°42'33"E, 1006 m, Coll. Priyanka Prabhakaran; Maruthimala (Muttara), 1♀, 8°57'19"N 76°45'24"E, 562 m, 18.VI.2022, Coll. Priyanka Prabhakaran. Thiruvananthapuram district: Chaliyakkara, 1♀, 9°02'21"N 76°57'47"E, 70 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Cheenikkala, 4♂6♀, 8°30'43"N 77°10'30"E, 192 m, 15.VI.2022, Coll. Priyanka Prabhakaran; Irinchayam, 1♂5♀, 8°38'14"N 76°58'27"E, 139 m, 16.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.50 mm- 3.95 mm; Maximum width: 1.90 mm- 2.50 mm.

Form elongate oval. Head testaceous; reticulation double, large polygonal meshes on the disc, small round meshes on rest of the surface; series of large punctures along inner margin of eyes and at the clypeal groove. Pronotum testaceous; black narrow bands at the anterior and posterior borders, band at the posterior border slightly curved inward and narrowly extend laterally but not reaching the lateral margins; reticulation double, large polygonal meshes least visible, small rounded and well-impressed meshes on the entire surface. Elytra testaceous with double brownish-black flexuous lines; row of moderately large punctures along the suture extending up to the apex, reticulation consists of small polygonal meshes, punctures large and scattered on disc (Plate 4 (50) a). Ventral surface pale brown, appendages testaceous; prosternal process laterally compressed, elongated apically pointed; apical sternite smooth; males with basal three segments of the pro and meso tarsi strongly dilated. Median lobe curved, long and broad, ventral margin indented at the middle, apex truncate with a deep rounded notch (Plate 4 (50) b).

Habitat: The species is collected in muddy puddles Plate 5 (113; 198)), rock pools (Plate 5 (18; 62; 241)), margin of a river (Plate 5 (101)), margin of a stream (Plate 5 (81; 162)), margin of a quarry pond (Plate 5 (220)), paddy field (Plate 5 (162; 163)), margin of a pond (Plate 5 (166)), ephemeral pool (Plate 5 (53)), ditch in an abandoned paddy field (Plate 5 (109)), road-side ditch (Plate 5 (91)) and an abandoned pond (Plate 5 (213)).

Distribution: The species is distributed in the Australian, Oriental and Palaearctic region. India (Andaman & Nicobar Islands, Assam, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Pondicherry, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal).

Genus: *Neptosternus* Sharp, 1882

Many of the species in this genus are marked dorsally with maculae and fasciae. some are nearly entirely black. Body size varies between 2.40 mm- 4.50 mm. They are easy to distinguish from other genera by the presence of an apically trifurcate prosternal process and metatarsal lobes comparatively short.

There are 98 described species within this genus. Four species, which are endemic to Kerala, have already been documented. The current study recorded these four previously reported species.

51. *Neptosternus annettae* Hendrich & Balke, 2000 (Plate 4 (51))

2000. *Neptosternus annettae* Hendrich & Balke, 1286.

Material examined: Pathanamthitta district: Punnala, 1♂1♀, 9°04'59"N 76°55'05"E, 51 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Ranni, 2♂, 9°22'51"N 76°46'43"E, 35 m, 21.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.90 mm- 4.00 mm; Maximum width: 2.10 mm-2.20 mm.

Form oval, broad, slightly curved lateral outline. Head reddish brown; micro reticulated with polygonal meshes; densely punctate at middle. Pronotum reddish brown ; darker on anterior and posterior borders, punctation dense, some large punctures medially at the anterior border, micro reticulated with polygonal meshes at anterior and lateral margins. Elytra black with four yellow spots: i) sub basal transverse band ii) two post medial spots iii) one sub apical spot. Outer post medial spot and the apical spots are confluent with each other laterally; fine and densely punctate, micro reticulation's of slightly transverse orientated, few large punctures between suture and discal row of punctures, discal row of punctures distinct, lateral rows of punctures less distinct (Plate 4 (51) a). Ventral surface reddish brown appendages paler. Median lobe uniform in width, slightly curved and narrowed near the apex, tip pointed, lateral margin of median lobe curved in lateral view (Plate 4 (51) b).

Habitats: This species is collected from the fibrous root system of a palm tree at the margin of a stream (Plate 5 (243)) and from the roots of submerged vegetation at the shallow marginal zone of a river.

Distribution: Endemic to Kerala. India (Kerala)

52. *Neptosternus boukali* Hendrich & Balke, 1999 (Plate 4 (52))

1999. *Neptosternus boukali* Hendrich & Balke, 58.

Material examined: Pathanamthitta district: Ranni, 2♂2♀, 9°22'51"N 76°46'43"E, 35 m, 21.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.60 mm- 4.00 mm; Maximum width: 1.90 mm- 2.05 mm.

Form oval, slightly arched lateral outline. Head reddish-yellow; densely punctate, reticulations of polygonal meshes. Pronotum reddish-yellow, anterior and posterior margins with black bands in the middle that narrowly extend to the lateral sides, densely punctate, large punctures at the middle of the anterior margin; micro reticulated with polygonal meshes on lateral region. Elytra black with five yellow spots: i) two sub basal spots ii) two medial spots and iii) one sub apical spot. Inner spots not touching the suture, outer spots not touching the lateral border, subapical spot confluent with the lateral border; reticulation consists of transversely aligned polygonal meshes; coarse punctures on disc, fine and dense punctures all over; distinct discal row of punctures; lateral rows of punctures less distinct (Plate 4 (52) a). Ventral surface reddish-brown; epipleura anteriorly yellowish; appendages reddish-yellow. Median lobe curved at just before midlength with a narrow apical region, tip rounded (Plate 4 (52) b).

Habitats: The species is collected at the shallow marginal zone from the fibrous roots of submerged vegetation.

Distribution: Endemic to Kerala. India (Kerala).

53. *Neptosternus kerala* Hendrich & Balke, 1999 (Plate 4 (53))

1999. *Neptosternus kerala* Hendrich & Balke, 59.

Material examined: Pathanamthitta district: Punnala, 2♂, 9°04'59"N 76°55'05"E, 51 m, 13.VI.2022, Coll. Priyanka Prabhakaran; Ranni, 1♂, 9°22'51"N 76°46'43"E, 35 m, 21.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3.00 mm- 3. 20 mm; Maximum width: 1.68 mm- 1.77 mm.

Form oval, slightly arched. Head yellowish; micro reticulated with polygonal meshes medially densely punctate. Pronotum yellowish, dark colouration at anterior and posterior borders and broader at the middle and narrowed laterally; punctation dense, few large punctures medially at the anterior border; polygonal meshes on the laterally. Elytra black with five yellow patches: i) two sub basal spots ii) two median spots iii) one sub apical spot. Outer sub basal spot longitudinal and confluent with lateral margin; lateral median spot and apical spot confluent with lateral border; punctation fine and dense, coarse punctures on disc; micro reticulated with transversely oriented polygonal meshes; distinct discal row of punctures; lateral rows of punctures indistinct (Plate 4 (53) a). Ventral surface reddish brown, elytral epipleura yellowish anteriorly, appendages reddish-brown. Median lobe curved at midlength with a pointed apex (Plate 4 (53) b).

Habitats: This species is collected from the root system of a palm tree at the margin of a stream (Plate 5 (243)) and at the shallow marginal zone of a river from the roots of submerged vegetation.

Distribution: Endemic to Kerala. India (Kerala).

54. ***Neptosternus leyi*** **Hendrich & Balke, 2000 (Plate 4 (54))**

2000. *Neptosternus leyi* Hendrich & Balke, 1287.

Material examined: Pathanamthitta district: Ranni, 1♂, 9°22'51"N 76°46'43"E, 35 m, 21.VI.2022, Coll. Priyanka Prabhakaran.

Diagnosis: Total length: 3. 25 mm; Maximum width: 1.80 mm.

Form broadly oval. Head reddish brown; punctation dense at middle; micro reticulated with polygonal meshes. Pronotum reddish brown; dark on anterior and posterior borders; punctation dense; few large punctures at the middle of anterior border; polygonal meshes at anterior and lateral margins. Elytron black with four yellow spots: i) a sub basal transverse band ii) a post median spot iii) a sub apical spot; post median and sub apical spots confluent with the lateral border; punctation fine and dense, micro reticulated with transversely positioned polygonal meshes; few large punctures on the disc between suture and discal row of punctures; discal row of punctures well defined making it a longitudinal stria; two lateral rows of punctures less distinct (Plate 4 (54) a). Ventral surface reddish brown, appendages paler (Plate 4 (54) b).

Habitats: The species is collected at the shallow marginal zone from the fibrous roots of submerged vegetation.

Distribution: This species is endemic to Kerala. India (Kerala).

3.4.2 Taxonomic key for the identification of recorded species

3.4.2.1 Key to the subfamilies of family Dytiscidae

1 Scutellum is visible when elytra is closed……………………………………..……..…**2**

1' Scutellum is not visible with elytra closed……………………………………………….**3**

2 Eyes anteriorly rounded; males with pro and meso tarsomeres expanded into rounded or oval palette with adhesive setae ventrally…………………………………....**4**

2' Eyes anterolaterally emarginated; pro and mesotarsomeres in males not forming a palette ventrally, instead bears adhesive setae ……………..………..………..……**5**

3 Protarsi pseudo tetramerous in both sexes (IVth tarsomere small and concealed within lobes of IIIrd); prosternum strongly declivitous (prosternal process in different from medial part of prosternum) ………... …….………. **Hydroporinae**

3' Protarsi pentamerous (tarsomere IIIrd not lobed; tarsomere IV distinct); prosternum not strongly declivitous but, anterior margin of prosternum may be in different plane from ventral surface of head ……………………..………………………...**6**

4 Metatibial spur with similar size and shape……………………. **Dytiscinae** (in part)

4' Metatibial spur with different size and shape, anterior spur wider and acuminated apically…………………………………..……………………….…..**Cybistrinae**

5 Metatarsal claws equal in length or nearly equal, metacoxal lines very close or absent ……………………………………..………………...……**Copelatinae**

5' Metatarsal claws not equal in length, anterior claw longer than posterior claw, metacoxal lines distinct but not closely approximated…..……..……**Colymbetinae**

6. Metatarsus with a single claw; anteroapical margin of metatarsomeres I-IV distinctly lobed …………………...**Laccophilinae**

6' Metatarsus bears two claws; posteroapical margin of metatarsomeres I-IV not lobed………………………………………………........…………**Dytiscinae**

3.4.2.2 Key to the genera of the subfamilies

3.4.2.2.1 Key to the genera of the subfamily Colymbetinae

1 Apical margin of metatarsomeres I-IV sinuate, apically lobed; prosternal process carinate; narrow medial pronotal beads; metatibia with a linear series of setigerous punctures ……..………………………………………..……………. ***Rhantus***

1' Apical margin of metatarsomeres I-IV neither sinuate nor apically lobed; prosternal process flat; medial pronotal beads absent; metatibia covered with setigerous punctures ……….……………………………………………………..**others**

3.4.2.2.2 Key to the genera of the subfamily Copelatinae.

1 Metacoxal lines distinct, visible/ rarely obscured; dorsal surface with longitudinal striae ………..……………………………………………….…….…***Copelatus***

1' Metacoxal lines absent; dorsal surface smooth without striae ………. ***Lacconectus***

3.4.2.2.3 Key to the genera of the subfamily Cybistrinae

1 Meso tarsomeres of males and pro and meso tarsomeres of females with a series of setae at the posteroventral apical margin; males with VIIIth abdominal sternum emarginated at medial margin; metatarsal claw single, females with one or two metatarsal claws (if two posterior claw small)……………………..……... .***Cybister***

1' Pro and meso tarsomeres of both sexes without a series of setae at the posteroventral apical margin; males with medial margin of VIIIth abdominal sternum straight; males and females with two metatarsal claws…………… **Others**

3.4.2.2.4 Key to the genera of the subfamily Dytiscinae

1 Anterior margin of metaventrite straight or slightly concave…………..…. ***Hydaticus***

1' Anterior margin of metaventrite not straight………………………….. ***Sandracottus***

3.4.2.2.5 Key to the genera of the subfamily Hydroporinae

1 Elytra strongly carinated …………………………….………..…………….**2**

1' Elytra not strongly carinated ………………………..…………………….…..**3**

2 Presence of prominent discal carinae ………………..…………………... ***Peschetius***

2' Prominent discal carina absent……….……………………………………***Yola***

3 Prosternal process reaching anterior margin of metaventrite……………………..…**4**

3' Prosternal process not reaching anterior margin of metaventrite……………….……..**5**

4 Prosternal process with distinct medial prominence……………………...***Microdytes***

4' Prosternal process without distinct medial prominence………………….***Hyphydrus***

5 Basal pronotal and basal elytral striae present…………………..……………..…. **6**

5' Basal pronotal and basal elytral stria absent…………………….....……***Hydrovatus***

6 Sutural striae present………………………………..………………***Hydroglyphus***

6' Sutural striae absent…………………………………………………..***Clypeodytes***

3.4.2.2.6 Key to the genera of the subfamily Laccophilinae

1 Prosternal process apically trifid………………..……………………..***Neptosternus***

1' Prosternal process not apically trifid……………………..……..……***Laccophilus***

3.4.2.3 Key to the species of genera

3.4.2.3.1 Key to the species of genus *Rhantus*

1 Median lobe of aedeagus moderately curved, narrowed at the apical region, slightly bended inward just before the rounded tip ((Vazirani, 1970a)……………………….
…………………………………………………….….…***Rhantus* cf *taprobanicus***

2' Median lobe of aedeagus not moderately curved, narrowed near the apical region, slightly bended inward just before the rounded tip …………..……..………**Others**

3.4.2.3.2 Key to the species of genus *Copelatus*

1 Elytral striae 11+1…………………………………………………………...**2**

1' Elytral striae 6+1…………………………………………………………**4**

2 6th elytral stria not shortest…………………………...……..…***Copelatus boukali***

2' 6th elytral stria shortest…………………………………………………...………**3**

3 Median lobe less strongly curved in lateral view; prominent denticle present at the tip……..……………………..……………………………………***Copelatus davidi***

3' Median lobe sickle-shaped in lateral view; denticle absent at the tip………………..
....***Copelatus neelumae***

4 Median lobe without a ventral projection …......................***Copelatus cryptarchoides***

4' Median lobe with ventral projection ……………………………………...…..**5**

5 Median lobe with a finger-like ventral projection…………………***Copelatus oblitus***

5' Median lobe with a spoon-like ventral projection……………..***Copelatus sociennus***

3.4.2.3.3 Key to the species of genus *Lacconectus*

1 Median lobe of aedeagus strongly curved in lateral view and constant in width …….

…………..……….…………………………………………..***Lacconectus satoi***

1' Median lobe of aedeagus evenly curved in lateral view and not constant in width….

……………………………………………………………………..……..**2**

2 In lateral view median lobe broadened at the middle……… .***Lacconectus blandulus***

2' In lateral view, median lobe is broadened after middle up to just before……………

apex……………….……………...……….……………***Lacconectus regimbarti***

3.4.2.3.4 Key to the species of genus *Cybister*

1 Median lobe with its apical region in the form of a tubular spine ………………..….**2**

1' Median lobe with the apical region not in the form of a tubular spine……………..**3**

2 More or less uniform in width from base to just after midlength; apical $^1/_3$ of the

length of median lobe narrowed to form tubular spine………....…***Cybister posticus***

2' Median lobe uniform only at the base, gradually widen up to the midlength; apical

$^1/_4{}^{th}$ of the length of median lobe narrowed in the form of a tubular spine………...

…………………………………………….…...…………….***Cybister sugillatus***

3 Apex of yellow lateral line on elytra slightly hooked………………………………...

…………………………………………………….……***Cybister tripunctatus lateralis***

3' Apex of yellow lateral line on elytra not hooked…………………………………….

……….…………………………………………………………………..………………**4**

4 Yellow lateral line submarginal and narrowed towards posterior, not touching the suture….. …………………………………………………..…..***Cybister confusus***

4' Yellow lateral line marginal and uniformly broad towards the apex, touching the suture…... …………………...………………………………..…***Cybister cardoni***

3.4.2.3.5 Key to the species of the genus *Hydaticus*

1 Presence of yellow lateral line on elytra …… …… …… …... ……………………**2**

1' Yellow lateral line absent …… …… …… …… …… ….. …… ……… …… ….**3**

2 Species with dark reddish- brown colouration……….…… …… …… ….. …… ..**4**

2' Species with black colouration……… … …… ..….. …… …… …… …… ……..**5**

3 Median lobe straight with two tufts of small hairs at the tip……... ***Hydaticus ricinus***

3' Median lobe slightly curved with a small bristle plate at the apex…… …… …… …...…...…….…….….…….….…….….……….….……… …***Hydaticus incertus***

4 Median lobe apically less broadened ……………..…....…… ***Hydaticus luczonicus***

4' Median lobe well broadened apically…..……...………...…… ***Hydaticus discindens***

5 Humeral and submarginal stripes do not merge; submarginal stripe broad and ends before midlength; humeral stripe extends up to the apex……***Hydaticus bipunctatus***

5' Humeral and submarginal stripes join after midlength and extend up to the apex ….………… ……………………………… ……… … ..………***Hydaticus vittatus***

3.4.2.3.6 Key to the species of the genus *Sandracottus*

1 Penis nearly rectangular at apical two third; narrowed at base, apex bifurcate with a

'V' shaped notch ………………………………………….… …***Sandracottus festivus***

1' Penis not rectangular at apical two third; base not narrowed, apex without a 'V' shaped notch ……..… ………………..……………………………………**Others**

3.4.2.3.7 Key to the species of the genus *Clypeodytes*

1 Elytra ferruginous with distinct black markings; median lobe with a pointed tip…………………………………………………………………..***Clypeodytes* cf *feryi***

1' Elytra fawn coloured without distinct black bands; median lobe with a rounded tip ………..……………………………………………….….……… ***Clypeodytes bufo***

3.4.2.3.8 Key to the species of the genus *Hydroglyphus*

1 Elytra testaceous with transverse black bands, median lobe narrowed only at apical one fifth..…..…….……….…..…………….….………. ***Hydroglyphus flammulatus***

1' Elytra testaceous with two longitudinal black bands ending in a crochet shape apically, median lobe gradually narrowed to the apex…………………………….. …………………………………………….………. ***Hydroglyphus pendjabensis***

3.4.2.3.9 Key to the species of the genus *Leiodytes*

2 Median lobe with an abruptly broadened apical region……..***Leiodytes orissanensis***

2' Median lobe without an abruptly broadened apical region ……...……...…..**Others**

3.4.2.3.10 Key to the species of the genus *Peschetius*

1 Head black except testaceous occipital region……...………..***Peschetius toxophorus***

1' Head ferruginous or pale ferruginous with or without blackish colour patterns…….. ………………………………………………………….…………………...……**2**

2 Median lobe of aedeagus ‘C’ shaped and abruptly narrowed from the midlength …...

towards the apex ……………………………………..…………………………..**3**

2' Median lobe gently curved and gradually narrowed towards the apex………………

…………………………..……………………………..***Peschetius quadricostatus***

3 Lateral lobes of aedeagus broad at base narrowing towards the apex; apical part

club- shaped; hairs from the midlength to the apex..…………. ***Peschetius bistroemi***

3' Lateral lobe broad, basally lateral sides parallel, narrowing towards a club shaped

apex, hairs on apex dense, hairs at midlength sparse……. ***Peschetius taprobanicus***

3.4.2.3.11 Key to the species of the genus *Yola*

1 Elytra testaceous with three transverse black bands; median lobe moderately curved

and broadest in the middle..…..…...…..…..…..…..…..…..……..***Yola consanguinea***

1' Elytra not testaceous with three transverse black bands; median lobe not

moderately curved and broadest in the middle…………………………………..**Others**

3.4.2.3.12 Key to the species of the genus *Hydrovatus*

1 Elytra black; elytral markings reddish-yellow, never black……***Hydrovatus cardoni***

1' Elytra reddish brown to dark brown; with or without black markings, markings

never yellow…………………………………..……………..………..……….**2**

2 Median lobe evenly curved, ‘C’ shaped ……………………………………………**3**

2' Median lobe not distinctly curved and ‘C’ shaped……………………..………..**4**

3 Ventral margin evenly curved up to the tip in lateral view .... ***Hydrovatus picipennis***

3' Ventral margin straight at the tip in lateral view …………… ***Hydrovatus rufoniger***

4 Median lobe after midlength more or less straight in lateral view and abruptly narrow into a pointed apex turned slightly inwards....……...***Hydrovatus seminarius***

4' Median lobe in lateral view apical $^1/_3$rd slightly bend inwards and narrowed into a curved pointed apex……………………….....………..……***Hydrovatus confertus***

3.4.2.3.13 Key to the species of the genus *Hyphydrus*

1 Elytra ferruginous with black markings; lateral margins of median lobe emarginated after the base in dorsal view (Biström, 1982)……….……..***Hyphydrus intermixtus***

1' Elytra testaceous with black markings; lateral margins of median lobe not emarginated after the base in dorsal view …………………….. ***Hyphydrus renardi***

3.4.2.3.14 Key to the species of the genus *Microdytes*

1 Reddish brown with yellow diffuse maculae anteriorly and posteriorly on elytra and laterally on pronotum; Median lobe more or less equal in width throughout, slightly narrowed near the apical region with a abruptly widened tip (Miller and Wewalka, 2010) ……………………..…………………………...…***Microdytes cameroni***

1' Colouration not reddish brown with yellow diffuse maculae anteriorly and posteriorly on elytra and laterally on pronotum; Median lobe not equal in width throughout, not narrowed near the apical region with a abruptly widened tip ………..…………………………………………………………...…….**Others**

3.4.2.3.15 Key to the species of the genus *Laccophilus*

1 Small species; aedeagus with a ventral lobe …………...….…***Laccophilus anticatus***

1' Large species; aedeagus without a ventral lobe…………………………….....……..**2**

2 Elytra reddish-yellow with posterior half dark; absence of distinct elytral markings

………........……………………………….……..……***Laccophilus flexuosus***

2' Elytra not reddish-yellow; elytral markings present……………………...……...**3**

3 Elytral markings consists of three yellow fasciae………..……………..…………..**4**

3' Elytral markings are not fasciae……………………….….…………………...**5**

4 Fascia on elytra consists of confluent spots ………………. ***Laccophilus auropictus***

4' Fascia on elytra does not consists of confluent spots……….…***Laccophilus elegans***

5 Elytral markings are irrotations ….………..………………………………..…**7**

5' Elytral markings are not irrotations …………………………………………..… **6**

6 Elytra pale red…………………………………...…………***Laccophilus ellipticus***

6' Elytra testaceous with long double black lines…………………..…***Laccophilus sharpi***

7 Median lobe with sharp pointed tip……………….……….***Laccophilus inefficiens***

7'Median lobe without a sharp pointed tip……………………………………………**8**

8 Apical region of median lobe distinctly narrowed………..……***Laccophilus obtusus***

8' Apical region of median lobe not distinctly narrowed…...…..***Laccophilus parvulus***

3.4.2.3.16 Key to the species of the genus *Neptosternus*

1 Median lobe of aedeagus moderately curved…………………………….…….**2**

1' Median lobe of aedeagus not curved…………………...……...………...…….…**3**

2 Median lobe curved at midlength with a pointed apex…………***Neptosternus kerala***

2' Median lobe curved just before midlength with rounded apex ……………………...

……………………………………………………………….….***Neptosternus boukali***

3 Lateral margin of median lobe curved in ventral view…..…..***Neptosternus annettae***

3' Lateral margin of median lobe not curved in ventral view (Hendrich and Balke, 2000)……..………………………………………...……..…….***Neptosternus leyi***

3.5 Discussion

The current study recorded 53 species of diving beetles under six subfamilies and 16 genera. Two species are first reports from India and eight from South India. Twenty-three species were recorded for the first time from Kerala. One subfamily (Colymbetinae) and three genera (*Rhantus* & *Clypeodytes*) are also first reports from Kerala.

The genus *Clypeodytes* contains 40 species, of which 31 species belongs to subgenus *Clypeodytes*. Species of this subgenus are mainly distributed in Africa and Asia (Nilsson, 2001). The species *Clypeodytes feryi* has been reported from Western and Northern parts of Australia (Hendrich & Wang, 2006). Identification of this species in this study is based only on the morphology and the features of genitalia of the specimens collected. These features correspond well to that of *Clypeodytes feryi* recorded from Australia. But as Kerala and Australia are widely separated regions, the occurrence of *Clypeodytes feryi* in India needs to be confirmed using molecular methods and also by collaborations with museums in Germany and Australia where the type specimens are stored for comparisons. In the context of this study, it has been reported as first record of (*Clypeodytes* cf *feryi*) from India.

Clypeodytes feryi has been reported in stagnant or slow-moving aquatic habitats with a substratum of sand, gravel or decaying vegetation in Australia. The species was reported from several places in Australia having tropical climatic conditions with distinct wet and dry seasons. In Kerala, during this study, the species was mostly collected from similar habitats. The climatic condition of Kerala– wet tropical climate with seasonal heavy rainfalls leading to the formation of temporary and seasonal freshwater habitats were very similar to those sites in Australia from which *C. feryi* was collected. In Kerala, the specimens of this species were collected in this study from muddy puddles, paddy fields, streamlets, remnant pools in drying rivers, edges of ponds and reservoirs where there is a muddy substratum. Since the sequencing of the specimens of *Clypeodytes* cf *feryi* from India in the current study was unsuccessful, further gene sequencing and comparisons are need to confirm if the specimens collected are indeed *C. feryi* or a completely different species which has evolved independently.

Peschetius cf *taprobanicus* is another first report from India. Twelve species are known under the genus *Peschetius* (Nilsson & Hájek, 2024) of which four species had been reported from India (Sheth *et al.*, 2021). *Peschetius taprobanicus* was first described from Sri Lanka Biström and Bergsten in 2015 and has not been reported till date from anywhere else (Sheth *et al.*, 2021). Thus, the report from Kerala, India is a range extension of the species. In addition, insights into the habitats of *P. taprobanicus* could also be obtained during the current study. The type specimen and the specimens of the current study were collected from under 100 MASL indicating its preference for low altitude regions.

Considering the first reports, eight species recorded in this study are first reports from South India. Of which *Copelatus oblitus* and *Copelatus sociennus* were recorded under genus *Copelatus*. *Copelatus oblitus* was first described from Singapore (Sharp, 1882). Four species and one subspecies in *Copelatus* were later synonymised with *Copelatus oblitus* (Hendrich *et al.* 2004; Sheth *et al.* 2018). After the first description in 1952, *Copelatus karnatakus* was synonymised with it (Sheth, Ghate and Hájek, 2018). In India, both the species showed a cosmopolitan distribution with reports ranging from northern and southern India and Andaman & Nicobar Islands (Ghosh and Nilsson, 2012; Sheth *et al*., 2018)

In the genus *Cybister*, *C. cardoni* as well as *C. posticus* are new reports from South India. C. *cardoni* was known only from Jharkhand (Severin, 1890) till this study. Jharkhand experiences a hotter and drier climate when compared to the wet tropical climate in Kerala. This indicate that *C. cardoni* could have much wider distribution than what is known now. Its conspecific species *C. posticus* is also widely distributed from the rest of India. Unlike the previous species, *C. posticus* is very widely distributed in India.

Hydaticus incertus is a species which can be easily misidentified as *Hydaticus fabricii*. Ghosh and Nilsson's catalogue (2012) based on previous studies shows its distribution in Northern, Western as well as Central India (Ghosh & Nilsson, 2012). During fieldwork, this species was commonly found all over Kerala, but is being recorded for the first time in the state as well as in South India.

On one hand there is a possibility that the catalogue may have given wrong distributions as it is based on previous studies. On the other hand, the phenomenon of a commonly seen species never being formally reported indicates the lack of dedicated studies.

H. picipennis and *H. rufoniger* are new records for South India in the genus *Hydrovatus*. The genus *Hydrovatus* was mostly recorded from small and temporary habitats. The species were very frequently found. *Hydrovatus picipennis* was the largest species of the genus observed in this study. Till date, this species was known only from the lowlands of Kolkata, West Bengal (Vazirani, 1970a). In the present study, this species was recorded from midlands as well as coastal plains. This indicates a geographical range extension and also extension of known information about habitats suitable for the genus.

Genus *Leiodytes* is a new record for Kerala. *Leiodytes orissaensis* was known from the Eastern and Western parts of India (Vazirani, 1969 & 1977a,c). The species under this genus was first described under the genus *Clypeodytes* but later transferred to the genus *Leiodytes* (Biström 1988).

Copelatus neelumae, *Cybister confusus*, *Cybister sugillatus*, *Cybister tripunctatus lateralis*, *Hydaticus discindens*, *Hydaticus luczonicus*, *Sandracottus festivus*, *Clypeodytes bufo*, *Hydroglyphus pendjabensis*, *Microdytes cameroni*, *Yola consanguinea*, *Laccophilus elegans* and *Laccophilus auropictus* are all the new reports from Kerala state.

From Kerala, only three species were known under the genus *Copelatus* (Mukherjee & Sengupta, 1986; Hendrich & Balke, 1998; Vazirani, 1970 b). This study could report three additional species in this genus from Kerala. *Copelatus neelumae* shows variable elytral colouration and is found only in the southern states of India. (Sheth *et al.*, 2018). Specimens of the current study were darker but similar in other aspects to specimens reported from Goa and Maharashtra.

Cybister confusus is distributed all over the country except the Northern region (Ghosh & Nilsson, 2012). In south India they had been reported from Karnataka and Tamil Nadu (Nahar, 2004), but this is the first time the species is being reported from Kerala. On the other hand, *C. sugillatus* and *C. tripunctatus lateralis* were considered to be wide spread in India (Ghosh and Nilsson, 2012), but had not yet been reported from Kerala till date.

From Kerala, only four species (*Hydaticus bipunctatus*, *Hydaticus histrio Hydaticus ricinus* and *Hydaticus vittatus*) were known under genus *Hydaticus* (Mukherjee & Sengupta, 1986). Based on this study the number of *Hydaticus* species has increased to seven. *Hydaticus discindens*, *Hydaticus incertus* & *Hydaticus luczonicus* are new reports for Kerala. Previously *Hydaticus discindens* was known only from the southern and eastern parts of India, while *Hydaticus luczonicus* was widespread in India especially in Kerala.

Sandracottus is a widespread species in the Southeast Aia and Australia (Miller & Bergsten, 2016). Thus far three species were known from Kerala (*S. dejeani*, *S. vijayakumari* & *S. mixtus*) (Anandh et.al., 2021; Deb & Subramanian, 2023). *S. festivus* was added as a new report from Kerala through this study. According to Ghosh & Nilsson (2012), *S. festivus* was more or less widely distributed in all other regions of India.

In addition to *Clypeodytes* cf *feryi*, *C. bufo* is also been recorded under the genus *Clypeodytes*. *C. bufo* was previously reported from northeastern, eastern, southern and western states of India (Ghosh & Nilsson, 2012). In South India, Tamil Nadu is the only state with a previous report of the species.

Hydroglyphus is a genus which can be found in a variety of habitats and are abundant (Miller & Bergsten, 2016) *Hydroglyphus pendjabensis* is one of the two species recorded under the genus *Hydroglyphus*. *H. pendjabensis* was previously reported only from Andhra Pradesh & Tamil Nadu states of South India (Ghosh & Nilsson, 2012). In this study they found only in remnant muddy puddles of paddy fields and was frequently were observed with *H. flammulatus.* There is no previous data on the habitat of this species. found coexisting with *Hydroglyphus flammulatus*.

Microdytes is a species-rich genus that is distributed throughout southern and southeastern Asia. *Microdytes svensoni* and *Microdytes belli* were already been recorded from Kerala (Miller &Wewalka, 2010). In this study, *Microdytes cameroni* was the only species recorded under that genus. *M. cameroni* was previously reported from Karnataka (Ghosh & Nilsson, 2012).

The genus *Yola* is distributed in southern & central Europe, Africa, Madagascar, India as well the Southern Arabian Peninsula (Miller & Bergsten, 2016). The genus and species *Yola consanguinea* are being recorded for the first time from Kerala. Previous reports indicate *Yola consanguinea* being present in the eastern, western and southern regions of India (Ghosh & Nilsson, 2012). In South India, it was only known from Andhra Pradesh. The range of the elytral colouration of the species varies from red-brown to dark brown (Miller & Wewalka, 2010). Specimens collected during the study had a reddish-brown colouration.

Laccophilus elegans is distributed in the northeastern, eastern and southern states of India. In south India, it was reported only from Andhra Pradesh and Karnataka. *Laccophilus auropictus* was only seen in south India (Karnataka & Tamil Nadu). *L. elegans* as well as *L. auropictus* are new records to Kerala.

Many of the species reported in this study were collected from temporary pools rather than from their previously known permanent habitats. This indicates the ability of many species to disperse. They leave their permanent freshwater habitats to find newly formed seasonal temporary habitats and migrate back to their permanent habitats (Hilsenhoff, 1986).

For many of the species already reported from Kerala, the details of collection such as locality and habitat data were not provided. Only the most recent studies provide such information. The data generated from the current study provides habitat, locality, morphology and genitalic information on the species collected. This could serve as a baseline for further taxonomic and biodiversity studies.

Of the 51 species previously recorded in Kerala (Manivannan & Madani, 2011; Ghosh & Nilsson, 2012; Wewalka, 2017; Anand et al., 2021; Sheth et al., 2021; Deb & Subramanian, 2023), 23 species were not observed in this study.

In summary, the study had many first reports and geographical range extensions. Species which are commonly found all over the country and also in the state had not been formally reported. This indicates the lack of sustained and extensive study to further understand the diversity and distribution of this marvellous group of insects.

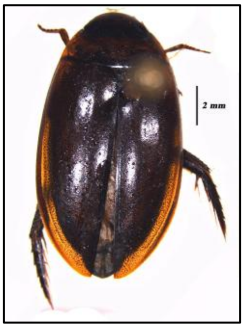
3.6 Conclusion

Fifty-three species collected were studied. Detailed descriptions of each species has provided. Details of habitat and locality of species and its distribution in India are also provided. Taxonomic keys for the identification of collected species were prepared up to species-level.

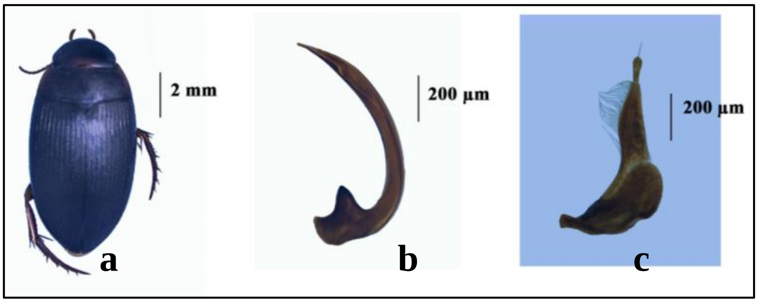
PLATE- 4

DIVING BEETLES RECORDED DURING THE STUDY

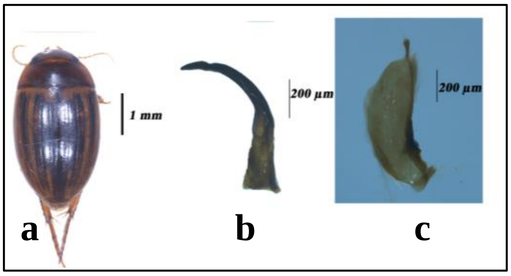
PLATE 4- Diving Beetles Recorded During the Study



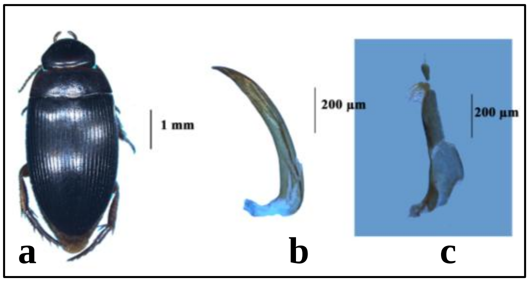
4 (1). *Rhantus* cf. *taprobanicus*



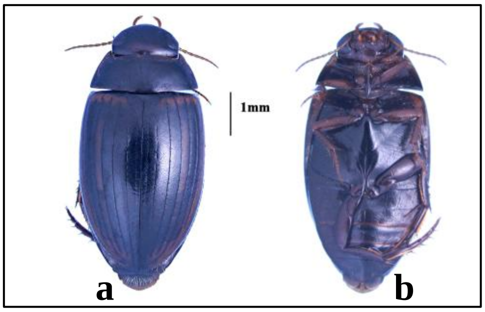
4 (2). *Copelatus boukali*



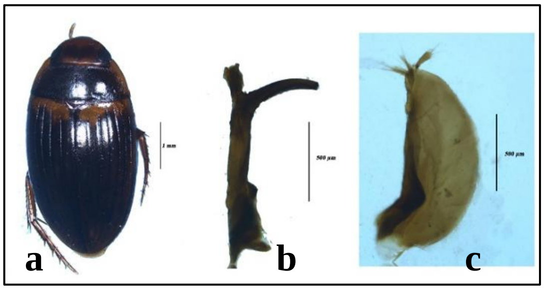
4 (3). *Copelatus cryptarchoides*



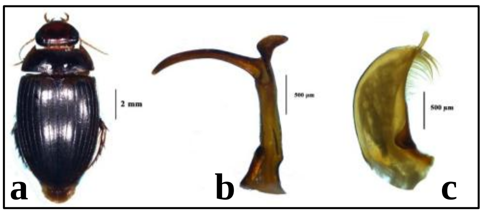
4 (4). *Copelatus davidi*



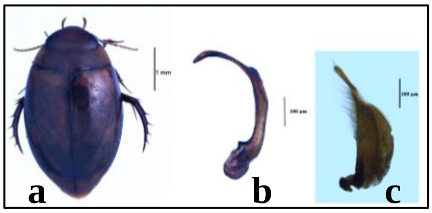
4 (5). *Copelatus neelumae*



4 (6). *Copelatus oblitus*

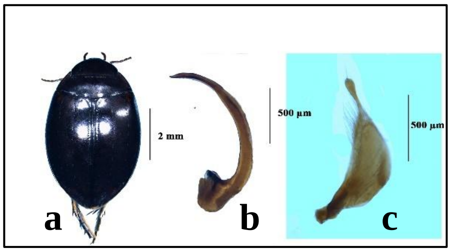


4 (7). *Copelatus sociennus*

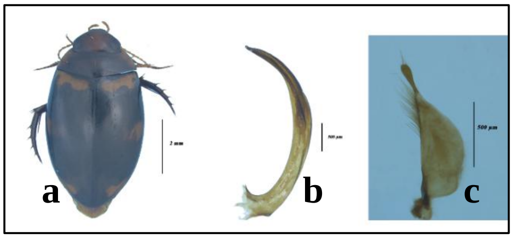


4 (8). *Lacconectus blandulus*

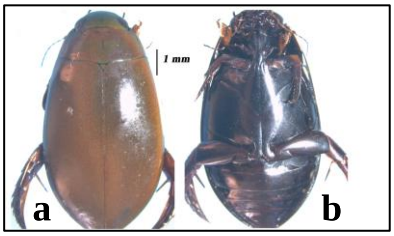
PLATE 4- Diving Beetles Recorded During the Study



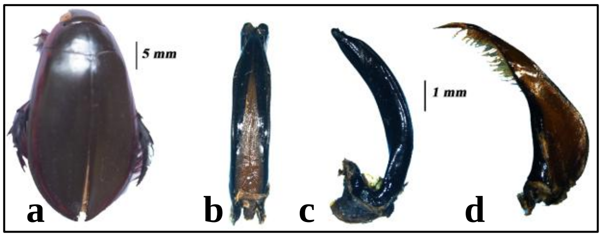
4 (9). *Lacconectus satoi*



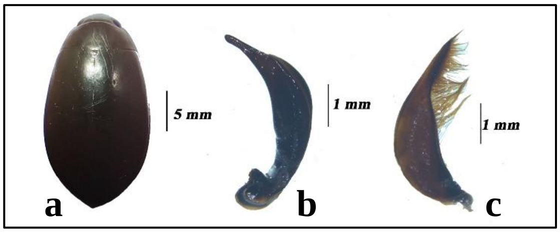
4 (10). *Lacconectus regimbarti*



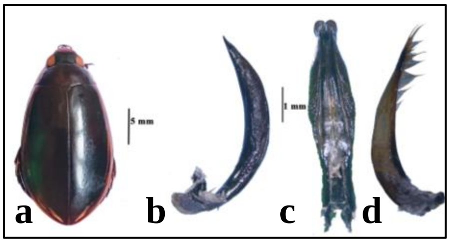
4 (11). *Cybister cardoni*



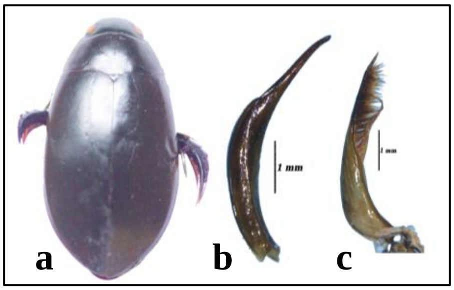
4 (12). *Cybister confusus*



4 (13). *Cybister sugillatus*



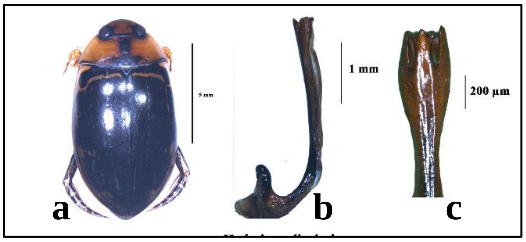
4 (14). *Cybister t. lateralis*



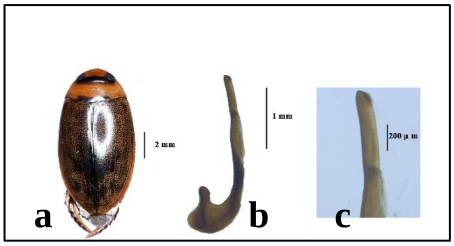
4 (15). *Cybister posticus*

4 (16). *Hydaticus bipunctatus*

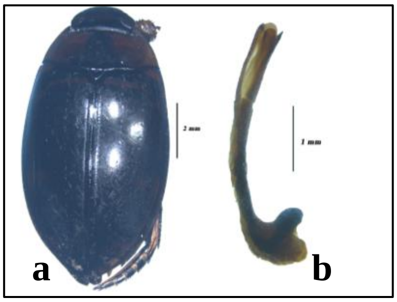
PLATE 4- Diving Beetles Recorded During the Study



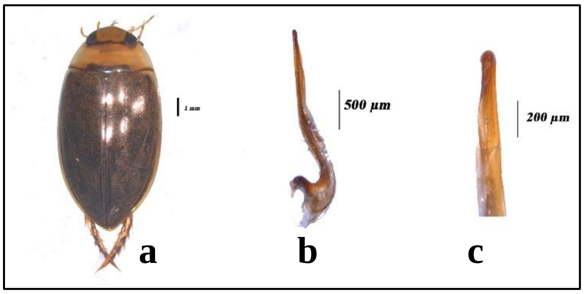
4 (17). *Hydaticus discindens*



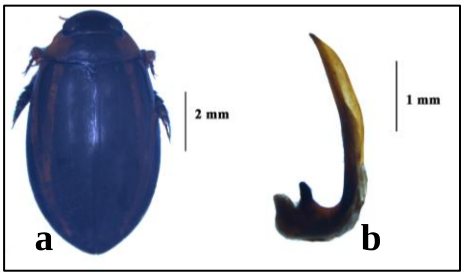
4 (18). *Hydaticus incertus*



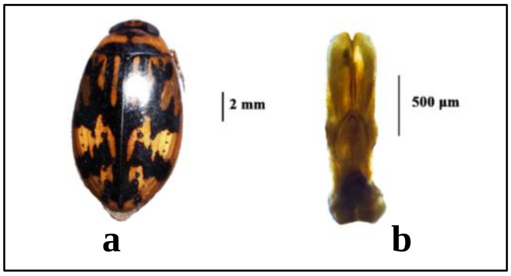
4 (19). *Hydaticus luczonicus*



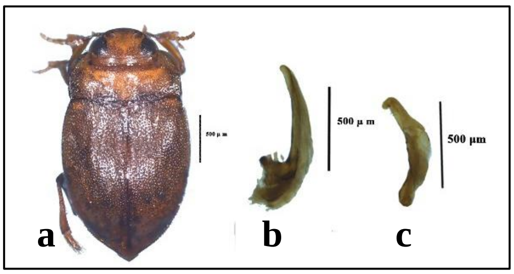
4 (20). *Hydaticus ricinus*



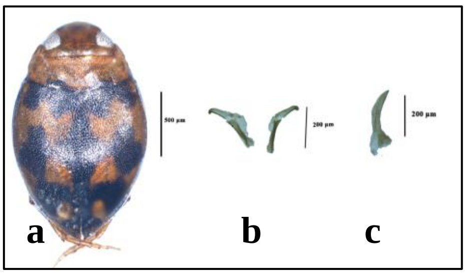
4 (21). *Hydaticus v.* vittatus



4 (22). *Sandracottus festivus*

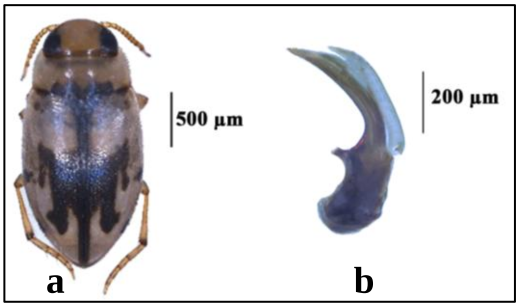


4 (23). *Clypeodytes bufo*

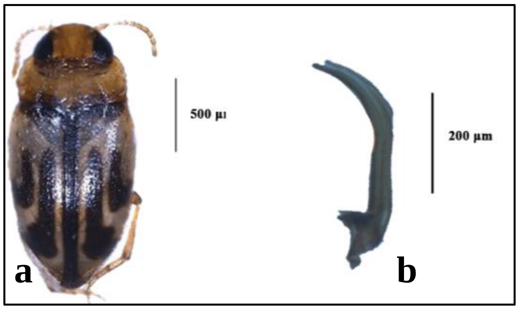


4 (24). *Clypeodytes* cf *feryi*

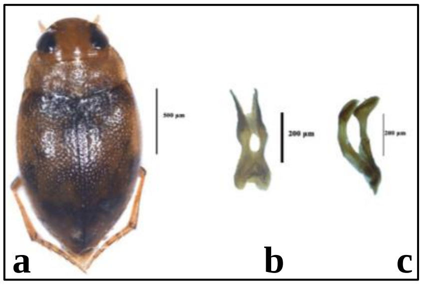
Plate 4. Diving Beetles Recorded During the Study



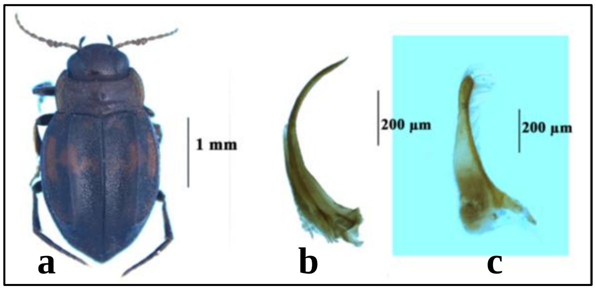
4 (25). *Hydroglyphus flammulatus*



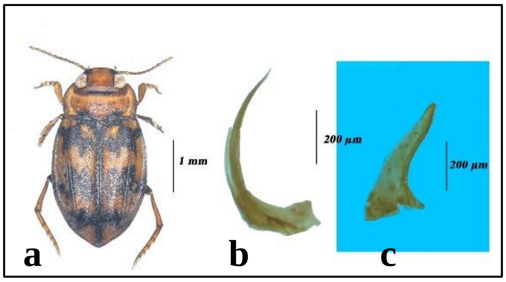
4 (26). *Hydroglyphus pendjabensis*



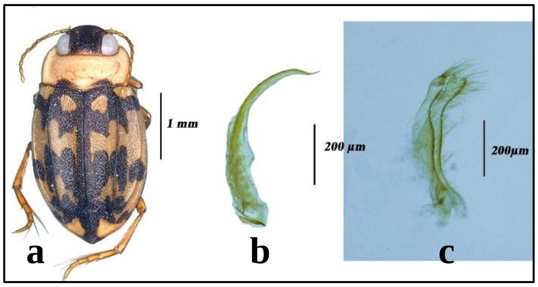
4 (27). *Leiodytes orissaensis*



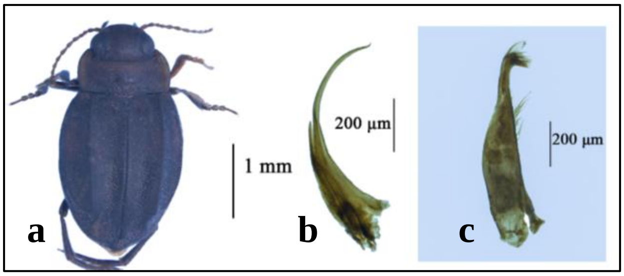
4 (28). *Peschetius bistroemi*



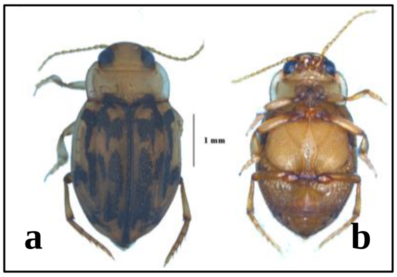
4 (29). *Peschetius quadricostatus*



4 (30). *Peschetius toxophorus*

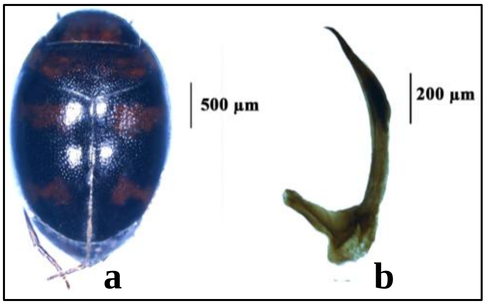


4 (31). *Peschetius taprobanicus*

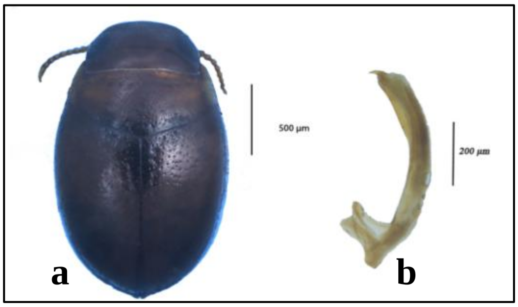


4 (32). *Peschetius* sp.

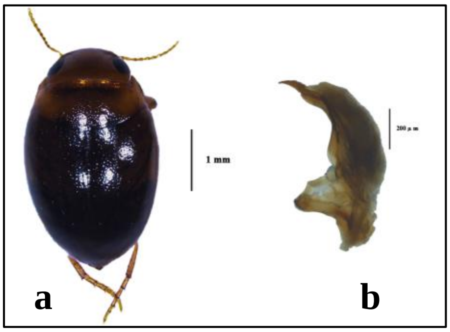
Plate 4. Diving Beetles Recorded During the Study



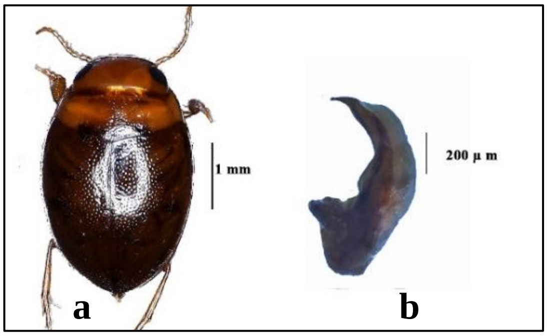
4 (33). *Hydrovatus cardoni*



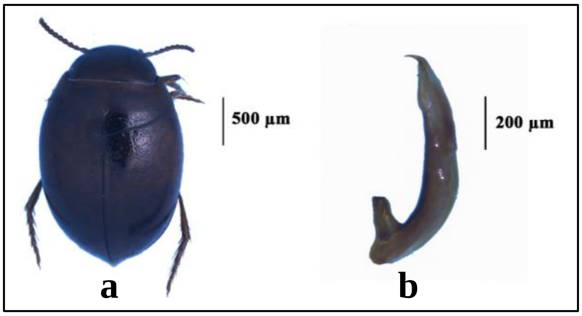
4 (34). *Hydrovatus confertus*



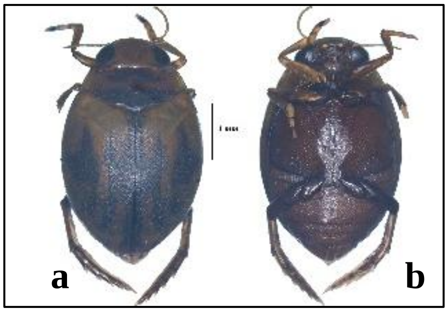
4 (35). *Hydrovatus picipennis*



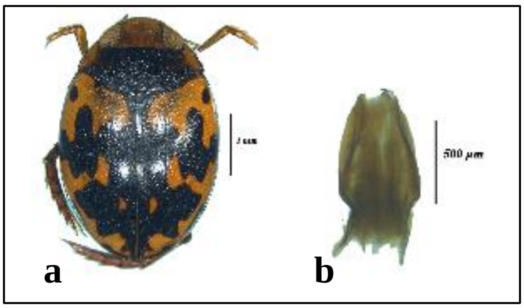
4 (36). *Hydrovatus rufoniger*



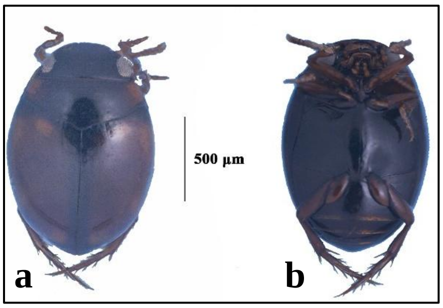
4 (37). *Hydrovatus seminarius*



4 (38). *Hyphydrus intermixtus*

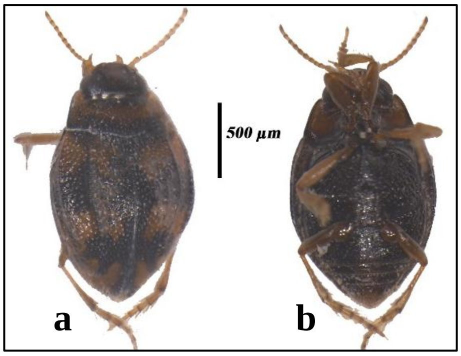


4 (39). *Hyphydrus renardii*

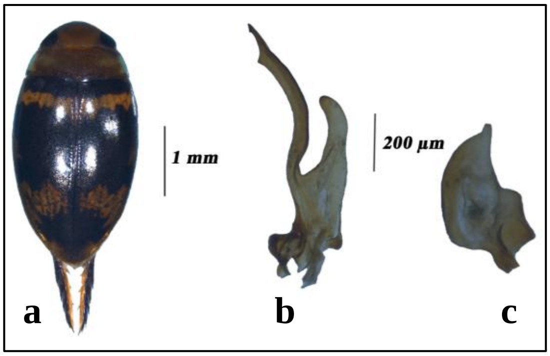


4 (40). *Microdytes cameroni*

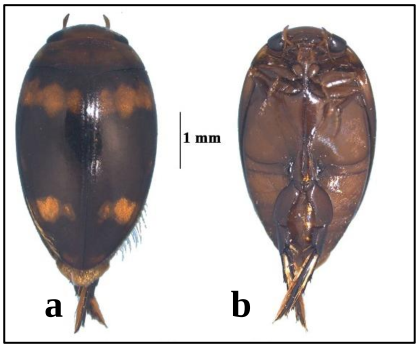
Plate 4. Diving Beetles Recorded During the Study



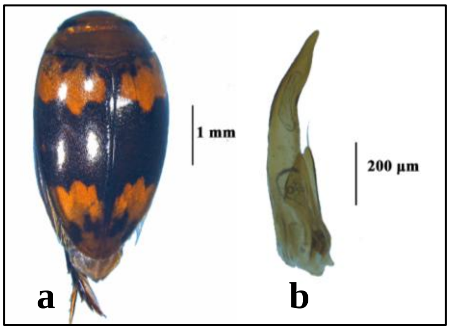
4 (41). *Yola consanguinea*



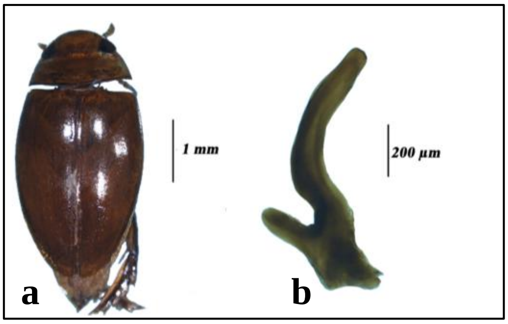
4 (42). *Laccophilus a. anticatus*



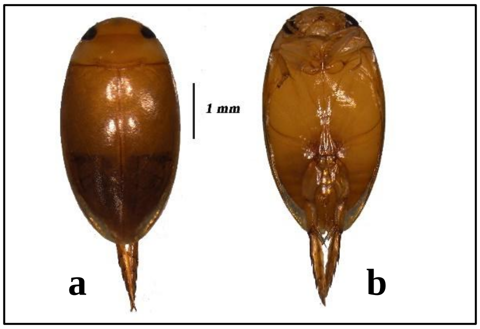
4 (43). *Laccophilus auropictus*



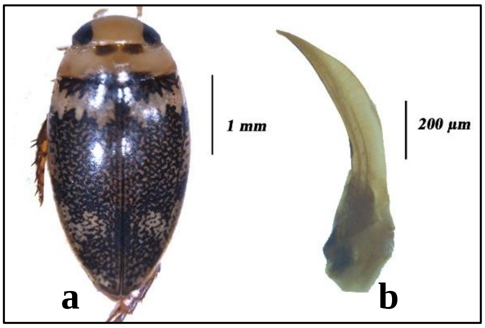
4 (44). *Laccophilus elegans*



4 (45). *Laccophilus ellipticus*



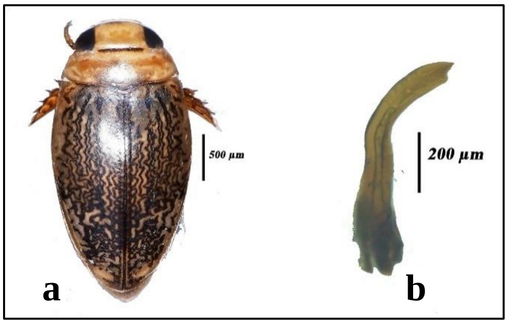
4 (46). *Laccophilus flexuosus*



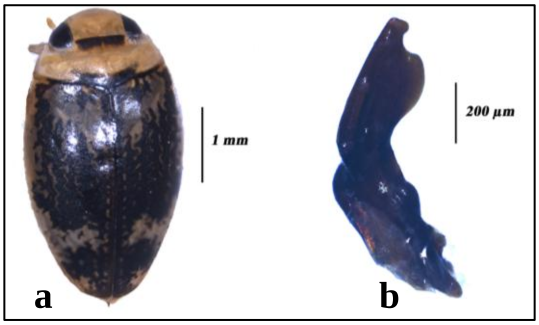
4 (47). *Laccophilus inefficiens*

4 (48). *Laccophilus p. parvulus*

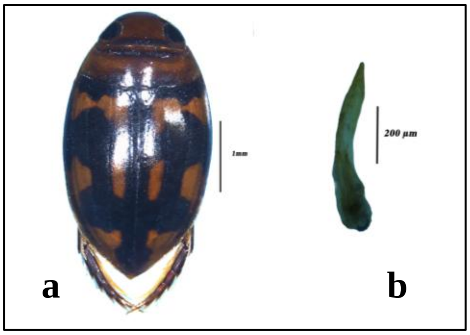
Plate 4. Diving Beetles Recorded During the Study



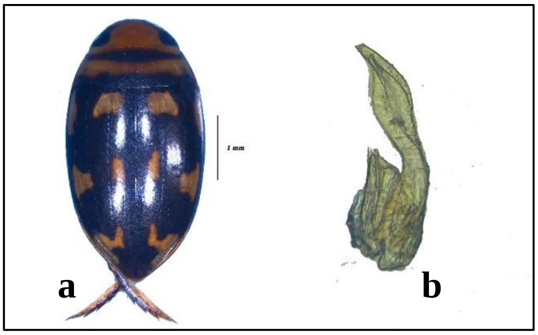
4 (49). ***Laccophilus p. obtusus***



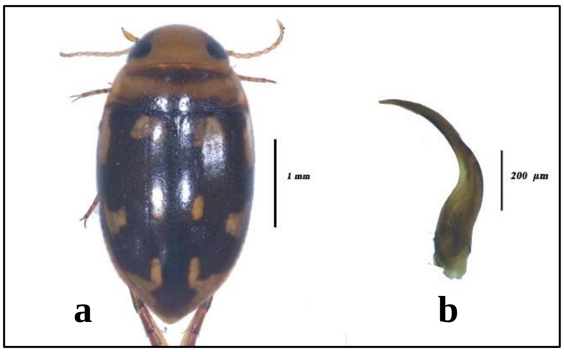
4 (50). ***Laccophilus sharpi***



4 (51). ***Neptosternus annettae***



4 (52). ***Neptosternus boukali***



4 (53). ***Neptosternus kerala***

4 (54). ***Neptosternus leyi***

PLATE- 5

HABITATS

PLATE 5- Habitats

5 (1). Remnant rock pool in river bed (Shantharuvi)

5 (2). Remnant rockpool in river bed (Kallar)

5 (3). Remnant pool in a ditch (Kallar)

5 (4). Rock pool in river bed (Adivaram)

5 (5). Muddy puddle (Darbha)

5 (6). Remnant rock pool in a river bed (Moonnekkar)

5 (7). Remnant rock pool in a stream bed (Padagiri)

5 (8). Remnant rock pool in river bed (Puthuppariyaram)

PLATE 5- Habitats

5 (9). Remnant rock pool on a river bed (Puthukkad)

5 (10). Remnant rock pool in a river bed (Puthukkad)

5 (11). Remnant rock pool in a river bed (Puthukkad)

5 (12). Remnant rock pool on a river bed (Padinjarathara)

5 (13). Remnant pool in a river bed (Manikkadavu)

5 (14). Remnant rock pool in a waterfall (Edumbapalam)

5 (15). Remnant rock pool in a river bed (Vayathur)

5 (16). remnant rock pool in a river bed (Vayathur)

PLATE 5- Habitats

5 (17). Remnant pool in a waterfall (Vellad)

5 (18). Remnant rock pool in a waterfall (Kanjiramkolli)

5 (19). Remnant pool in a waterfall (Marottichal)

5 (20). Remnant rock pool in river bed (Kothamangalam1)

5 (21). Remnant rock pool in river bed (Kodenjery)

5 (22). Remnant rock pool in a river bed (Chembukadavu)

5 (23). Ephemeral pool (Cheppara)

5 (24). Rain water-fed plastic container (Assarikkadu)

PLATE 5- Habitats

5 (25). Remnant pool in an abandoned ditch (Nileswaram (Mundemmad Road)

5 (26). Muddy puddle (Assarikkadu)

5 (27). Remnant pool in road-side drain (Manjumala)

5 (28). Leaf-choked remnant rock pool in a waterfall

5 (29). Small hill-side pool (Kamakshi)

5 (30). Remnant rock pool in a river bed (Urulanthanni)

5 (31). Remnant rock pool in a stream bed (Pazhampyllichal)

5 (32). Small pool (Kollengode south)

PLATE 5- Habitats

5 (33). Remnant rock pool in a waterfall (Vellad)

5 (34). remnant pool in a streamlet (Chittur)

5 (35). Remnant rock pool in a stream bed (Vellachal)

5 (36). Spring-fed rock pool (Kuttikkanam)

5 (37). Muddy puddle (Punnala)

5 (38). Stagnant water in a road-side drainage (Mankayam)

5 (39). Rock pool (Pazhayakunnummel)

5 (40). Remnant pool in a streamlet (Thalikkode)

PLATE 5- Habitats

5 (41). Spring-fed pool (Peermade)

5 (42). Spring-fed pool (Peermade)

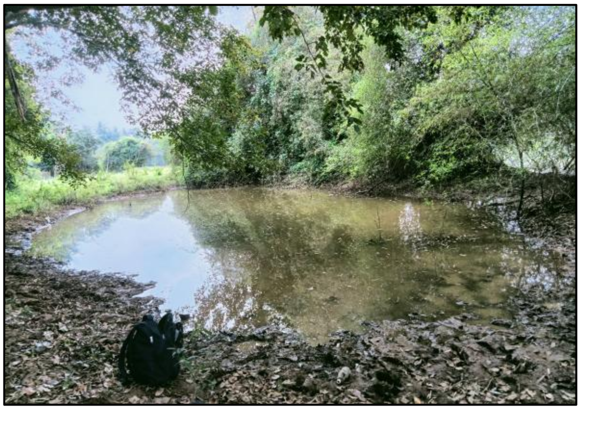
5 (43). Margin of the plunge pool of a waterfall (Peerumade)

5 (44). Remnant pool in a waterfall (Kodom)

5 (45). Margin of a river (Kolathur)

5 (46). Remnant pool in a river (Kanjiramkolli)

5 (47). Pool in an abandoned paddy field (Malavayal)



5 (48). Pond in the floodplain of a river (Thenmavinkadavu)

PLATE 5- Habitats

5 (49). Stream (Poomala)

5 (50). Pool in an abandoned paddy field (Naduvannur)

5 (51). Pool in an abandoned paddy field (Palazhi)

5 (52). Pond with rocky bottom (Cheppara)

5 (53). Ephemeral pool on road-side (Ezhukone)

5 (54). Rock pool (Muttara)

5 (55). Quarry pond (Vilappilsala)

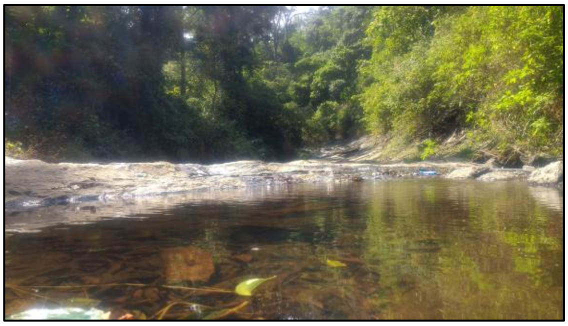
5 (56). Abandoned paddy field (Iringal)

PLATE 5- Habitats

5 (57). Abandoned ditch(Thottuppoyil)

5 (58). Small pool (Murukkumpara)

5 (59). Small pool (Murukkumpara)



5 (60). Remnant pool in river bed (Cheriyar)

5 (61). Ditch in agricultural field(Pazhupathur)

5 (62). Rock pool (Panavally)

5 (63). Remnant pool in a ditch
(Vythiri)

5 (64). Remnant pool in a well
(Assarikkadu)

PLATE 5- Habitats

5 (65). Remnant pool in a streamlet (Thalikkode)

5 (66). Muddy puddle (Pavumba)

5 (67). Small pool (Ezhukone)

5 (68). Abandoned ditch (Sasthamkotta)

5 (69). Small pool (Venkode)

5 (70). Rock pool (Panavally)

5 (71). Ditch in an abandoned paddy field (Thavinhal)

5 (72). Remnant rock pool in a waterfall (Kudiyanmala)

PLATE 5- Habitats


5 (73). Remnant rock pool in a waterfall (Kudiyanmala)


5 (74). Remnant rock pool in a waterfall (Kudiyanmala)


5 (75). Remnant pool in a stream (New Naduvil)


5 (76). Ephemeral pool (New Naduvil)


5 (77). Margin of a river (New Naduvil)


5 (78). Margin of a river (Puthussery)


5 (79). Remnant pool in a streamlet (Palchuram)


5 (80). Pool in an abandoned paddy field (Purameri)

PLATE 5- Habitats

5 (81). Margin of a stream (Pappadi)

5 (82). Pool in abandoned paddy field (Aikkaranadu)

5 (83). Roadside ditch (Manjumala)

5 (84). Pool on a mud road (Thanneermukkom)

5 (85). Remnant pool in a streamlet (Mukkada)

5 (86). Remnant rock pools in a stream (Mukkada)

5 (87). Rock pool (Chepra)

5 (88). Ephemeral pool (Kizhakkekallada)

PLATE 5- Habitats

5 (89). Rock pool (Muttara)

5 (90). Pool on a mud road (Valiyode)

5 (91). Road-side ditch (Cheenikkala)

5 (92). Ditch (Kuttimoodu)

5 (93). Pond (Neyyar)

5 (94). Rock pool (Oduvallithattu)

PLATE 5- Habitats

5 (95). Rock pool (Ayyampuzha)

5 (96). Rock pool (Murukkumpara)

5 (97). Rock pool (Ayyampuzha)

5 (98). Ditch in agricultural field (Karette)

5 (99). Rock pool (Padinjarathara)

5 (100). Muddy puddle in a dirt road (Darbha)

5 (101). River margin (Perikkallur)

5 (102). Irrigation canal (Maneed)

PLATE 5- Habitats

5 (103). Muddy puddle on dirt road (Maneed)

5 (104). Muddy puddle (Kottakkavala)

5 (105). Margin of a river (Mulappuram)

5 (106). Ditch in abandoned paddy field (Chenkulam)

5 (107). Spring –fed pool (Kudavattoor)

5 (108). Pool in abandoned paddy field (Kaithode)

5 (109). Pool in abandoned paddy field (Chaliyakkara)

5 (110). Pond (Cheruvathur)

PLATE 5- Habitats


5 (111). Pool in an abandoned paddy field (Shiriya)


5 (112). Paddy field (Chiranellur)


5 (113). Muddy puddle (Vettithara)


5 (114). Ephemeral pool (Kalavoor)


5 (115). Paddy field (Kunnumma)


5 (116). Ditch (Sasthamkotta)


5 (117). Margin of a reservoir (Kallikkad)


5 (118). Paddy field (Panayara)

PLATE 5- Habitats

5 (119). Pool in an abandoned paddy field (Arai bridge)

5 (120). Ditch in agricultural field (Arai Kadavu)

5 (121). Paddy field (Kariyamkode)

5 (122). Rock pool (Kolathur)

5 (123). Margin of a river (Kottody)

5 (124). Muddy puddle (Majibial)

PLATE 5- Habitats

5 (125). Muddy puddle(Manjeswaram)

5 (126) Pool in abandoned paddy field (Pallikkara II)

5 (127). Remnant pool in a pond (Panayal)

5 (128). Remnant pool in an irrigation canal (Puthiyavalapu)

5 (129). Pool in the floodplains of a river (Vavadukkam)

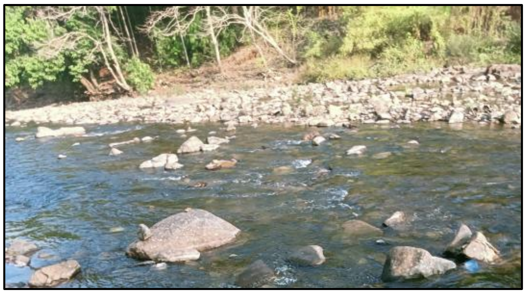
5 (130). Remnant rock pool in a waterfall (Kalliad)

PLATE 5- Habitat

5 (131). Pool in abandoned paddy field (Madathil)

5 (132). Abandoned ditch (Vallyad)

5 (133). Remnant pool in a stream (Kalpetta)



134. Margin of a river (Kottiyur)

5 (135). Rock pool (Mananthavady)

5 (136). Paddy field (Padichira)

5 (137). Paddy field (Pazhupathur)

5 (138). Ditch in agricultural field (Purameri)

PLATE 5- Habitats

5 (139). Pool in abandoned paddy field (Thamarassery)

5 (140). Ephemeral pool (Chembikkal)

5 (141). Puddle (Thottuppoyil)

5 (142). Paddy field (Manchira)

5 (143). Muddy puddle (Neerakkode)

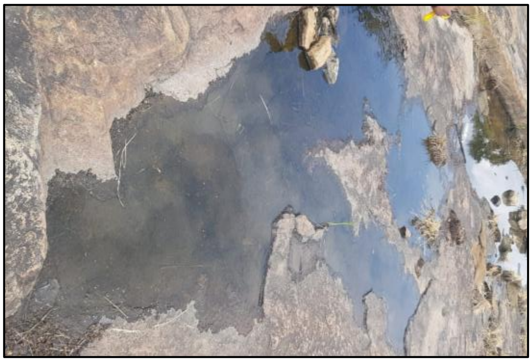
5 (144). Remnant pools in a river (Parali)

5 (145). Remnant pool in a river (Parali)

5 (146). Margin of a river (Parudur)

PLATE 5- Habitats

5 (147). Paddy field (Thalur)



5 (148). Rock puddle (Viruthi)

5 (149). Margin of a river (Yakkara)

5 (150). Paddy field (Adat)

5 (151). Paddy field (Adat)

5 (152). Paddy field (Adat)

5 (153). Paddy field (Chembuthra)

5 (154). Remnant pool in irrigation canal (Darbha)

PLATE 5- Habitats

5(155). Muddy puddle at margin of a river Kannamkuzhy)

5 (156). Paddy field (Mullur)

5 (157). Ephemeral pool (Murukkumpara)

5 (158). Remnant pool in paddy field (Nandhikkara)

5 (159). Ephemeral pool (Pariyaram)

5 (160). Rock pool (Peechi)

5 (161). Margin of a reservoir (Peechi)

5 (162). Margin of a stream (Pullu)

PLATE 5- Habitats

5 (163). Paddy field (Pullu)

5 (164). Pool in abandoned paddy field (Aikkaranadu)

5 (165). Rock puddle (Elanji)

5 (166). Pond (Karikkattupadi)

5 (167). Ditch in abandoned paddy field (Karingachira)

5 (168). Muddy puddle (Memury)

5 (169). Paddy field (Nechoor)

5 (170). Margin of a stream (Piravom)

PLATE 5- Habitats

5 (171). Paddy field (Edathua)

5 (172). Ephemeral pool (Kalavoor)

5 (173). Pool (Govindamuttom)

5 (174). Ephemeral pool (Kayamkulam)

5 (175). Paddy field (Kidangara)

5 (176). Ditch (Valady)

5 (177). Pool in abandoned paddy field Varanad)

5 (178). Margin of Stream(Kadamuri)

PLATE 5- Habitats

5 (179). Stream (Kangazha)

5 (180). River margin (Kulathurmuzhy)

5 (181). Pool in the floodplains of a river (Peroor)

5 (182). Pool in abandoned paddy field (Kurumbanadam)

5 (183). Pool (Vellavoor)

5 (184). Ditch in abandoned paddy field (Angadickal)

5 (185). Pond margin (Manthuka)

5 (186). Ditch (Chenkulam)

PLATE 5- Habitats

5 (187). Muddy puddle (Kummil)

5 (188)). Ditch (Malackal)

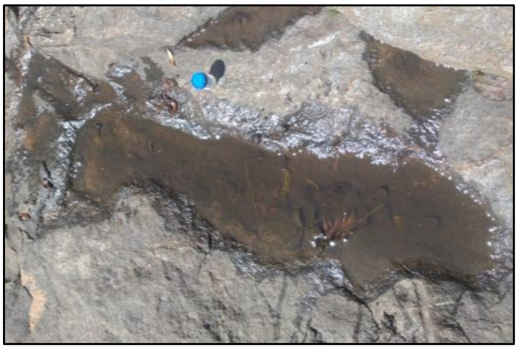
5 (189). Margin of reservoir (Neyyar)

5 (190). Muddy puddle (Palai)

5 (191). Pool in abandoned
paddy field (Pantha)

5 (192). Small pool (Vithura)

5 (193). Muddy puddle (Erattayar)



5 (194). Rock puddle (Kollengode South)

PLATE 5- Habitats

5 (195). Ephemeral pool (Kunnam)

5 (196). Abandoned stream (Ithithanam)

5 (197). Ephemeral pool (Kallara)

5 (198). Muddy puddle (Kanjiramkolli)

5 (199). Margin of a stream (Valiya Paramba)

5 (200). Remnant pool in a stream (Chittur)

5 (201). Quarry pond (Punnachuvadu)

5 (202). Pool (Thalikkode)

PLATE 5- Habitats

5 (203). Remnant pools in a waterfall (Pampakkuda)

5 (204). Remnant pools in a stream (Kuzhimattom)

5 (205). Ditch in agricultural field (Purameri)

5 (206). Margin of a stream (Mangalpady)

5 (207). Rock pool (Chuttippara)

5 (208). Abandoned paddy field (Kumaranellur)

5 (209). Ephemeral pool (Kundukad)

5 (210). Stream (Pathiramanal)

PLATE 5- Habitats

5 (211). Ditch in agricultural field (Elappuram)

5 (212). Ditch in agricultural field (Elappuram)

5 (213). Abandoned pond (Irinjayam)

5 (214). Abandoned pond (Ponganadu)

5 (215). Rock pool (Vilappil)

5 (216). Muddy puddle (Kanhangad)

5 (217). Abandoned paddy field (Iringal)

5 (218). Abandoned paddy field (Kozhukkallur)

PLATE 5- Habitats

5 (219). Ephemeral pool (Murukkumpara)

5 (220). Quarry pond (Cheppara)

5 (221). Lake (Vellayani)

5 (222). Garden pool (Assarikkadu)

5 (223). Abandoned paddy field (Thalap)

5 (224). Muddy puddle (Payyoli)

5 (225). Road-side drainage (Azhutha)

5 (226). Small pool (Nellanad)

PLATE 5- Habitats


5 (227). Remnant pool in a river (Vayathur)


5 (228). Muddy puddle (Purameri)


5 (229). Margin of a river (Kumbalakkode)


5 (230). Ditch (Perumpanachy)


5 (231). Small pool (Perumpanachy)


5 (232). Small pool (Vakathanam)


5 (233)Small pool (Choondakkulam)


5 (234). Spring-fed pool (Peermade)

PLATE 5- Habitats

5 (235). Remnant pool in a ditch (Brimore)

5 (236). Pond (Nagalassery)

5 (237). Pond (Chinganchira)

5 (238). Paddy field (Chowallur)

5 (239). Ditch (Kodali)

5 (240). Ephemeral pool (Nedumudi)

PLATE 5- Habitats

5 (241). Rock pool (Kummil)

5 (242). Abandoned pond (Elevanchery)

5 (243). Stream (Punnala)

CHAPTER- 4

PHYLOGENETIC ANALYSIS OF FAMILY DYTISCIDAE BASED ON COI GENE SEQUENCES

4. Phylogenetic analysis of family Dytiscidae based on COI gene sequences

4.1 Introduction

Beetles constitute the most biodiverse animal order with over 380 000 described species and possibly several million more yet unnamed. Recent phylogenomic studies have arrived at considerably incongruent topologies and widely varying estimates of divergence dates for major beetle clades (Cai, 2022). The beetle superfamily Dytiscoidea, placed within the suborder Adephaga, comprises six families. The phylogenetic relationships of these families, whose species are aquatic, remain highly contentious (Vasilikopoulos *et al*, 2019). Many previous studies on the phylogeny of the Dytiscidae family have shown discrepancies between morphological characteristics and molecular data (Oh *et al*, 2024). DNA barcoding is a taxonomic method that uses a short genetic marker in an organism's DNA to identify at the species level. Several loci have been suggested, but the mitochondrial cytochrome oxidase 1 (COI) gene proposed by Hebert *et al*. (2003) is the most commonly used marker. Due to the conserved nature of COI gene its sequencing and comparison has become a popular, easily accessible and relatively cheap tool for identification or confirmation of species identity. But (Mc Donagh *et al*, 2016) conducted a study where phylogenies were constructed for nine insect orders and three outgroups, using 12 protein-coding genes and two rRNA genes; 153 genomes were analysed and trees were constructed using PhyML They found that no single gene appeared to outperform all others and recommended that phylogenetic reconstructions of insect relationships use a multi-gene approach, using as many genes and taxa as possible.

4.1.1 Phylogenetic Studies on Family Dytiscidae

Molecular studies on the phylogenetic relation within the family Dytiscidae have provided valuable insight into the evolutionary relationships of the members of the family. The findings of such studies question the placement and composition of certain subgroups within Dytiscidae, such as *Hydroporini*, *Bidessini*, and *Coptotomus* (Alarie & Watts, 2005).

Comprehensive studies on phylogenetics of Dytiscidae at a broader level include Miller & Bergsten (2014), whose work included a large number of species and genera and sequence data of four genes.

Phylogeny of Dytiscidae have been studied using larval morphology, chaetotaxy and gene sequences (Wolfe, 1988; Alarie and Nisson, 1997; Alarie *et al*., 2000; Miller, 2001 & 2003; Alarie *et al*., 2002; Ribera *et al*., 2002 & 2003; Balke and Ribera, 2004; Michat, 2006; Miller *et al*., 2007; Alarie and Michat, 2007; Michat *et al*., 2007; Michat, 2008; Michat and Alarie., 2008; Alarie *et al*., 2009; Michat and Alarie, 2009; Alarie *et al*., 2011; Hernando *et al*., 2012; Alarie and Michat, 2014; Michat *et al*., 2015; Sheth *et al*., 2021; Miller and Bergsten, 2014). The scope and resources of this study permitted phylogenetic tree construction only using COI sequences. While it is understood that the reconstructions of relationship using single gene may not be accurate, it would serve as a baseline data as no similar study has been conducted in the study area.

4.2 Review of Literature

In addition to Miller & Bergsten (2014), who conducted a comprehensive study using four gene fragments and included a large number of species and genera, phylogenetic studies on Dytiscidae have been conducted in the United States, Germany, Brazil, Turkey, China and Australia. The most relevant studies are mentioned below.

Drotz (2003) investigated the diversification of population of *Agabus wollastoni* and *A*. *bipustulatus*. The two species are morphologically similar and are under the *Agabus tristis* group. The analysis was done based on partial mtDNA cytochrome b (Cyt b) sequences, allozymes and landmark-based morphometrics. Population genetic and morphological variation of *A. wollastoni* was compared to *A. bipustulatus.* The results of maximum parsimony analysis of the Cyt b sequences showed that both the *A. bipustulatus* and *A. wollastoni* specimens form well-supported monophyletic groups.

Balke *et al*. (2004b) conducted a phylogenetic and biogeographic analysis of subfamily Copelatinae based COI (cytochrome oxidase I), Cyt b (cytochrome b), and 16S rRNA gene sequences from 50 species. They found out that subfamily

Copelatinae is monophyletic and is not sister to any others in the family Dytiscidae. Genus *Copelatus* was paraphyletic with *Lacconectus* and *Aglymbus*. The subgenus *Papuadytes* of the genus *Copelatus* was sister to all other species in Copelatinae. So, it was proposed to elevate the status of *Papuadytes* to genus level. Two Western Palaearctic *Copelatus* were removed and assigned the genus name *Liopterus*. Asian species were paraphyletic with respect to Oriental *Lacconectus*, which was grouped with a clade of Neotropical species. Asian species were also paraphyletic with respect to a species from Sulawesi which was grouped with the species from New Guinea. Afrotropical and New Guinean + Australian species of *Copelatus* were monophyletic.

Miller *et al*. (2007) studied the phylogenetic relationships among members of the tribe *Cybistrini* based on 47 adult and larval morphological characters and partial COI (cytochrome oxidase I), COII (cytochrome oxidase II), H3 (histone III) and wnt (wingless) gene sequences from 33 species. The analysis revealed the monophyly of *Cybistrini*. Results also showed that only some of the historically recognized subgenera or species groups were monophyletic in the genus *Cybister*. The subgenus *Sternhydrus* Brinck was elevated to genus rank. Four new subgenera were recognized in the genus *Cybister*. (*C. (Melanectes*) Brinck, *C. (Megadytoides)* Brinck, *C. (Neocybister)* Miller, Bergsten and Whiting and *C. (Cybister)* Curtis, *Trochalus* Dejean, and *Scaphinectes* Ádám were synonymised to *Cybister (Cybister)*. Since *Cybister parvus* Trémouilles did not fit into any genus group, it is retained in the genus *Cybister* but is considered *incertae sedis* with respect to its subgenus.

Ribera *et al*. (2008) studied phylogenetic relations in diving beetles based on the sequences of SSU, COI, H3 and rrnL gene fragments from 222 species under 116 genera and 25 tribes. They obtained 28 well-supported lineages corresponding to the tribes or group of genera. Polyphyly of the subfamily Dytiscinae, grouping *Pachydrini* with *Bidessini*, *Peschetius* with *Methlini* and *Coptotomus* within Copelatinae, monophyly of all Australian *Hydroporini* (*Necterosoma* group), and the sister relationship of *Laccophilini* with Copelatinae and *Cybistrini* were some of the major findings.

Miller *et al*. (2009) conducted a phylogenetic analysis of tribe *Hydaticini* both morphological and multigene molecular data and found *Hydaticini* to be monophyletic. At generic level they elucidated the paraphyletic relationship of genus *Hydaticus* Leach to *Prodaticus* Sharp and the subgenus *H. (Guignotites)* Brinck to *Prodaticus* Sharp, *H. (Pleurodytes)* Régimbart and *H. (Hydaticinus)* Guignot. The subgenus *Hydaticus (Hydaticus)* was determined to be monophyletic.

Bilton *et al*. (2017) investigated the evolutionary relationships between populations and subspecies of *Hydroporus necopinatus* and the related *Hydroporus melanarius*. They found a discrepancy between morphology and variations in mitochondrial DNA sequence. They proposed that *H. melanarius* and *H. necopinatus sstr*. could be hybridogenic origin as opposed to defining distinct evolutionary lineages. Such discrepancies could also be because COI evolves comparatively slower than nuclear genes which could limit its effectiveness in making a distinction between closely related species.

Angus *et al*. (2015) studied the evolutionary relationship of the Western Palaearctic species of the genus *Boreonectus* based on mitochondrial COI gene sequences and found that it formed a well-supported monophyletic clade. *Boreonectes emmerichi* was positioned as the sister species to the North American forms of *B*. *griseostriatus* (De Geer, 1774) with low support.

The only molecular study on the phylogeny of Dytiscidae from India was carried out by Sheth *et al*. (2021) where the relatedness between the species of the genus *Peschetius* using COI gene and morphological data revealed the presence of four species in the genus *Peschetius* from India, including one species that remained unrecognised for more than 100 years.

4.3 Materials and Methods

Out of the 53 species identified during the study, 33 species were selected for mitochondrial COI gene sequencing. They belong to 10 genera and five subfamilies. A minimum of one or two species were randomly selected from each genus. Required supplementary sequences were downloaded from NCBI GenBank database.

4.3.1 Sample Preparation

DNA Isolation and PCR amplification was done using standard protocols from specimens stored in 70% ethyl alcohol. For large specimens a single metathoracic leg was detached using forceps. The entire specimen was used for small specimens.

4.3.1.1 Isolation of Genomic DNA

Genomic DNA was isolated from the tissue samples using NucleoSpin® Tissue Kit (Macherey-Nagel) following the manufacturer's instructions.

1. Tissues were kept in a microcentrifuge tube of 1.5 ml capacity and 180 µl of T1 buffer and 25 µl of proteinase K were added to the tube. The contents were incubated at 56°C in a water bath to let the tissue be completely lysed.
2. After this, 5 µl of RNase A (100 mg/ml) was added to the tube and incubated for 5 minutes at room temperature.
3. To the content in the microcentrifuge tube, 200 µl of B3 buffer was added and incubated for 10 minutes at 70°C.
4. To this, 210 µl of 100% ethanol was added and vortexed to mix the content thoroughly
5. Later the mixture was pipetted into a NucleoSpin® Tissue column placed in a 2 ml collection tube followed by centrifugation for one minute at 11000 x g.
6. NucleoSpin® Tissue column was placed in another 2 ml tube.
7. Column was washed with 500 µl of BW buffer.
8. Column was washed again with 600 µl of B5 buffer.
9. NucleoSpin® Tissue column was transferred into a clean 1.5 ml tube.
10. DNA was eluted using 50 µl of BE buffer.

4.3.1.2 DNA Quality Check Using Agarose Gel Electrophoresis

1. 0.8% agarose gel was prepared in 0.5X TBE (Tris-Borate-EDTA) buffer having 0.5 µg/ml ethidium bromide.
2. To 5µl of DNA, added 1µl of 6X gel-loading buffer (0.25% bromophenol blue, 30% sucrose in TE buffer pH-8.0).
3. Then the samples were loaded to the agarose gel.

4. Electrophoresis was performed (at 75 V with 0.5X TBE as electrophoresis buffer) till the bromophenol dye front had migrated to the bottom of the gel.
5. UV transilluminator (Genei) was used to visualize the gel.
6. Images were taken under UV light with the help of Gel documentation system (Bio-Rad).

4.3.1.3 COI Gene Amplification

Primers used for COI gene amplification were chosen from literature (Folmer *et al*., 1994). The chosen primers were customised from Sigma, diluted to a concentration of 10 pM/µl and was used for PCR to amplify the COI gene. Details of the primer sequences are given in Table 3. The PCR reaction mix and the cyclic conditions used are given in the Tables 4 & 5. Conditions of the PCR were optimised using different concentrations of reagents at temperatures ranging from 54-66°C. The PCR amplification was performed in a PCR thermal cycler (GeneAmp PCR System 9700, Applied Biosystems)

Table 3. Details of primers used for COI gene amplification

Target	Primer Name	Direction	Sequence (5' →3')
COI	LCO	Forward	GGTCAACAAATCATAAAGATATTGG
	HCO	Reverse	TAAACTTCAGGGTGACCAAAAAATCA

Table 4. PCR mix used for amplification of COI gene

Sl. No.	Constituents	Quantity
1.	2X Phire Master Mix	5 µL
2.	D/W	4 µL
3.	Forward Primer	0.25 µL
4.	Reverse Primer	0.25 µL
5.	DNA	1µL
	Total	10.5 µL

Table 5. PCR Conditions optimised for amplification of COI gene

Sl. No.	Step	Temperature (0C)	Time	Number of cycles
1.	Initial denaturation	98°C	30 Sec	1
2.	Denaturation	98°C	5 Sec	10
3.	Annealing	45°C	10 Sec	
4.	Extension	72°C	15 Sec	
5.	Denaturation	98°C	5 Sec	30
6.	Annealing	50°C	10 Sec	
7.	Extension	72°C	15 Sec	
8.	Final extension	72°C	60 Sec	1
9.	Hold	4°C	∞	

4.3.1.4 Agarose Gel Electrophoresis

1.2% agarose gels were prepared with 0.5X TBE buffer containing 0.5 µg/ml ethidium bromide. 4 µl of the PCR products were mixed with 1 µl of 6X loading dye and loaded in well along with a 2-log DNA ladder (NEB). Electrophoresis was run at 75V power supply for about 1-2 hours with 0.5X TBE as electrophoresis buffer. Electrophoresis was performed till the bromophenol blue front had migrated to almost the bottom of the gel. The gels were visualized in a UV transilluminator (Genei). The image was taken under UV light with the aid of a Gel documentation system (Bio-Rad).

4.3.2 Sequencing

Sequencing of respective PCR products was done commercially at the National Centre for Biotechnology, Trivandrum. It was carried out in an automated DNA sequencer based on Sanger's dideoxy chain termination sequencing method. Forward as well as reverse sequences were sequenced. Final complete sequences were obtained in FASTA as well as AB1 file formats containing chromatogram.

4.3.3 Analysis of Sequences Obtained

Chromatograms were checked and final quality of the sequences was analysed. Twelve sequences had to abandoned due to less than expected quality. Better quality sequences were processed with the help of different Bioinformatics tools. The 'Reverse Complement' bioinformatics tool was used to get the reverse complement of the reverse sequence. The reverse complement thus obtained and the forward sequence were run in the 'Emboss Merger'. This allows the overlapping nucleic acids to merge into one (Bell & Kramvis, 2013). NCBI's BLAST (Basic Local Alignment Search Tool) was used to check the similarity of the resultant sequences with other nucleotide sequences in the database. Then the 'Expasy' translate tool was used to translate the COI gene sequences into amino acid sequences in order to find premature stop codons occurring through sequencing errors.

4.3.4 Retrieval of Additional Sequences

For the construction of the tree of family Dytiscidae, sequences of different genera under the family were searched in the GenBank database. Available sequences were downloaded. Sequences with good product size were considered for analysis (Table. 6). The sequences were checked for alignment with the sequences generated from the study using Clustal Omega alignment tool. The sequences from the study were mostly consisting of base pairs from 1-700. But many sequences in the public database had base pairs not aligning to this region, hence such sequences were not selected.

Table 6. List of additional sequences downloaded from GenBank and used to construct phylogenetic tree at family level

Sl. No	Species	Accession Number	Size(bp)	Subfamily
1.	*Cybister vulneratus*, Sweden	KP280095	1285 bp	Cybistrinae
2.	*Sandracottus mixtus*, Thailand	KF979027	1305 bp	Dytiscinae
3.	*Sandracottus bakewellii*, Australia	KF979059	1296 bp	
4.	*Sandracottus insignis,* Philippines	KF979028	1308 bp	

Sl. No	Species	Accession Number	Size(bp)	Subfamily
5.	*Sandracottus guerini*, Papua New Guinea	KF979061	1282 bp	
6.	*Leiodytes frontalis*, Japan	LC727250	658 bp	Hydroporinae
7.	*Leiodytes migrator*, Germany	MZ209001	727 bp	
8.	*Clypeodytes meridionalis*, Germany	FJ819628	658 bp	
9.	*Hydroglyphus japonicus*, Japan	LC727242	658 bp	
10.	*Dineutus indicus*, India	KF638572	658 bp	Outgroup

4.3.5 Construction of Phylogenetic Tree

The molecular phylogenetic trees was constructed using MEGA 11 (Molecular Evolutionary Genetics Analysis version 11) software. The sequences were aligned in MEGA by using MUSCLE alignment program. The aligned sequences were saved in MEGA format. Then the best fitting model was found. Model with a lowest BIC (Bayesian Information Criterion) value was considered for tree construction. The substitutional models available in MEGA are General Time Reversible (GTR), Tamura–Nei, Hasegawa–Kishino–Yano, Tamura-3-Parameter, Kimura-2-Parameter, Tajima–Nei and Jukes–Cantor (Tamura *et al*. 2011). The phylogenetic tree was constructed using Maximum Likelihood Method (Hasegawa *et al*. 1991) and the best fitting model with a bootstrap value of 500 (Felsenstein, 1985).

4.3.6 Calculation of Genetic Divergence

The interspecific genetic divergence values of the sequences involved in the construction of individual trees were calculated using the best fitting model (Model with lowest BIC value). The values are provided in the table 8.

4.3.7 Gaps in Methodology

COI sequencing was done for only 33 species documented in the current study due to paucity of funds. Sequencing was done only once from one sample. The chromatograms for some sequences indicated low quality but due to lack of funds the extraction and sequencing of DNA could not be repeated for such organisms. To compensate for such errors additional sequences were obtained from public databases as explained in 4.3.4. Public databases did not have records for many species documented from the study area.

4.4 Results

4.4.1 COI Gene Characterization

Of the 53 species of diving beetles dealt in the current study, 33 species were chosen for molecular characterisation. They come under five subfamilies and 10 genera. DNA was isolated from the selected species. The partial coding sequence of the COI gene was amplified using the primer given in Table 4 and the same were sequenced. Out of the sequences resulted, better quality sequences were submitted in the public database of NCBI (National Centre for Biotechnology Information) GenBank of INSDC (International Nucleotide Sequence Database Collaboration) and accession numbers were obtained. The accession number and the product size are given in Table 7.

Table 7. Details of COI gene sequence submission and novel sequence records of the present study

Sl. No.	Scientific Name	Accession Number	Product Size (bp)	Novel records of COI gene sequences of diving beetles in the GenBank database		
				Global	National	State
1.	*Copelatus boukali*	OP328823	649	✓	✓	✓
2.	*Copelatus boukali*	OM274036	692	✓	✓	✓
3.	*Copelatus cryptarchoides*	OR776929	643	✓	✓	✓
4.	*Copelatus davidi*	OP328824	643	✓	✓	✓
5.	*Copelatus neelumae*	OR770560	648	×	×	✓
6.	*Hydaticus discindens*	OK668194	661	×	×	✓

Sl. No.	Scientific Name	Accession Number	Product Size (bp)	Novel records of COI gene sequences of diving beetles in the GenBank database		
				Global	National	State
7.	*Hydaticus incertus*	OK641849	642	✓	✓	✓
8.	*Hydaticus ricinus*	MN852446	618	×	✓	✓
9.	*Hydaticus ricinus*	OR793322	518	×	✓	✓
10.	*Hydaticus vittatus vittatus*	OK668266	486	×	×	×
11.	*Clypeodytes bufo*	OP538556	630	✓	✓	✓
12.	*Hydroglyphus*	OK641915	692	✓	✓	✓
13.	*Hydrovatus cardoni*	OR776932	642	✓	✓	✓
14.	*Hydrovatus confertus*	OP328827	642	✓	✓	✓
15.	*Hydrovatus picipennis*	OR776933	590	✓	✓	✓
16.	*Hydrovatus rufoniger*	OL257865	643	×	✓	✓
17.	*Hydrovatus seminarius*	OP328826	640	✓	✓	✓
18.	*Laccophilus anticatus*	OP328825	650	✓	✓	✓
19.	*Laccophilus auropictus*	OR776931	588	✓	✓	✓
20.	*Laccophilus elegans*	OP328828	651	✓	✓	✓
21.	*Laccophilus ellipticus*	OR800374	539	✓	✓	✓
22.	*Laccophilus flexuosus*	OP538555	651	✓	✓	✓
23.	*Laccophilus inefficiens*	OK641911	645	×	✓	✓
24.	*Laccophilus parvulus*	OK641910	645	✓	✓	✓
25.	*Laccophilus sharpi*	OP522280	642	×	✓	✓
26.	*Neptosternus annettae*	OR784565	699	✓	✓	✓

Of the sequences of 24 species submitted in GenBank, sequences of 16 species are new records in GenBank database. The COI gene sequences for 21 and 23 species were submitted the first time from India and Kerala respectively.

4.4.2 Phylogenetic Analysis of Family Dytiscidae

Phylogenetic analysis involved sequences in the current study (Table 7) and those downloaded from GenBank database (Table 6). The COI gene sequence of *Dineutus indicus* was used as outgroup. The phylogenetic tree (Fig. 5) reveals two major clusters. The first one is the larger and include most of the sequences involved in the analysis. This further divides into two sub groups formed of Hydroporinae+ Copelatinae+ Laccophilinae + Dytiscinae and Dytiscinae+ Cybistrinae+ Hydroporinae. The second major group is composed of Laccophilinae+ Dytiscinae. Species under the genera *Leiodytes*, *Clypeodytes*, *Hydroglyphus*, *Hydrovatus* and *Sandracottus* formed distinct monophyletic groups.

The tree revealed the following sister relationships: *Leiodytes frontalis*+ *Leiodytes migrator*, *Clypeodytes bufo* + *Clypeodytes meridionalis*, *Hydroglyphus flammulatus* + *Hydroglyphus japonicus*, *Copelatus davidi*+ (*Copelatus cryptarchoides*= *Copelatus neelumae*), *Neptosternus annettae*+ *Laccophilus obtusus*, *Laccophilus inefficiens*+ *Laccophilus sharpi*, *Laccophilus elegans*+ (*Laccophilus ellipticus*= *Laccophilus auropictus*), *Hydaticus ricinus*+ (*Hydaticus ricinus*= *Hydaticus vittatus*), *Hydrovatus rufoniger*+ *Hydrovatus confertus*, *Sandracottus bakewellii*+ *Sandracottus mixtus*, *Sandracottus insignis*+ *Sandracottus guerini*.

Sequences of *Copelatus cryptarchoides* & *Copelatus neelumae*, *Laccophilus ellipticus* & *Laccophilus auropictus*, *Hydaticus ricinus* & *Hydaticus vittatus* and *Hydrovatus cardoni* & *Hydrovatus picipennis* did not exhibit any divergence.

Genera *Laccophilus*, *Copelatus* and *Hydaticus* form paraphyletic groups since they exclude one species from each of the genera.

When looking at the subfamily-level, genus *Hydrovatus* is placed distant from all the other genera in the subfamily Hydroporinae. Similarly, *Copelatus davidi*, *Hydaticus* *discindens* and *Laccophilus flexuosus* are placed distantly from other species in their respective subfamilies.

When looking at the genetic divergence between the sequences involved in the phylogeny analysis, there was not any divergence between *Copelatus neelumae* and *Copelatus cryptarchoides*, *Hydaticus vittatus* and *Hydaticus ricinus* and *Hydrovatus picipennis* and *Hydrovatus cardoni*. The genetic divergence values ranged between 0-36.8%. The highest divergence was observed between *Sandracottus insignis* and *Hydaticus discindens*.

Figure 5. Phylogenetic tree of family Dytiscidae

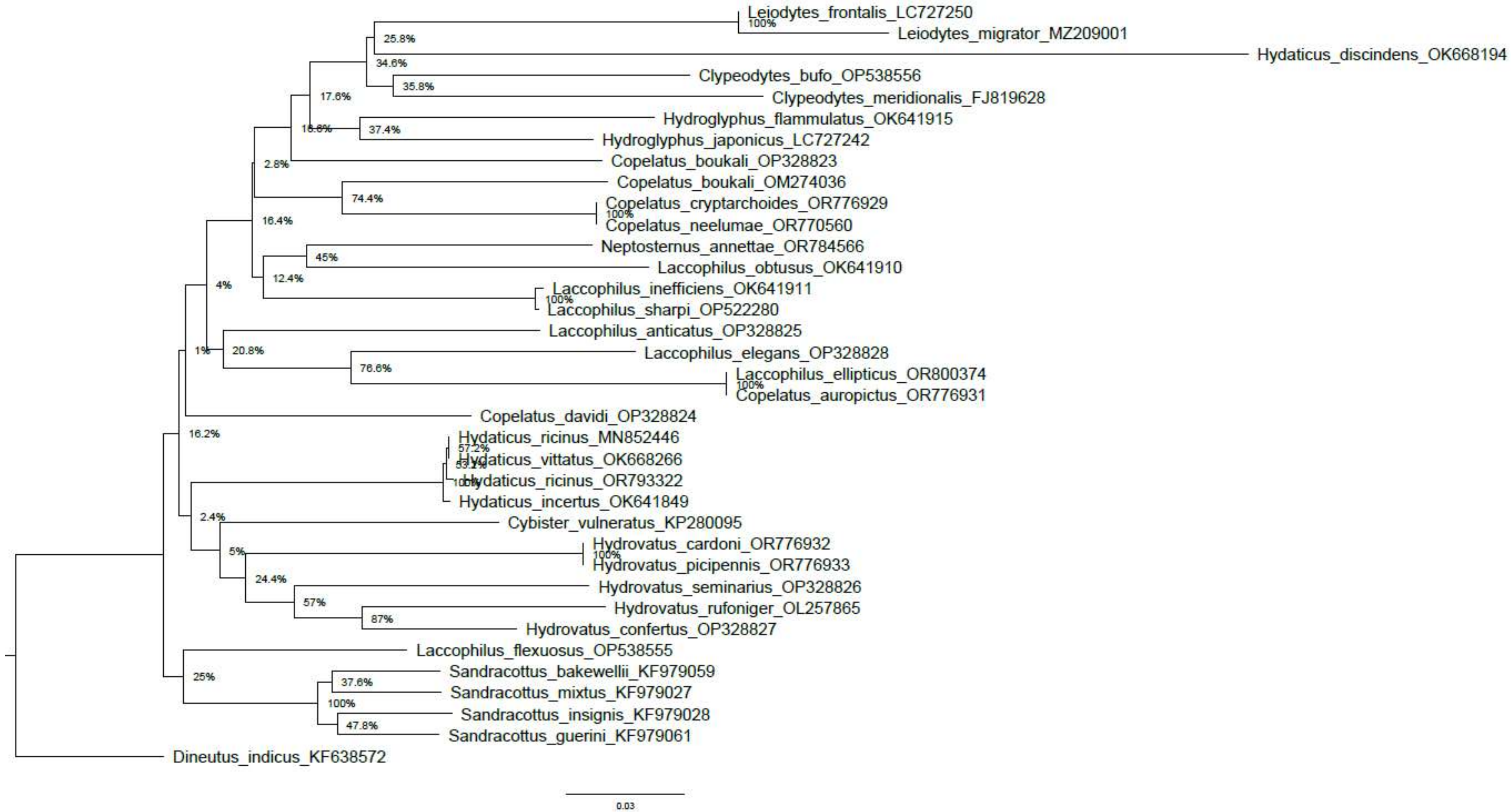


Table 8. Interspecific genetic divergence values of sequences involved in the phylogeny analysis of family Dytiscidae

*Hydaticus_ricinus*_MN852446																																			
*Hydaticus_vittatus*_OK668266	0.000																																		
*Neptosternus_annettae*_OR784566	0.152	0.152																																	
*Copelatus_cryptarchoides*_OR776929	0.174	0.174	0.178																																
*Copelatus_neelumae*_OR770560	0.174	0.174	0.178	0.000																															
*Hydrovatus_cardoni*_OR776932	0.163	0.163	0.206	0.198	0.198																														
*Laccophilus_ellipticus*_OR800374	0.209	0.209	0.239	0.224	0.224	0.224																													
*Hydrovatus_picipennis*_OR776933	0.163	0.163	0.206	0.198	0.198	0.000	0.224																												
*Copelatus_auropictus*_OR776931	0.209	0.209	0.239	0.224	0.224	0.224	0.000	0.224																											
*Hydroglyphus_flammulatus*_OK641915	0.181	0.181	0.182	0.168	0.168	0.191	0.234	0.191	0.234																										
*Hydaticus_discindens*_OK668194	0.328	0.328	0.320	0.327	0.327	0.336	0.344	0.336	0.344	0.346																									
Hydrovatus_rufoniger	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.3																								

_OL257865	03	03	19	95	95	85	20	85	20	85	43																								
*Laccophilus_obtusus*_OK641910	0.182	0.182	0.159	0.166	0.166	0.222	0.249	0.222	0.249	0.187	0.362	0.219																							
*Hydaticus_incertus*_OK641849	0.003	0.003	0.149	0.171	0.171	0.166	0.212	0.166	0.212	0.178	0.324	0.207	0.179																						
*Laccophilus_inefficiens*_OK641911	0.178	0.178	0.163	0.158	0.158	0.178	0.206	0.178	0.206	0.191	0.312	0.202	0.159	0.174																					
*Copelatus_boukali*_OM274036	0.195	0.195	0.189	0.132	0.132	0.181	0.243	0.181	0.243	0.180	0.342	0.190	0.198	0.191	0.168																				
*Copelatus_boukali*_OP328823	0.190	0.190	0.171	0.189	0.189	0.188	0.248	0.188	0.248	0.147	0.334	0.206	0.190	0.187	0.155	0.162																			
*Copelatus_davidi*_OP328824	0.139	0.139	0.192	0.168	0.168	0.166	0.217	0.166	0.217	0.198	0.335	0.179	0.224	0.142	0.155	0.189	0.168																		
*Laccophilus_flexuosus*_OP538555	0.130	0.130	0.172	0.186	0.186	0.159	0.209	0.159	0.209	0.205	0.347	0.172	0.158	0.133	0.144	0.155	0.179	0.163																	
*Laccophilus_sharpi*_OP522280	0.174	0.174	0.160	0.155	0.155	0.175	0.209	0.175	0.209	0.191	0.308	0.202	0.163	0.171	0.003	0.171	0.151	0.155	0.141																
*Laccophilus_elegans*_OP328828	0.203	0.203	0.212	0.198	0.198	0.197	0.167	0.197	0.167	0.213	0.353	0.231	0.229	0.206	0.177	0.214	0.164	0.172	0.184	0.177															
*Laccophilus_anticatus*_OP328825	0.155	0.155	0.189	0.207	0.207	0.217	0.190	0.217	0.190	0.236	0.360	0.191	0.197	0.158	0.154	0.194	0.189	0.161	0.152	0.157	0.203														
*Hydrovatus_seminarius*_OP328826	0.162	0.162	0.194	0.176	0.176	0.176	0.235	0.176	0.235	0.215	0.363	0.161	0.232	0.165	0.207	0.167	0.206	0.211	0.179	0.204	0.199	0.179													
*Hydrovatus_confertus*_OP328827	0.149	0.149	0.183	0.192	0.192	0.139	0.202	0.139	0.202	0.197	0.350	0.101	0.200	0.152	0.201	0.183	0.188	0.153	0.137	0.201	0.180	0.177	0.123												

*Clypeodytes_bufo*_OP538556	0.200	0.200	0.172	0.221	0.221	0.223	0.265	0.223	0.265	0.186	0.294	0.187	0.219	0.196	0.186	0.199	0.194	0.200	0.191	0.182	0.241	0.215	0.181	0.158											
*Hydaticus_ricinus*_OR793322	0.003	0.003	0.148	0.177	0.177	0.166	0.212	0.166	0.212	0.185	0.324	0.207	0.186	0.005	0.181	0.191	0.187	0.142	0.133	0.178	0.206	0.152	0.159	0.152	0.196										
*Cybister_vulneratus*_KP280095	0.138	0.138	0.194	0.179	0.179	0.170	0.256	0.170	0.256	0.182	0.358	0.155	0.169	0.141	0.204	0.166	0.172	0.154	0.130	0.204	0.197	0.178	0.159	0.143	0.206	0.141									
*Sandracottus_bakewellii*_KF979059	0.143	0.143	0.179	0.166	0.166	0.202	0.231	0.202	0.231	0.227	0.359	0.193	0.189	0.146	0.159	0.193	0.183	0.130	0.124	0.156	0.183	0.160	0.175	0.159	0.217	0.146	0.146								
*Sandracottus_insignis*_KF979028	0.143	0.143	0.163	0.189	0.189	0.190	0.226	0.190	0.226	0.212	0.368	0.193	0.210	0.146	0.183	0.189	0.175	0.129	0.126	0.179	0.203	0.194	0.188	0.145	0.205	0.146	0.146	0.055							
*Sandracottus_guerini*_KF979061	0.143	0.143	0.166	0.171	0.171	0.200	0.234	0.200	0.234	0.212	0.341	0.195	0.193	0.146	0.165	0.173	0.179	0.142	0.105	0.162	0.192	0.173	0.174	0.158	0.202	0.146	0.156	0.058	0.055						
*Sandracottus_mixtus*_KF979027	0.133	0.133	0.158	0.161	0.161	0.196	0.245	0.196	0.245	0.214	0.348	0.177	0.199	0.136	0.173	0.172	0.200	0.144	0.135	0.173	0.198	0.176	0.151	0.151	0.210	0.130	0.152	0.055	0.077	0.063					
*Clypeodytes_meridionalis*_FJ819628	0.215	0.215	0.212	0.218	0.218	0.206	0.238	0.206	0.238	0.215	0.328	0.223	0.255	0.212	0.208	0.211	0.199	0.222	0.230	0.204	0.227	0.243	0.205	0.225	0.169	0.212	0.210	0.194	0.199	0.211	0.206				
*Hydroglyphus_japonicus*_LC727242	0.167	0.167	0.172	0.182	0.182	0.185	0.232	0.185	0.232	0.134	0.328	0.184	0.203	0.164	0.177	0.182	0.161	0.159	0.169	0.177	0.197	0.197	0.195	0.135	0.131	0.170	0.179	0.179	0.173	0.190	0.177	0.187			
*Leiodytes_frontalis*_LC727250	0.198	0.198	0.184	0.230	0.230	0.187	0.254	0.187	0.254	0.186	0.310	0.181	0.227	0.195	0.209	0.221	0.194	0.188	0.243	0.209	0.227	0.256	0.220	0.174	0.179	0.201	0.178	0.212	0.214	0.229	0.229	0.192	0.172		
*Leiodytes_migrator*_MZ209001	0.245	0.245	0.226	0.271	0.271	0.223	0.298	0.223	0.298	0.215	0.352	0.227	0.265	0.242	0.254	0.261	0.237	0.232	0.290	0.254	0.272	0.300	0.260	0.219	0.224	0.249	0.221	0.257	0.258	0.266	0.278	0.231	0.210	0.034	
*Dineutus_indicus*_KF638572	0.146	0.146	0.180	0.177	0.177	0.187	0.182	0.187	0.182	0.201	0.356	0.214	0.201	0.146	0.163	0.224	0.209	0.148	0.133	0.163	0.207	0.163	0.173	0.166	0.260	0.149	0.173	0.155	0.156	0.149	0.141	0.271	0.186	0.247	0.291

4.5 Discussion

The phylogenetic tree constructed based on COI gene sequences somewhat agree with the classification of the family Dytiscidae based on morphology. However, it also includes results that contradict the traditional classification and systematic positions based on morphology.

The tree representation at family-level relationship was found to be less reliable as many taxa conventionally placed in a particular subfamily or genus did not cluster together. Similarly, some taxa traditionally considered to be closely related were placed far apart. Also, while some clades showed high bootstrap value indicating well supported evolutionary relationships, certain other clades showed ambiguity expressed as lower statistical confidence.

In contrast, the relationships within smaller groups (genera) are well supported by the tree in most cases. In addition, trees, constructed using few sequences from lower levels of a taxonomic hierarchy were showed more agreement to established systematic positions (see Appendix C). But such trees do not serve much purpose in studying the phylogeny of an entire family.

Several constraints, which could have influenced the phylogenetic tree construction demonstrating ambiguous phylogenetic relationships within the family Dytiscidae, were identified.

4.5.1 Quality of Sequences

Errors which occur during the various steps of gene isolation, amplification and sequencing procedures may lead to the generation of poor-quality sequences. All the available sequences in the NCBI GenBank could not be used for tree construction as many of these sequences did not align with the regions of the sequences in the current study. The authenticity of some sequences in public databases were also questionable. Errors could occur at any stage starting from sequencing to the submission in public databases. Contamination of the initial samples could also be possible. But these are not checked for their quality. Previous studies also highlight this challenge (Nilsson *et al*., 2006; Buhay, 2009; Kappel and Schröder, 2020).

The sequences from this study could also have errors and some were excluded from the tree due to poor quality as indicated by the chromatograms. Due to time and financial constraints fresh specimens could not be sequenced.

4.5.2 Number of Genes Used for Phylogenetic Tree Construction

The current study considered only a single gene for the resolution of evolutionary relationships. It is not necessary that a single gene provides enough variation to resolve relationships among closely related species or taxa (Gontcharov *et al*., 2004). Current systematics is solely based on external characters. But COI is highly conserved and need not reflect very recent changes in closely allied species especially which are co-existing in a very small habitat. Ranarilalatiana *et al*. (2019) studied in a taxonomic revision of *Copelatus* of Madagascar based on both morphological and molecular (mitochondrial COI) data found that

1.Most specimens of morphologically identified species clustered as monophyletic in the Bayesian analysis except few, which were then considered as part of a closely related group of species the *Copelatus insuetus* complex for the time being as it could not be evolved.

2. The GMYC species delimitation analysis by Ranarilalatiana *et al*. (2019) resulted in 11 separate evolutionary units that were largely but not entirely consistent with their morphological delimitation

3. Ranarilalatiana *et al*. (2019) based on their findings suggested that a better classification system based on phylogenetic relationships can likely be approached by using the shape of male aedeagus especially for their species complex which needed to be tested on a larger sample. They felt that many recent species need not be yet delimitable based on the mitochondrial COI gene.

Another study by Maddison (2008) on Bembidion beetles using multiple morphological characters and seven genes (28S, 18S, COI, wg, CAD, ArgK, Pol2) found that phylogenetic trees constructed with different genes showed slight differences and were different from the tree constructed using all the gene sequences. The study also concluded that COI and wingless are least successful at delimiting species, in part because of the multiple copies in each individual. The article goes on to suggest variation across organisms as to which gene fragments are most beneficial for species delimitation and for *Pseudoperyphus* recommended 28S ribosomal DNA over COI.

In addition to the above-mentioned issues, relying on one or two genes may not successfully separate the species. Analysis involving multiple gene sequences as well as the morphological features can significantly improve the proper resolution of evolutionary relationship within the family (Gontcharov *et al*., 2004; Aguileta *et al*., 2008; Jacques *et al*., 2023; Van der Valk *et al*., 2024).

All these may have led to the unconclusive result. Similarly, addition of more sequences in the analysis may significantly change the overall result of the analysis.

4.5.3 Limitations of COI in Phylogenetic Study

Hendrich *et al* (2010) demonstrated that mtCOI data while reliably representing patterns of insect diversity suffered from high lineage-idiosyncratic error rates. They concluded that while large datasets of COI provide fairly precise species richness estimates using either preset thresholds (clustering) or inferences from the specific dataset performance at the genus level varied greatly due to idiosyncratic lineage data structures (or lineage evolution), where fixed threshold approaches cannot accurately capture species diversity. Different models could not overcome problems associated with species para- or polyphyly. Also, a small percentage of species as delineated by taxonomists based on numerous morphological characters were not retrieved as monophyletic using COI sequences which also included sequences from Copelatinae.

4.5.4 COI-LIKE'' a Problem in Molecular Systematics and DNA barcoding Studies

Buhay (2009) highlights the problem of COI sequences in public databases. She demonstrated various studies where erroneous analyses was based not only on supposed mitochondrial sequences but also incorporated many questionable sequences due to the possible presence of numts and manual editing or sequencing errors. She mentions that 22 of 86 sequences in a study were flagged as ''COI-like'' by GenBank due to the presence of stop codons and indels in what should be the open reading frame of a conservative protein-coding gene. “COI-like” accessions in GenBank turned up a multitude of taxa which called for studies on quality control, pseudogenes and sequence composition of DNA barcodes.

When family trees in this study did not follow known systematic positions, many sequences in GENBANK were examined by “BLASTING” them with confirmed COI sequences. Top hits in the top 250 hits were selected. Very few sequences could be found. When GenBank via Taxonomy Browser for a taxon (eg: Copelatinae) was searched for many more COI gene sequences were found but they did not align to the rest of the sequences. This indicated that all COI sequences in the public databases need not be robust and at least some of the sequences we found and had to omit could be COI-like or pseudogenes.

Maddison (2008) found that for 103 of 266 beetle specimens sequenced for the mitochondrial gene (COI) showed double peaks in both sequencing reactions which was not expected due to the presumed uniparental inheritance of mitochondria (Thalmann *et al*. 2004). Maddison suggested that the other copies of COI are in the nuclear genome, having moved from the mitochondrion (numts) but could be non-functional pseudogenes, having frameshift mutations, large deletions, or early stop codons. It could be possible that in unsophisticated laboratories including many of our own country these could be passed on as COI leading to the many COI-like sequences in public databases and confusions when these are relied on for construction of phylogeny.

4.6 Conclusion

This chapter deals with the resolution of phylogenetic relationships within Dytiscidae of the study area. Thirty-three species were sequenced. Twenty- six sequences were submitted to GenBank. Sixteen species were new records in the GenBank database. Twenty-one and twenty-three species are new records from India and Kerala respectively. Construction of phylogenetic trees with COI sequences while resolving the relationships at lower- taxonomic levels and could not establish the relationships for all the taxa at family level. Further readings indicated that such gaps could be resolved only be including larger samples (more species and multiple genes for such analysis).

CHAPTER- 5

A STUDY ON HABITAT SIMILARITY AND THE INFLUENCE OF SELECTED WATER PARAMETERS ON SPECIES CO-OCCURRENCE

5. A study on habitat similarity and the influence of selected water parameters on species co-occurrence

5.1 Introduction

The geographical range sizes of individual species vary considerably in extent, although the factors underlying this variation remain poorly understood, and could include a number of ecological and evolutionary processes. A favoured explanation for range size variation is that this result from differences in fundamental niche breadths, suggesting a key role for physiology in determining range size, although to date empirical tests of these ideas remain limited (Calosi *et al*., 2010). A variety of lotic and lentic ecosystems provide diverse microhabitats for freshwater aquatic insects due to the presence varied substrata and other abiotic factors (Rosenberg and Resh, 1993). Aquatic insects provide essential ecosystem services by participating in the energy flow and nutrient cycling (Whiles and Wallace, 1997). The community structure of aquatic insects depends on a number of factors, such as water quality, type of substrate, particle size of sediment, water flow, sediment organic matter availability, oxygen concentration as well as environmental conditions surrounding the water course (Ward *et al*., 1995; Buss *et al*., 2004). Because of this dependency on abiotic features, these insects are considered as bioindicators. These insects feed on other insects, invertebrates and smaller vertebrates and are also fed upon by birds, reptiles, etc thus becoming an important link in food chains and food webs. As the abiotic factors govern the presence and absence of aquatic insects, characterizing these in water bodies could help in better understanding of the distribution of aquatic organisms in general and Dytiscidae in particular.

5.2 Review of Literature

Sheth *et al*. (2019) investigated the diversity and distribution of aquatic beetles in the Northern Western Ghats and recorded 66 species, the majority of which belonged to the family Dytiscidae. Key factors influencing beetle communities included water temperature, pH, conductivity, land use, aquatic vegetation, habitat age, hydroperiod and altitude. Different habitat types such as streams, ponds and temporary pools supported distinct beetle communities. The study highlighted the importance of preserving a variety of aquatic habitats to maintain beetle diversity and gave insight into the ecological factors shaping aquatic beetle communities in the Northern Western Ghats.

While there are many studies on the taxonomy, phylogeny (See the review of literature of chapter 3 and chapter 5), morphology, anatomy and physiology (Blunck, 1912; Günther, 1912; Ege, 1915; Jahn and Wulff, 1941 & 1943; Hughes, 1952; Jackson, 1952, 1956a, 1956b & 1956c; Larsen, 1966; Balfour-Browne, 1967; Rahn and Paganelli, 1968; Urbani and Russo- Russo-Caia, 1969; Kallapur, 1970; Galewski, 1971; Urbani and Russo- Russo-Caia, 1972; Jackson, 1973; Meyer-Rochow, 1973; Nachtigall, 1977; Formanowics and Brodie, 1981; Smrž, 1981; Werner, 1982; Classen and Dettner, 1983; Wolfe and Zimmerman, 1984; Dallai and Afzelius, 1985; De Marzo and Nilsson, 1986b; Dettner *et al*., 1986; Gilbert, 1986; Dallai and Afzelius,1987; Deding, 1988; Frisbie and Dunson, 1988; Hicks and Larson, 1991; Jensen and Zacharuk, 1991, 1992; Schwind, 1995; Ribera *et al*., 1997; Jamieson *et al*., 1999; Gorb and Beutel, 2000; Kehl and Dettner, 2003; Mandapaka *et al*., 2006; Wall *et al*., 2006; Buschbeck *et al*., 2007; Sbita *et al*., 2007; Kehl and Dettner, 2009; Herbst *et al*., 2011; Maksimovic *et al*., 2011; Calosi *et al*., 2012; Higginson *et al*., 2012a; Madsen, 2012) there are very few studies delineating the relationships of Dytiscidae and abiotic parameters of their habitats. Notable studies on this topic are mentioned below.

Larson (1985) analysed the collection records of adult dytiscid beetles from 312 sites in Alberta, Canada, to identify patterns of species distribution and community structure. He grouped the sites into 12 principal clusters based on species occurrence, though many sites were outliers. Salinity, productivity, stability, water temperature, substrate type, flow, and vegetation were significant in differentiating these clusters. An analysis of species co-occurrence patterns revealed distinct communities, with species clustering more effectively than sites. Principal species groups were associated with saline water, alpine or subalpine lotic sites, other lotic habitats and lentic habitats with further subdivisions based on forest and grassland areas. The study highlighted the continuum nature of these communities, with species showing overlap in occurrence along ecological gradients. This study underscores the complexity of diving beetle communities and the importance of various environmental factors in shaping their structure

In 1996, Nilsson and Söderberg investigated the patterns of abundance and species richness of diving beetles across 98 lakes in northern Sweden and the study found that protected sites with vegetation harboured significantly more specimens and species than exposed sites lacking vegetation. They found no significant differences in species richness and abundance across geographical factors such as latitude or distance from the coast. Lake area, altitude, and water chemistry were found to have low predictive power for beetle abundance and species richness.

Lundkvist *et al*. (2001) examined diving beetle communities in southeastern Sweden, focusing on how environmental factors affect these beetles across twelve wetlands. These wetlands varied in permanence (temporary or permanent), size (25 to 4,800 m^2), age (11 to over 50 years), and shadiness (open to wooded). They found that shaded wetlands of intermediate size (240-1,100 m^2) had the highest species richness. Species composition was most similar among environmentally alike wetlands. The study identified permanence and shadiness as key factors in shaping beetle assemblages. It concluded that a diverse range of wetland types, incorporating different ages, successional stages, and environments, promotes high diving beetle diversity.

A study (Vamosi *et al*., 2007) on body size and species richness along geographical gradients in Albertan diving beetle communities uncovered some intriguing patterns. The research revealed that species richness varied predictably along both latitudinal and elevational gradients. Generally, species richness decreased as latitude and elevation increased. There was a noticeable trend in body size variation along these gradients, with larger-bodied species being more prevalent at higher latitudes and elevations. The study emphasized that temperature and habitat heterogeneity were significant factors influencing these patterns.

Calosi *et al*. (2007) investigated how temperature and water acidity affect the diving behaviour of the European diving beetle, *Ilybius montanus*. At higher temperatures (20.5°C), beetles surfaced more frequently due to shorter dive durations, likely caused by increased metabolic rates. However, the time spent at the surface for gas exchange remained constant, suggesting a balance between gas exchange needs and minimizing surface time to avoid predation. While acidity did not affect surfacing frequency or dive duration, it disrupted the beetles' ability to regulate diving behaviour with temperature. This effect was more pronounced with sulphuric acid compared to hydrochloric acid, indicating the importance of the anion as well as acidity itself. The study highlights the potential of using diving behaviour as an integrative biomarker for environmental changes in aquatic insects.

Calosi *et al*. (2008, 2010) explored the thermal tolerance and geographical range size in the *Agabus brunneus* group of European diving beetles and other species, examining the relationship between thermal performance, geographical range and body size. They found that widespread species in this group have higher upper thermal tolerances (UTTs) and lesser lower thermal tolerances (LTTs) compared to range-restricted species. Species with larger geographical ranges tend to have broader thermal tolerance ranges, indicating a link between thermal physiology and latitudinal range extent. The study provided limited evidence for acclimation to extreme temperatures, suggesting that physiological plasticity may not significantly influence the distribution of these beetles. Restricted-range species may be more susceptible to the direct effects of climate change, while widespread species might face indirect effects such as habitat reduction. Unlike thermal tolerance, differences in dispersal ability, such as wing size, play a lesser role in determining range size. Although thermal acclimation abilities may influence biogeography, they do not seem to correlate with increased range size. These findings support both Brown's hypothesis and the environmental variability hypothesis, emphasizing the role of thermal niche in determining species distribution.

Han *et al*. (2011) documented 26 species from 15 genera of diving beetles in the paddy ecosystem and monitored 290 sites across 138 cities or counties in South Korea. Species richness and diversity differed in terraced valley paddy fields and plain paddy fields.

Sánchez-Fernández *et al*. (2012) investigated how various habitat types affect the distribution of Iberian diving beetles in relation to climatic conditions. They discovered that lentic species were generally closer to climatic equilibrium than lotic species. Their findings highlight the importance of habitat type in mediating the relationship between species distribution and climatic conditions.

Cioffi *et al*. (2016) studied the physiological niche and geographical range in European diving beetles, exploring how various physiological traits influence their distribution and suggested that physiological traits such as thermal tolerance, metabolic plasticity and immunocompetence play significant roles in shaping the geographical ranges of diving beetles.

Enkhnasan and Boldgiv (2019) recorded a total of 99 species across 20 genera and five subfamilies of predaceous diving beetles in Mongolia, revealing detailed insights into their species richness, spatial distribution and biogeographical composition.

Enkhnasan and Boldgiv (2020) provided essential baseline data for understanding the factors influencing diving beetle communities through their analysis of predaceous diving beetle (Coleoptera: Dytiscidae) communities and habitats in central and western Mongolia. A total of 4,193 diving beetle specimens, encompassing 66 species from 15 genera, were collected from 146 sites. The study identified distinct variations in species richness and community composition across different basins, subbasins and habitat types. Altitude and dissolved oxygen were recognized as significant factors affecting dytiscid communities.

Liao *et al*. (2020) studied the environmental determinants of diving beetle assemblages (Coleoptera: Dytiscidae) in an urban landscape, highlighting several key factors. The study found that urbanization negatively impacts species richness but not abundance. Urban ponds with gently sloping margins and no predatory fish exhibit higher species richness and abundance. Presence and absence of fish, steepness of pond margins and interconnectedness of water bodies affected diving beetle communities.

5.3 Materials and Methods

5.3.1 Study Area and Insect Collection

Different fresh water habitats in all the 14 districts of Kerala were visited. Details of insect sampling and identification are given in methodology of Chapter 3.

5.3.2 Measurement of Water Parameters

Even though there are many abiotic parameters which determine water quality, previous studies (Balfour-Browne, 1940; Rawson and Moore, 1944; Galawski, 1971; Cuppen, 1986; Eyre *et al*., 1986; Friday, 1987; Frisbie and Dunson, 1988; Ribera *et al*., 1996; Eyre *et al*., 2006; De Mendoza, 2012) indicate that water parameters such as temperature, pH and salinity are the major determinants of the structure of diving beetle assemblages. In sake of time and expenditure, temperature, pH, salinity, TDS and conductivity were selected and measured on site using a waterproof handheld multiparameter testing equipment (Company: Eutech; Model: PCStestr 35). Readings were taken just before collecting the beetles from the habitat. For habitats with only few centimetres water depth, the sensor of the instrument was directly inserted into the water column of that habitat and wait till the reading get stabilised. For habitat with enough depth (>5cm), around 30 ml of water was collected in a small clean glass beaker and readings were immediately recorded at the site itself.

5.3.3 Grouping of Habitats

Following the previous publications (Yee, 2014; Miller & Bergsten, 2016; Sheth *et al*., 2018 & 2019) the collection sites were named and each considered as a group to conduct statistical analysis. All habitats' names and their descriptions are furnished in Table 9.

5.3.4 Data Analysis

The data collected from the field was consolidated in MS Excel. Statistical analysis were performed using PAST ver 4.17 (PAleontological STatistics) to understand and visualize the relationships between the abiotic parameters and diving beetle assemblages in the habitats. Similarity of different habitats based on species composition was visualized using Neighbour joining clustering using Jaccard similarity index in PAST ver4.17 and a dendrogram was generated. CCA (Canonical Correspondence Analysis) is a powerful multivariate technique that can be used to investigate the relationship between species and environmental variables. Every observation (selected environmental variables and species abundance) for each habitat was entered against it. Environmental variables were selected based on previous studies (see review of literature and discussion) and also by avoiding variables which showed collinearity. Five abiotic variables- temperature, pH, EC, TDS and salinity were selected. CCA map visualizing the relations were generated. Coexistence of species was visualized and findings of the CCA were validated using (Kendal Tau Correlation Analysis). Correlation matrix was generated.

5.4 Results

Table 9. Grouping and description of habitats

Sl. No.	Name of Habitat	Description
1.	Remnant pool in the downstream of waterfall	Pools formed in the streambed down the waterfalls during summer season
2.	Ephemeral pool in a dirt road	Pools formed on dirt roads during monsoon season
3.	Paddy field (Uncultivated)	Paddy fields filled with water during the monsoon and before cultivation.
4.	Pool in abandoned paddy field	Pools formed (during monsoon/throughout the season) in a land which was a paddy field in the past.
5.	Rock pool	Small pool of water contained in a depression or holes on rocks.
6.	Slow moving stream	Streams which have restricted flow or remain almost stagnant due to various reasons.
7.	Remnant pools in irrigation canal	Pool of water remaining at the bottom of irrigating canals during monsoon season or after the canal is drained
8.	Marginal zone of Reservoir	Shallowest region of water column near the edges

Sl. No.	Name of Habitat	Description
9.	Muddy puddle	Small pools of water on ground formed either by the rain or by drying of paddy fields.
10.	Ditch in agricultural field	Small to medium channels which carry water to the agricultural fields
11.	Paddy field	Paddy fields undergoing active cultivation
12.	Pool	Small area of stagnant water
13.	Remnant pool in a pond	Pool of water formed as a result of drying of a large pond
14.	Remnant pool in floodplains of river	Pool of water formed as a result of drying of the flooded area on the banks of a river
15.	River margin	The zone where the water is closest to the bank and is least affected by water current
16.	Remnant pool in river	Pool formed on river bed as a result of drying of the river
17.	Abandoned ditch	Small discarded channels of water in agricultural field
18.	Ditch	Small channels of water
19.	Ephemeral pool in quarry	Small pools formed in a quarry during monsoon
20.	Remnant pool in stream	Pool formed as a result of drying of stream
21.	Pond	Body of stagnant water
22.	Ephemeral pool	Accumulation of water on ground as a result of rain
23.	Stream margin	The zone where the water is closest to the bank and is least affected by water current/nearly stagnant
24.	Remnant pool in ditch	Pools forded in summer season as a result of drying of river
25.	Spring-fed pool	Pools resulted from water of springs
26.	Pond margin	Edge of the pond
27.	Roadside ditch	Small channels of water near the road

Sl. No.	Name of Habitat	Description
28.	Margin of quarry pool	Edge of a pool formed as a result of quarrying
29.	Drying stream	Rivers which keeps drying in the summer season
30.	Small pool in a quarry	Pools formed in quarry as a result of rain
31.	Abandoned pond	Ponds which are neglected and so much weeded
32.	Ephemeral pool in the road side	Temporary pools formed on roadside in monsoon season
33.	Margin of lake	The zone where the water is closest to the bank, has minimum depth and is least affected by water current.
34.	Ditch	Ditches in agricultural fields used for irrigation
35.	Other	Habitats which cannot classify into any of the other habitats
36.	Ditch in abandoned paddy field	Ditches found in abandoned paddy fields which previously used for irrigation in that particular paddy field
37.	Drying stream	Shallow streams getting dried in summer

Thirty-seven different habitats could be identified. Some were seasonal and found only during rainy season or present only when extreme heat dried up larger water bodies giving rise to a unique and transient habitat. Some were present throughout the year and were larger ecosystems. A part of such large ecosystem, like muddy/vegetated/sandy shallow marginal zones was utilized by diving beetles as their habitat.

5.4.1 Habitat Similarity Based on Presence and Absence of Species

The dendrogram constructed based on the presence and absence of species (Fig. 6) indicated that none of the habitats showed more than 60% of similarity based on the presence and absence of diving beetle species.

Two main groups could be identified in the dendrogram. The second and smaller of the habitat groups included three habitats. This group, consisted of ditches in abandoned paddy fields (DAP), pools in downstream of waterfalls (RPIDSWF) river margins (RM). This was basically due to the presence of *Laccophilus anticatus* which was common in all the three habitats and *Peschetius quadricostatus* which was present in RPIDSWF and DAP.

All other habitats were grouped together which had two distinct clusters consisting of smaller habitat clusters. Remnant pools in ponds and pools in quarry were clustered together. This group showed similarity to pond margin habitat. All the above habitats showed similar species presence and absence to pools formed in irrigation canals and uncultivated paddy fields.

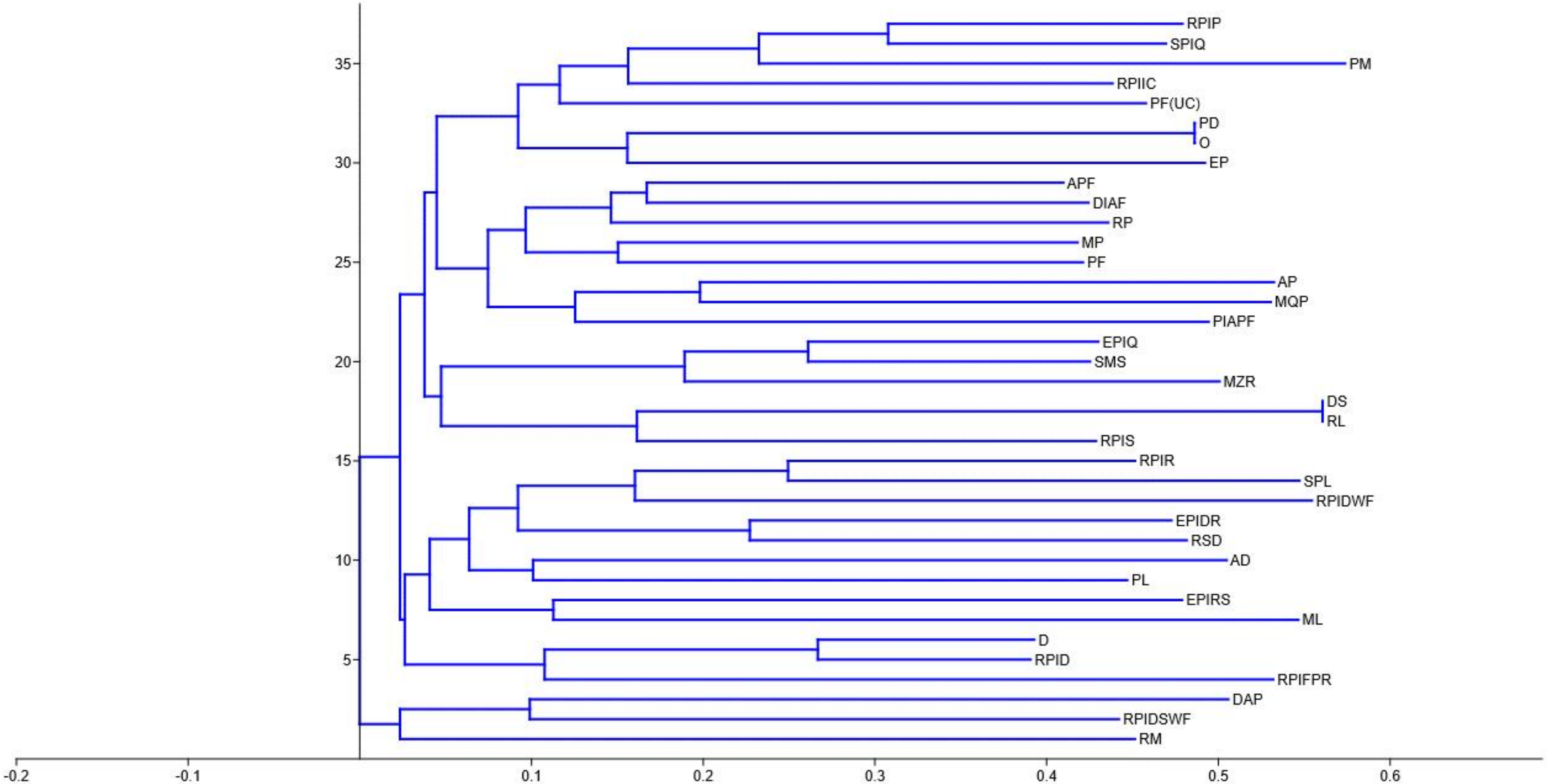
Abandoned paddy fields and ditches in agricultural fields were highly similar in terms of presence of species. These two habitats had similar species composition to rock pools, muddy puddles, abandoned ponds and margins of quarry pool.

Ephemeral pool in quarry and slow-moving stream and marginal zones of reservoirs were similar in species presence and absence. Drying streams were also found to be similar to rock pools and remnant pools in streams. Ephemeral pools on dirt road, roadside ditches, ephemeral pools in roadside and margins of lakes had similar species composition. Ditches and remnant pools in ditches showed similar species composition to remnant pools in the floodplains of rivers.

5.4.2 Canonical Correspondence Analysis (CCA)

As the two axes covered more than 80% variance the test is robust. Canonical correspondence analysis (Fig. 7) reveals relationship among water parameters and how different species are distributed in relation to the parameters. TDS and Salinity show strong correlation with each other. These two parameters have a correlation with conductivity. Temperature shows a strong negative correlation to the pH. Of the five water parameters, EC shows less influence on species' cooccurrence. While TDS have high influence on species occurrence. Most of the species clustered into small groups, indicating the similarity in their ecological optimum.

Figure 6. Dendrogram of habitat similarity based on presence and absence of species



5.4.3 Analysis of species coexistence (Kendal Tau Correlation Analysis)

The Kendall Tau correlation graph (Fig. 8) reveals a positive correlation between many species, indicating that they coexist in various habitats. In some cases, congeneric species found to be coexisting. Meanwhile, species of different genera also show successful inhabitation in the same habitat.

Three species in the genus *Copelatus* (*C. boukali*, *C. davidi* and *C. sociennus*) shows strong positive correlation with each other and coexisted. These three species show a significant correlation with *Clypeodytes feryi*. Three species of *Lacconectus* (*L. blandulus*, *L. regimbarti* and *L. satoi*) also seemed to be coexisting as they are highly correlated with each other. These three species of *Lacconectus* are significantly positively correlated to *Laccophilus elegans*. *Lacconectus regimbarti* also shows high correlation to *Hydaticus ricinus* and *Hyphydrus renardii*. *Lacconectus satoi* and *Laccophilus elegans* are highly correlated and co-occur.

Cybister sugillatus is significantly correlated to the species of four different genera (*Hydrovatus confertus*, *Hydaticus discindens*, *Hydaticus ricinus*, *Laccophilus anticatus anticatus*, *Laccophilus sharpi* and *Clypeodytes bufo*). *Peschetius quadricostatus* and *Peschetius taprobanicus* are significantly positively correlated to *Laccophilus inefficiens* and *Laccophilus anticatus* respectively. Three species of genus *Hydrovatus* (*H. confertus, H. picipennis* and *H. seminarius*) are highly positively correlated. *H. confertus* is significantly positively correlated to *Cybister sugillatus*, *Hydroglyphus flammulatus*, *Clypeodytes bufo*, and *Hyphydrus renardii*. *Hydrovatus picipennis* shows significant positive correlation with *Hydroglyphus pendjabensis*, *Laccophilus ellipticus*, *Laccophilus inefficiens*, *Clypeodytes bufo* and *Hyphydrus renardii*. *Hydrovatus seminarius* is significantly correlated to *Hydrovatus confertus*, *H. picipennis*, *Hydroglyphus pendjabensis*, *Laccophilus ellipticus* and *Clypeodytes bufo*. *Hydroglyphus flammulatus* is significantly positively correlated to *Hydroglyphus pendjabensis*, *Leiodytes orissaensis* and *Laccophilus sharpi*. *Hydroglyphus pendjabensis* shows a strong positive correlation to *Laccophilus ellipticus*. It is also significantly positively correlated to *Hydrovatus seminarius*, *Laccophilus parvulus*, *Laccophilus sharpi* and *Hydrovatus picipennis* in addition to *Hydroglyphus flammulatus*.

Leiodytes orissaensis is significantly positively correlated to *Hydroglyphus flammulatus*, *Laccophilus anticatus anticatus* and *Laccophilus sharpi*. *Hydaticus discindens* is significantly positively correlated to both *Cybister sugillatus* and *Hyphydrus renardii*. Whereas, *Hydaticus incertus* possess significant positive correlation only with *Laccophilus parvulus*. *Hydaticus ricinus* shows significant correlation to *Lacconectus regimbarti*, *Cybister sugillatus Peschetius toxophorus*, *Hydaticus vittatus* and *Laccophilus anticatus*.

Hydaticus vittatus exhibit positive correlation to *Peschetius toxophorus* and *Hydaticus ricinus*. Likewise, many species show significant correlation to other species: *Laccophilus anticatus anticatus* to *Cybister sugillatus*, *Peschetius taprobanicus*, *Leiodytes orissaensis*, *Hydaticus ricinus* and *Laccophilus flexuosus*; *Laccophilus elegans*, *Lacconectus regimbarti*, *Lacconectus satoi* and *Lacconectus blandulus*; *Laccophilus ellipticus* to *Hydrovatus picipennis*, *Hydrovatus seminarius*, *Hydroglyphus pendjabensis*, *Laccophilus parvulus* and *Clypeodytes bufo*; *Laccophilus flexuosus* to *Laccophilus anticatus*, *Laccophilus parvulus*, *Clypeodytes bufo* and *Clypeodytes feryi*; *Laccophilus parvulus parvulus* to *Hydroglyphus pendjabensis*, *Hydaticus incertus*, *Laccophilus flexuosus*, *Laccophilus ellipticus* and *Clypeodytes feryi*; *Laccophilus sharpi* to *Cybister sugillatus,* Hyd*roglyphus flammulatus*, *Hydroglyphus pendjabensis* and *Leiodytes orissaensis*; *Clypeodytes bufo* to *Cybister sugillatus*, *Hydrovatus confertus*, *Hydrovatus picipennis*, *Laccophilus ellipticus*, *Laccophilus flexuosus* and *Clypeodytes feryi*; *Hyphydrus renardii* to *Lacconectus regimbarti*, *Peschetius picipennis*, *Hydrovatus confertus* and *Hydaticus discindens*. *Laccophilus inefficiens* is only positively correlated to *Peschetius quadricostatus*. *Laccophilus elegans* shows high positive correlation to *Lacconectus satoi*. *Clypeodytes feryi* shows a high positive correlation to *Copelatus. boukali*, *C. davidi*, *C. sociennus*, *Laccophilus flexuosus*, *Laccophilus parvulus* and *Clypeodytes bufo*.

Species under genus *Neptosternus* (*N. annettae*, *N. boukali*, *N. kerala* and *N. leyi*) show strong positive correlation to each other and found always coexisting.

Some species were never found together in a habitat so it is deduced that there may be a very less chance of them to co-occur. Here, the correlation graph generated show significant negative correlation between some species: *Peschetius quadricostatus* to

Hydaticus vittatus; *Hydrovatus confertus* to *Hydroglyphus flammulatus*, *Hydaticus incertus* and *H. vittatus*; *Hydrovatus picipennis* to *Laccophilus anticatus*, *Laccophilus inefficiens*, *Hydaticus vittatus* and *Hydaticus ricinus*; *Hydrovatus seminarius* to *Laccophilus anticatus anticatus* and *Hydaticus vittatus*; *Hydroglyphus flammulatus* to *Hydrovatus confertus*, *Hydaticus ricinus*, *Hydaticus vittatus* and *Laccophilus inefficiens*; *Hydaticus vittatus* to *Peschetius quadricostatus*, *Hydrovatus confertus*, *Hydrovatus picipennis*, *Hydrovatus seminarius*, *Hydroglyphus flammulatus*, *Laccophilus inefficiens, Laccophilus parvulus parvulus* and *Clypeodytes bufo; Laccophilus inefficiens* to *Hydroglyphus flammulatus*, *Hydrovatus picipennis* and *Hydaticus vittatus*.

When looking into the water parameters, conductivity (EC) has high positive correlation TDS and salinity. While TDS and salinity has strong positive correlation. None of the parameters shows negative correlation to any parameters.

When examining the relationship of species to the water parameters, *Hydrovatus picipennis* shows positive correlation to water temperature suggesting its ability to survive in a habitat with higher water temperature or its ability to survive in warmer regions. *Hydrovatus seminarius*, *Hydroglyphus flammulatus* and *Leiodytes orissaensis* are positively correlated to conductivity (EC), TDS and salinity, which implies their ability to survive in habitat with higher levels of EC, TDS and salinity. *Laccophilus flexuosus* show positive correlation to conductivity. *Peschetius taprobanicus*, *Hydrovatus seminarius*, *Hydrovatus rufoniger*, *Hydroglyphus flammulatus* and *Leiodytes orissaensis* are positively correlated to salinity.

Temperature has a negative influence on species such as *Lacconectus regimbarti*, *Lacconectus satoi* and *Laccophilus elegans*. *Lacconectus regimbarti*, *Lacconectus satoi* and *Hydaticus vittatus* are negatively correlated to EC, TDS and salinity. *Laccophilus elegans* and *Lacconectus blandulus* are also negatively influenced by conductivity (EC). *Hydrovatus confertus*, *Hydrovatus picipennis*, *Clypeodytes bufo* and *Clypeodytes feryi* are negatively correlated to pH. This suggests their preference for habitats with lower levels of water pH.

The Kendal Tau correlation graph (Figure 8) almost comply with the correlation between species and with environmental parameters as visualised in CCA triplot

(Figure 7). Coexistence of congeneric species in the genera *Copelatus*, *Neptosternus, Hydaticus* and *Hydroglyphus* can be visualised in CCA triplot. The coexistence of some species of different genera is well established in the Kendel Tau correlation analysis.

The correlation between conductivity, TDS, and salinity is clearly demonstrated in both analyses. Similarly, the positive and negative correlations between species and water parameters were also well established in the two analysis.

Figure 7. CCA triplot visualizing species' presence, absence, coexistence and effect of environmental parameters

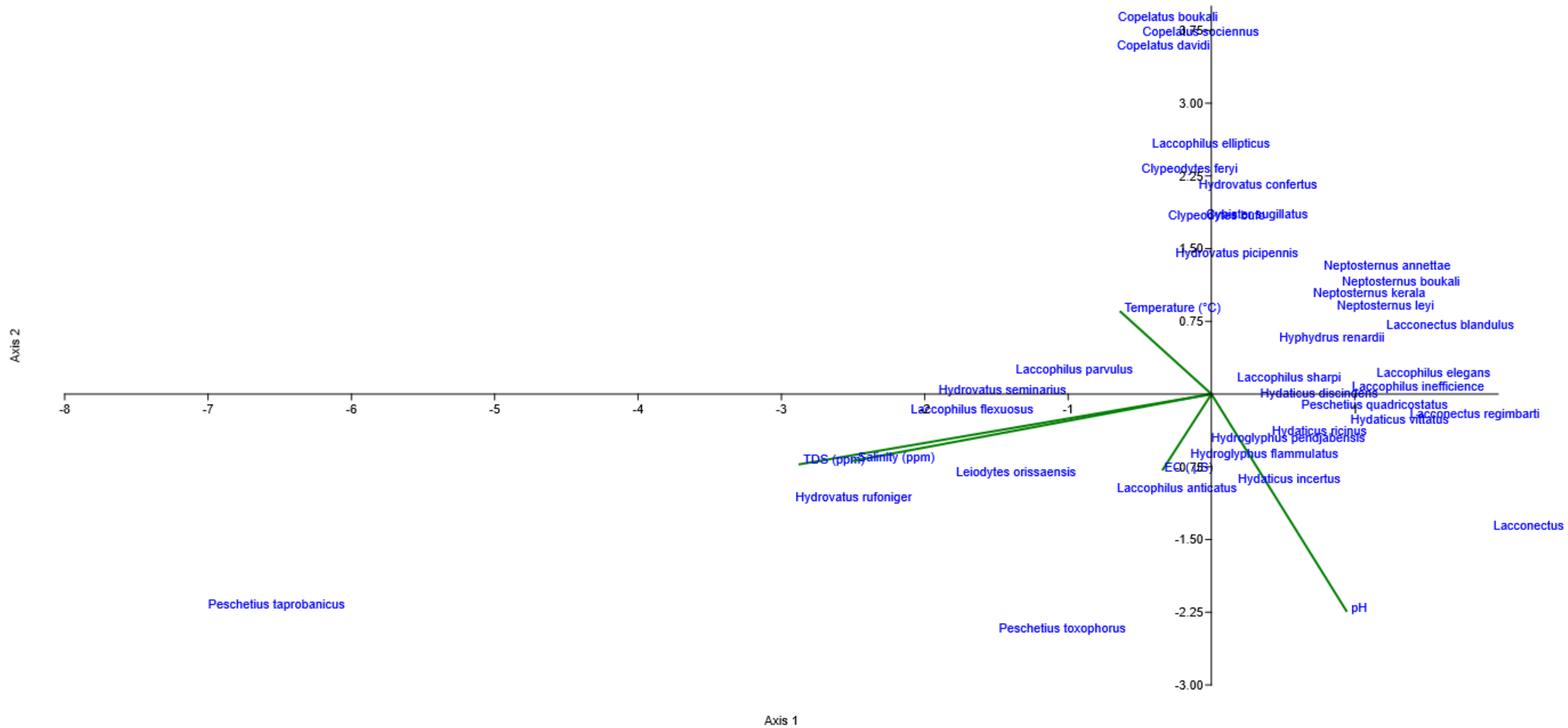
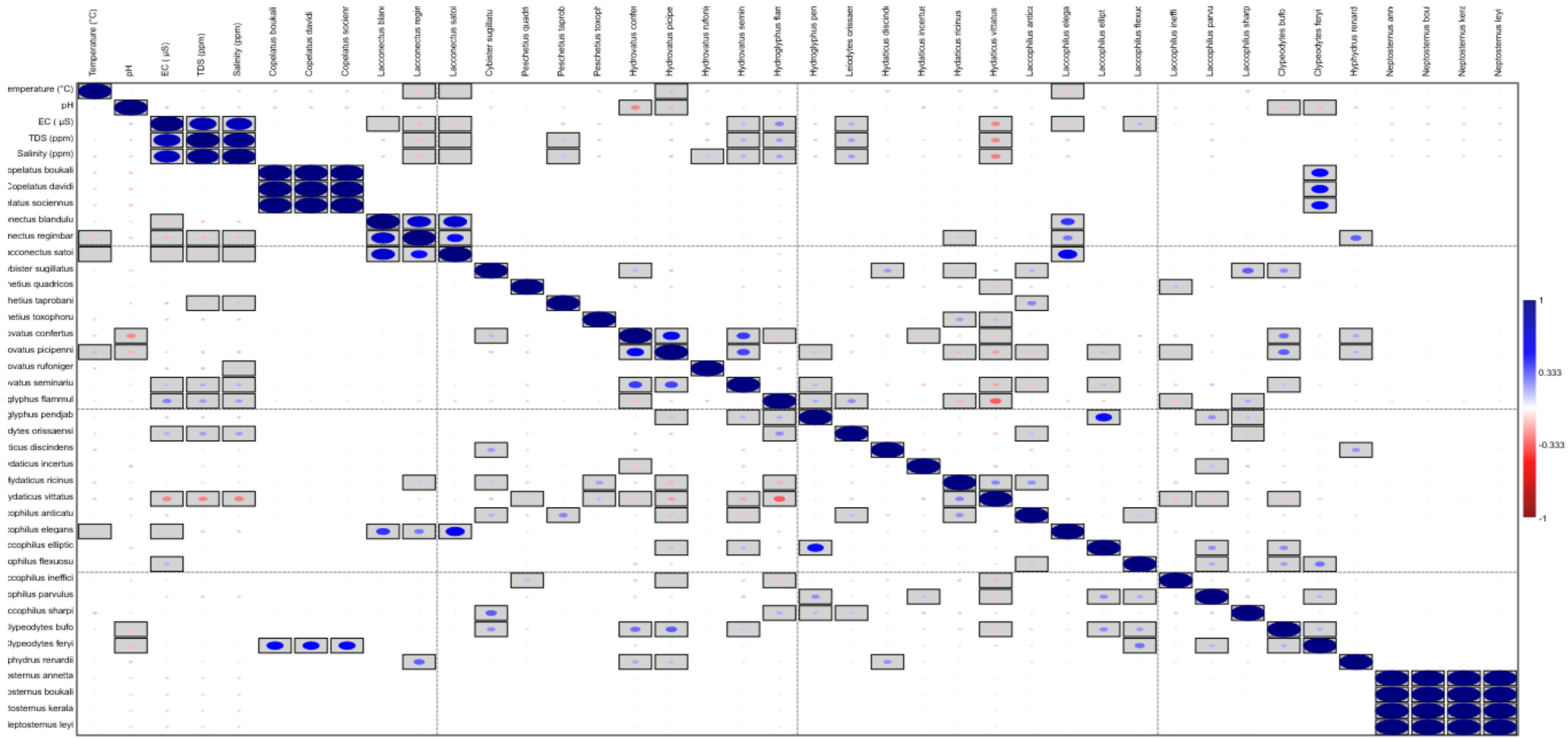


Figure 8. Coexistence of species (Kendal Tau Correlation Matrix)



5.5 Discussion

The co-occurrence of species in relation to five key water parameters and the similarity between different habitats based on presence or absence of species were statistically analysed. From the habitat similarity analysis, it can be understood that small and temporary habitats (eg. Remnant pools in different freshwater ecosystem such as ponds and rivers) are inhabited by similar species. Previous studies shows that the temporary nature of these types of habitats, tend to support diving beetle communities with a high degree of similarity in species composition (Kholin and Nilsson, 1998). Also, many species have affinity for temporary habitats (Young, 1954; Zimmerman, 1959, 1960, 1970; Pitcher, 2011). The similarity in depth of these habitats is important as the shallow water support smaller species (Juliano, 1991). Most of the species which are collected in such habitats have small body size. Some studied indicate that there is no competition among the coexisting species having similar body size (Juliano and Lawton, 1990; Nilsson, 1986c).

On the other hand, the study also revealed similarity between larger ecosystems and small habitats (eg. Margins of lakes and ephemeral pools). This may be due to the ability of some species to disperse to the newly formed temporary habitats from a large, more permanent habitats in order to favour their survival will be common to these types of habitats (Hilsenhoff, 1986). Also, similarity in substratum may also have influence on similarity in species present. Because the study reveals the similarity between muddy puddles and paddy fields. Muddy or clayey substratum in these habitats can support species (*Hydroglyphus* & *Clypeodytes*) which prefer that kind of substratum. Because type of substratum has major role in the distribution of diving beetle species (Gioria, 2014)

The coexistence of congeneric species as well as species in different genera visualised in the CCA is confirmed in the Kendal Tau correlation analysis.

Hydrovatus picipennis shows significant positive correlation to the water temperature. Similarly, several species show either positive or negative correlation towards the water parameters (Temperature, pH, TDS, conductivity (EC) and salinity). As per the environmental variability hypothesis the positive correlation could be because the species has evolved traits which allow it to cope with increase in these water parameters or they can survive in wider range of conditions. It also highlights the importance of thermal niche in the distribution of certain species. Most of the species does not show any significant dependency on water parameters. This could be due to there is no role of water parameters on species occurrence or abundance (Nilsson and Söderberg, 1996). Therefore, the influence of other abiotic and biotic factors cannot be overlooked for the proper understanding of diving beetle composition in freshwater habitats.

5.6 Conclusion

This chapter involved the study of similarity between different freshwater habitats based on presence or absence of species and relationship between species assemblages and water parameters. Thirty-six species and 160 sites were involved. Several congeneric species as well as species of different genera were found to be coexisting. The results showed that selected water parameters may not significantly influence the diving beetle's composition in different freshwater habitats of this study.

CHAPTER- 6

Recommendations

6. Recommendations

Drawing on the insights from this study, specific recommendations have been formulated for scholars, policy makers and other stakeholders.

6.1 Recommendations for the Academia

Intensive studies in smaller areas: One of the challenges of this study was the inability to observe every site for seasonal and other changes. Due to the large study area and study-sites it became difficult to repeatedly visit sites, especially due to the pandemic conditions. As a result, the effect of seasonal changes in waterbodies and thereby on the diving beetles could not be observed. For aspiring researchers, it would be better to focus on smaller areas with the possibility of repeated samplings and visits.

Need for studies in protected areas: This study excluded forests and reserve areas and focussed on regions which were not protected. Further intensive studies focussing on the reserved and protected areas of Kerala especially those associated with freshwater habitats could unveil the actual diversity of diving beetles in the state and country.

Ecology, Physiology and life cycle of diving beetles in the study area have not been explored and could be considered for future research. There is very little knowledge on the egg, larvae, egg-laying sites and female egg-laying behaviours of diving beetles.

Studies which allude to the challenges of diving beetle systematics mention that an approach which includes selected morphology and morphometry, internal organs especially male and female genitalia, habitat preferences and utilization and multiple genes could be unravel the evolution of this group.

Ecological interactions: Dytiscids can be easily handled and observed. So, they are ideal for testing ecological theories of predator-prey interactions, species co-existence, and consumptive and non-consumptive effects on prey. Future studies on their role involved in the structuring of freshwater lentic communities is also recommended.

6.2 Recommendations for Policymakers

Vector and pest control: Adults and larvae of diving beetles are predators of vector and pests like mosquitoes and blackflies. Studies on effect of diving beetles on such prey populations and other biotic and abiotic characters could be investigated to tap their potential as a biological control agent.

Bioindicators: Diving beetles are useful indicators of water/wetland quality or toxins/similar environmental concerns (Foster, 1996; Painter, 1999; Mebane *et al*. 2012). Together with other aquatic beetle families they are useful as indicators of biodiversity and as a tool for selecting areas worthy of conservation (Foster and Eyre, 1992; Foster *et al*. 1990; Ribera and Foster, 1992; Dong *et al*, 2014). Even though the selected abiotic water characters did not seem to affect the beetle distribution in this study, many previous studies indicate habitat selection by this group of beetles. Further studies in this regard are recommended to confirm their role as bioindicators and biological control agents.

Funding basic studies: Continued financial support for studies which include extensive field work and lab work to delineate taxonomic identity and other aspects is essential to produce good quality work.

6.3 Recommendations for Public Databases of Gene Sequences

Public databases of gene sequences are replete with many erroneous sequences, not only in terms of quality but also due to misidentification of the original source specimen. While many publications recognise this problem, the databases have shown no initiative to identify and prevent the submission of erroneous sequences. As these sequences are accessible to researchers all over the globe who make use of it in their study, it can affect the proper resolution of evolutionary relationships and confusions as discussed in the phylogeny chapter. It is recommended that when a sequence is submitted at least a description and good quality images of the source organism be made mandatory for the submission.

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CHAPTER- 7

CONCLUSIONS

7. Conclusions

This chapter summarizes the key findings of this study. It highlights how the data gathered contributes to our understanding of family Dytiscidae. This chapter will revisit the results, and discuss the implications of the study.

The study recorded 53 species from the state. A checklist which included both previously known species and those recorded in the present study was compiled which raised the number of diving beetle species in Kerala from 51 to 74. Taxonomic key for the identification of the 53 species identified during this study were constructed.

Phylogenetic relationships within family Dytiscidae was studied including COI gene sequences of 33 species of this study coming under five subfamilies and 12 genera. Twenty-six good quality sequences from 24 species, 10 genera and five subfamilies were obtained. Phylogenetic relationships could not be delineated with the COI sequences. The relationships were ambiguous and call for studies considering morphology and multiple genes.

A study was also conducted to know the similarity of habitats based on presence or absence of diving beetle species. In addition, the influence of selected water parameters on co-occurrence of species was also investigated. Different habitats shows similarity irrespective of their size, may be because of the similar substratum, water depth, tendency of certain species for dispersal or the presence of specialist or generalists. Water parameters did not seem to have a significant role in the co-occurrence of species.

The new reports of species in this study indicates the lack of studies in this particular group of beetles. The checklist shows how the study helped to increase the number of species documented from the state to 74 species. Checklist as well as the taxonomic key on this group are made for the first time from Kerala.

The study faced many challenges like time and financial constraints as well as unforeseen events like flood, Covid pandemic etc., Many specimens are kept unidentified due to the high similarity with other species in the genera. Median lobe of male aedeagus is a must in such cases and female descriptions are not available.

Further studies should involve the female anatomy to check whether there is any considerable variations associated with their reproductive system, which in turn helpful in the identification at species level. A much higher infrastructure and facilities could increase the quality of images taken, thereby that of the study.

Over all this study has increased the knowledge about the diving beetles in Kerala. Many aspects of diving beetles including taxonomy, physiology, ecology needs further exploration for the complete understanding of these organisms. So, findings of this study as a baseline for further research on Dytiscidae. The role of dytiscids as bio-indicators and biocontrol agents should also be considered in future research in order to make policies for the well-being of our ecosystem as well as the society.

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APPENDICES

APPENDIX A: Distribution of diving beetles in Kerala

Sl. No.	Taxa	Distribution in Kerala (Location and District)
1.	*Rhantus taprobanicus* cf. Sharp, 1890	Shantharuvi (Idukki)
2.	*Copelatus biswasi* Mukherjee & Sengupta, 1986	Silent Valley (Palakkad)
3.	*Copelatus boukali* Hendrich & Balke, 1998	Kallar (Idukki) Mamalakandam (Ernakulam) Adivaram (Kozhikode)
4.	*Copelatus cryptarchoides* Régimbart, 1899	Thumburmuzhy & Darbha (Thrissur)
5.	*Copelatus davidi* Wewalka, 2017	Moonnekkar, Padagiri & Puthuppariyaram (Palakkad) Puthukkad & Padinjarathara (Wayanad) Manikkadavu, Edumbapalam, Vayathur, Vellad & Kanjirakolli (Kannur) Marottichal (Thrissur) Kothamangalam & Mamalakandam (Ernakulam) Adivaram, Kodenjery & Chembukadavu (Kozhikode)
6.	*Copelatus neelumae* Vazirani, 1973	Cheppara (Thrissur)
7.	*Copelatus oblitus* Sharp, 1882	Assarikkadu (Thrissur)
8.	*Copelatus sociennus* J. Balfour-Browne, 1952	Nileswaram (Kasargod) Assarikkadu (Thrissur)
9.	*Copelatus wayanadensis* Manivannan & Madani, 2011	Panamaram (Wayanad)
10.	*Lacconectus blandulus* Brancucci, 2003	Murinjapuzha (Kottayam) Kallar, Thommankuthu, Pazhampyllichal & Kamakshi (Idukki) Urulanthanni (Ernakulam) Kollengode South, Moonnekkar & Puthuppariyaram (Palakkad) Adivaram & Kodenjery (Kozhikode)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
		Kanjirakolli (Kannur)
11.	*Lacconectus freyi* Guéorguiev, 1968	Anamalai Hills, Central Kerala
12.	*Lacconectus munnarensis* Brancucci, 2003	Kallar Valley & Cardamom Hills (Idukki) Kallar bridge (Thiruvananthapuram)
13.	*Lacconectus pacholatkoi* Brancucci, 2003	Kallar Valley & Cardamom Hills, (Idukki) Kallar Bridge (Thiruvananthapuram)
14.	*Lacconectus regimbarti* Brancucci, 1986	Thalikkode (Thrissur) Peermade, Kuttikkanam & Murinjapuzha (Idukki)
15.	*Lacconectus satoi* Brancucci, 2003	Mankayam & Pazhayakunnummel (Thiruvananthapuram) Punnala (Kollam) Murinjapuzha (Kottayam) Kuttikkanam, Thommankuthu, Kamakshi, Kallar & Wellardi (Idukki) Assarikkadu & Vellachal (Thrissur) Chittoor, Moonnekkar & Puthuppariyaram (Palakkad) Adivaram, Chembukadavu & Kodenjery (Kozhikode) Edumbapalam, Vellad & Vayathur (Kannur) Nileswaram (Kasargod)
16.	*Cybister confusus*	Assarikkadu (Thrissur)
17.	*Cybister cardoni* Severin, 1890	Marottichal (Thrissur)
18.	Cybister dejeanii Aubé, 1838	Malabar
19.	*Cybister javanus* Aubé, 1838	Malabar
20.	*Cybister limbatus* (Fabricius, 1775)	Thalassery, Kannur
21.	*Cybister posticus* Aubé, 1838	Iringal (Kozhikode)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
22.	*Cybister sugillatus* Erichson, 1834	Kodom & Kolathur (Kasargod) Kanjirakolli, Manikkadavu & Vellad (Kannur) Malavayal, Malayilpedika, Perikkallur, & Poomala (Wayanad) Naduvannur & Palazhi (Kozhikode) Cheppara (Thrissur) Santhipuram (Kottayam) Ezhukone, Vilappishala & Maruthimala
23.	*Cybister tripunctatus lateralis* (Fabricius, 1798)	Cheppara, Thrissur
24.	*Hydaticus bipunctatus* Wewalka, 1975	Puthukkad (Wayanad) Thottuppoyil (Malappuram) Murukkumpara (Thrissur) Adimali & Cheriyar (Idukki)
25.	*Hydaticus discindens* Walker, 1858	Nileswaram (Kasargod) Edumbapalam (Kannur) Pazhupathur, Thenmavinkadavu, Panavally & Vythiri (Wayanad) Chittur & Moonnekkar (Palakkad) Assarikkadu, Punnachuvadu & Thalikkode (Thrissur) Pavumba (Alappuzha) Ezhukone, Punnala & Sasthamkotta (Kollam) Venkode (Thiruvananthapuram)
26.	*Hydaticus histrio* Clark, 1864	Silent Valley, Palakkad

Sl. No.	Taxa	Distribution in Kerala (Location and District)
27.	*Hydaticus incertus* Régimbart, 1888	Kolathur (Kasargod) Vayathur (Kannur) Panavally & Thavinhal (Wayanad) Murukkumpara (Thrissur) Cheriyar & Thommankuthu (Idukki) Poovanthode (Kottayam) Varanad (Alappuzha)
28.	*Hydaticus luczonicus* Aubé, 1838	Assarikkadu (Thrissur)
29.	*Hydaticus ricinus* Wewalka, 1979	Kanjirakolli, Kudiyanmala, New Nduvil, Puthussery, Vayathur & Vellad (Kannur) Puthukkad, Padinjarathara, Palchuram, Panavally & Thenmavinkadavu (Wayanad) Thottuppoyil (Malappuram) Purameri (Kozhikode) Agali, Chittur, Pappadi & Puthuppariyaram (Palakkad) Murukkumpara (Thrissur) Aikkaranadu (Ernakulam) Manjumala & Pazhampyllichal (Idukki) Thanneermukkom (Alappuzha) Mukkada (Kottayam) Chepra, Kizhakkekallada, Maruthimala & Valiyode (Kollam) Cheenikkala, Kuttimoodu & Neyyar (Thiruvananthapuram)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
30.	*Hydaticus vittatus* (Fabricius, 1775)	Kolathur (Kasargod) Edumbapalam, Kanjirakolli, Oduvallithattu, New Naduvil, Vellad & Vayathur (Kannur) Puthukkad, Padinjarathara & Vythiri (Wayanad) Chembukadavu (Kozhikode) Chittur & Puthuppariyaram (Palakkad) Murukkumpara & Ayyampuzha (Thrissur) Manjumala (Idukki) Mukkada & Santhipuram (Kottayam) Kizhakkekallada, Maruthimala & Valiyode (Kollam) Cheenikkala & Karette
31.	*Sandracottus dejeanii* (Aubé, 1838)	Silent Valley (Palakkad)
32.	*Sandracottus festivus* (Illiger, 1801)	Assarikkadu & Darbha (Thrissur)
33.	*Sandracottus mixtus* (Blanchard, 1843)	Kolathupuzha (Trivandrum)
34.	*Sandracottus vijayakumari* Anand, Ashiq, Smitha, Adhithya, Tibin & Suresh, 2021	Nelliyampathy (Palakkad)
35.	*Clypeodytes bufo* Sharp, 1890	Perikkallur (Wayanad) Maneed (Ernakulam) Kottakkavala & Mulappuram (Idukki) Chenkulam, Kudavattoor, Kaithode, Chepra, Chaliyakkara & Ezhukone (Kollam) Panayara (Thiruvananthapuram)
36.	*Clypeodytes feryi* Hendrich & Wang, 2006	Cheruvathur & Shiriya (Kasargod) Chiranellur (Thrissur) Vettithara (Ernakulam) Kottakkavala (Idukki) Kalavoor & Kunnumma (Alappuzha) Sasthamkotta (Kollam) Kallikkad & Panayara

Sl. No.	Taxa	Distribution in Kerala (Location and District)
		(Thiruvananthapuram)
37.	*Geodessus kejvali* Balke & Hendrich, 1996	Munnar (Idukki)
38.	*Hydroglyphus crassifrons* (Régimbart, 1903)	Mahe (Kannur)
39.	*Hydroglyphus flammulatus* Sharp, 1882	Arai Bridge, Arai Kadavu, Cheruvathur, Kariyamkode, Kolathur, Kottody, Majibial, Manjeswaram, Nileswaram, Pallikkara- II, Panayal, Puthiyavalapu & Vavadukkam (Kasargod) Kalliad, Madathil, Puthussery & Vallyad (Kannur) Chembikkal & Thottuppoyil (Malappuram) Kalpetta, Kottiyur, Mananthavady, Padichira, Panavally & Pazhupathur (Wayanad) Purameri & Thamarassery (Kozhikode) Manchira, Neerakkode, Pappadi, Parali, Parudur, Thalur, Viruthi & Yakkara (Palakkad) Adat, Chembuthra, Cheppara, Darbha, Kannamkuzhy, Mullur, Murukkumpara, Nandhikkara, Pariyaram, Peechi, Pullu & Puzhakkal (Thrissur) Aikkaranadu, Elanji, Karikkattupadi, Karingachira, Malayatur, Memury, Nechoor, Piravom & Vettithara (Ernakulam) Kottakkavala, Mulappuram, Erattayar, Kamakshi, Shantharuvi & Chillithodu (Idukki) Edathua, Govindamuttom, Kayamkulam, Kalavoor, Kidangara, Kunnumma, Valady & Varanad (Alappuzha) Kadamuri, Kangazha, Kulathurmuzhy, Peroor, Perumpanachy, Thiruvanchoor & Vellavoor (Kottayam) Angadickal & Manthuka (Pathanamthitta) Chaliyakkara, Chenkulam, Ezhukone

Sl. No.	Taxa	Distribution in Kerala (Location and District)
		Kummil, Malackal & Chepra (Kollam) Mankayam, Mylakkara, Neyyar Palai, Pantha, Vithura & Venkode (Thiruvananthapuram)
40.	*Hydroglyphus pendjabensis* Gugnot, 1954	Arai Bridge (Kasargod) Nandhikkara (Thrissur) Erattayar (Idukki)
41.	*Leiodytes orissaensis* (Vazirani, 1969)	Panayal (Kasargod) Padichira & Pazhupathur (Wayanad) Kollengode South & Yakkara (Palakkad) Puzhakkal (Thrissur) Vettithara (Ernakulam) Edathua, Kunnam & Varanad (Alappuzha) Kottakkavala & Mulappuram (Idukki) Ithithanam (Kottayam) Chaliyakkara (Kollam) Kallara & Kallikkad (Thiruvananthapuram)
42.	*Peschetius bistroemi* Sheth, Ghate, Dahanukar & Hájek, 2021	Vavadukkam, Kolathur & Majibail (Kasargod) Kanjirakolli (Kannur) Thommankuthu (Idukki)
43.	*Peschetius quadricostatus* (Aubé, 1838)	Panayal (Kasargod) Valiyaparamba (Kozhikode) Agali, Chittoor, Pappadi & Parali (Palakkad) Cheppara, Darbha, Punnachuvadu, Thalikkode & Thekkumkara (Thrissur) Pampakkuda (Ernakulam) Kadamuri, Kuzhimattom, Peroor & Santhipuram (Kottayam) Kudavattoor (Kollam)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
44.	*Peschetius toxophorus* Guignot, 1942	Puthuppariyaram (Palakkad) Darbha & Thalikkode (Thrissur)
45.	*Peschetius taprobanicus* Biström & Bergsten, 2015	Purameri (Kozhikode)
46.	*Peschetius sp.*	Purameri (Kozhikode)
47.	*Yola consanguinea* (Régimbart, 1892)	Viruthi (Palakkad)
48.	*Hydrovatus acuminatus* Motschulsky, 1859	Chalakkudy (Thrissur)
49.	*Hydrovatus cardoni* Severin, 1890	Kottakkavala (Idukki)
50.	*Hydrovatus castaneus* Motschulsky, 1855	Mahe (Kannur)
51.	*Hydrovatus confertus* Sharp, 1882	Mangalpady (Kasargod) Puthussery (Kannur) Padichira (Wayanad) Adivaram & Palazhi (Kozhikode) Kundukad & Kumaranellur (Thrissur) Kottakkavala; Pathiramanal (Alappuzha) Chuttippara (Pathanamthitta) Kadamuri, Perumpanachy, Santhipuram & Vellavoor (Kottayam) Chepra, Malackal, Chepra, Malackal, Maruthimala & Sasthamkotta (Kollam) Elappuram, Irinchayam, Kallara, Karette, Panayara, Ponganadu, Venkode & Vilappil (Thiruvananthapuram)
52.	*Hydrovatus picipennis* Motschulsky, 1860	Arai bridge, Arai Kadavu, Kanhangad, Pallikkara- II, Puthiyavalapu (Kasargod) Padichira (Wayanad) Adivaram, Iringal, Kozhukkallur & Purameri (Kozhikode) Kumaranellur, Nandhikkara, Cheppara &

Sl. No.	Taxa	Distribution in Kerala (Location and District)
		Murukkumpara (Thrissur) Perumpanachy (Kottayam) Chuttippara (Pathanamthitta) Chuttippara, Chepra, Ezhukone, Kaithode & Sasthamkotta (Kollam) Elappuram, Karette, Panayara, Ponganadu, Venkode & Vilappil (Thiruvananthapuram)
53.	*Hydrovatus rufescens* Motschulsky, 1859	Kumily, Idukki
54.	*Hydrovatus rufoniger* (Clark, 1863)	Manchira (Palakkad) Chembuthra & Chiranellur (Thrissur) Karingachira & Vettithara (Ernakulam)
55.	*Hydrovatus seminarius* Motschulsky, 1860	Arai bridge (Kasargod) Padichira (Wayanad) Adivaram, Palazhi & Purameri (Kozhikode) Thalur (Palakkad) Adat, Cheppara, Kumaranellur, Kundukad, Murukkumpara, Poomala & Pullu (Thrissur) Perumpanachy (Kottayam) Chuttippara (Pathanamthitta) Chepra & Sasthamkotta (Kollam) Elappuram, Kallara, Karette, Vellayani & Vilappil (Thiruvananthapuram)
56.	*Hyphoporus pugnator* Sharp, 1890	Nilgiri Hills, Wayanad
57.	*Hyphydrus intermixtus* (Walker, 1858)	Assarikkadu (Thrissur)
58.	*Hyphydrus renardi* Severin, 1890	Manjeswaram & Puthiyavalapu (Kasargod) Puthussery & Thalap (Kannur) Payyoli (Kozhikode) Kumily & Manjumala (Idukki)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
		Pavumba (Alappuzha) Ezhukone (Kollam) Irinchayam, Nellanad & Ponganadu (Thiruvananthapuram)
59.	*Microdytes cameroni* cf. Miller & Wewalka, 2010	Kallar (Idukki)
60.	*Microdytes belli* J. Balfour-Browne, 1946	Kallar Valley (Idukki)
61.	*Microdytes boukali* Wewalka, 1997	Kallar Valley & Munnar (Idukki)
62.	*Microdytes svensoni* Miller & Wewalka, 2010	Kallar Valley (Idukki)
63.	*Laccophilus anticatus anticatus* Sharp, 1890	Manjeswaram (Kasargod) Kanjirakolli & Vayathur (Kannur) Mananthavady, Padinjarathara, Palchuram, Pazhupathur & Perikkallur (Wayanad) Payyoli& Purameri (Kozhikode) Kumbalakkode (Palakkad) Varanad (Alappuzha) Kurumbanadam, Vakathanam, Peroor & Perumpanachy (Kottayam) Chenkulam & Maruthimala (Kollam)
64.	*Laccophilus aurofasciatus* Vazirani, 1972	Peermade (Kottayam)
65.	*Laccophilus auropictus* cf. Régimbart, 1899	Choondakulam (Palakkad)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
66.	*Laccophilus elegans* Sharp, 1882	Nileswaram (Kasargod) Edumbapalam & Kanjirakolli (Kannur) Palchuram (Wayanad) Adivaram (Kozhikode) Padagiri (Palakkad) Thalikkode (Thrissur) Kallar, Manjumala, Peermade & Thommankuthu (Idukki) Murinjapuzha (Kottayam) Brimore (Thiruvananthapuram)
67.	*Laccophilus ellipticus* Régimbart, 1889	Arai Bridge (Kasargod) Nagalassery (Palakkad)
68.	*Laccophilus flexuosus* Aubé, 1838	Manjeswaram & Shiriya (Kasargod) Chembikkal (Malappuram) Chinganchira (Palakkad) Chiranellur & Chowallur (Thrissur) Panayara (Thiruvananthapuram)
69.	*Laccophilus inefficiens* Walker, 1859	Kalliad, Kanjirakolli & New Naduvil (Kannur) Perikkallur (Wayanad) Purameri (Kozhikode) Chittur (Palakkad) Cheppara & Murukkumpara (Thrissur) Chaliyakkara & Nellanad (Thiruvananthapuram)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
70.	*Laccophilus parvulus parvulus* Aubé, 1838	Arai Bridge & Shiriya (Kasargod) Vayathur (Kannur) Panavally (Wayanad) Chembikkal (Malappuram) Chittur, Kumbalakkode, Pappadi & Yakkara (Palakkad) Adat, Chembuthra, Cheppara, Murukkumpara, Kodali, Puzhakkal & Thalikkode (Thrissur) Malayatur & Vettithara (Ernakulam) Chillithodu, Erattayar, Kamakshi, Kottakkavala & Shantharuvi (Idukki) Vellavoor (Kottayam) Kalavoor, Aryad South & Nedumudi (Alappuzha)
71.	*Laccophilus parvulus obtusus* Sharp, 1882	Malayilpedika (Wayanad) Chittur, Elavanjery, Kumbalakkode & Parali (Palakkad) Adat, Cheppara, Murukkumpara & Ayyampuzha (Thrissur) Shantharuvi (Idukki) Kurumbanadam & Santhipuram (Kottayam)
72.	*Laccophilus sharpi* Régimbart, 1889	Kanjirakolli (Kannur) Panavally & Perikkallur (Wayanad) Pappadi (Palakkad) Adat, Cheppara, Murukkumpara, Nandhikkara, Poomala, Pullu (Thrissur) Karikkattupadi & Vettithara (Ernakulam) Kummil, Ezhukone & Maruthimala (Kollam) Chaliyakkara, Cheenikkala & Irinchayam (Thiruvananthapuram)
73.	*Neptosternus annettae* Hendrich & Balke, 2000	Perunad, Punnala & Ranni (Pathanamthitta)

Sl. No.	Taxa	Distribution in Kerala (Location and District)
74.	*Neptosternus boukali* Hendrich & Balke, 1999	Pambaiyar & Ranni (Pathanamthitta)
75.	*Neptosternus kerala* Hendrich & Balke, 1999	Pambaiyar, Punnala & Ranni (Pathanamthitta)
76.	*Neptosternus leyi* Hendrich & Balke, 2000	Perunad & Ranni (Pathanamthitta)

APPENDIX B: Details of specimen deposition at ZSI, WGRC, Calicut, Kerala

Annex-II

Acknowledgement for Receiving the Deposits by Designated Repositories

Sl.No	Particulars	Remarks
1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28373
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Copelatus neelumae* Vazirani, 1973
8.	Description and quantity of the deposit	1♀

30/12/24

Name and Signature of the authorized signatory of the Repository.

Seal

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Sl.No	Particulars	Remarks
1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28374
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Copelatus oblitus* Sharp, 1882
8.	Description and quantity of the deposit	1♀

30/12/24
....

Name and Signature of the authorized signatory of the Repository.

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28375
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Copelatus sociennus* J. Balfour-Browne, 1952
8.	Description and quantity of the deposit	1♂

30/12/24

....

Name and Signature of the authorized signatory of the Repository.

Seal

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Sl.No	Particulars	Remarks
1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28376
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	Cybister confusus Sharp, 1882
8.	Description and quantity of the deposit	1 ♂

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Name and Signature of the authorized signatory of the Repository.

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28377
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Cybister sugillatus* Erichson, 1834
8.	Description and quantity of the deposit	1♂

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Name and Signature of the authorized signatory of the Repository.

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28378
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	Cybister tripunctatus lateralis (Olivier, 1795)
8.	Description and quantity of the deposit	1 ♂

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2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28379
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Cybister posticus* Aube, 1838
8.	Description and quantity of the deposit	1 ♂

30/12/24
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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28380
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Hydaticus incertus* Regimbart, 1888
8.	Description and quantity of the deposit	1 ♂

30/12/24
....

Name and Signature of the authorized signatory of the Repository.

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2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28381
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Hydaticus discindens* Walker, 1858
8.	Description and quantity of the deposit	1♂

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28382
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Sandracottus festivus* (Illiger, 1802)
8.	Description and quantity of the deposit	1 ♂

30/12/24
....

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28383
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	Hydrovatus picipennis Motschulsky 1859
8.	Description and quantity of the deposit	1 ♂

30/12/24

....

Name and Signature of the authorized signatory of the Repository.

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28384
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Hydrovatus rufoniger* (Clark, 1863)
8.	Description and quantity of the deposit	1 ♂

30/12/24

....

Name and Signature of the authorized signatory of the Repository.

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28385
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Lacconectes orissaensis* (Vazirani, 1969)
8.	Description and quantity of the deposit	1♂

30/12/24

....

Name and Signature of the authorized signatory of the Repository.

Seal

श्री. श्रीजीत एस. कुमार / Shri. Sreejith S. Kumar
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Western Ghat Regional Centre
कोझिक्कोड, केरल / Kozhikode, Kerala - 673006

Annex-II

Acknowledgement for Receiving the Deposits by Designated Repositories

Sl.No	Particulars	Remarks
1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28386
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	Clypeodytes bufo (Sharp, 1890)
8.	Description and quantity of the deposit	1 ♂

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Name and Signature of the authorized signatory of the Repository.

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3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	Clypeodytes feryi Hendrich & Wang, 2006
8.	Description and quantity of the deposit	1♂

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Name and Signature of the authorized signatory of the Repository.

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Sl.No	Particulars	Remarks
1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28388
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Laccophilus auropictus* Regimbart, 1899
8.	Description and quantity of the deposit	1 ♀

30/12/24
....
Name and Signature of the authorized signatory of the Repository.

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1.	Name of the Designated Repository	Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala, India
2.	Repository Reference number	ZSI/WGRC/I.R.-INV. 28389
3.	Date of receipt	30.12.2024
4.	NBA reference number	N.A.
5.	Name and address of the depositor	Priyanka Prabhakaran Vallikattil House, Mannamangalam, Thrissur, Kerala, India
6.	Common name of the deposit	Diving beetles (Coleoptera: Dytiscidae)
7.	Scientific name of the deposit	*Laccophilus elegans* Sharp, 1882
8.	Description and quantity of the deposit	1♂

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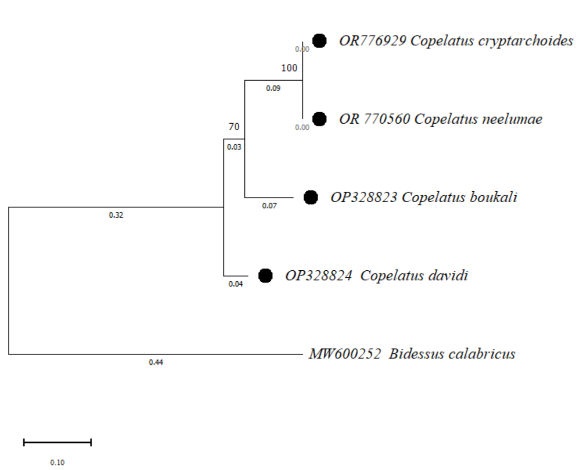
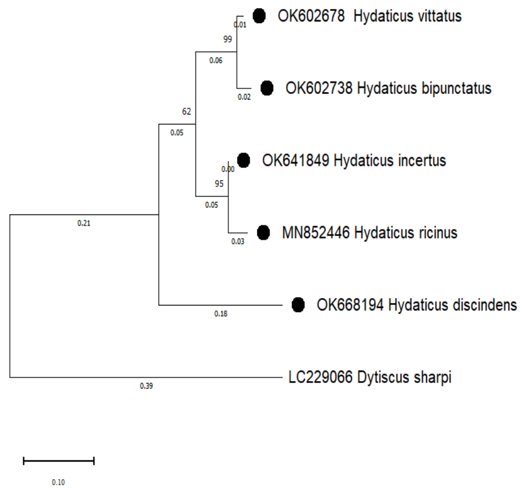
कोझिक्कोड, केरल / Kozhikode, Kerala - 673006

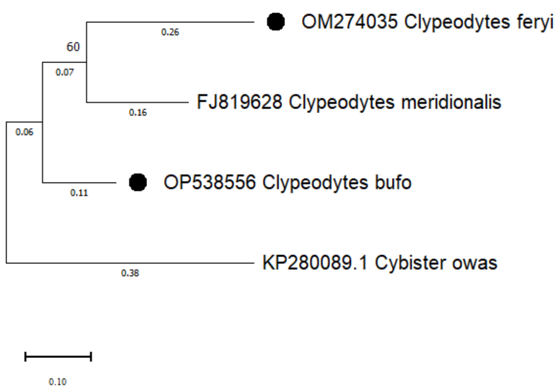
APPENDIX C: Genus-level phylogenetic trees of family Dytiscidae constructed in MEGA 11 software showing good resolution of phylogenetic relationships



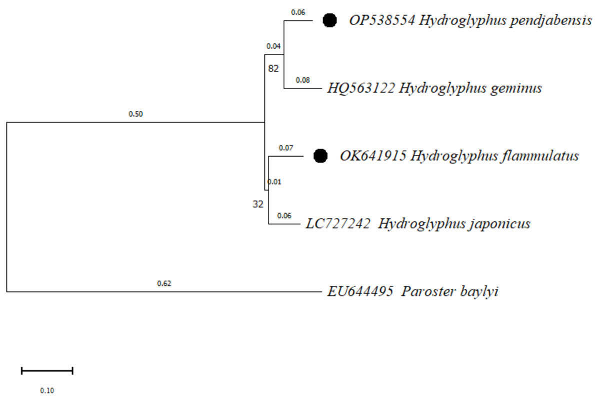
Genus: *Copelatus*



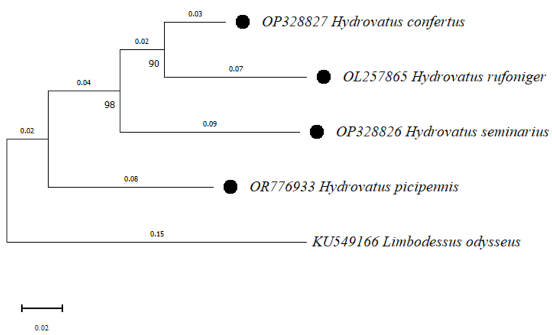
Genus: *Hydaticus*



Genus: *Clypeodytes*



Genus: *Hydroglyphus*



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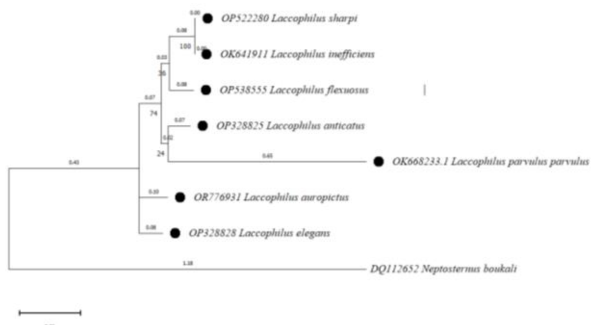
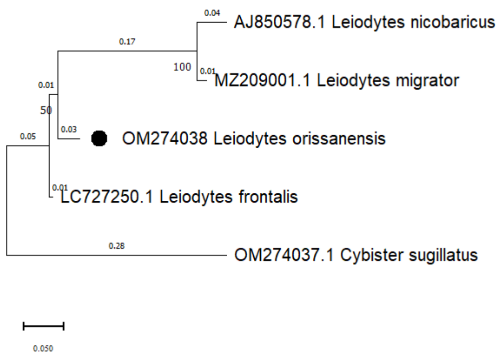
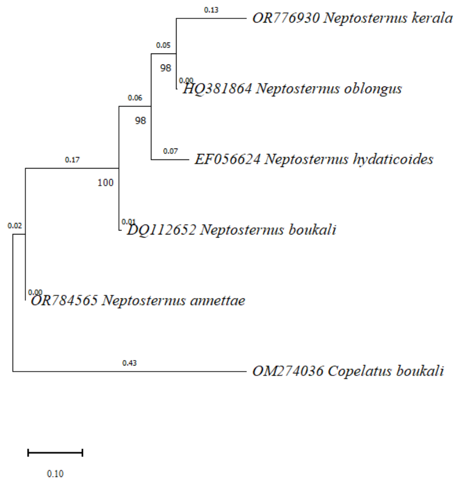


Genus: *Laccophilus*



Genus: ***Leiodytes***



Genus: ***Neptosternus***

APPENDIX D: Abbreviations of habitat names used in habitat similarity study

Sl No.	Habitat names	Abbreviation of habitat names
1.	Remnant pool in the downstream of waterfall	RPIDSWF
2.	Ephemeral pool in a dirt road	EPIDR
3.	Paddy field (Uncultivated)	PF (UC)
4.	Others	O
5.	Pool in abandoned paddy field	PIAPF
6.	Rock pool	RP
7.	Remnant pools in irrigation canal	RPIIC
8.	Marginal zone of Reservoir	MZR
9.	Muddy puddle	MP
10.	Ditch in agricultural field	DIAF
11.	Paddy field	PF
12.	Pool	PL
13.	Remnant pool in a pond	RPIP
14.	Remnant pool in floodplains of river	RPIFPR
15.	River margin	RM
16.	Remnant pool in river	RPIR
17.	Abandoned ditch	AD
18.	Ditch	D
19.	Ephemeral pool in quarry	EPIQ
20.	Remnant pool in stream	RPIS
21.	Pond	PD
22.	Ephemeral pool	EP
23.	Abandoned paddy field	APF
24.	Remnant pool in ditch	RPID
25.	Spring-fed pool	SPL
26.	Pond margin	PM
27.	Roadside ditch	RSD
28.	Margin of quarry pool	MQP
29.	Drying stream	DS
30.	Small pool in a quarry	SPIQ
31.	Abandoned pond	AP
32.	Ephemeral pool in the road side	EPIRS
33.	Slow moving stream	SMS
34.	Margin of lake	ML
35.	Remnant pool in the downstream of a water fall	RPIDWF
36.	Ditch in abandoned paddy field	DAP
37.	Rock pool	RL

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CERTIFICATE ON PLAGIARISM CHECK

1.	Name of the Research Scholar	PRIYANKA PRABHAKARAN	
2.	Title of thesis / dissertation	STUDIES ON DIVING BEETLES (COLEOPTERA: DYTISCIDAE) OF KERALA	
3.	Name of the Supervisor	Dr. JOYCE JOSE	
4.	Department/Institution	Research Scholar, Research & Postgraduate dept. of Zoology, St. Thomas' College (Autonomous), Thrissur, Kerala, India- 680001	
5.		Non-Core	Core
		Introduction/ Theoretical overview/Review of literature/ Materials & Methods/ Methodology	**Analysis/Result/Discussion / Summary/Conclusion/ Recommendations**
	Similar content (%) identified	**6**	**5**
	Acceptable maximum limit (%)	10	10
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Name and signature of the Supervisor. Dr. Joyce Jose

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