TAXONOMIC STUDIES OF DRAGONFLY NYMPHS (ORDER: ODONATA) FROM SELECTED HABITATS OF KERALA BY USING THEIR EXUVIAE

Thesis submitted to the
University of Calicut for the award of the Degree of
Doctor of Philosophy in Zoology

by

Mr. SHAUN PAUL ADAMBUKULAM

Under the Supervision of

Dr. JOYCE JOSE

RESEARCH AND POSTGRADUATE DEPARTMENT OF ZOOLOGY
ST.THOMAS COLLEGE (AUTONOMOUS) THRISSUR

University of Calicut, Kerala

June 2025

DEDICATED TO DR. FRANCY K. KAKKASSERY

Remembering with gratitude my mentor and former guide who was the driving force behind this work with his insight, brilliance and special interest until his last breath.

UNIVERSITY OF CALICUT

CERTIFICATE ON PLAGIARISM CHECK

1.	Name of the Research Scholar	SHAUN PAUL ADAMBUKULAM	
2.	Title of thesis / dissertation	TAXONOMIC STUDIES OF DRAGONFLY NYMPHS (ORDER: ODONATA) FROM SELECTED HABITATS OF KERALA BY USING THEIR EXUVIAE	
3.	Name of the Supervisor	DR. JOYCE JOSE	
4.	Department/Institution	Research & Postgraduate Department of Zoology St. Thomas College (Autonomous) Thrissur	
5.	Similar content (%) identified	Non-Core **Introduction/ Theoretical overview/Review of literature/ Materials & Methods/ Methodology**	Core **Analysis/Result/Discussion/ Summary/Conclusion/ Recommendations**
		1	2
	Acceptable maximum limit (%)	10	10
6.	Software used	**iThenticate**	
7.	Date of verification	17.08.24	

**Report on plagiarism check, specifying included/excluded items with % of similarity to be attached.*

Checked by (with name, designation & signature)

Dr. Nasirudheen. T
Assistant Librarian
University of Calicut, Kerala.

Name and signature of the Researcher: SHAUN PAUL ADAMBUKULAM

Name and signature of the Supervisor: Dr. JOYCE JOSE

The Doctoral Committee* has verified the report on plagiarism check with the contents of the thesis, as summarized above and appropriate measures have been taken to ensure originality of the Research accomplished herein.

Name & Signature of the HoI (Chairperson of the Doctoral Committee):

23-08-24

Dr. Martin K. A.
Principal-in-Charge
St Thomas College (Autonomous)
Thrissur - 680 001

ST. THOMAS COLLEGE
(AUTONOMOUS),
Thrissur-1.
Kerala, India
https://stthomas.ac.in/zoology/zoology-faculty/dr-joyce-jose/

Dr. Joyce Jose
Dean of Research
Assistant Professor and Research Guide
Research and Post Graduate Department of Zoology
dor@stthomas.ac.in
joycejose@stthomas.ac.in
91 9446812852

CERTIFICATE

This is to certify that the thesis entitled **"TAXONOMIC STUDIES OF DRAGONFLY NYMPHS (ORDER: ODONATA) FROM SELECTED HABITATS OF KERALA BY USING THEIR EXUVIAE"** is an authentic record of research work carried out by **Mr. SHAUN PAUL ADAMBUKULAM** for the award of the Ph. D. Degree of the University of Calicut under my guidance. He has carried out this work at the Research & Postgraduate Department of Zoology, St. Thomas College (Autonomous) Thrissur, and the results in this thesis have not been included in any other thesis submitted previously for the award of any degree of any other university or institution. Also certified that the contents of the thesis have been checked using an anti-plagiarism database and no unacceptable similarity was found in the check.

Dr. Joyce Jose

Supervising Teacher

Dr. JOYCE JOSE, Ph.D.
Assistant Professor
Research & Postgraduate Department of Zoology
St. Thomas' College, Thrissur - 680 001, Kerala
E-mail : joyceofthejungle@gmail.com

Place: Thrissur

Date: 11/06/2025

DECLARATION

I hereby declare that the work presented in the thesis entitled **"TAXONOMIC STUDIES OF DRAGONFLY NYMPHS (ORDER: ODONATA) FROM SELECTED HABITATS OF KERALA BY USING THEIR EXUVIAE"** 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 **iTenticate** 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.

Shaun Paul Adambukulam

Place: Thrissur

Date: 11/06/2025

ACKNOWLEDGEMENT

It is my great pleasure to acknowledge all those who have helped me with the successful completion of my research work.

First and foremost, I thank God Almighty, who blessed me with health, confidence and strength to complete my study successfully.

I express my sincere and heartfelt gratitude and indebtedness to my former research supervisor, ***Dr. Francy K. Kakkassery,*** *Associate Professor & Head (Retd.), Research and Postgraduate Department of Zoology, St. Thomas College (Autonomous), Thrissur, for his expert guidance, creative advice, and timely and valuable suggestions that resulted in the conceptualization and execution of this work. His untimely demise on 29/06/2024 is an irreversible loss for me.*

I would like to express my honest gratitude to my present guide ***Dr. Joyce Jose****, Dean of Research and Assistant Professor, Research and Postgraduate Department of Zoology, St. Thomas College (Autonomous), Thrissur, for her guidance, support and encouragement throughout my study and her assistance in completing my thesis.*

I extend my sincere gratitude to ***Dr. Roby T.J.,*** *Assistant Professor, Department of Botany, Carmel College (Autonomous), Mala, Thrissur, for helping me to prepare the study area map.*

I extend my sincere gratitude to ***Dr. Joby Paul,*** *Assistant Professor, Department of Botany, St. Thomas' College (Autonomous), Thrissur, for his help in stacking and editing photographic plates.*

I am also happy to express my gratitude to my friends, ***Mr. Joshy****,* ***Mr. Vinod*** *and* ***Mr. Anoop,*** *for their assistance during field trips.*

I am grateful to our principal, ***Dr. Martin K.A.,*** *and former principals,* ***Dr. Joy K. L., Dr. Ignatius Antony,*** *and* ***Dr. Jenson P. O.*** *St. Thomas College (Autonomous), Thrissur, for the facilities given for my study.*

I am grateful to ***Dr. V. M. Chacko,*** *former Dean of Research, for his timely interventions and guidance regarding administrative matters.*

I express my gratitude to our Head of the Department, ***Dr. Vimala K. John****, former H.O.D.s* ***Dr. C. F. Binoy , Dr. C. V. David,*** *for the support given to me. I also express my gratitude to*

my teachers, ***Dr. Britto Joseph K.,*** *former Dean of Science for all support. I also want to thank my colleagues****,*** *and* ***Mrs. Sheeba Raphael****, for their constant encouragement.*

*I would like to thank my teachers D****r. Joseph Louis Olekkengil, Dr.C. C. John, Dr. P.T.C. Ponnachan*** *and* ***Mr. Jimmi Mathew*** *for the support and encouragement throughout my life.*

I am also thankful to ***Dr. Sanjo Jose****, Librarian, St. Thomas College Thrissur, for providing library facilities and to* ***Dr. Nasirudheen T.,*** *Asst. Librarian, University of Calicut, for assistance in similarity checking of the thesis and associated procedures.*

I express my sincere gratitude to my family members. The care, love, and endless support of my family members will be remembered forever. I express my sincere gratitude to my mother ***Annie Paul,*** *my wife* ***Minumol T. M.,*** *and my children* ***Daniel, Samuel*** *and* ***Esther*** *for their love and sacrifice.*

Shaun Paul Adambukulam

Place: Thrissur
Date: 11/06/2025

Abstract

Odonata is a primitive order of the class Insecta, which is divided into three suborders, namely Anisoptera (Dragonflies), Zygoptera (Damselflies), and Anisozygoptera. Anisozygoptera possesses the features of both Anisoptera and Zygoptera and is a living fossil with three extant species.

Odonates are hemimetabolous and amphibiotic organisms with an aquatic nymphal stage and terrestrial adults. Adult females lay their eggs in all types of natural and man-made freshwater ecosystems, such as ponds, wells, lakes, rivers, streams, irrigation canals and all types of wetlands. The nymphs that hatch from the eggs live in these aquatic habitats. At the end of their aquatic life, the nymphs climb up to suitable vertical substratum such as submerged and marginal vegetation, tree roots, steep banks, exposed rocks, or even horizontal surfaces such as leaves of floating plants and sometimes even flat sand in the bank to shed their skin for the last time and emerge as adults. This last instar moulted skin is called exuvia.

In Kerala, studies on odonates were mainly focused on the diversity, taxonomy, ecology, habitats and ecosystem of the adults. Kerala was home to 174 species of Odonates of which Dragonflies become dominant with 100 species (Gopalan *et al.,* 2022). Among the 100 species of Dragonflies, nymphal features of only two species were studied in Kerala till 2013. This could be due to certain limitations in the nymphal studies.

The present study was conducted in natural and man-made freshwater ecosystems located in Kasaragod, Kannur, Wayanad, Thrissur and Palakkad districts of Kerala. A total of 45 sites were selected for the study. The study documented the taxonomic descriptions of 30 species of dragonfly nymphs belonging to four families and 27 genera, along with their breeding sites. These descriptions were based on the taxonomical features present in their exuviae. Of the 30 species, nymphs of ten species, including five endemics were described for first time in the field of nymphal taxonomy. They are *Anax indicus* Lieftinck, 1942; *Gynacantha dravida* Lieftnck, 1960; *Burmagomphus laidlawi* Fraser, 1924; *Burmagomphus pyramidalis* Laidlaw , 1922; *Microgomphus souteri* Fraser, 1924; *Onychogomphus malabarensis* (Fraser, 1924), *Megalogomphus superbus* Fraser, 1931; *Hydrobasileus croceus*

(Brauer, 1867), *Zygonyx iris* (Selys,1869) and *Macromia indica* Fraser, 1924. Of the remaining 20 descriptions, 15 are first reports from Kerala and South India, and five species were already described as a part of pilot study conducted for this work. Taxonomic features present on the exuviae were photographed and a taxonomic key was prepared for the collected and identified exuviae from the study area.

The collection of the exuviae, being a non-invasive method, will not affect the existing diversity of both adults and nymphs in a particular ecosystem. Hence, this method could be adopted for the study of nymphs of protected and endangered dragonfly species and also for those species that are scarcely seen as adults in the field. Extensive studies are required to understand the taxonomy and ecology of nymphs of the Odonates of Kerala, and hence more studies in this field are suggested.

Key words: odonata, dragonfly, exuvia, taxonomy, nymph & breeding

സംഗ്രഹം

ജീവികളിൽ ഏറ്റവും പ്രധാനപ്പെട്ട ഒരു വംശമാണ് ഷഡ്പദങ്ങൾ. ഈ വംശത്തിലെ തുമ്പികൾ ഉൾപ്പെടുന്ന ഒരു പ്രാചീന ഗണമാണ് ഒഡോണേറ്റ. ഇവ അനൈസോപ്റ്റീറ, സൈഗോപ്റ്റീറ, അനൈസോസൈഗോപ്റ്റീറ എന്നിങ്ങനെ മൂന്ന് ഉപഗണങ്ങളായി വിഭജിക്കപ്പെട്ടിരിക്കുന്നു. ഇവയിൽ അനൈസോപ്റ്റീറ കല്ലൻ തുമ്പികളുടെയും സൈഗോപ്റ്റീറ സൂചിതുമ്പികളുടെയും ഉപഗണങ്ങളാണ്. എന്നാൽ അനൈസോസൈഗോപ്റ്റീറ കല്ലൻ തുമ്പികളുടെയും സൂചിത്തുമ്പികളുടെയും സവിശേഷതകൾ പ്രകടിപ്പിക്കുന്ന മൂന്നാമത്തെ അപൂർവ്വ ഉപഗണമാണ്.

അപൂർണ്ണ രൂപാന്തരീകരണത്തിലൂടെ ജീവിതചക്രം പൂർത്തിയാക്കുന്ന ഉഭയജീവിതകളായ തുമ്പികൾക്ക്, ഒരു ജലാശയ നിംഫ് ഘട്ടവും, കരയിൽ ജീവിക്കുന്ന പൂർണ്ണവളർച്ചയെത്തിയ ഘട്ടവും ഉണ്ട്. കരയിൽ ജീവിക്കുന്ന പൂർണ്ണവളർച്ചയെത്തിയ പെൺതുമ്പികൾ പ്രജനന കാലമാകുമ്പോൾ വിവിധ തരത്തിലുള്ള ശുദ്ധജല ആവാസവ്യവസ്ഥകളായ കുളങ്ങൾ, കിണറുകൾ, പുഴകൾ, തടാകങ്ങൾ, ജലസേചന കനാലുകൾ, തടയിണകൾ, തണ്ണീർതടങ്ങൾ, അരുവികൾ, നീർച്ചാലുകൾ, പാർക്കുകളിലും പൂന്തോട്ടങ്ങളിലും കാണപ്പെടുന്ന മനുഷ്യനിർമ്മിതമായ ചെറുകുളങ്ങൾ എന്നിവയിൽ മുട്ടകളിടുന്നു. മുട്ട വിരിഞ്ഞു വരുന്ന നിംഫുകൾ ഈ ആവാസവ്യവസ്ഥകളിൽ ജീവിക്കുന്നു. പൂർണ്ണ വളർച്ചയെത്തുന്ന നിംഫുകൾ, തങ്ങൾക്കു അനുയോജ്യമായ, ജലോപരിതലത്തിൽനിന്നു മുകളിലേക്കു നിൽക്കുന്ന ചെടികളുടെ തണ്ടുകൾ, ഇലകൾ, വേരുകൾ, ചെറു പാറക്കൂട്ടങ്ങൾ, കുളങ്ങളുടെ ഭിത്തികൾ അല്ലെങ്കിൽ തീരത്തേക്ക് ഇഴഞ്ഞുകയറി അവിടെവെച്ച് തങ്ങളുടെ പുറംതോൽ ഉരിഞ്ഞുകളഞ്ഞ് പറന്നുപോകുന്നു. ഇത്തരത്തിൽ നിംഫുകൾ അവശേഷിപ്പിച്ചു പോകുന്ന പുറംതോലിനെ 'എക്സൂവിയ' എന്നാണ് പറയുന്നത്.

കേരളത്തിൽ 174 ഇനം തുമ്പികളെ കണ്ടെത്തിയിട്ടുണ്ട്. ഇവയിൽ 100 ഇനം കല്ലൻതുമ്പികൾ ഉണ്ട്. കേരളത്തിൽ തുമ്പികളുമായി ബന്ധപ്പെട്ടു നടക്കുന്ന ഗവേഷണങ്ങൾ പ്രധാനമായും മുതിർന്ന തുമ്പികളുടെ വൈവിധ്യം, വർഗ്ഗീകരണം, പരിസ്ഥിതി, ആവാസ വ്യവസ്ഥ എന്നിവയെ ബന്ധപ്പെടുത്തിയാണ്. കേരളത്തിൽ നിന്ന് കണ്ടെത്തിയിട്ടുള്ള 100 ഓളം കല്ലൻതുമ്പികളിൽ, കേവലം 2 കല്ലൻതുമ്പികളുടെ നിംഫുകളെ കുറിച്ച് മാത്രമേ 2013 വരെയുള്ള കാലയള

വിൽ പഠനം നടത്തിയതായി കാണപ്പെടുന്നത്. നിംഫുകളെ നേരിട്ട് ഉപയോഗിച്ചുകൊണ്ടുള്ള പഠനത്തിൽ നേരിടുന്ന ചില പരിമിതികളായിരിക്കാം ഇതിന് കാരണം. ഈ സാഹചര്യത്തിൽ നിംഫുകളെ നേരിട്ടു ഉപയോഗിക്കാതെ, അവ ഉപേക്ഷിച്ചുപോകുന്ന പുറംതോലുകളായ എക്സൂവിയകളെ (Exuviae) ഉപയോഗിച്ചു നിംഫുകളുടെ വർഗ്ഗീകരണ പഠനം നടത്തുന്നത് വളരെയധികം പ്രാധാന്യം അർഹിക്കുന്നു.

കേരളത്തിലെ അഞ്ച് ജില്ലകളായ കാസർകോഡ്, കണ്ണൂർ, വയനാട്, പാലക്കാട്, തൃശൂർ എന്നിവിടങ്ങളിലെ വ്യത്യസ്തങ്ങളായ 45 ഓളം പഠനമേഖലകളിൽ ഉൾപ്പെട്ട ശുദ്ധജല ആവാസ വ്യവസ്ഥകളിൽ നിന്നു ശേഖരിച്ച എക്സൂവിയകളെയാണ് ഈ പഠനത്തിൽ ഉപയോഗിച്ചത്.

കേരളത്തിൽ കാണപ്പെടുന്ന നാല് കല്ലൻതുമ്പി കുടുംബങ്ങളിൽ ഉൾപ്പെടുന്ന ഇരുവത്തിയേഴോളം ജനുസ്സുകളിൽപ്പെട്ട മുപ്പതോളം കല്ലൻതുമ്പികളുടെ നിംഫുകളുടെ വിവരണമാണ് അവയുടെ എക്സൂവിയ മാത്രം ഉപയോഗിച്ച് നടത്തിയിരിക്കുന്നത്. ഈ മുപ്പതെണ്ണത്തിൽ പത്തെണ്ണം [അനാക്സ് ഇൻഡിക്കസ് ലിഫ്റ്റ്നിക്, 1942; ഗൈനാക്കാന്ത ദ്രാവിഡ ലിഫ്റ്റിനിക്, 1960; ബർമാഗോമ്പസ് ലെയ്ഡ്‌ലാവി ഫ്രേസർ, 1924; ബർമാഗോമ്പസ് പിരമിഡാലിസ് ലെയ്ഡ്‌ലാ, 1922; മൈക്രോഗോമ്പസ് സൗട്ടേരി ഫ്രേസർ, 1924; ഒണിക്കോഗോമ്പസ് മലബാരെൻസിസ് (ഫ്രേസർ 1924); മെഗാലോഗോമ്പസ് സൂപ്പർബെസ് ഫ്രേസർ 1931; സൈഗോണിക്സ് ഐറിസ് സെലിസ്, 1869; ഹൈഡ്രോബേസീലിയസ് ക്രോക്കിയസ് (ബ്രൂവർ, 1867); മാക്രോമിയ ഇൻഡിക്ക (ഫ്രേസർ, 1924)] നിംഫുകളുടെ വർഗ്ഗീകരണ പഠനത്തിൽ ആദ്യത്തേതാണ്. ഇവയിൽ പശ്ചിമഘട്ടത്തിൽ മാത്രം കാണപ്പെടുന്ന അഞ്ച് സ്ഥാനീയ തുമ്പികളുടെ നിംഫുകളും ഉൾപ്പെടുന്നു. (അടിയിൽ വരയിട്ടത്). ബാക്കിയുള്ള ഇരുപത് വിവരണങ്ങളിൽ പതിനഞ്ചെണ്ണം കേരളത്തിൽനിന്നും, തെക്കേ ഇന്ത്യയിൽ നിന്നുമുള്ള ആദ്യ വിവരണങ്ങളും അഞ്ചെണ്ണം ഈ ഗവേഷണം നടത്തുന്നതിന് മുൻപ് നടത്തിയ പ്രാഥമിക പഠനത്തിൽ വിവരിക്കപ്പെട്ടതുമാണ്. പഠനമേഖലയിൽ നിന്ന് ശേഖരിച്ച എക്സൂവിയകളുടെ വർഗ്ഗീകരണത്തിനുപയോഗിച്ച സവിശേഷതകൾ ഉൾപ്പെടുത്തിയ ചിത്രഫലകങ്ങളും വർഗ്ഗീകരണ സൂചികയും തയ്യാറാക്കിയിട്ടുണ്ട്. കൂടാതെ പഠനമേഖലയിൽ നിന്നു ശേഖരിക്കപ്പെട്ട എക്സൂവിയകളുടെ അടിസ്ഥാനത്തിൽ കല്ലൻതുമ്പികളുടെ നിംഫുകളുടെ പ്രജനന ആവാസവ്യവസ്ഥകളെ കുറിച്ചും അവയുടെ ആവിർഭാവ കാലഘട്ടത്തെക്കുറിച്ചുമുള്ള വിവരണങ്ങളും തയ്യാറാക്കിയിട്ടുണ്ട്. ഇവയെല്ലാം ഭാവിയിൽ ഈ മേഖലയിലുള്ള പഠനങ്ങൾക്ക് ഉപകാരപ്രദമാണ്.

കേരളത്തിലെ തുമ്പികളുടെ നിംഫുകളെ പറ്റിയുള്ള പഠനങ്ങൾ ഇനിയും ഏറെ നടത്തേണ്ടതായിട്ടുണ്ട്. വിപുലവും തീവ്രവുമായ പഠനങ്ങൾ ഇനിയും വിവരിക്കപ്പെടാത്ത നിംഫുകളെ പറ്റിയും അവരുടെ ആവാസവ്യവസ്ഥകളെ പറ്റിയും ഉള്ള അറിവുകൾ ശാസ്ത്രലോകത്തിനു നൽകാൻ സാധിക്കും എന്നതിനാൽ കൂടുതൽ പഠനങ്ങൾ ശുപാർശ ചെയ്യുന്നു.

താക്കോൽ വാക്കുകൾ:

ഒഡോണേറ്റ, കല്ലൻതുമ്പി, എക്സൂവിയ, വർഗ്ഗീകരണം, നിംഫ്, പ്രജനനം.

TABLE OF CONTENTS

LIST OF TABLES IN CHAPTERS

LIST OF TABLES IN APPENDICES

LIST OF FIGURES

LIST OF PLATES

CHAPTER 1
INTRODUCTION

CHAPTER 1
INTRODUCTION

1.1 Class Insecta

Insects, the most diverse land organisms constitute around 75% of the world's faunal diversity. Insect diversity reduces from the tropics to polar regions and is completely absent in marine ecosystems (Loxdale, 2016). They are primitive organisms that appeared in the late Devonian period and play a significant role in ecosystems as pollinators, indicators of ecosystem health, predators of other insects, agricultural pests, parasites and disease-causing vectors (Price *et al.,* 2011). They are the largest class in the phylum Arthropoda, with more than one million described species (Bybee *et al.,* 2016). The morphology of adult insect constitutes head, thorax and abdomen and is supported by a hard body wall, the exoskeleton made up of keratinized chitin (Kalish, 2014). The appendages on insect head are a pair of antennae, compound eyes and mouth parts. In insects, mouth parts are ectognathous (external to the head capsule) and are related to diet. The thorax is divided into three distinct regions the pro, meso and metathorax and each bears a pair of legs. Two pairs of wings are present on the meso and metathorax. The abdomen is divided into eleven segments (Chapman, 2013). Abdominal appendages are absent in adults but present in the larval forms of many insects. Class Insecta is broadly divided into two sub-classes, namely Apterygota and Pterygota. Apterygotes include wingless, primitive insects, while Pterygotes are advanced and winged insects.

1.2 Order: Odonata

The order Odonata belongs to the subclass Pterygota and is one of a primeval orders of insects which appeared during the lower Permian (Wooton, 1981). The largest insect, *Meganeuropsis permiana,* having a wing span of 70 cm, belonged to this order (Kalkman *et al.,* 2008). The term Odonata is originated from a Greek word *"odonoto"* meaning tooth which refers to the strong mandibular teeth, characteristic of most adults and nymphs. They are amphibiotic insects with a terrestrial adult and an aquatic nymph. Nymphs display high habitat selectiveness and utilize both lotic and lentic ecosystems for breeding (Subramanian & Babu, 2018). Hence, freshwater ecosystems such as rivers, streams, waterfalls, swamps, kole wetlands, lakes, ponds, pools (natural and man-made artificial garden pools) and ditches became the natural

breeding sites of odonates. They are good indicators of freshwater habitat quality and could be used for this purpose on a regional and national basis (Kalkman *et al.,* 2020).

The order Odonata comprises three extant and morphologically distinct suborders, namely Anisoptera (Dragonflies) with 11 families, Zygoptera (Damselflies) with 34 families and Anisozygoptera with a single family (Paulson *et al.,* 2024; Bybee *et al.,* 2008, 2021). Dragonflies and Damselflies are carnivorous and voracious predators throughout their aquatic and terrestrial life stages. Nymphs feed on aquatic organisms, *viz*. mosquito larvae, tadpoles, beetles and even small fishes. Adults feed on mosquitoes, flies, termites, aphids, small moths, etc (Subramanian & Babu, 2018). There are 6,406 known extant species (Paulson *et al.,* 2024) of which 493 known species have been reported from India and 174 species from Kerala (Gopalan *et al.,* 2022).

1.3 Suborder: Anisoptera (Dragonflies)

The members of the suborder Anisoptera, are commonly known as Dragonflies. They are different from the Damselflies by having a robust body, with large compound eyes covering the major part of the head. Wings are kept in horizontal position to their body at rest. As the suborder name Anisoptera ("Aniso" means unequal and "ptera" means wings) point towards the unequal wing size with the hind wings broader at the base than the fore wings. India is represented by seven families out of the 11 families worldwide (Paulson *et al.,* 2024). They are Aeshnidae, Gomphidae, Chlorogomphidae, Cordulegastridae, Corduliidae, Macromiidae and Libellulidae (Kalkman *et al.,* 2020). With the exception of Cordulegastridae, Kerala is home to representatives of all other six families, totalling 100 species of which 36 were endemic. Libellulidae is the most dominant family with 50 species (Gopalan *et al.,* 2022).

1.3.1 General morphology of adult dragonfly (Fig. 1)

The dragonfly body is divided into the head, thorax and abdomen, with three pairs of legs and two pairs of wings. The head bears a pair of large compound eyes, reduced filiform antennae, three ocelli and biting mouth parts, along with thick and strongly toothed mandibles (Tillyard, 1917). It is freely movable over the neck and the compound eyes can provide 360˚ vision for predatory behaviour. In members of the

families Gomphidae and Chlorogomphidae, the compound eyes are kept slightly separated, eg: *Ictinogomphus rapax* (Gomphidae), whereas in others they meet medially and cover more than half of the head, eg: *Anax immaculifrons* (Aeshnidae). The thorax is divided into two parts: a small prothorax and a large synthorax. Synthorax is formed by the fusion of the meso and metathorax (Tillyard, 1917). The fused thoracic segment resulted shifting of legs slightly forward and hence these legs are well adapted for the purpose of prey catching and perching and not for walking.

The abdomen is slender and elongated, with ten segments that end in terminal appendages. A pair of anal appendages called superior anal appendages are present on the tenth segment in males and females. In males, a median appendage used for holding females during tandem flight is also present (Wheldon, 1918).

1.3.2 Life cycle (Fig. 2)

Dragonflies are hemimetabolous insects with incomplete metamorphosis and a life cycle comprising three stages: egg, nymph and adult (Tillyard, 1917).

Eggs: The eggs are either elongated or round shaped, depending on the ovipositor (Tillyard, 1917). Members of Zygoptera and two families of Anisoptera, such as Aeshnidae and Petaluridae, have well developed and complete ovipositor, they lay their eggs on the surface of aquatic plants (epiphytic) or insert them into the plant tissues by drilling holes in the stem (endophytic). In such cases, eggs are elongated. Others (Libellulidae, Chlorogomphidae, Corduliidae, Cordulegastridae, Gomphidae and Macromiidae) have reduced ovipositor and lay rounded eggs as clutches into water or damp soil (exophytic) (Corbet, 1999). A typical dragonfly egg has the following parts: a large vesicular nucleus embedded deeply in the yolk and located at the center of the egg; a protoplasm; a periplasm surrounding the yolk; a vitelline membrane; and a chorionic membrane. Outside the chorion, there is a gelatinous layer that protects the egg from contact with air. The egg hatches into a pronymph which is surrounded by a close envelope called the pronymph sheath. The pronymph stage lasts only a few minutes, then it undergoes the first moulting by breaking the pronymph sheath, resulting in the second instar (Tillyard, 1917).

Nymphs: Nymphs refers to the aquatic larvae of those insects which have an incomplete metamorphosis (Tillyard, 1917). The nymphs of two suborders show differences in two aspects. (1) Dragonfly nymphs are shorter and bulkier than damselfly nymphs, (2) the respiratory organs in dragonfly nymphs are rectal gills, which are located inside the abdomen, whereas in damselfly nymphs, external gills are present at the end of the abdomen and are called caudal gills **(Fig. 3)**. Nymphs feed on small aquatic organisms, viz., mosquito larvae, beetles and tadpoles. Last-instar nymphs of large species feed on small fish and newly emerged imagos of their own species (Subramanian & Babu 2018). They exhibit two types of feeding behaviors: sit- and-wait or active searching for prey (Pimento, 2019). Nymphs are classified based on their behavior patterns in aquatic ecosystems, such as wandering, crawling and fossorial.

Wanderers live associated with the roots of submerged plants, but crawlers occupy the underside of the stones of the beds of rivers, streams and lakes as their microhabitat. Fossorial forms live buried in the substrate, such as sand or mud (Costa *et al.,* 2011). The nymph passes through 11–15 instar stages depending on the external conditions such as drought and warmth (Tillyard, 1917). Depending on altitude and latitude, nymphal stages vary from a few weeks to seven years (Kalkman *et al.,* 2008).

General structure of dragonfly nymph (Fig. 4)

The morphological description of the nymphs follows Tillyard (1917) and Tennessen (2019). The body plan of the nymph is same as that of the adults i.e., a distinct head, thorax and abdomen.

Head: The head is closely attached to the thorax with limited mobility. The eyes are relatively small and never touch each other (Tennessen, 2019). Four to seven segmented antennae are functionally more important in the nymphs (Tillyard, 1917). The mouthparts are of the biting and chewing type, with paired mandibles and maxillae, the hypopharynx, a well developed labrum and a labium. Mandibles are toothed, stout, roughly pyramidal structures with a triangular base. They bear two sets of teeth: the distal, apical incisors and the proximal molars. Watson (1956) studied the general pattern of mandibular teeth of different Anisopteran nymphs and standardized a mandibular formula for the Anisopteran families. Maxillae with fork-like teeth on

the lacinia aids to pull the prey, held by palpi into the mouth (Tennessen, 2019). The hypopharynx is tongue-like and helps to ingest food (Tillyard, 1917). The labrum is a large, sclerotized, movable flap in front of the head. Labium is a large, extendable prey catching structure, which became the most important diagnostic anatomical feature of all odonate nymphs. It comprises of two parts: a proximal postmentum and a distal prementum **(Fig. 5)**. The prementum is attached to the postmentum by an elbow-like joint (Tennessen, 2019). This type of labium is unique among animal kingdom and is called as 'mask' since it hides all other mouth parts and sometimes covers the whole face (Tillyard, 1917).

Thorax: The thorax is divided into a small prothorax and a large fused pterothorax or synthorax. The prothorax bears a pair of short prothoracic legs. The pterothorax bears the meso and meta-thoracic legs and two pairs of wing sheaths (Tennessen, 2019). The legs have different functions such as locomotion, digging and prey capture hence is always longer than in adults (Tillyard, 1917; Tennessen, 2019) where legs primarily aid in perching. The wing sheaths lie above the anterior abdominal segment and are either parallel or divergent (Tennessen, 2019).

Abdomen: The abdomen is composed of 10 segments with a vestigial eleventh segment. Different families present varied abdominal shapes like cylindrical and elongated, wide, depressed and short. The terminal part of the abdomen ends in anal appendages, which consist of a dorsomedial epiproct, a pair of dorsolateral cerci and a pair of ventral paraprocts (Tennessen, 2019).

Emergence

Metamorphosis in hemimetabolous insects (Tillyard, 1917) is characterized by the emergence of the imago (adult) from exuvia. Moulting during the final emergence is one of the most spectacular events in the life of a dragonfly (Miller, 1995). As the nymph attains full growth, they show remarkable changes in their color and behavior pattern. The color may change from light to dark and the nymph becomes inactive and stops feeding. The nymph climbs out of the water and finds a suitable support, such as a reed-stem, stick, rock or even sand in the river bank where the adult can split its last instar nymphal skin. Nymphs of some species cannot climb (Gomphids) and they just crawl out of water for emergence. (Tillyard, 1917). The positioning and attachment of

the nymph and the exuvia determines the survival of the insect (Corbet, 1999; Andrew & Patankar, 2010) by providing protection from the predators, reducing competition by ensuring emergence at the different sites (Corbet, 1962) and providing a strong attachment to the substrate of the emergence site (Corbet, 1999).

According to Frantsevich and Frantsevich (2018) the emergence of the adult comprises of three stages. These are (1) "A preparatory stage", which includes attachment to the substrate with the flexed legs and sharp claws and detachment of the imaginal integument from the larval integument, (2) "Ecdysis" or releasing of the larval integument and (3) "Maturation" of the free imago (post-ecdysis) including expansion of the body, spreading of the wings, tanning and hardening of the new cuticle and vibration of the wings (Frantsevich & Frantsevich, 2018).

During the moulting process the skin splits along the mid-dorsal line of the thorax and tears till the head by constant arching of the back by the nymph in an attempt to withdraw the head into the thoracic cavity. The thorax bulges out followed by the complete withdrawal of the head followed by the thorax. Next the wings and legs withdraw causing the abdomen to be partially free. This is followed by the head hanging downwards and backwards for some time. During this time the legs become hardened. As soon as the legs becomes strong enough, the insect attempts to hold on to the head of the exuvia or to the stem and succeeds in it. The insect generates enough force to withdraw its abdomen completely from the nymphal sheath by holding tightly to a stem or exuviae and climbs out to be completely free (Tillyard, 1917).

The whole process of emergence begins after sunset and moulting is completed before sunrise. As the body of the teneral adult is wet and fragile, they wait till the sunrise, dry up and fly away. Maturation of a teneral adult takes a few days to weeks (Subramanian & Babu, 2018).

1.3.3 Exuviae

When the dragonflies fly away after emergence, the nymphal skin that remains at the emergence site is called exuvia (plural: exuviae). Thus, the exuviae are the skin of the last nymphal instar. Hence, it possesses all the nymphal features of last instar and could be used to identify the species (Adambukulam & Kakkassery, 2013a). Exuviae

could be seen on any substratum used by the nymphs for their emergence such as plant stems or on rocks near water bodies. These substrata are always between 2 cm to 60 cm above the water surface. Dragonflies prefer vertical substrates for emergence. They may also be found on horizontal surfaces such as floating plants and flat banks (Stainer, 2012). Exuviae could persist on the vegetation or rock substratum for a considerable period of time even under adverse weather conditions because the interlocking mechanism of exuviae with the substrate is extremely firm (Frantsevich & Frantsevich, 2018).

1. 4 Ecological importance

Odonates are notable invertebrate predators of the wetland ecosystem with adults feeding on a variety of insects including pests and vectors and can be used as a bio-control agent against these harmful insects (Subramanian & Babu, 2018). Nymphs, being aquatic in habitat, feed extensively on mosquito larvae, beetles and tadpoles. The nymphs of *Bradinopyga geminata, Crocothemis servilia, Rhyothemis variegata,* and *Ceriagrion coromandelianum* show high predatory efficiency towards the larvae of *Aedes agypti* and *Culex quinquefasciatus* under laboratory conditions and they could be successfully used as a biocontrol agents against these disease-causing vectors. (Andrews *et al.,* 2008; Venkatesh & Tyagi, 2013, & Rahman *et al.,* 2022). Nymphs inhabit both lentic and lotic ecosystems but these choices are species specific making them a model organism for monitoring the health of freshwater ecosystems (Subramanian & Babu, 2018). Dragonflies alter ecosystems through transport of materials and energy between land and water which happens during the various life cycle stages such as egg laying in which terrestrial adult contributes egg to water and emergence of an aquatic nymph to terrestrial adult, results in the transport of materials in the opposite direction (May, 2019).

In addition to their ecosystem functions, odonates are also good bioindicators of water quality. They are considered as an effective group of ecological indicators because they can be easily sampled and identified. This is because of their species richness and varied tolerance to habitat disturbance. The generalist species have high tolerance while specialist species have low tolerance to habitat disturbances. Secondly, they have high habitats specificity i.e., assemblage of these species tends to be abundant only in those habitats that meet the specific environmental conditions demanded by

the species (Uyizeye, *et al.,* 2021). Surveys based on adult male odonata were quite useful at identifying habitat characteristics (Clark & Samways, 1996). For example, the presence of *Bradinopyga geminata* indicates excellent and high water quality status; *Trithemis festiva* for medium, *Zyxomma petiolatum* for bad and *Ceriagrion cerinorubellum* for ponds with very bad water quality (Jacob *et al.,* 2017).

1.5 Research background

In India, research on odonates mainly focusses on taxonomy, diversity and abundance of adults. Fraser (1919, 1925, 1931 & 1943) described the nymphal features of twenty-eight species of odonates by using the nymphs and exuviae. After Fraser, nymphal studies were done by Kumar (1970–1991). Still gaps exist in the description of nymphal stages and their ecology. Larval stages of only about 80 Indian species are known and full life histories are worked out for less than 25 species (Subramanian & Babu 2018). A summarized account of the odonates of Kerala by Gopalan *et al.,* (2022) 174 species of odonates, of which 100 species of dragonflies have been reported so far. But nymphal descriptions of only a few were available. Kumari and Nair (1981 &1983) studied the nymphal features of *Rhodothemis rufa* and *Urothemis signata* by rearing them in the laboratory. There were no nymphal studies till 2013. A pilot study was conducted in temporary ponds associated with paddy fields in Thrissur district inorder to check the avialbility of exuviae for nymphal taxonomy studies during 2012–2013 period by Adambukualm and Kakkassery. The nymphal features of *Anax immaculifrons, A. guttatus, Paragomphus lineatus, Pantala flavescens, Trithemis festiva* and *Lathrecista asiatica* were described by using their exuviae (2013a & 2013b). Though a good understanding of larval ecology can diagnose aquatic ecosystem health, paucity of ecological information can hinder the design of a biomonitoring tool (Subramanian & Babu, 2018). Therefore studies on dragonfly nymphs assumes significance.

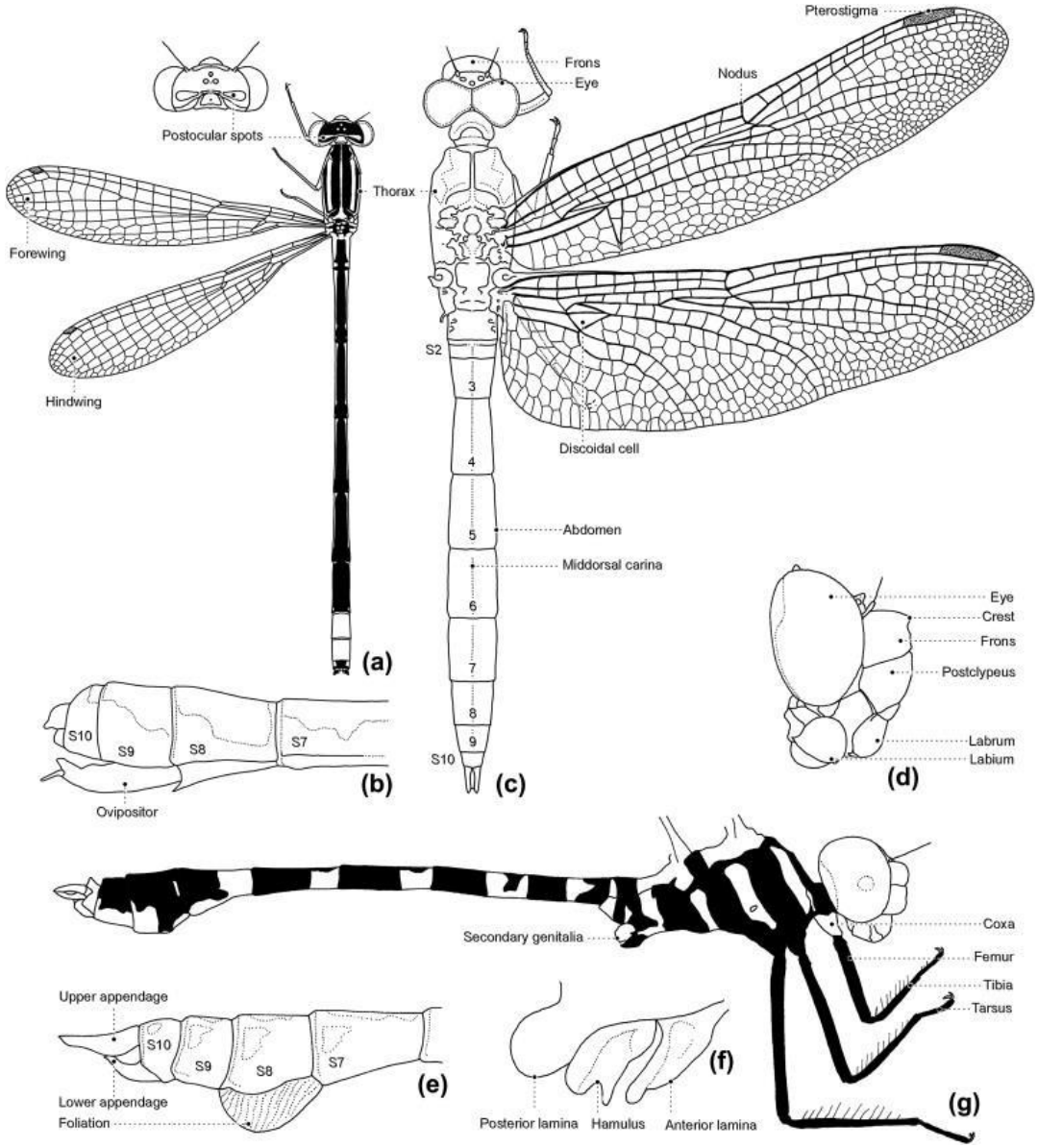
1.6 Significance of the study

So far taxonomic studies of dragonfly nymphs were conducted either by collecting the nymphs from the breeding sites or by collecting eggs from ovipositing females, and rearing the hatched nymphs in the laboratory. Both methods are time consuming and require continuous evaluation.

Also, the collection and rearing of nymphs may affect the natural assemblage of odonates by removing potential adults in the particular aquatic ecosystem to some extent. Moore and Corbet (1990) have suggested regular counts of exuviae during emergence season as an efficient method to monitoring odonate assemblages. Foster and Soluk (2004) suggested that evaluating exuvia collection as a management tool for monitoring endangered species. Exuviae indicates breeding success of a dragonfly population and exuviae counts can help in quantifying dragonfly population of particular habitats (Reel, 2009). Surveys based on the exuviae in a particular habitat are suitable for the reliable assessment of the presence or absence of Odonates (Raebel *et al.,* 2010) This method being non-invasive ensures that while studying endemic, protected or red-listed species (Arguel *et al.,* 2022) insects need not be removed from the natural habitat or sacrificed. Thus, this approach can be applicable in odonate diversity studies of particular habitats without destroying the diversity of adults and nymphs in that region. Moreover, exuvial study definitely helps to know the presence of rare and endemic dragonflies, which are difficult to observe as adult in the field. Although sampling of exuviae needs repeated searching of sites, fewer people and with less expertise are required. Therefore exuvial surveys could be a very effective tool for monitoring populations of dragonflies and their nymphs. Thus, the exuvial studies assume significance.

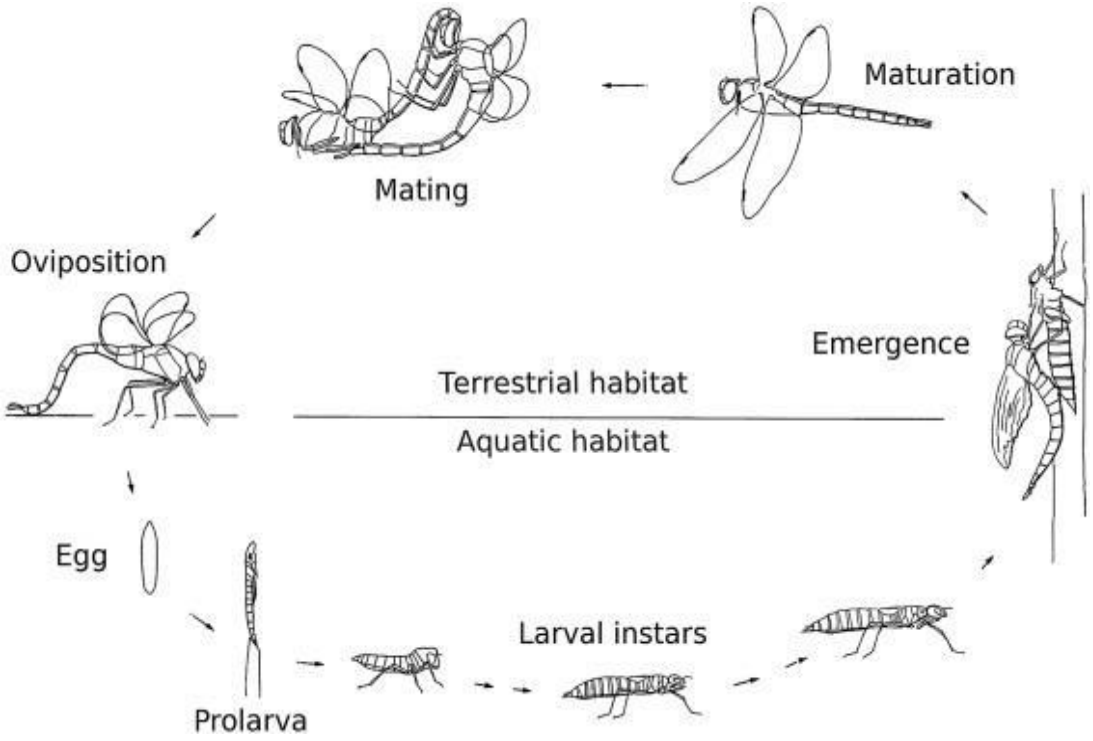
1.7 Objectives of the study

1. To make a check list of the dragonfly nymphs based on the exuviae collected from the study area.
2. To describe the taxonomy of the dragonfly nymphs by using the exuviae of species from the study area.
3. To describe the rare and endemic dragonfly nymphs with their breeding sites using the exuviae of the study area.
4. To make a photographic document of taxonomic features of the collected exuviae of the study area.
5. To prepare a preliminary taxonomic key for the identification of exuvia of dragonflies of the study area.



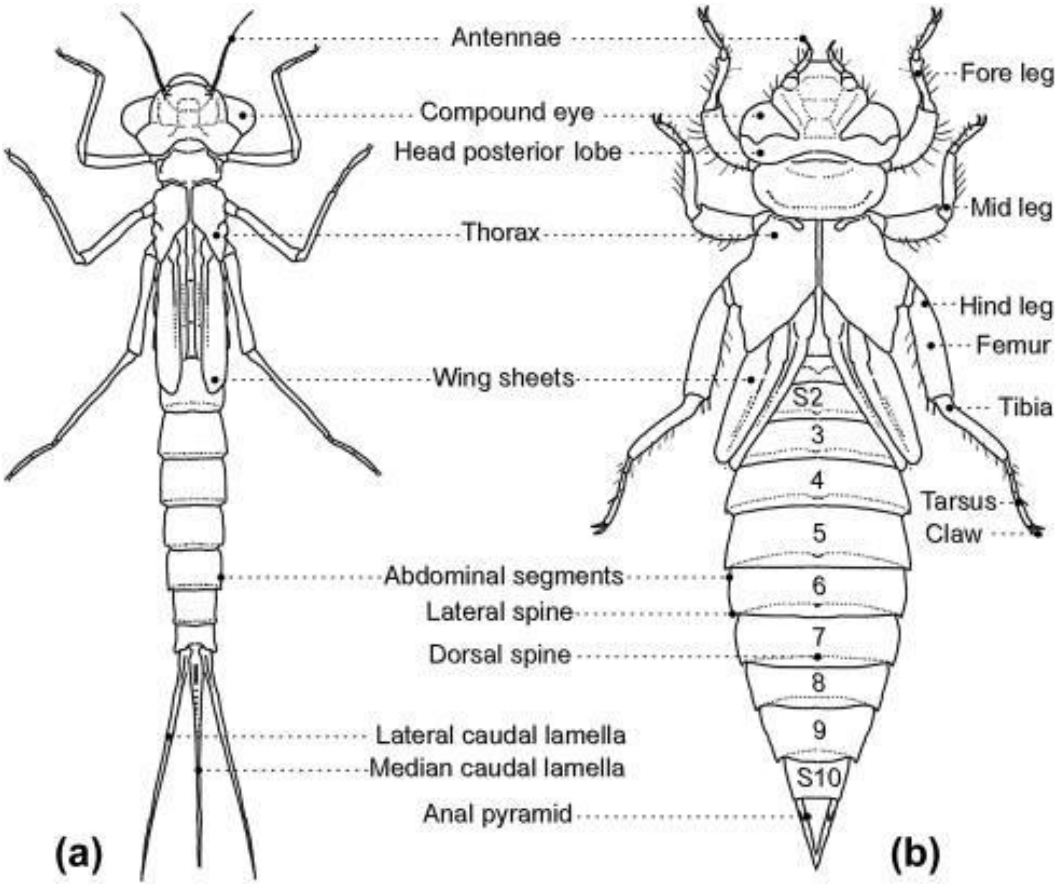
Source: Suhling *et al.,* 2015

Fig. 1 General structure of an adult dragonfly.



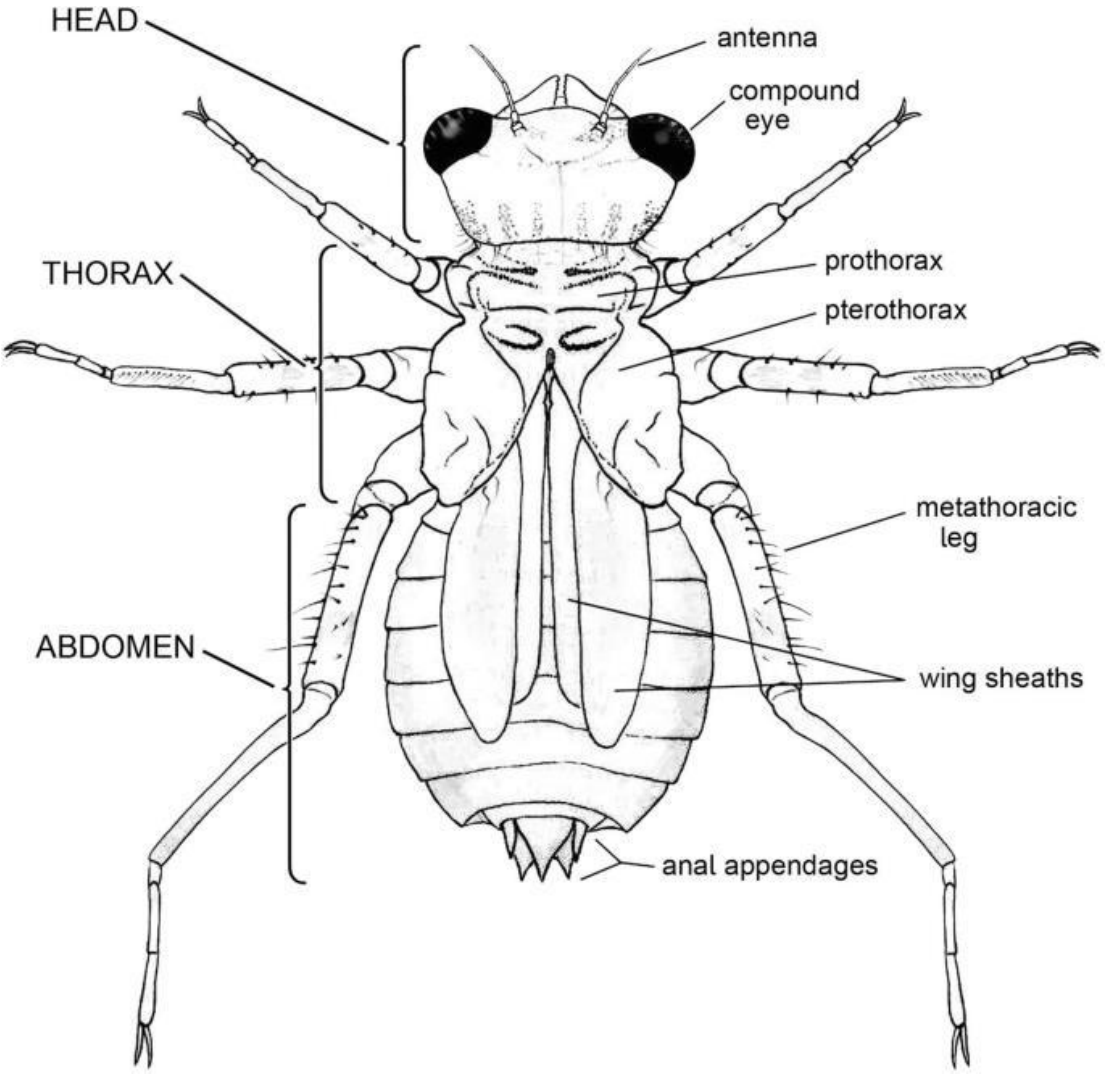
Source: Suhling *et al.,* 2015

Fig. 2 Life cycle of a dragonfly.



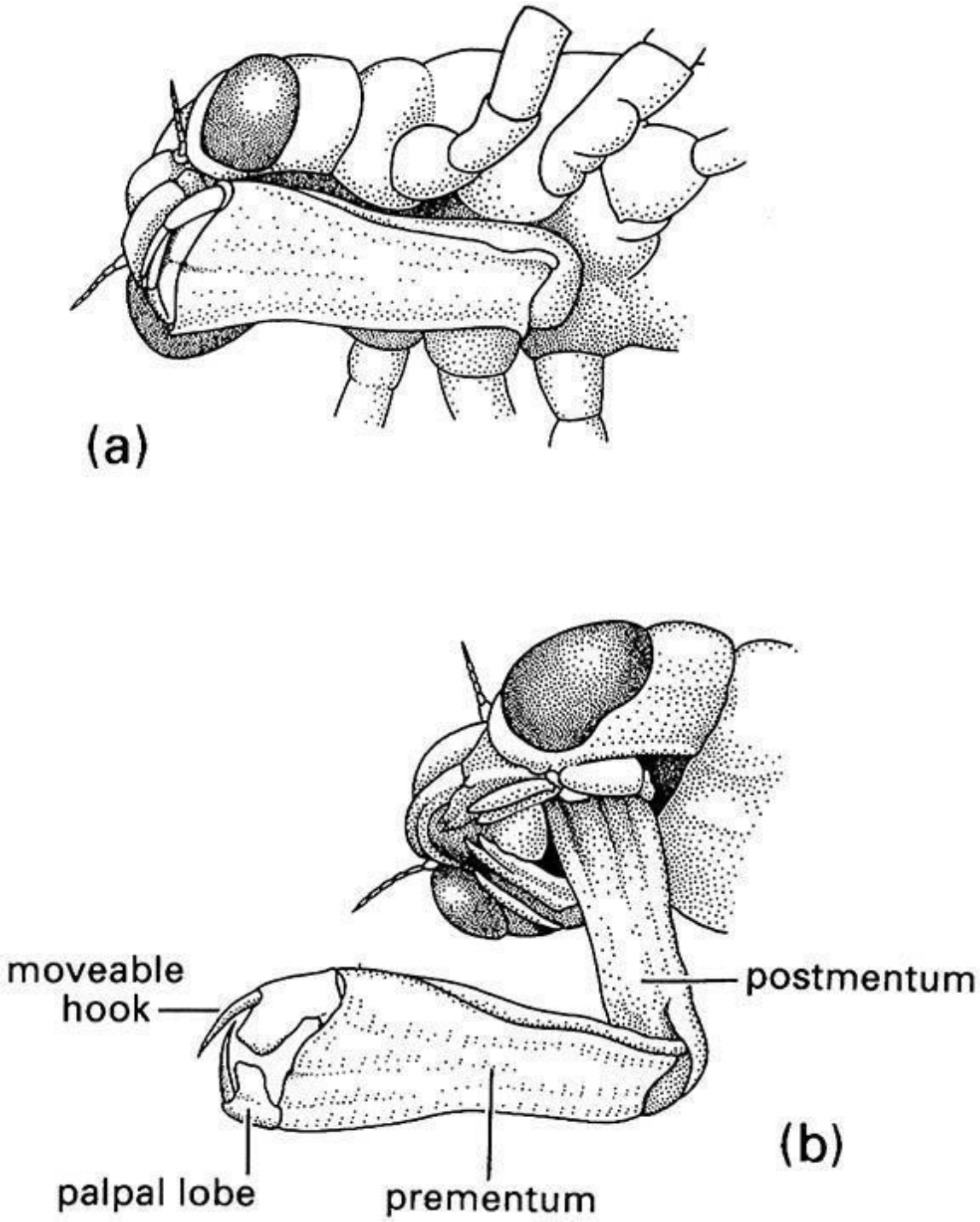
Source: Tennessen, 2019

Fig. 3 External morphology of odonate nymphs (a) Zygoptera (b) Anisoptera.



Source: Suhling *et al.,* 2015

Fig. 4 General structure of a dragonfly nymph.



Source: Wigglesworth, 1964

Fig. 5 Head of a dragonfly nymph (Odonata: Aeshnidae: Aeshna) showing the labial "mask" (a) in folded position and (b) extended during prey capture with opposing hooks of the palpal lobes forming claw-like pincers.

CHAPTER 2
REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Odonates have been used as indicators of different aquatic ecosystems around the world (Sonia *et al.,* 2017). Most of the studies in Odonata have focused on two suborders, Anisoptera and Zygoptera, because of their high habitat specificity and well-resolved taxonomy (Bybee *et al.,* 2016). Studies were mainly focused on the taxonomy, ecology and behavior of adults. Research in biogeography, parasitism, intra and interspecies competition, evolutionary and phylogenetic relationships, eggs and larval exuviae is scarce (Oliveira-Junior *et al.,* 2022).

2.1 Life history and taxonomic studies of dragonfly nymphs worldwide

The nineteenth century saw the first study on dragonfly nymphs, which involved the collection of nymphs from their habitat, laboratory rearing and analysis of taxonomic features. Cabot (1872) published a monograph of descriptions of the nymphal features of seventeen species of the subfamily Gomphina collected from America, Asia and Europe. Of the three species from Asia, two were from the Himalayan region and one from Japan. In Part II (1881) of the monograph, he described the nymphal features of twenty-four species of the subfamily Aeshnina, including two species from the Himalaya and the Kooloo region. The third monograph (1890) described the features of immature stages of the subfamily Corduliinae. Hagen (1885) described the features of forty-eight species of nymphs belonging to two subfamilies Gomphina and Cordulegastrina, using both the nymphs and their skin (Exuvia).

In the beginning of the twentieth century, extensive studies were conducted on the taxonomy, habitat, life history, emergence and distribution of different families of odonate nymphs throughout the world. Calvert (1904) described the nymphal features of *Micrathyria berenice.* Needham (1911 & 1937) described the nymphs of *Agrioninae* and *Pseudagrion superbum.* Fischer and Needham (1936) described the nymphs of North American dragonflies. Walker (1913, 1914, 1916, 1917, 1921, 1928, 1933, 1934 & 1941) conducted extensive studies on Odonate nymphs of Canada and North America. He described the nymphal features of *Leucorrhinia*, *Sympetrum*, *Onychogomphus, Aeshna stichensis, A. junea*, *A. subarctica, A. verticalis* and the Stylurus group of the genus Gomphus with notes on their distribution in Canada. Kennedy (1917, 1919, 1923 & 1924) described the nymphs of *Coryphaeschna*,

Pantala hymenea and the naiads of dragonfly genus belonging to *Helocordulia.* Byers (1927a & 1936) described the nymphal features of *Libellula incesta* and *Brachymesia gravida* He (1927b) prepared a key for the known nymphs of the genus Libellula and described the emergence and life history of the dragonfly *Pantala flavescens* (1941). Broughton (1928) gives an account of some new Odonate nymphs from Canada. Mike and Alvah (1944) published a key to the genera of Anisopterous dragonfly nymphs of United States and Canada. Nevin (1929) studied the larval development of *Sympetrum vicinum.* He used the larvae and their exuviae for his studies. Lamb (1929) studied the later larval stages of *Pantala flavescens* and gives a comparison of the features of the tenth instar and penultimate instar in tabular form. Bird (1934) studied the emergence pattern and the nymphal features of *Gomphus militaris*. Bick (1941, 1951a, 1951b, 1953 & 1955) studied the life history of *Erythemis simplicicollis, Libellula semifaciata*, *Tramea lacerata*, *Miathyria marcella* and *Macrodiplax balteata*. Wright and Peterson (1944) published a work on the anisopterous dragonfly nymphs of the United States and Canada. They provided a taxonomic key for the identification of the anisopterous dragonfly nymphs known from North America and the north of Mexico with neatly labelled diagrams. Louton (1983) studied the larvae of *Gomphurus ventricosus.* Folsom and Manuel (1983) studied the life cycle of the dragonfly *Lanthus vernalis*. Steffens and Smith (2006) conducted a study on the larvae of *Somatochlora incurvata* with a description of the larval habitat. Ferro and Site (2006) described the larvae of *Gomphidictinus perakensis* with its distributional notes. Quintana and Tur (2008) described the last instar larvae of *Erythrodiplax fervida* with notes on the biology of the species. Borisov (2008) described the larvae of *Anormogomphus kritishenkoi.* Meurgey (2009 & 2010) described the larval features of *Macrothemis meurgeyi* and *Protoneura romanae* from West Indies.

Belle (1972, 1991 & 1992) studied the larval features of the Central American species *Progomphus belyshevi, Progomphus geijskesi,* and Neotropical gomphidae *Tibiagomphus.* Westfall Jr. (1989) described the larvae of *Desmogomphus pausinervis* and *Perigomphus pallidstylus.* Gutierrez (1989, 1993, 2002, 2005, & 2009) described the larval features of *Agriogomphus tumens, Phyllogomphoides,* and *Ophibolus.* Ramirez (1996) described six dragonfly larvae of the family Gomphidae *Phyllogomphoides bifasciatus, Epigomphus subsimilis, E. subobtuses, E. echeverrii, Erpetogomphus constrictor* and *E. tristani* with a key to the Central American genera.

Costa and Assiss (1994) described the larval features of *Tauriphila argo.* Costa *et al.,* (1999, 2005 & 2008) described the last instar larvae of *Phyllogomphoides annectens, Perithemis lais* and *Agria crocipennis*.

In Argentina, Rodrigues *et al.,* (1990) studied the larval instars of *Orthemis nodiplaga*. Ellenrieder (2007b) described the larvae of *Macrothemis hahneli*, *Brechmorhoga nubecula* and *Dasythemis mincki clara.* Muzon (1993) described the last instar larvae of *Lestes spatula.* Muzon and Pessaque (2005) described the last larval instar of *Ishunura ultima.* Gutierrez (2007) described the larvae of *Teinopodgrion caquetanum* and *T. vallenatum.* Carvalho (1987 & 1989) described the larvae of *Neuraeshna costalis* and *Gynacantha bifida* with notes on its biology. He provided a key for the genera of Brazilian Aeshindae larvae. Carvalho *et al.,* (2002) described the larvae of two species of *Dasythemis* and prepared a key for the Brazilian libellulidae.

In South America, Marmels (1981) described the larvae of *Progomphus abbreviates* and *Gynacantha auricularis* with Neiss in (2011). Tennessen (1993) described the larvae of *Progomphus bellei.* Muller and Suhling (2001) studied the final instar larvae of *Phyllogompoides litoralis* and with Schiel (2012a) described the final instar larvae of *Rhynoaeschna elsia* by rearing the larvae in the laboratory. Muller *et al.,* (2012b) described the larvae of *Boyeria cretensis* and compared the then described larval features of *B. irene*.

In Africa, Corbet and Mc Crae (1981) described the larval features of *Hadrothemis scubrifrons* which was collected from a tree hole cavity. Martens and Duomont (1983) described the larval stages of desert dragonfly *Paragomphus siniaticus* with notes on the larval habitat. They also made a morphological comparison of *P. siniaticus* with three related species of Gomphidae. Carchini *et al.,* (1992 & 1995) described the larval features of *Trithemis arteriosa, T. dorsalis, T. furva, T. kirby ardens, T. stictica* and *Agriocnemis pinhey.* Carchini and Domenico (1996 & 2008) described the larval features of *Orthetrum hintzi* and *Gynacantha villosa.* Samway *et al.,* (1993 & 1997) described the last larval features of *Trithemis werneri* and *Notiothemis jonesi*. Chelmick (2001) described the larvae of *Aeshna scotias, A.elloiti* and *A.rileyi* belonging to the genus Aeshna from the South of Sahara.

In Europe, Butler (1992, 1993, 2002, 2003a, 2003b, 2004, 2007a, 2007b, 2012, & 2013) conducted extensive studies on odonate nymphs and described the larvae of *Orthetrum nitidinerve, O. newman, Aeshna affinis, A. caerulea, A. crenata, A. cynea, A. grandis, A. juncea, A. mixta, A. serrate subarctica, A. viridis, Anaciaeshna isosceles, Anax immaculifrons*, *A. imperator, A. parthenope, Hemianax ephippiger, Brachyton pratenese, Caliaeshna microstighma, Boyeria cretensis, B. irene, Macromia euterpe, Isomma hieroglyphicum, Phyllomacromia trifasciata, Onychogomphus aequistylus, Gomphidia t-nigrum, Idionyx stevesi, Brachydiplax farinose,* and *Orthemis pulcherrima.* He prepared a taxonomic key (1998) for the larvae and final instar exuviae of European Aeshnidae. Butler *et al.,* (2006 & 2016) described the last instar larvae of *Neodythemis hildebrandti, N. afra and Acrogomphus jubilaris.* Schutte *et al.,* (1998) studied the life history pattern of *Onychogomphus uncatus.* Etscher *et al.,* (2006) described the larvae of *Polythore spaeteri* and compared features with other Polythoid larvae. Brochard *et al.,* (2013) prepared an illustrated key for the identification of the European libellulidae belonging to the genus *Trithemis* using their exuviae.

In Australia, Macklin (1963) conducted studies on the life history of *Anax junius* by collecting eggs from an ovipositing female in the field and rearing the larvae in the laboratory. Theischinger (1998) published an elaborate work on the larvae of Gomphidae which consists of descriptions and illustrations of 38 species of Gomphids reported from Australia. Watson and Theischinger (1980) described the last stage terrestrial larvae of *Antipodophlebia asthenes.* The most interesting feature of the larva was its habitat. The authors collected the larvae from the underside of a log on the dry slope of the valley of Cedar creek which centers Joalah National Park, North Tamborine, Queensland. It was the first record of terrestrial anisopteran larvae from Australia. Hawking and Theischinger (2002) described the larvae of *Orthetrum balteatum* and its features were compared with those of other species of Australian Orthtetrum.

In Asia, Verschuren *et al.,* (1987) described the larvae of Cordulegaster mzymtae with its taxonomic position. In Thailand, Matsuki and Lien (1984a) described the larva of *Periaeschna magdalena.* Boonsoong and Chainthong (2014a, 2014b & 2016) described the final instar nymphs of *Heliogomphus selysi, Microgomphus thailandica, Onychogomphus castor* and *Onychogomphus duaricus* by collecting the nymphs.

Makbun *et al.,* (2022) described the larval features of newly described *Anax aurantiacus.* Gutierrez and Sites (2019a & 2019b) described the nymphs of *Anotogaster gregoryi, Phaenandrogomphus tonkinicus* and *P. asthenes.* Kim *et al.,* (2010) studied the life history of endangered dragonfly *Nannophya pygmaea* in Korea. Wong *et al.,* (2012) described the final stadium larvae of *Polycanthagyna omithocephala* from Taiwan, with a key to the known larvae of the genus. In China Jiang and Wang (2007) described the larva of *Cordulegaster pekinensis* and with Zhang (2008) he described the larval features of *Cephalaeshna partrorum* and *Planaeschna shanxiniensis*. Zhang and Tong (2009 & 2011) described the final instar larvae of *Paragomphus wuzhishanensis, Boyeria karubei* and *Periaseshna flinti*. Xu (2012) described the last instar larva of *Amphigomphus hansoni* with notes on the systematic status of the genus. In (2014) with Zhang described the final stadium larva of *Periaeschna zhangzhouensis* with the taxonomic features of the genus.

In the Oriental region, studies on the nymphs and their life history were done by various authors. In Bangladesh, Begum *et al.,* (1980, 1982a, 1982b, 1985, 1991 & 1993) conducted life history studies of *Ictinogomphus rapax, Brachythemis contaminata, Zyxomma petiolatum*, *Crocothemis servilia servilia, Urothemis signata signata* and *Potamarcha congener* by rearing the eggs and larvae in the laboratory. Asahina (1982b) studied the larval stage of Himalayan *Neallogaster hermoionae* by rearing the larvae.

In Pakistan, Hassan (1977a & 1977b) studied the larval features of *Urothemis assignata* and *Palpopleura lucia* by rearing the larval stages from egg to adult in the laboratory. Features of each instar have been studied and described, mainly focusing on the morphological features like antennary segments, size of compound eyes, setal arrangements on prementum and palpus, wing sheath, tarsal segments etc. Khaliq and Murtaza (1994) described the last instar larvae of *Anax nigrolineatus*. Khaliq *et al.,* (1994a, 1994b, 1995a, & 1995b) studied the last instar larvae of *Anax immaculifrons, Orthetrum pruinosum neglecutm*, six species of odonate naiads from Poonch Valley and three species of naiads of genus Orthetrum. Hussain and Riaz (1999a, 1999b, & 2000) described the naiads of *Rhyothemis variegata variegata, Acisoma panorpoides panorpoides, Gomphidia t-nigrum,* and *Anax parthenope*. Hussain and Ahamed (2004) described the naiads of *Orthetrum, Trithemis*, and *Sympetrum* from the Sindh province of Pakistan. Chesalmah *et al.,* (1999) studied the life history of *Neurothemis*

tullia. Naeem *et al.,* (2022) studied the diversity of Odonate naiads in the sub himlayan hill tracks of Pakistan.The study revealed the presence of 23 speices of which members of Anisoptera were dominant with 16 [Libellulidae (11), Aeshnidae (2), Gomphidae (2) & Macromiidae (1)] speceis followed by Zygotptera with seven species [Chlorocyphidae (1) & Coenagrioniidae (6)].

Lieftinck **(**1932, 1940, 1941, 1953 & 1964**)** conducted studies on the larvae of Gomphids of the Malay Peninsula, Odonates of Ceylon, Oriental Gomphids, and Protoneuridae with special reference to the genus *Selysioneura.* Gutierrez and Che salmah (2006) described the larva of *Macromia cincta* with a key to the known Macromia larvae of the Malaysian Peninsula.

2.2 Studies of odonate nymphs in India

The earliest record of study on the larval stages of Indian Odonata is found in the three monographs published by Cabot in (1872, 1881 & 1890). He mentioned the two species each of *Gomphidae* and *Aeshnidae* collected from the Himalaya, East India and Kooloo River and also the larva of *Macromia moorei* collected from Himalya. Laidlaw (1920) published notes on some interesting larvae of dragonflies in which the larval characters of *Rhynocypha unimaculata, Megalestes major* and *Anotogaster* sp. were described. Tillyard (1921) described the larva of *Epiophelbia laidlawi* from Darjeeling for which the adult was unknown for many years. Fraser (1919a, 1920, 1921, & 1925) described the larval features of *Micromerus lineatus, Rhynocypha* sp., *Heliocypha bisgnata, Orogomphus atkinsoni and O. campioni*. He conducted an extensive study on Odonates of British India including Ceylon and Burma (1933, 1934 & 1936) and published his findings as Fauna of British India Odonata in three volumes which included the drawings of the species but with out descriptions. Lieftnick (1940) described larvae of five Dragonfly species *viz. Macromia zeylonica, Burmagomphus pyramidalis, Megalogomphus ceylonicus, Ictinogomphus rapax* and *Anax immaculifrons.* Fraser (1943) published a paper on new oriental odonate larvae in which he described the larval features of eight species belonging to both Zygoptera (*Protosticta mortoni, Disparoneura apicalis, Caconeura gomphoides,* and *Caliphaea confusa*) and Anisoptera (*Sieboldius nigricolor, Merogomphus longistigma, Anax immaculifrons and Cephalaeshna orbifrons*). Sangal and Kumar (1970a & 1970b) described the larvae of *Crocothemis servilia servilia, Bradinopyga geminata, Anax guttatus and A.*

immaculifrons. Kumar (1971a, 1971b, 1972a, 1972b, 1973a, 1973b, 1973c, 1973d, 1980, 1981, 1984a, 1984b, 1984d, 1984e, 1984i, 1988b, 1989a & 1990a) studied the taxonomic studies of last instar larva of Odonata from the Dehra Dun valley and studied the life history of several species of Odonata. He described the larval stages of *Orthetrum brunneum brunneum, Orthetrum taeniolatum, Lestes praemorsus, Trithemis festiva, Desparoneura campioni, Copera marginipes, Pseudagrion rubriceps, Pseudagrion laidlawi, Ceriagrion coromandelianum, Ishnura delicata, I. senegalensis, I. nursei, Agriocnemis pygmaea, Rhinocypha unimaculata, Bayadera indica, Neurobasis chinensis chinensis, Anisogomphus occipitalis, Burmagomphus sivalikensis, Mesogomphus lineatus, Cordulegaster* sp., *Macromia moorei, Potamarcha obscura, Brachythemis contaminata, Sympetrum commixtum, Trithemis aurora, Zyxomma petiolatum, Tholymis tillarga, Anax nigriofasciatus nigrolineatus, Anax parthenope parthenope, Acisoma panorpoides panorpoides, Diplacodes trivialis, Pantala flavescens, Ictinogomphus rapax, Neurothemis tullia tullia, Orthetrum sabina sabina,* and *Tramea virginia.* Kumar and Prasad (1977b, 1977d, 1977f & 1978) described the larvae of genus *Tramea virginia, Rhynocypha, Tramea* and *Agriocnemis.* Kumar (1973a & 1973b) published a taxonomic key to odonate nymphs of Zygoptera and Anisoptera collected from Dehra Dun valley. No further work regarding the nymphal taxonomy has been published from India.

Kumar and Khanna (1983) published a review on larval studies of Odonates in India, in which they tabulated 102 species but did not provide descriptions. Srivastava *et al.,* (1992) described the larval features of *Ischnura aurora.* In Kerala, Kumari and Nair (1981 & 1983) described the nymphal features of *Rhodothemis rufa* and *Urothemis signata signata* by rearing the larvae in the lab. Further studies on Odonate nymphs were done by Adambukulam and Kakkassery in (2013a & 2013b) as part of a pilot study in preparation for doctoral research. In that study the larval features of *Anax immaculifrons, A. guttatus, Paragomphus lineatus, Pantala flavescens, Trithemis aurora, and Lathrecista asiatica* was described by using their exuviae.

2.3 Studies on dragonfly nymphs by using their exuviae

Fraser (1919b) published a pioneering work on Indian odonate larvae and exuviae. In this paper, he describes the features of sixteen odonate larvae consisting of both Anisoptera (*Epophthalmia frontalis*, *Tholymis tillarga, Tramea limbata,*

Macrogomphus annulatus, Cyclogomphus heterostylus, Cyclogomphus verticalis, Cyclogopmhus minusculus and *Onychogomphus lineatus)* and Zygoptera (*Matrona basilaris*, *Lestes* sp.*, Copera marginipes, Calicnemia miniata, Protosticta gravelyi, Chloroneura quadrimaculata, Pseudagrion microcephalum* and *Pseudagrion hypermelas).* Larval features of *Acanthaeschna intermis, Gynacantha mocsaryi* and *Acanthaeschna tripunctata* (Theischinger 1975, 2001 & 2007), *Progomphus abbreviatus* (Marmels, 1981), *Phyllogomphus brunnerus, Agriocnemis falcifera, Chalcostephia flavifrons*, *Hadrothemis scabrifrons, H. cacta, H. camarensis* and *Gynacantha cylindrata* (Domenico *et al.,* 1994, 1996, 2001, 2006 & 2016), *Hemistigma albipunctum* (Whiteley *et al.,* 1999), *Pseudagrion decorum* and *Neurothemis intermedia* (Babu 1998 & 2000) *Epophthalmia vittata cyanocephala* (Bedajenic 2000), *Hylaeothemis clementia* and *Anax ephippiger* (Sasamoto and Kawashima, 2009 & 2022), *Phyllocycla gladiata* (Carrico *et al.,* 2011), *Anax immaculifrons*, and *Tetracanthagyna waterhousie* (Wan *et al.,* 2011), *Urothemis edwardsii* (Khelifa *et al.,* 2013), *Gynacantha millardi* (Dawn & Chandra 2016) and *Calicnemia eximia* (Dawn, 2019) and *Micrathyria venezuelae* (Hartung, 2022) were described by using their exuviae. Winstanley (1981 & 1984) studied the emergence of *Uropetala carovei* and the larvae of the endemic dragonfly *Synthemis ariadne* by examining the exuviae. Hoekstra and Smith (1999) studied the final instar larvae of *Argia sabino* and *A. pima* by using the preserved exuviae and prepared a dichotomous key for the two species which was integrated into the existing larval key for North American *Argia* species. Brochard *et al.,* (2013) prepared an illustrated key for the identification of the European Libellulidae belonging to the genus *Trithemis* using their exuviae.

For the last 25 years, different parts of the world have substantially contributed to the knowledge on odonate nymphs. These studies included work from Sri Lanka (Fonseka, 2000), Australia (Thieschinger, 2009), South America (Heckman, 2006) and North America (Tennessen, 2019), Namibia (Suhling *et al.,* 2014). But in India, no such comprehensive work is available so far (Dawn, 2016). After Fraser (1919a, 1919b, 1920, 1921, 1929, 1931 & 1943), Kumar (1970-2000) studied the nymphs of Indian odonates by rearing them in the laboratory. In Kerala, Kumari and Nair (1981 & 1983) studied the nymphal features of *Rhodothemis rufa* and *Urothemis signata*. There were no nymphal studies of Dragonflies till 2013, when Adambukulam and Kakkassery (2013a & 2013b) described the nymphal features of six species using their exuviae

(mentioned at 2.2 & 2.3 in Chapter 2). Adambukulam and Kakkassery (2023a & 2023b) described the final instar larva of *Burmagomphus laidlawi* Fraser, 1924, an endemic species of Western Ghats and nymphal features of *Acisoma panorpoides, Bradinopyga geminata*, *Neurothemis tullia* , *Orthetrum sabina*, *Rhyothemis variegata*, *Tholymis tillarga* and *Zyxomma petiolatum* respectively by using their exuviae (See List of papers attached in the Appendix). Rearing the nymphs in the laboratory is a time-consuming process. For some species nymphal life extends from 1–2 years and requires continuous evaluation. Moreover, the nymphs may not emerge successfully due to many unknown factors even though all known conditions are provided. In case of rare and endemic species, the collection of the nymphs from the habitat may affect the existing diversity of nymphs and adults to some extent. Thus, it is preferable to recommend exuvial studies, especially for rare and endemic species.

CHAPTER 3
MATERIALS AND METHODS

CHAPTER 3
MATERIALS AND METHODS

3.1 Study area

Kerala is located in the southernmost part of India, situated between the Arabian Sea and the Western Ghats, one of the "hottest hot spots" in the world. It lies between 8° 18'N and 12° 48' N and 74°52'E and 72°22' E. Kerala has a coastal line of 590 km. Geographically, the state has been divided into three distinct regions: the eastern highlands, the central midlands and the western lowlands. The Western Ghats, which form a wall of mountains with an average height of 1500 m ASL and a maximum height of 2500 m ASL determine the climate and thus the vegetational characteristics of the state. Forty-four rivers originating from these mountain ranges flow through the state. Of these, three are east flowing.

Kerala has a wet and tropical climate with an average of 120–140 rainy days per year. The state has two monsoons, namely South West monsoon (June–August) and North East monsoon (October–November). The mean annual rainfall of the state averages 2923 mm, with the lowest mean of 1250 mm in drier areas in the lowlands and the highest of 5000 mm, in the eastern high mountain areas. Due to these two monsoons, the state has a good number of aquatic ecosystems, including ponds, streams and kole lands. The average temperature range is between 19.8°C to 36.7°C. The state has an area of 9400 km^2 under forest cover, which includes tropical wet evergreen, semi-evergreen, tropical moist and dry deciduous forests, montane subtropical and temperate (shola) forests, mangrove and fresh water swamp forests which altogether constitute 29.65% of Kerala's land area (Sources: http://www. stateofkerala.in., forest. kerala. gov. in).

3.2 Field survey

Field survey was confined to five randomly selected districts: Kasaragod, Kannur, Wayanad, Palakkad and Thrissur **(Fig. 6)**. The study sites were different types of fresh water aquatic ecosystems such as lakes, canals, rivers, check dams, small streams, man–made ponds and pools (cement bottomed and natural substrates), temporary ponds associated with paddy fields and kole wetlands in human inhabited areas **(Fig.7: a–f)**. The collection sites along with its coordinates and habitat type, is given

in Table 1. Collection was done during August 2015–February 2020 and November 2022–May 2023. No collection was possible during March 2020–October 2022 due to the restrictions of COVID–19 pandemic.

Table 1: Study sites with Geographical coordinates

SL.NO	Collection site	District	Latitude(N)	Longitude (E)	Habitat type
1.	Kudumboor	Kasaragod	12.46120	75.27213	River
2.	Palamthadi	Kasaragod	12.46524	75.22833"	Small stream
3.	Eranjipuzha	Kasaragod	12.49497	75.15636	River
4.	Poliyamthuruth	Kasaragod	12.50832	75.16938	River
5.	Kolikkund	Kasaragod	12.30501	75.11072	Small stream
6.	Sankarampadi	Kasaragod	12.30247	75.12632	Small stream
7.	Churithode	Kasaragod	12.28827	75.16452	Pond
8.	Manadukkam	Kasaragod	12.48117'	75.27397	Small stream
9.	Mudiyakkal	Kasaragod	12.42119	75.03164	Stream/River
10.	Kunnumkai	Kasaragod	12.29618	75.28274	River
11.	Malom	Kasaragod	12.39344	75.34540	River
12.	Madayippara	Kannur	12.03221	75.25667	Pond
13.	Kottiyoor	Kannur	11.88265"	75.88837	River
14.	Mambaram	Kannur	11.82803	75.50403	Pond
15.	Cherupuzha	Kannur	12.27606	75.36587	River
16.	Dharmadam	Kannur	11.77684	75.45568	Pond
17.	Meenmutty	Wayanad	11.74068	75.90203	Waterfall
18.	Pookode	Wayanad	11.54168	76.02768	Lake
19.	Thonikkadavu	Wayanad	11.86493	76.14408	River
20.	Wayanad	Wayanad	11.70758	76.08942	River
21.	Krishnagiri	Wayanad	11.66253	76.19483	Small stream
22.	Kuruva	Wayanad	11.82217	76 09244	River
23.	Panamaram	Wayanad	11.74133	76.07277	Paddy field
24.	Pakkam	Wayanad	11.80202	76.10154	River
25.	Ambalavayal	Wayanad	11.61680	76.21132	Pond
26.	Vythiri	Wayanad	11.55170	76.04030	Small stream
27.	Thrissur	Thrissur	10.52768	76.21592	Pond
28.	Poomala	Thrissur	10.60111	76.24228	Dam reservoir
29.	Palakkal	Thrissur	10.47312	76.21257	Paddy field
30.	Kanimanglam	Thrissur	10.47687	76.21519	Pond
31.	Alapad	Thrissur	10.44890	76.17300	Kole wetland
32.	Marottichal	Thrissur	10.47652	76.34390	Waterfall
33.	Athirappilly	Thrissur	10.28521	76.56980	River
34.	Thumoormuzhy	Thrissur	10.29902	76.45038	Artificial pond
35.	Ammadam	Thrissur	10.46355	76.19233	Paddy field
36.	Chalakkudy	Thrissur	10.17255	76.32400	River
37.	Kinassery	Palakkad	10.72853	76.66546	Pond
38.	Kollengode	Palakkad	10.61248	76.69675	Paddy field
39.	Chittur	Palakkad	10.69858	76.75673	Pond
40.	Malampuzha	Palakkad	10.83472	76.68258	Lake
41.	Olassery	Palakkad	10.72072	76.69839	Pond
42.	Kalpathy	Palakkad	10.79182	76.65099	River
43.	Thathamanglam	Palakkad	10.68283	76.70813	Pond
44.	Thenkurissi	Palakkad	10.69025	76.61868	Pond
45.	Elamanam	Palakkad	10.70769	76.64653	Canal

3.3 Collection and Preservation of exuviae (Fig. 8: a–f)

Based on the pilot study conducted, substrates on which exuviae were found and time of emergence was identified. Exuviae are found on vegetation, rocks, exposed roots and even on sandy shores (Garrison & Tennessen, 2020).They may be washed by rain or wind (Arguel *et al.,* 2022). Experiments were also conducted to determine the degradation of the exuviae in the field, by placing freshly emerged exuviae in an observable substratum. It was observed that exuviae exposed to rain and wind shows considerable damage or degradation of body parts which includes breakage of antennae, legs, labium and even head or abdomen.Thus exuviae affected by the weathering process were not used for this study. Collection was done either by walking along the shoreline of waterbodies or in the waterbody for checking the presence of exuviae in vegetation, exposed substrates such as rocks in water and on the bank **(Fig.8: a–c)**. Exuviae were collected during early morning between 6.00 a.m and 8.00 a.m, so that the teneral adults associated with the exuvia or in the nearby vegetation could be observed **(Fig.8A & 8B: a-f)** and the primary level identification of the species could be done in the field itself. Exuviae were collected by handpicking and transferred to plastic containers. Dry or wet preservation was done. In dry preservation, wet exuviae were first dried in the sunlight and pinned in insect boxes using entomological pins. Care was taken to insert the pin through the opening of the thorax formed during emergence. Dried exuviae were kept in the insect box for further studies **(Fig.8: d–e).** For wet preservation, exuviae were transferred to vials containing 70% alcohol (**Fig.8: f)** (Garrison & Tennessen, 2020).

3.4 Dissection and identification of exuviae

The exuviae were examined and dissected under a stereo dissection microscope (CZM 4, LABOMED) for observing the last instar nymphal features. Since the exuviae are very fragile, extreme care should be taken during dissection; otherwise they will break. Hence dissection is done after dipping the exuviae in a small amount of water to soften the parts to prevent breakage of small structures. Measurements of the entire exuviae and its body parts were taken. All measurments were taken in mm. Abbreviations used for this purpose and their expansion are given (Refer Table 2). Photographs of the dissected parts were taken using a Leica S80AP0 stereo microscope with an in-built camera (Leica MC 170 HD) and LAS auto-imaging

software. The photographs of some large exuviae (entire) were taken using the Nikkon Coolpix L27, Nikkon D750, LG K10 and Vivo T3. The photographs were further processed and edited using Adobe Photoshop version 23.2.1.

Table 2: Abbreviations used in the measurements and their expansion

Abbreviations	Expansion
TBL	Total Body Length : From the tip of labium to end of the anal appendage
AL	Abdominal Length : Length of abdomen from S1–S10
AW	Abdominal Width : The maximum width of abdomen
HL	Head Length : The maximum distance from the frons to labium
HW	Head Width : The maximum distance including the compound eyes
LL	Labium Length : From the tip of palpus to elbow joint
LW	Labium Width : The maximum width of labium
FFL	Fore-leg Femur Length
FTbL	Fore-leg Tibial Length
FTaL	Fore-leg Tarsal Length
MFL	Mid-leg Femur Length
MTbL	Mid-leg Tibial Length
MTaL	Mid-leg Tarsal Length
HFL	Hind-leg Femur Length
HTbL	Hind-leg Tibial Length
HTaL	Hind-leg Tarsal Length
EPL	Epiproct Length : From the end of S10 to tip of epiproct
PPL	Paraporct Length : From the end of S10 to tip of paraproct
CRL	Cerci Length : From the end of S10 to tip of cerci
S	Abdominal Segment

The family level identification of the exuviae was done with the general morphology given by Tennessen, 2019. The exuvial features used for the identification were tabulated in Table 3. Species level identification of the exuviae was done primarily from the field itself by observing the teneral adults, and the confirmation of the species were done by comparing published literatures (Fraser, 1934 & 1936 Fonseka, 2000, Subramanian, 2009, Sadasivan *et al.,* 2023).

Table 3: Family level features on exuviae used for the identification following Tennessen, 2019

Features	Family				
	Aeshnidae	**Corduliidae**	**Gomphidae**	**Libellulidae**	**Macromiidae**
Habitus	Elongated & Cylindrical	Flat & Oval Shaped	Dorso-Ventrally Flattened	Stream Lined	Flat & Oval Shaped
Antenna	7 segmented	4 segmented	7 segmented	7 segmented	7 segmented
Labium	Pear shaped	Rectangular/ Sub quadrate	Rectangular/ Sub quadrate	Spoon /Cup shaped	Rectangular/ Sub quadrate
Abdominal mid dorsal spines	Absent	Present	Present	Present/ absent	Present
Lateral spines	S6-S9/S7-S9	S6-S9/S7-S9	S2/S3/S4/S5-S9	S8–S9	S6-S9/S7-S9
Anal appendages	Elongated	Reduced	Reduced	Short	Reduced

3.4.1 Nymphal features on the exuviae used for the species level identification

a) Habitus or body form (Fig. 9: a–l)

Nymphs of the five dragonfly families that occur in Kerala distinctly vary in their habitus or body form. In some families, the body is elongated and cylindrical as in Aeshnidae; in others it may be dorso-ventrally flattened, as in Gomphidae; in

Libellulidae it may be streamlined; in Corduliidae and Macromiidae the body is flat and more or less oval-shaped.

b) Antennae (Fig. 10: a–l)

Nymphal antennae are well developed and obvious when compared to those on adults. The number of segments or antennomeres varies from four to seven (Tennessen, 2019). In Kerala, all families except Gomphidae have seven segmented filiform antennae. In Gomphidae, it is four segmented. The first two segments are short and cylindrical and the third segment is the longest. The fourth segment shows variations within the family. It could be vestigial and inconspicuous or knob-like and in some others, it may be elongated and hanging.

c) Labium (Fig. 11: a–d)

The labium refers to the lower lip. It is the most unique feature of Odonate nymphs. The shape and size of the labium vary among different families. It may be pear-shaped and elongated (Aeshnidae), spoon or cup-shaped (Libellulidae and Macromiidae) or sub-rectangular or sub-quadrate (Gomphidae, Codruliidae and Cordulegastridae).

d) Prementum and Premental setae (Fig. 12: a–d)

Another taxonomic feature is the presence of setae on the prementum known as premental setae**.** They are present in all members of the families Libellulidae, Macromiidae, Corduliidae and Codrulegastridae. The number of premental setae vary from one to twenty. It is absent in members of Aeshnidae and Gomphidae.

e) Palp and Palpal setae (Fig. 12: e–f)

The prementum at its distal end bears a pair of labial palps which are highly modified for prey grasping. The shape of the palpus also varies among different families. In Gomphidae and Aeshnidae, it is a short finger-like structure with a blunt or sharp end with tooth-like projections called palpal teeth along the inner margin.

In all other families (Libellulidae, Corduliidae, Macromiidae and Cordulegastridae) the palpus is an incurved flap with crenations along the distal margin. Palpus also

bears setae called palpal setae which are present in all families except Gomphidae and some Aeshnidae**.** The palpal setae also vary in their number among the members of the same family (Tennessen, 2019).

f) Abdomen (Fig. 13: a–d)

The abdomen is composed of 10 segments. The shape of the abdomen varies among different families. It may be cylindrical, oval, elongated or tapering. The abdomen is characterized by the presence or absence of mid-dorsal spines or protuberances and lateral spines.

g) Lateral spines on abdomen (Fig. 13: a–d)

The presence of lateral spines also contributes to species-level identification. Lateral spines are located along the posterolateral side of the abdomen. The spines can be seen from S3–S9. In the family Libellulidae, these spines are confined to S8 and S9. In members of the families Aeshnidae, Macromiidae and Corduliidae*,* the lateral spines are confined to either S6–S9 or S7–S9. In Gomphidae, they show maximum variation in their position range, i.e., in some species it could be seen from S3–S9, in others it could be on S4–S9 and in some others it is seen on S5–S9 and so on.

h) Mid-dorsal spines on abdomen (Fig. 13. e–f)

Mid-dorsal spines or protuberances present from S1–S10. In some species, it may be present in S2–S9, S3–S9, S4–S9 or S5–S9 and so on. The shape of the spines or protuberances also shows variation among the members of a family or genus. They may be sharp-pointed, backwardly directed or curved like a hook. In some species, it may be with a blunt end instead of a sharp pointed end.

3.4.2 Taxonomic key using exuviae

A preliminary taxonomic key was prepared based on nymphal features present on the exuviae collected from the study sites. The taxonomic features observed for the key preparation includes body shape and size; number of antennal segments; shape of labium; presence or absence and number of premental setae if present; palpal setae and their number; palpal teeth and their number; crenations on palp; presence or absence of mid dorsal spines, their shape and range of abdominal segments on which

they are present; presence of lateral spines and their range on abdominal segments; shape and size of anal appendages. This key was prepared by using simple features which are easily perceivable by both experts and amateurs.

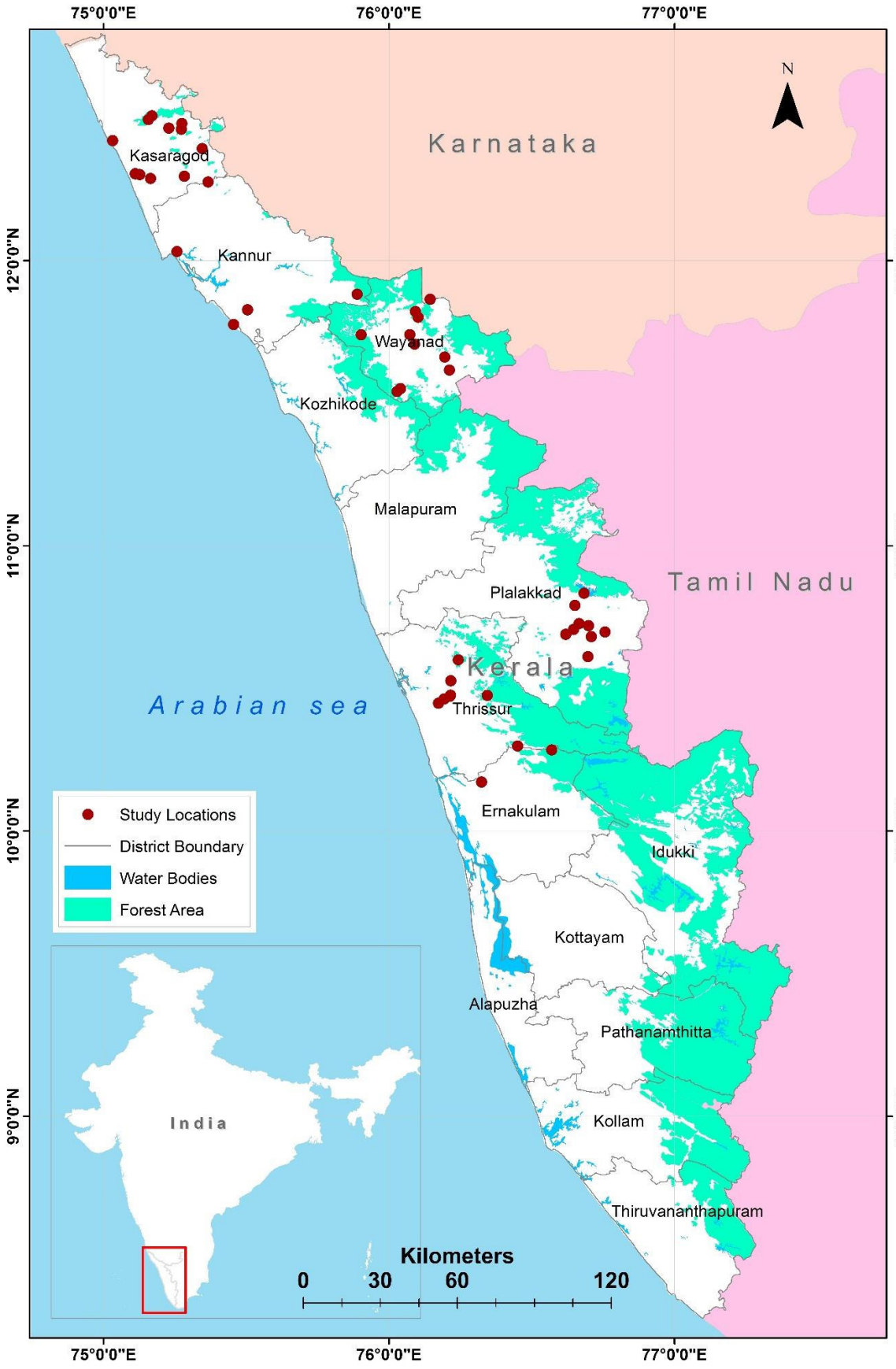


Fig.6: Study Area Map

Different types of Freshwater Aquatic Ecosystems

Fig. 7: a. Natural pond, b–c. Natural stream, d. River, e. Canal, f. Check dam, g. Man-made cement bottomed pool.

Collection and Preservation of Exuviae

Fig. 8: a–c. Collection of exuviae, d–e. Dry preservation of exuviae, f. Wet preservation of exuviae.

Freshly emerged

Fig. 8A : a–f a. ***Acisoma panorpoides,*** **b.** ***Gynacantha dravida,*** **c.** ***Lathrecista asiatica,*** **d.** ***Bradinopyga geminata,*** **e.** ***Neurothemis tullia,*** **f.** ***Orthetrum sabina***

Freshly emerged

Fig. 8B: a–f a. ***Rhodothemis rufa,*** **b.** ***Rhyothemis variegata,*** **c.** ***Anax indicus,*** **d.** ***Ictinogomphus rapax,*** **e.** ***Macrogomphus annulatus,*** **f.** ***Pantala flavescens***

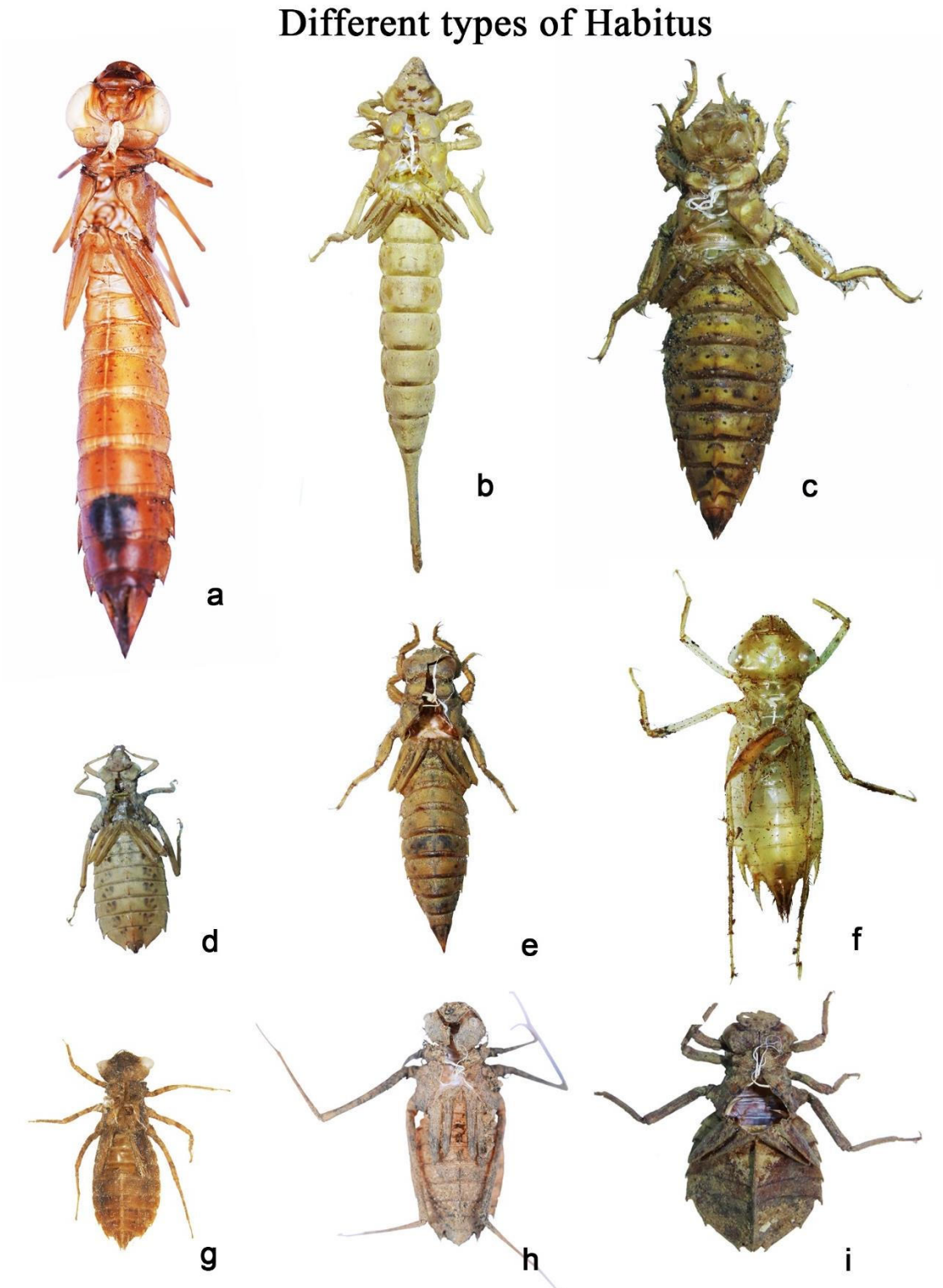


Fig. 9: a. Elongate and cylindrical (*Anax indicus*), b. Cylindrical with siphon (*Macrogomphus annulatus*), c. Well built and robust (*Megalogomphus superbus*), d. Dorso-ventrally flattened (*Microgomphus souteri*), e. Cylindrical with tapering end (*Paragomphus lineatus*), f–g. Cylindrical with streamlined (*Tramea basilaris* & *Neurothemis tullia*), h. Flat and oval (*Macromia indica*), i. Stout bodied with limbet shaped (*Ictinogomphus rapax*).

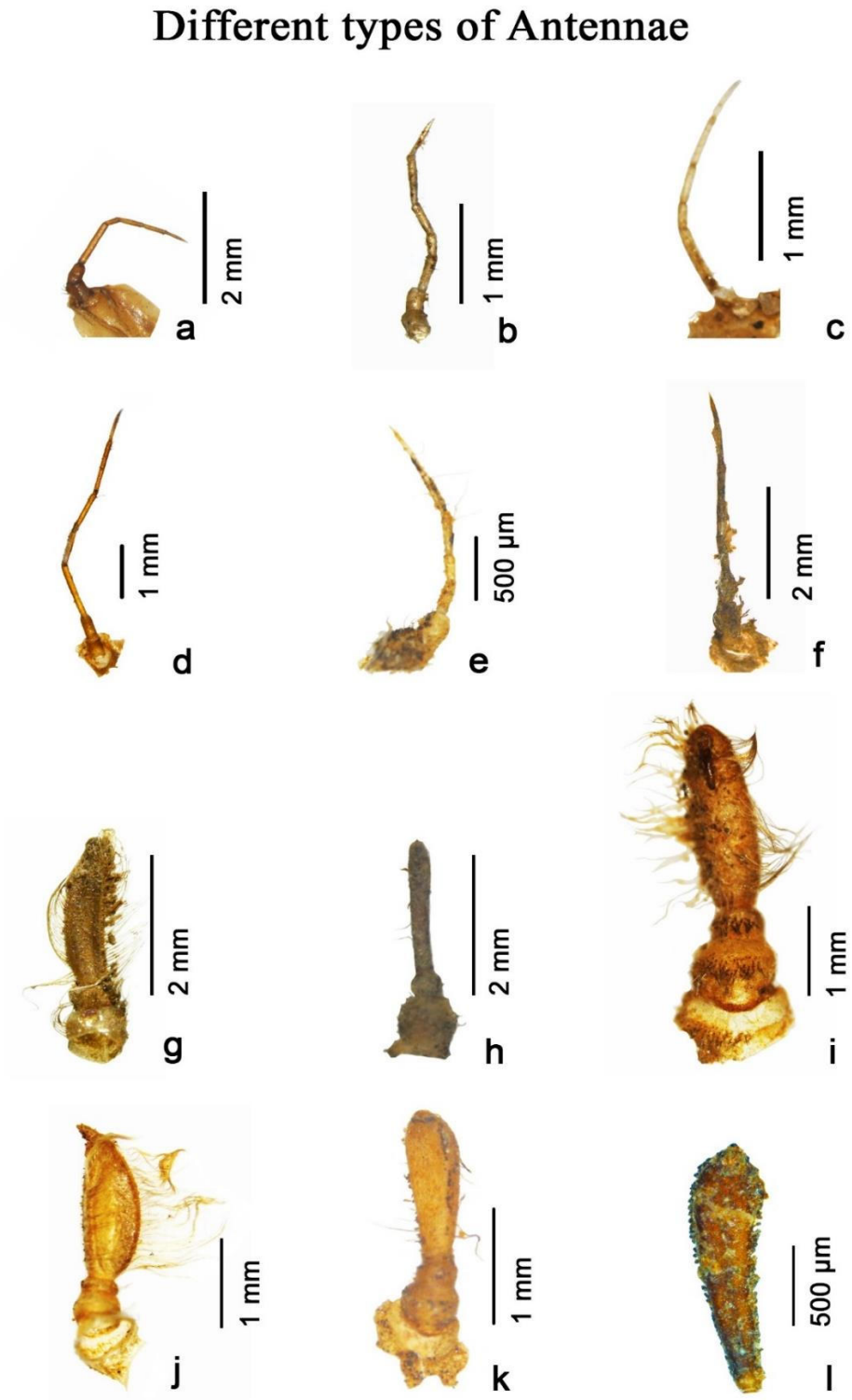


Fig. 10: a–d. 7 segmented filiform (a. *Anax indicus*, b. *Brachythemis contaminata*, c. *Pantala flavescens*, d. *Tramea basilaris*), e–f. 7 segmented setose (e. *Macromia indica*, f. *Macromia flavocolorata*), g–l. 4 segmented clubed (g. *Burmagomphus laidlawi*, h. *Ictinogomphus rapax*, i. *Paragomphus lineatus*, j. *Megalogomphus superbus*, k. *Onychogomphus malabarensis*, l. *Microgomphus souteri*).

Different types of Labium

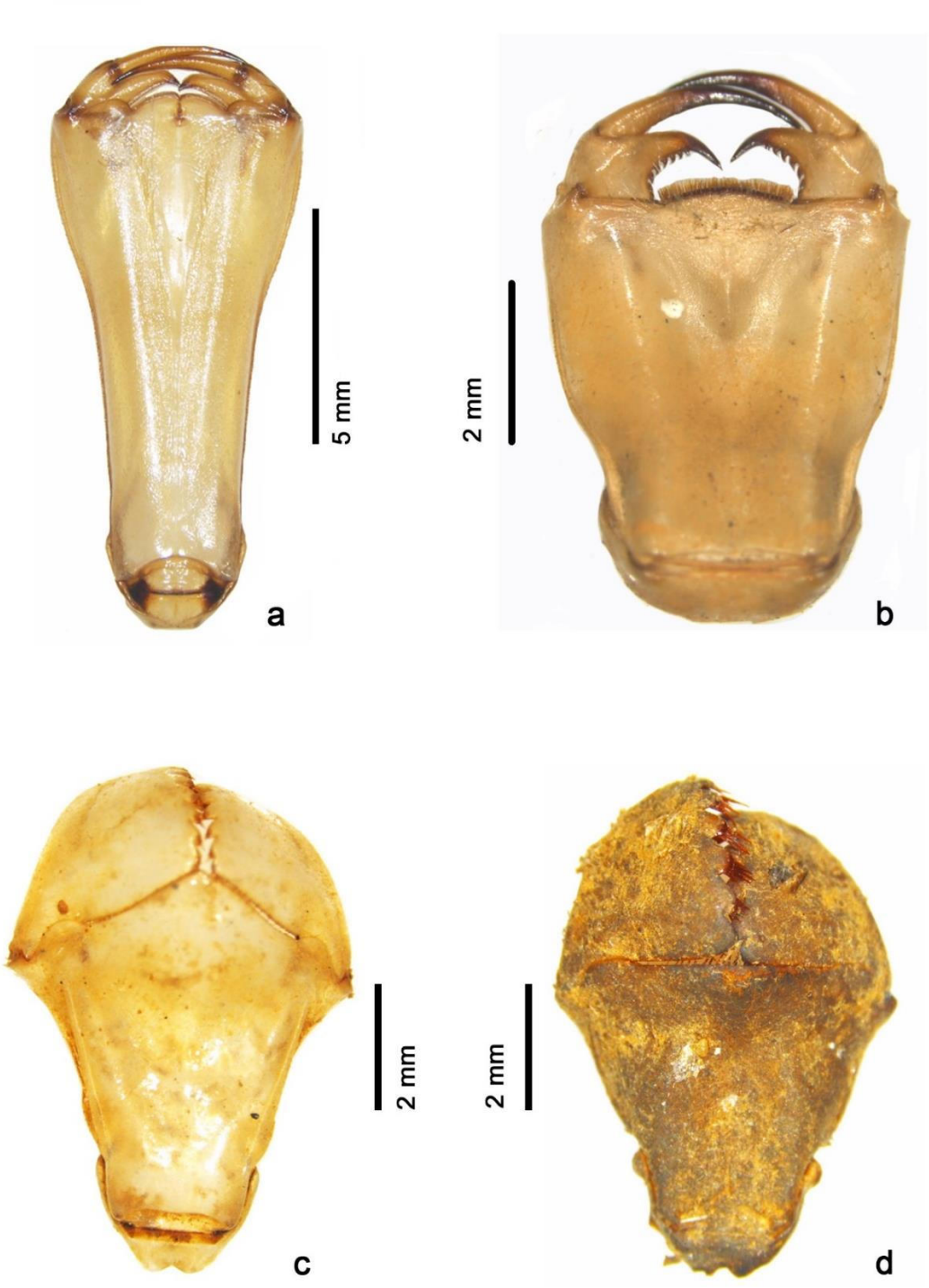


Fig. 11: a. Pear-shaped (*Anax indicus*), b. Trapezoid (*Megalogomphus superbus*), *c.* Spoon-shaped *(Pantala flavescens*), d. Cup-shaped (*Macromia flavocolorata*).

Premental and Palpal setae

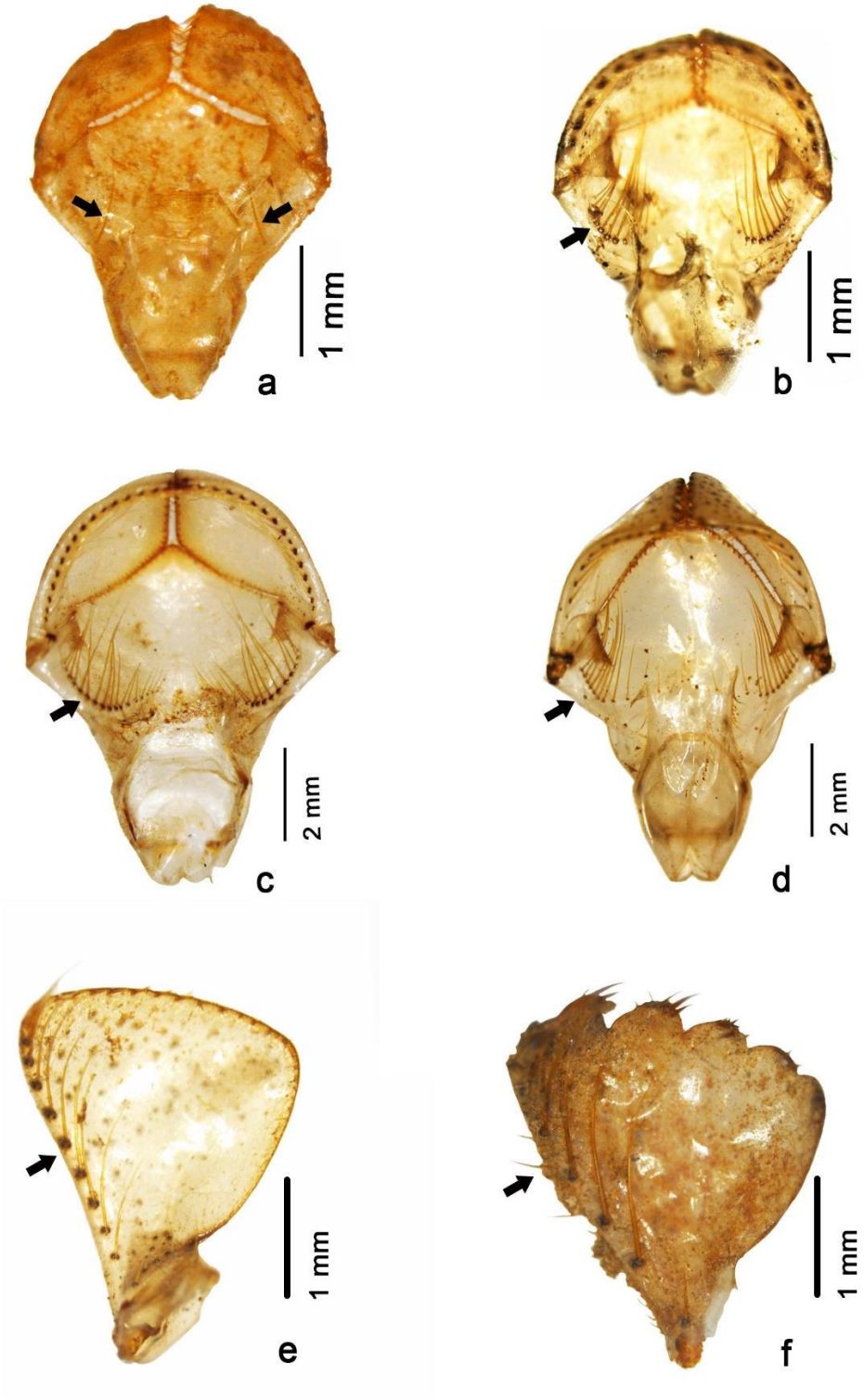


Fig. 12: a–d. Labium showing Premental setae (a. *Rhyothemis variegata*, b. *Brachythemis contaminata*, c. *Bradinopyga geminata*, d. *Tramea basilaris*), e–f. Palpus with setae (e. *Diplacodes trivialis*, f. *Macromia indica*).

Different types of Abdomen with lateral and dorsal spines

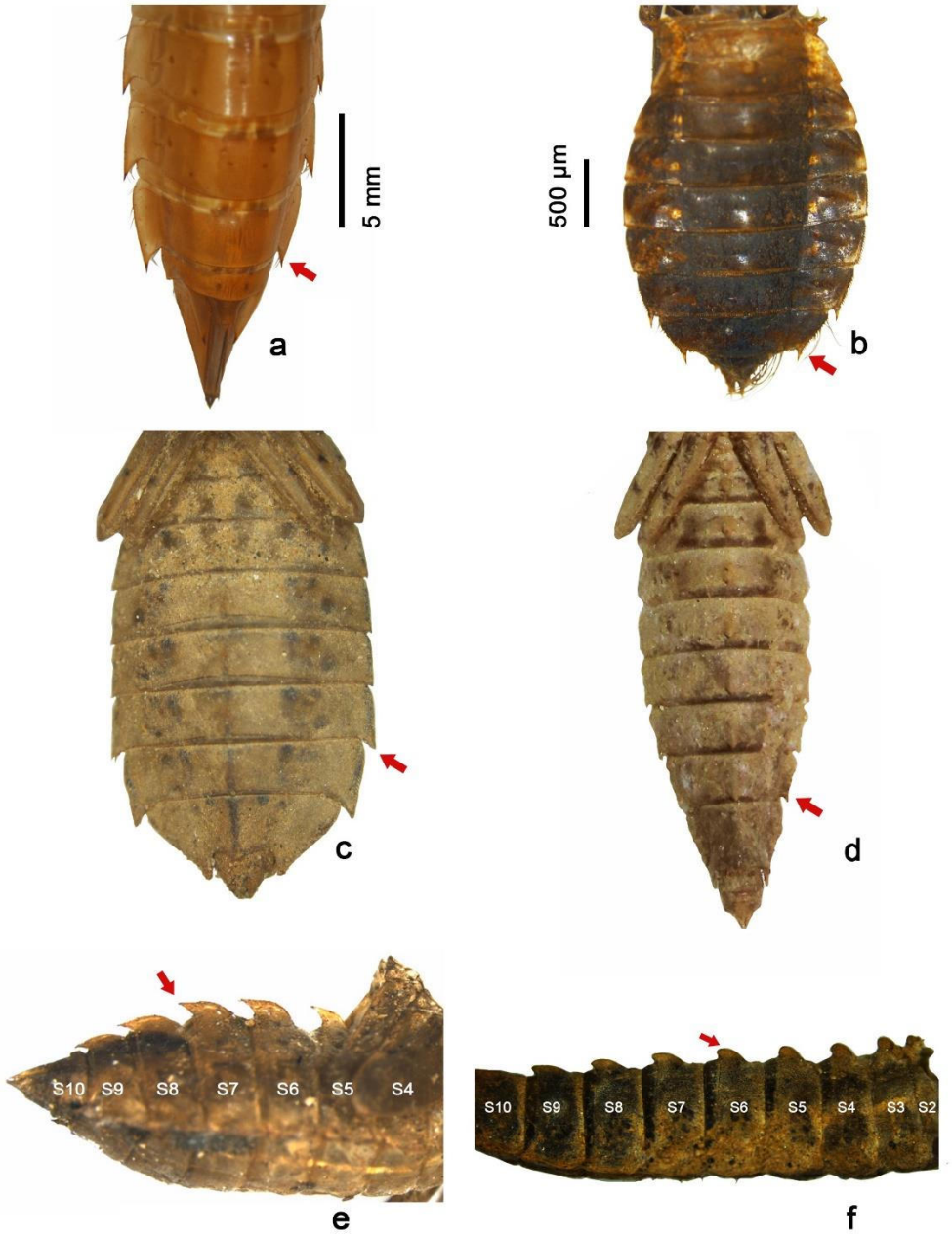


Fig.13: a. Cylindrical (*Anax indicus*), b. Egg-shaped (*Diplacodes trivialis*), c. Oval shaped (*Microgomphus souteri*), d. Tapering (*Burmagomphus pyramidalis)*,e. Dorsal spines with sharp end (*Brachythemis contaminata)*, f. Dorsal spines with blunt end (*Burmagomphus pyramidalis).*

CHAPTER 4
RESULTS

CHAPTER 4

RESULTS

4.1 Check list of dragonfly nymphs identified based on the exuviae from the study sites

Nymphal descriptions of thirty species belonging to twenty-seven genera and four families were recorded from the study area. The check list of all species with remarks was given (Table 4). Among the thirty, ten were described for the first time in the field of nymphal taxonomy.This includes five endemic species of Western Ghats (Table 5). Fifteen species were described for the first time from Kerala and South India, and the remaining five were already described from Kerala as a part of pilot study conducted for this research work (Adambukulam & Kakkassery, 2013a & 2013b).

Table 4: Checklist of dragonfly nymphs identified by using the exuviae

Family	Species	IUCN status & Endemicity	Plate no	Remarks
Aeshnidae	*Anax indicus* Lieftinck, 1942	LC	1	***First description from World
	Gynacantha dravida Lieftinck,1960	DD	2	***First description from World
Gomphidae	*Burmagomphus laidlawi* Fraser,1924	DD & E	3	***First description from World
	Burmagomphus pyramidalis Laidlaw, 1922	LC	4	***First description from World
	Ictinogomphus rapax (Rambur, 1842)	LC	5	$$$First description from Kerala
	Macrogomphus annulatus (Selys, 1854)	DD	6	@@@First report from Kerala
	Megalogomphus superbus Fraser 1931	DD & E	7	***First description from World
	Microgomphus souteri	LC & E	8	***First

	Fraser, 1924			**description from World**
	Onychogomphus malabarensis (Fraser, 1924)	DD & E	9	***First description from World**
	Paragomphus lineatus (Selys, 1850)	LC	10	First description from Kerala in 2013
Libellulidae	*Acisoma panorpoides* Rambur, 1842	LC	11	**$$$**First description from Kerala
	Brachythemis contaminata (Fabricius, 1793)	LC	12	**$$$**First description from Kerala
	Bradinopyga geminata (Rambur, 1842)	LC	13	**$$$**First description from Kerala
	Diplacodes trivialis (Rambur, 1842)	LC	14	**$$$**First description from Kerala
	Hydrobasileus croceus (Brauer, 1867)	LC	15	###**First description from India**
	Lathrecista asiatica (Fabricius, 1798)	LC	16	First description from Kerala in 2013
	Neurothemis tullia (Drury, 1773)	LC	17	**$$$**First description from Kerala
	Orthetrum sabina (Drury, 1773)	LC	18	###First description from Kerala
	Pantala flavescens (Fabricius, 1798)	LC	19	First description from Kerala in 2013
	Rhodothemis rufa (Rambur, 1842)	LC	20	First description from Kerala in 1981
	Rhyothemis variegata (Linnaeus, 1763)	LC	21	**$$$**First description from Kerala
	Tholymis tillarga (Fabricius, 1798)	LC	22	**$$$**First description from Kerala
	Tramea basilaris (Palisot	LC	23	**$$$**First

	de.Breauvois, 1817)			description from Kerala
	Trithemis aurora (Burmeister, 1839)	LC	24	**$$$** First description from Kerala
	Trithemis festiva (Rambur, 1842)	LC	25	**$$$** First description from Kerala
	Urothemis signata (Rambur, 1842)	LC	26	First description from Kerala in 1983
	Zygonyx iris Selys, 1869	LC	27	**###First description from India**
	Zyxomma petiolatum Rambur, 1842	LC	28	**$$$**First description from Kerala
Macromiidae	*Macromia flavocolorata* Fraser, 1922	LC	29	**$$$** First description from Kerala
	Macromia indica Fraser, 1924	LC & E	30	***First description from World**

LC–Least concerned, DD–Data deficient, IUCN status, E–Endemic Source: Gopalan *et al.,* (2022).

*** First description of the nymph from World

First description of the nymph from India

$$$ First description of the nymph from Kerala

@@@ First report of the nymph from Kerala

Table 5: List of Dragonfly nymphs described for the first time in the World & India with IUCN status & Endemicity

SL.NO	Name of the Species	Family	Breeding site	IUCN status & Endemicity
1.	*Anax indicus* Lieftinck, 1942	Aeshnidae	Temporary pond in paddy field	LC
2.	*Gynacantha dravida* Lieftinck, 1960			DD
3.	*Burmagomphus laidlawi* Fraser, 1924	Gomphidae	Rivers	DD & E
4.	*Burmagomphus pyramidalis* Laidlaw, 1922			LC
5.	*Megalogomphus superbus* Fraser, 1931			DD & E
6.	*Microgomphus souteri* Fraser, 1924			LC & E
7.	*Onychogomphus malabarensis* (Fraser, 1924)			DD& E
8.	*Macromia indica* Fraser, 1924	Macromiidae	Rivers	LC & E
9.	*Hydrobasileus croceus* (Brauer, 1867)	Libellulidae	Canals in paddy field	LC
10.	*Zygonyx iris* Selys, 1869		Rivers	LC

LC–Least concerned, DD–Data deficient IUCN status, E–Endemic Source: Gopalan *et al.,* (2022)

Table 6: Breeding sites and emergence season of described species in the present study

SL .NO	Species	Different types of fresh water aquatic ecosystems								
		Weedy Pond	Man Made Pond	Cement bottomed Pool	Temporary Pond	Irrigation Canals	Natural Streams	Rivers	Paddy Field	Kole Wetland
1.	*Anax indicus* Lieftinck, 1942	+ M	0	0	+ M	0	0	0	0	0
2.	*Gynacantha dravida* Lieftinck, 1960	+ M	0	0	+ M	0	0	0	0	0
3.	*Burmagomphus laidlawi* Fraser, 1924	0	0	0	0	0	0	+ PRM	0	0
4.	*Burmagomphus pyramidalis* Laidlaw, 1922	0	0	0	0	0	0	+ PRM	0	0
5.	*Ictinogomphus rapax* (Rambur, 1842)	0	0	0	0	0	0	+ PRM	0	+ PRM & POM
6.	*Macrogomphus annulatus* (Selys, 1854)	0	0	0	0	0	0	+ PRM	0	0
7.	*Megalogomphus superbus* Fraser, 1931	0	0	0	0	0	+ PRM	+ PRM	0	0
8.	*Microgomphus souteri* Fraser, 1924	0	0	0	0	0	+ PRM	+ PRM	0	0
9.	*Onychogomphus malabarensis* (Fraser, 1924)	0	0	0	0	0	0	+ PRM	0	0
10.	*Paragomphus lineatus* (Selys, 1850)	0	0	0	0	0	+ PRM	+ PRM	0	0
11.	*Acisoma panorpoides* Rambur, 1842	+ M & POM	+ M & POM	0	+ M, PRM & POM	+ PRM & POM	0	+ PRM	0	PRM & POM
12.	*Brachythemis contaminata* (Fabricius, 1793)	+ PRM & POM	+ PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ PRM & POM	+ PRM	0	+ PRM & POM

13.	*Bradinopyga geminata (*Rambur, 1842)	0	0	+ M, PRM & POM	0	0	0	0	0	0
14.	*Diplacodes trivialis* (Rambur, 1842)	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	0	+ PRM	0	+ PRM & POM
15.	*Hydrobasileus croceus* (Brauer, 1867)	+ M, PRM & POM	+ M, PRM & POM	0	0	+ PRM & POM	0	0	0	+ PRM & POM
16.	*Lathrecista asiatica* (Fabricius, 1798)	+ M, PRM & POM	0	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	0	0	0	+ PRM & POM
17.	*Neurothemis tullia* (Drury, 1773)	+ M, PRM & POM	0	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	0	+ PRM	+ M, PRM & POM	+ PRM & POM
18.	*Orthetrum sabina* (Drury, 1773)	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ PRM & POM
19.	*Pantala flavescens* (Fabricius, 1798)	0	0	0	0	0	0	0	+ POM	+ POM
20.	*Rhodothemis rufa* (Rambur, 1842)	+ POM	0	0	+ POM	+ M & POM	0	0	0 PRM & POM	+ PRM & POM
21.	*Rhyothemis variegata* (Linnaeus, 1763)	+ M,	0	+ M, PRM	+ M, PRM &	+ M, PRM	0	0	+ PRM	+ PRM &

		PRM & POM		& POM	POM	& POM			& POM	POM
22.	*Tholymis tillarga* (Fabricius, 1798)	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ M, PRM & POM	+ PRM & POM	+ PRM & POM	+ PRM	+ PRM & POM	+ PRM & POM
23.	*Tramea basilaris* (Palisot de.Breauvois, 1817)	+ PRM & POM	+ PRM & POM	+ PRM & POM	0	0	0	0	0	0
24.	*Trithemis aurora* (Burmeister, 1839)	+ PRM & POM	0	0	0	+ PRM & POM	+ PRM & POM	+ PRM	0	0
25.	*Trithemis festiva* (Rambur, 1842)	+ PRM & POM	0	0	0	+ PRM & POM	+ PRM & POM	+ PRM	0	0
26.	*Urothemis signata* (Rambur.1842)	0	0	+ PRM & POM	0	0	0	0	0	0
27.	*Zygonyx iris* Selys, 1869	0	0	0	0	0	0	+ PRM	0	0
28.	*Zyxomma petiolatum* Rambur, 1842	+ M, PRM & POM	+ M, PRM & POM	+ PRM & POM	+ POM	+ POM	0	0	+ PRM & POM	+ PRM & POM
29.	*Macromia flavocolorata* Fraser 1922	0	0	0	0	0	0	+ PRM	0	0
30.	*Macromia indica* Fraser, 1924	0	0	0	0	0	0	+ PRM	0	0

+: Presence of exuvia, **0: Absence of exuvia**, **M: Monsoon season, PRM: Pre Monsoon season, POM: Post Monsoon season**

4.2 Taxonomic descriptions of the identified exuviae from the study area

Family: Aeshnidae Rambur, 1842

1. *Anax indicus* Lieftinck, 1942 (Plate 1, Figs. a–g)

Materials examined: 14 exuviae; *leg*. Shaun Paul Adambukulam

Collection sites: AMD & THT.

Measurements: TBL:53.5; AL:37.3; AW:8.5; HL:4.5; HW:9.0; LL:13; LW:5.8; FFL:6; FTbL:5.7; FTaL:2.1; MFL:8; MTbL:6.3; MTaL:3.2; HFL:10.0; HTbL:7.5; HTaL:4.1; EPL:5.1; PPL:5.7; CRL:3.

Habitus: A very large transparent exuvia with few spots on abdominal segments; body dorso-ventrally convex; cylindrical without hairs and setae.

Head: Broad; pentagonal in outline; compound eyes broad, rounded, and protruding antero-laterally; covering more than half of the dorsolateral margin of the head; posterior margin of the occiput rounded at each side; filiform antennae with seven segments; frons smooth; clypeus wrinkled; labium longer than width; prementum-postmentum articulation extends up to the base of the coxae of the hind leg pair; labium distally wide and pear shaped; lateral margin serrated; premental and palpal setae absent; prementum convex with a median cleft of 0.6 mm deep; palpus truncated distally; the movable hook is longer than the palpus.

Thorax: Narrower than the head; robust and well built; pronotum broadly rounded; legs long and slender; covered with minute spiniform setae; when pressed against the abdomen, the hind femur reaches up to the posterior margin of the S4; the wing sheaths parallel to the abdomen; the tip of the hind wing extends upto the posterior half of the S4; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorsally; widest at S7 and S8; abdominal terga S1–S9 with markings; well-developed lateral spines on S7–S9; anal appendages well developed; cerci shorter than epiproct and paraproct; epiproct emarginated; slightly shorter than paraproct and acuminate; paraproct acuminate.

Breeding sites: The exuviae were found in weedy and temporary shallow ponds associated with paddy field in Thrissur and Palakkad districts during the monsoon season. The large exuviae were found on reeds located within the pond.

2. *Gynacantha dravida* Lieftinck, 1960 (Plate 2, Figs. a–g)

Materials examined: 12 exuviae; *leg*. Shaun Paul Adambukulam

Collection sites: AMD & THT.

Measurements: TBL:32.5; AL:23.5; AW:6; HL:5.2; HW:6.8; LL:8.2; LW:4.2; FFL :4.5; FTbL:4.7; FTaL:1.6; MFL:5.5; MTbL:4.8; MTaL:1.9; HFL:6.3; HTbL:5.1; HTaL :2.1; EPL:0.6; PPL:0.8; CRL:0.5.

Habitus: Comparatively slender exuviae than *A. indicus*; colored light to dark brown; elongated body with two longitudinal stripes dorsally on abdomen; body surface without setae.

Head: Broad, pentagonal in outline; compound eyes large, rounded, protruding antero-laterally; covering more than half of the dorsolateral margin of head; filiform antennae with seven segments; labium longer than width and pear-shaped; prementum-postmentum articulation extends up to the base of the coxae of the middle leg pair; lateral margin serrated; prementum convex with a median cleft of 0.2 mm deep; premental setae absent; palpus truncated distally with curved inner margin; papal setae 3+3 present at the proximal end of palp and movable hook; movable hook is longer than palpus.

Thorax: Narrower than head, pronotum broadly rounded, not projecting laterally; wing sheaths parallel to the abdomen; the tip of the hind wing extends upto the posterior half of the S3; long, slender brown legs with dark bands towards the tibia; when pressed against the abdomen, hind femur reaches upto the posterior margin of the S3; tarsal formula: 3-3-3.

Abdomen: Elongated; tapering towards the end; convex dorsally, a pair of mid dorsal stripes on S2–S9; well-developed lateral spines on S6–S9; anal appendages well developed; cerci having ¾ th length of epiproct and paraproct; apex acuminate; epiproct emarginated; shorter than paraproct.

Breeding sites: The exuviae were found in weedy and temporary shallow ponds associated with paddy field in Thrissur and Palakkad districts during the monsoon season. The large exuviae were found on reeds located within the pond.

Family: Gomphidae Rambur, 1842

3. *Burmagomphus laidlawi* Fraser, 1924 (Plate 3, Figs. a–g)

Materials examined: 20 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: CRP & TKV.

Measurements: TBL:21.2; AL:15.0; AW:6.0; HL:3.0; HW:4.0; LL:4.0; LW:3.0; FFL :1.8; FTbL:2.4; FTaL:1.0; MFL:3.8; MTbL:2.9; MTaL:1.4; HFL:3.8; HTbL:2.9; HTaL:1.8; EPL:1.0; PPL:1.2; CRL:1.0.

Habitus: Body slender and fusiform; muddy brown in color; body dorsoventrally flattened with well-developed mid dorsal spines on S7–S9.

Head: Triangular; sloping downward; eyes large, protruding dorsolaterally; antennae typical gomphid type with four segments; first two segments small and cylindrical; the third segment flattened dorsoventrally and broader distally; the fourth segment vestigial and knob-like; the labium flat; prementum-postmentum articulation reaches the base of the coxae of the prothoracic leg; prementum subrectangular and flat; distal margin of the prementum slightly convex; premental and palpal setae absent; inner margin of the palpus bears 7–8 quadrate teeth; palpal lobes short with strongly incurved finger-like end hooks.

Thorax: Prothorax rectangular; two crescent-shaped ridges present dorsally along the side margin; the meso and metathorax almost equal in size; no setae present on the thorax. wing sheaths parallel and extend to the S4; legs short and robust; the femora of all three pairs have an inward curve; femora and tibia of the mid and hind legs have the same length; when pressed against abdomen, the hind leg femur reaches up to S4; tibia of the foreleg and mid leg bear digging spines; tarsal formula: 2-2-3.

Abdomen: Fusiform and tapering towards the end; widest on S5; first segment short and reduced; S2–S8 are of nearly equal length; S9 is slightly longer than the S8; S10 slightly longer than the anal appendages; irregular dark greyish-black spots on S5–S9; lateral edges of the abdomen with outwardly projecting spines on S7–S9 with sharp ends; the spine on S7 smaller than on S8–S9; those on S9 longest, reaching the half of the S10; well-developed dorsal spines present on S7–S9; spines on S7 and S8 slightly down-curved and hook-like, those on S9 straight, sharply pointed, directed

backwards; anal appendages, small and reduced; epiprocts and cerci with same length; paraprocts slightly longer; the cercus concave at the inner margin.

Breeding sites: Exuviae were found in riverine habitat of Kabani (Wayanad) and Thejaswini (Kannur). Emergence was found to occur during the pre-monsoon period, and they were found on rocks and sands of the riverbed, which were exposed due to the very low water level during the summer. The rocks were covered with mosses.

4. *Burmagomphus pyramidalis* Laidlaw, 1922 (Plate 4, Figs. a–g)

Materials examined: 8 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: CRP & TKV.

Measurements: TBL:22.0; AL:15.5; AW:5.8; HL:3.0; HW:4.0; LL:3; LW:2.1; FFL:2; FTbL:2.5; FTaL:1.2; MFL:2; MTbL:2.5; MTaL:1; HFL:4; HTbL:3; HTaL:2; EPL:1; PPL:1.2; CRL:1.

Habitus: Body slender, fusiform, and muddy brown in color; dorsoventrally flattened with small hairs along the lateral margin of abdomen.

Head: Triangular, sloping downward; eyes large and protruding dorso-laterally; antennae have four segments: the first two are small and cylindrical; the third flattened dorsoventrally; the fourth segment vestigial and knob-like; numerous long setae present on first three segments; labium flat; prementum-postmentum articulation reaches the base of the coxae of the prothoracic leg; the prementum sub-rectangular and flat; the distal margin of the prementum slightly convex; no premental and palpal setae; inner margin of the palpus bears 7–8 quadrate teeth; end hooks incurved and finger-like; movable hooks long, sharp, with a pointed end.

Thorax: Prothorax rectangular; wing sheaths parallel and extend to the midpoint of S3; legs are short and robust; femora of all three pairs have an inward curve; femora and tibia of the mid and hind legs have the same length; when pressed against the abdomen, the hind leg femur reaches up to S3; tarsal formula: 2-2-3.

Abdomen: Abdomen fusiform; tapering towards the end; widest on S5; the first segment short and reduced; S2–S8 are of nearly equal length; S9 slightly longer than S8; S10 slightly longer than anal appendages; lateral spines with sharp ends present on S7–S9; the spine on S7 is smaller than on S8–S9; those on S9 are the longest,

reaching the half of the S10; well-developed dorsal protuberances with blunt ends present on S2–S8; anal appendages short; epiprocts and cerci with equal length; paraprocts slightly longer; epiproct acuminate; triangular at base.

Breeding sites: Exuviae were found in River Kabani (Wayanad) and Thejaswini (Kannur). Emergence was found to occur during the pre-monsoon period, and they were found on rocks and sands of the riverbed, which were exposed due to the very low water level during the summer. The rocks were covered with mosses.

5. *Ictinogomphus rapax* (Rambur, 1842) (Plate 5, Figs. a–h)

Materials examined: 26 exuivae; *leg*. Shaun Paul Adambukulam

Collection sites: TKV, KUR, PKM, CRP, KTR, MLM, KUK, ATP & AMD.

Measurements: TBL:25; AL:10; AW:14; HL:4; HW:3.6; LL:4.2; LW:3.5; FFL:5; FTbL:5; FTaL:2; HFL:8; HTbL:8; HTaL:5; MFL:6; MTbL:5; MTaL:2; EPL:0.5; PPL:0.5; CRL:0.5.

Habitus: Exuviae are well built and stout-bodied with a limbet-like shape (Fraser, 1933), which is entirely different from other congeneric species of the Gomphidae family; color varies from muddy brown to dark greyish black.

Head: Pentagonal in outline; antero-laterally protruding compound eyes; antennae with four segments and the fourth segment being rudimentary; the third segment possesses serrations laterally; the post frons bear tubercles in between the antennae and also laterally; the labium broad and more or less square-shaped; postmentum and pre- mentum articulations reach up to anterior margin of mesocoxal leg; distal margin of the pre-mentum slightly convex; no palpal or pre-mental setae; the inner margin of the palp bears 8–10 quadrate teeths; the end hooks short finger like with the blunt end; the movable hook long and sharply pointed.

Thorax: Comparatively small; prothorax bears tubercles laterally; meso and meta thorax are equal in size; divergent wing sheaths; extends upto the anterior margin of S6; legs short and robust; when pressed against the abdomen, the hind femur reaches upto the posterior end of S5; tarsal formula: 2-3-3.

Abdomen: Broad and round-shaped; dorsally roof-shaped, flat ventrally; S1–S7 have same size but increasing width gradually; S8 slightly larger than S7; S9 the largest

segment; S10 small and vestigial; lateral spines present from S4–S9; mid-dorsal spines present on S1–S9; the spine on S1 very small and directed upwards; the S2 spine larger than S1; the spine on the S3–S8 ridge like; that on S9 smallest; anal appendages are small; epiproct shorter with broad base; acuminate; slightly longer than cerci; cerci shortest with triangular base; paraproct acuminate; slightly longer than epiproct.

Breeding sites: Exuviae were observed in both stagnant water bodies like ponds and also from streams and rivers. In the former case, the exuviae are found on reeds along the margin, whereas in the latter, the exuviae were collected from exposed rocks, sands, and also from the marginal vegetation.

6. *Macrogomphus annulatus* (Selys, 1854) (Plate 6, Figs. a–g)

Materials examined: 20 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: TKV, KUR, CRP & KUK.

Measurements: TBL: 48; AL:40; AW:5.2; HL:4; HW:5.1; LL:5; LW:3; FFL:2; FTbL :4; FTaL:1.5; MFL:2.8; MTbL:3.7; MTaL:2; HFL:5; HTbL:4; HTaL:3; EPL:0.2; PPL:0.2 CRL:0.1.

Habitus: A very long exuviae with a tapering abdomen ends in a siphon, which is a characteristic feature of the genus. Exuvia is muddy brown in color.

Head: Small triangular; sloping downward with large globular compound eyes covering the half of the head; antennae short, club shaped with four segments; first two short and cylindrical; third elongated, flat, and slightly curved distally; first three bears hairs; fourth segment vestigial, and knob like; the labrum bears fine hair like setae; the labium typical gomphid type flat; oblong; median lobe slightly concave with small setae; distal half square; without premental and palpal setae; palpal blade kukri-shaped; armed with five robust teeth on the inner border; very long movable hook.

Thorax: Narrower than head; prothorax rectangular; pterothorax more or less trapezoidal; the wing cases parallel; very narrow extending upto the midpoint of S3; the legs short and robust; when pressed against abdomen, the hind femora reaches

anterior margin of S3; the femora of fore and mid leg curved inwardly and shorter than their tibial part; tibial spur present; tarsi adapted for digging, the femora of the hind leg slightly curved and longer than the tibia; tarsus with tarsal formula: 2-3-3.

Abdomen: Greatly elongated; tapering; cylindrical; S1 small; S2–S6 equal sized and rectangular; S7 slightly narrower; S8 slightly longer having inverted trapezium shape; vestigial mid-dorsal protuberances present from S2–S8; S9 longest with a well-developed sharp pointed backwardly directed spine; S10 small cylindrical; S9 and S10 together form a long siphon which projects from the mud; anal appendages small; epiproct shorter with broad base; acuminate; slightly longer than cerci; cerci acuminate ;shortest with triangular base; paraproct acuminate; slightly longer than epiproct.

Breeding sites: The exuviae were found in River Kabani (Wayanad), Thejaswini (Kannur) and Chaithravahini (Kasaragod). Emergence was found to occur during the premonsoon season, exuviae were found on marginal vegetation, exposed rocks and sands of the riverbed, which were exposed due to the very low water level during the summer.

7. *Megalogomphus superbus* Fraser, 1931 (Plate 7, Figs. a–-g)

Materials examined: 5 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: KGR, CRP & KUK.

Measurements: TBL:42; AL:30; AW:10; HL:7; HW:7; LL:6; LW:4.7; FFL:4; FTbL:3; FTaL:2; MFL:4; MTbL:4; MTaL:2.5; HFL:6; HTbL:5; HTaL:4; EPL:1.8; PPL:2; CRL:1.6.

Habitus: Large well built robust exuviae with short hairs on legs, thorax and head; color yellowish brown.

Head: Broad; pentagonal in outline; compound eyes are broad, rounded, and protruding anterolaterally; covering more than half of the dorsolateral margin of the head; antennae typically four segmented; the first two small and cylindrical; third flattened dorso-ventrally; narrow proximally, and becoming broader distally; bear numerous long setae ; the fourth segment vestigial, inconspicuous, and knob-like; the

labium, inverted trapezoidal shape; longer than width; reaching beyond the coxae of the first pair of legs; no premental and palpal setae; distal margin of the prementum slightly convex with 25–26 square shaped teeth each with two setae embedded in it; palpus blade kukri shaped; armed with 8 robust teeths on the inner margin; end hook long and curved; movable hook sharp, pointed and longer than palpus.

Thorax: Narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing pads diverging; extends up to midpoint of S4; legs short and robust; long hair like setae present along posterior margin of all three pairs of legs; foreleg is the shortest and hind leg is the longest; when pressed against abdomen, the femora of hind leg reaches S5; well-developed digging spine present on the fore and mid tibia; femora of fore and mid leg equal in length; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorsally; widest at S7 and S8; dark black spots present on either side of the mid line and also along the lateral side from S2–S9; prominent lateral spines present on S7–S9; mid dorsal protuberances well developed on S2–S9; S10 smallest segment without dorsal or lateral spine; anal appendages short; cerci shorter than epiproct and paraproct; apex acuminate; shorter than paraproct; larger than epiproct.

Breeding sites: The exuviae were found in a natural canal in Krishnagiri (Wayanad), Thejaswini River (Kannur) and Chaitravahini River (Kasaragod). Exuviae were collected from the exposed rocks, and sand.

8. *Microgomphus souteri* Fraser, 1924 (Plate 8, Figs. a–f)

Materials examined: 8 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: KGR, TKV, VYT, PKM, KUR & KUK

Measurements: TBL:18.8; AL:11; AW:6.5; HL:2.9; HW:4; LL:3; LW:2.2; FFL:2; FTbL:2; FTaL:0.8; MFL:3; MTbL:2.5; MTaL:1; HFL:5; HTbL:3; HTaL:1.8; EPL: 0.65; PPL:0.70; CRL:0.65.

Habitus: Small dorso-ventrally flattened exuvia straw-sand colored. Exuvia were found on exposed rocks, marginal vegetation, and sands.

Head: Very small; flattened dorsally; sloping downward; broadest across compound eyes; eyes small, protruding from the head; three ocelli present as light spots; occipital

lobe bulging behind the eyes; antennae four segmented; the third segment elongated; narrow proximally and broader distally with the outer margin convex and inner margin slightly concave; minute setae present along the outer margin; fourth vestigial and nipple like; labium flat extends back to the coxae of the first leg pair; prementum as long as width; median lobe strongly convex with 20–22 short teeth; palpus finger-like with blunt end without end hook; inner margin of palpus with 9–11 sub-quadrate teeth.

Thorax: Prothorax narrower than the head; laterally possess tubercles; the ventral side covered by the base of the labium; pterothorax trapezoidal; wing sheaths divergent and extending back upto the end of S4; legs moderately long and slender; femur and tibia of foreleg having equal length; middle femur and hind femur longer than tibia; when pressed against the abdomen, hind femur reaches the midpoint of S5; tarsal formula: 2-2-3.

Abdomen: Dorso-ventrally flattened, oval-shaped; lateral margin of the abdomen beset with minute serrations; all segments are equal except the first segment; two longitudinal rows of small roundish dark spots on S3–S9; lateral spines present from S3–S9; prominent on S4–S9; dorsal hooks absent on S1–S7, but S8–S9 with small vestigial protuberance; epiproct and cerci of same length; paraprocts slightly longer; epiproct triangular and acuminate; each cercus concave at outer margin; terminal part pointing outwards.

Breeding sites: The exuviae were found in natural canal at Krishnagiri Thonikkadavu, Pakkom, Vaithiri and Kuruva island in Wayanad, and also from river Thejaswini at Cherupuzha (Kannur) Chithrawahini at Kunnukai (Kasaragod). Emergence was found during the premonsoon season. Exuviae were found on marginal vegetation, exposed rocks and sands of the riverbed, which were exposed due to the very low water level during the summer.

9. *Onychogomphus malabarensis* (Fraser, 1924) (Plate 9, Figs. a–g)

Materials examined: 14 exuviae, *leg.* Shaun Paul Adambukulam

Collection site: CRP.

Measurements: TBL:22; AL:14.5; AW:6.3; HL:3; HW:4; LL:3; LW:2; FFL:2.2; FTbL :2.5; FTaL:1; MFL:2.2; MTbL:2.5; MTaL:1.2; HFL:4; HTbL:3.2; HTaL:2; EPL:1.2; PP:1.2; CRL:1.2.

Habitus: Medium-sized exuviae with well-built body without hairs; colour dark brown.

Head: Medium-sized; pentagonal in outline; flattened dorsally; sloping downwards eyes are small protruding from the head; three ocelli present as light spots; antennae typically four segmented; third segment elongated; broader distally with outer; minute setae present along the third segment; fourth segment vestigial and knob-like; labium flat sub-rectangular; prementum-postmentum joint extends up to the coxae of the first leg pair; prementum as long as width; median lobe strongly convex with 16 short teeths between which hair-like scales inserted; palpus finger like with blunt end without end hook; inner margin of palpus with 12 sub-quadrate teeth.

Thorax: Small; prothorax narrower than head; pterothorax trapezoidal; wing sheaths divergent; extending to the midpoint of S4; legs short and robust; fore and mid femora have same length; fore tibia and mid tibiae slightly longer than their femoral segments; hind femur slightly longer than tibia and reaches posterior end of S4; tarsal formula: 2-2-3.

Abdomen: Less convex dorsally; dark brownish black; mid-dorsal spine absent on S1; short blunt spines present from S2–S9; lateral spines from S6–S9; S10 smallest segment without lateral and mid dorsal spine; anal appendages short, small, and triangular; epiproct and cerci with same length; paraprocts slightly longer; epiproct broad and triangular at the base with pointed end; cercus concave at outer margin; paraprocts pointed with sharp tips.

Breeding sites: Exuviae were collected from Thejaswini River at Cherupuzha (Kannur). They were found on exposed rocks which are covered with mosses. Also few exuviae were collected from sand.

10. *Paragomphus lineatus* (Selys, 1850) (Plate 10, Figs. a–g)

Materials examined: 11 exuviae; *leg*. Shaun Paul Adambukulam

Collection sites: PLD, KLK, MLM, DMD, MMT, TKV, WYD, PMR & ATP

Measurements: TBL:26; AL:18; AW:6; HL:3; HW:5; LL:3.5; LW:2; FFL:2.2; FTbL:2.5; FTaL:1.3; MFL:3; MTbL:2.6; MTaL:1.2; HFL:4; HTbL:3; HTaL:2; EPL:2.2; PPL:2.4; CRL:2.2.

Habitus: A long exuviae with sharply tapering abdomen; straw colored exuvia without hairs on body

Head: Broad; pentagonal in outline; compound eyes are broad; rounded; and protruding antero-laterally; covering more than half of the dorsolateral margin of the head; antennae typically four segmented; third antennomere broader distally and bear long hair like setae; fourth segment elongated and sharply bent outwards; labium longer than width; subrectangular; reside within the head capsule at rest; prementum postmentum joint reaches the coxae of the first leg pair; no premental and papal setae; distal margin of prementum strongly convex; with fine setae along the margin; palpus finger like with sharp end;movable hook longer than palpus with blunt end.

Thorax: Prothorax narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing buds diverging; tip of the hind wing reaching the posterior end of the S4; legs short and robust; all three pair of legs covered with minute spiniform setae along their posterior margin; when pressed against the abdomen the hind femur reaches the end point of S2; the fore and the mid tibiae bear a tibial spur for digging; the femur and the tibiae of all three pairs of legs are inwardly curved; tarsal formula: 3-3-3.

Abdomen: Elongated; tapering towards the end; cylindrical; all abdominal segments are equal-sized except S1 and S10; widest at S5 and S6; mid dorsal protuberances present as small spines from S2–S9; lateral spines present from S2–S9: dark black spots present on either side of the mid line and also along the lateral side from S2–S9; S10 smallest and without dorsal or lateral spines; abdominal appendages are slightly elongated and acuminate; epiproct and cerci are equal in length with a triangular base; paraproct slightly longer than epiproct.

Breeding sites: Exuviae were observed in all riverine habitats from Chalakkudy river at Athirapilly (Thrissur), Kabani river (Wayanad), Tejaswini river (Kannur) and Chaitrawahini river (Kasaragod). Emergence period was premonsoon. Exuviae were found associated with vegetation, exposed rocks and also from sand.

III. Family: Libellulidae Leach 1815

11. *Acisoma panorpoides* Rambur, 1842 (Plate 11, Figs. a–e)

Materials examined: 32 exuviae; *leg*. Shaun Paul Adambukulam

Collection sites: PLT, SKP, CHT, MNK, KTR, DMD, PKT, MMT, VYT, PML, PAL, KMG, ALP, AMD, KCY, MBR, CTR, MLP, THT & TNK

Measurements: TBL:10; AL:8; AW:4; HL:3; HW:4; LL:3; LW:2; FFL:2; FTbL:1.5; FTaL:1; MFL:3; MTbL:2; MTaL:1; HFL:4; HTbL:3; HTaL:2; EPL:0.2; PPL:0.3; CRL:0.1.

Habitus: Dark brown colored; very small exuviae; hairy and compact in appearance.

Head: Medium-sized; pentagonal in outline; compound eyes medium-sized, rounded, and protruding antero-laterally; filiform antennae with seven segments; frons and clypeus smooth; labium distally wide and spoon-shaped; longer than width; prementum extends upto the coxae of the third pair of legs; premental setae 11+11; distal margin of prementum triangular; small crenations present along the margin; palpal setae 8+8; distal margin of palpus crenated; crenations bear spiniform setae; end hook spiniform; movable hook sharp pointed.

Thorax: Prothorax narrower than the head; wing sheaths diverging and extend up to the anterior margin of S6; legs are long and slender; dark brown bands on the femurs of all three pairs of legs; hind leg is the longest usually extends beyond the abdomen; tibiae of fore and mid leg bears hair-like setae along the posterior margin; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorso-ventrally; all segments have same size except S1 and S10; maximum width on S6; mid dorsal protuberances absent; lateral spines absent from S1–S7; small lateral spines present on S8–S9; S10 smallest segment without lateral spine; anal appendages short triangular at base; epiproct and cerci have equal length; paraproct slightly longer than epiproct.

Breeding sites: Exuviae were observed in all types of fresh water ecosystems such as ponds, including natural and artificial man-made ponds, rivers, canals, streams. Exuviae were found to clinging on the lower side of the leaves of the plants along the marginal vegetations.

12. *Brachythemis contaminata* (Fabricius, 1793) (Plate 12, Figs. a–g)

Materials examined: 12 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: PLT, SKP, CHT, MNK, KTR, MPR, DMD, PKT, MMT, VYT, PML, PAL, KMG, ALP, AMD, KCY, MBR, CTR, MLP, THT, TNK, CKD, OLY, TMY, PKD, TKV, PMR, AMV & WYD.

Measurements: TBL:15; AL:11; AW:5.2; HL:3.6; HW:4; LL:3.2; LW:2.8; FFL:3.8; FTbL:3.2; FTaL:1.0; MFL:4; MTbL:3.5; MTaL:1.2; HFL:5; HTbL:3.8; HTaL:1.5; EPL:0.3; PPL:0.4; CRL:0.3.

Habitus: Medium sized exuviae; light brown to dark brown; abdomen oval with mid dorsal spines.

Head: Medium sized; triangular in outline; compound eyes are medium sized, rounded, and protruding antero-laterally; filiform antennae with seven segments; labium distally wide and spoon shaped; longer than width; prementum reaching the coxae of the third leg pair; premental setae 12+12; distal margin of prementum triangular; palpal setae 7+7; distal margin of palpus crenated; movable hook sharply pointed.

Thorax: Prothorax narrower than the head; wing sheaths diverging and extending up to the anterior margin of S5; legs long and slender; dark brown bands on the femurs of all three pairs of legs; hind leg extends beyond the abdomen; tibiae of the fore and mid leg bear hair like setae along the posterior margin; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorso-ventrally; all segments have the same size except S1 and S10; maximum width on S6; mid dorsal protuberances present from S2–S8; lateral spines absent from S1–S7; small lateral spines present on S8–S9; S10 smallest segment without mid dorsal and lateral spine; anal appendages short triangular at their base epiproct and cerci have equal length; acuminate; paraproct slightly longer than epiproct.

Breeding sites: Exuviae were observed in all types of fresh water ecosystems like ponds, lakes, paddy fields, canals, and rivers of all study sites Exuviae were found clinging on to lower side of the leaves of the marginal vegetation.

13. *Bradinopyga geminata* (Rambur, 1842) (Plate 13, Figs. a–e)

Materials examined: 22 exuviae; *leg*. Shaun Paul Adambukulam

Collection sites: TCR & AMD.

Measurements: TBL:20; AL:10; AW:5.8; HL:3.5; HW:4; LL:5; LW:4; FFL:4.5; FTbL:4; FTaL:1.8; MFL:4.5; MTbL:4; MTaL:1.8; HFL:6; HTbL:5; HTaL:2; EPL:1.5; PPL:2; CRL:1.

Habitus: A medium sized, clear transparent exuvia with no hairs on body

Head: Broad; pentagonal in outline; compound eyes rounded and protruding anterolaterally covering more than half of the dorso-lateral margin of the head; filiform antennae with seven segments; the first two segments short and sturdy; the third antennomere is larger than other antennomeres; labium spoon-shaped; prementum extends up to the base of the first leg pair; premental setae 19+19; distal margin of prementum triangular; small crenations present along the margin; palpal setae 16+16; distal margin of palpus crenated; movable hook sharp pointed.

Thorax: Narrower than head; wing sheaths diverging; tip of the hind wing extends up to posterior end of S5; legs long and slender; dark brown bands present on the femurs of all three pairs of legs; hind leg extends beyond the abdomen; tarsal formula: 3-3-3

Abdomen: Cylindrical; convex dorso-ventrally; all segments except S1 and S10 having nearly equal size; widest at S6 and S7; abdominal S1–S9 with markings; mid dorsal spines absent; lateral margin possessing small spiniform setae; lateral spines present on S8–S9; spine on S8 extends to half of S9; spine on S9 extends to end of S10; S10 having ¼ length of the anal appendage and smallest segment; anal appendages well developed; cerci shorter than the epiproct and paraproct; apex acuminate; epiproct and paraproct triangular at the base and acuminate; paraproct slightly longer than epiproct.

Breeding sites: Exuviae were found only in man-made cement bottomed pools placed in gardens and parks. They emerge throughout the year and exuviae can be seen on the wall of such tanks.

14. *Diplacodes trivialis* (Rambur, 1842) (Plate 14, Figs. a–h)

Materials examined: 36 exuviae, *leg.* Shaun Paul Adambukualm

Collection sites: PLT, CHT, MNK, KTR, DMD, PKT, MMT, VYT, PML, PAL, KMG, ALP, AMD, MBR, CTR, MLP, THT, TNK, CKD, OLY, TMY, PKD, TKV & PMR .

Measurements: TBL:17; AL:11; AW:4.5; HL:4; HW:3; LL:4.5; LW:3; FFL:3; FTbL:3; FTaL:1.5; MFL:4; MTbL:3.5; MTbL:1.5; HFL:5; HTbL:4.5; HTaL:2; EPL:1.2; PPL:2; CRL:1.2.

Habitus: A medium sized exuviae with slightly oval abdomen. Dark brown colored exuviae with no body hairs.

Head: Medium-sized; pentagonal in outline; compound eyes medium-sized, rounded and protruding antero-laterally; the posterior margin of the occiput rounded at each side behind the compound eyes; filiform antennae with seven segments; labium distally wide and spoon-shaped; longer than width; prementum reaching to the base of the hind leg pair; premental setae 14+14; distal margin of the prementum triangular; small crenations present along the distal margin; palpal setae 10+10; the distal margin of palpus crenated; movable hook sharply pointed.

Thorax: Prothorax narrower than the head; wing sheaths diverging and extending to the anterior margin of S6; legs long and slender; dark brown bands on the femurs of all three pairs of legs; the hind leg extends beyond the abdomen; tibiae of the fore and mid leg bear hair like setae along the posterior margin; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorso-ventrally; segments S2–S9 equal in size ; maximum width on S6; mid dorsal protuberances absent; lateral spines absent from S1–S7; small lateral spines present on S8–S9; S10 smallest segment without mid dorsal and lateral spine; anal appendages short triangular at their base epiproct and cerci equal length; acuminate; paraproct slightly longer than epiproct; apex acuminate.

Breeding sites: Exuviae were found in natural and man made ponds, cemented pools, natrual streams, irrigation canals, temporary ponds, paddy fields, kole wetland and rivers. Exuviae were usually found on clinging to vegetation.

15. *Hydrobasileus croceus* (Brauer, 1867) (Plate 15, Figs. a–g)

Materials examined: 14 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: PAL, KMG, ALP, AMD, MBR, CTR, MLP, THT, TNK & CKD.

Measurements: TBL;24.2; AL:15; AW:7.2; HL:5; HW:4; LL:8; LW:6; FFL:5; FTbL:4; FTaL:2; MFL:6; MTbL:5; MTaL:2.5; HFL:8; HTbL:7; HTaL:3; EPL:3; PPL:3.5; CRL:0.5.

Habitus: A medium sized exuviae with dark spots on the body with long legs. Abdomen with mid dorsal spines on S3–S8 and lateral spines on S8–S9 and elongated anal appendages.

Head: Broad; pentagonal in outline; compound eyes are broad, rounded, and protruding anterolaterally; covering more than half of the dorso-lateral margin of the head; filiform antennae with seven segments; labium longer than width; prementum reaching up to the upper half of the coxae of the third leg pair; labium distally wide and spoon-shaped; prementum convex; distal margin triangular; premental setae 12+12; palpal setae 9+9; distal margin without crenations.

Thorax: Prothorax narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing buds diverging; tip of the hind wing reaching the posterior half of the S4; legs long and slender; incomplete dark brown bands on the femurs of all three pairs of legs; hind leg extends to the midpoint of S7; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorsally; abdominal terga with small spines along lateral margin; widest at S6 and S7; all segments from S2–S8 are equal; S10 very small and vestigial; mid dorsal spines present from S3–S8; spine on S3 is smallest and then size gradually increases from S4–S8; the spine on S8 largest and directed backwards; well-developed long; lateral spines on S8–S9 with small spine like setae along the outer margin; the spine on S8 extends beyond the half of S9; the spine on S9 reaching up to the end of paraproct; anal appendages well developed with the spines along the lateral margin; epiproct slightly shorter than the paraproct; cerci shorter than epiproct; acuminate; paraproct longest with sharp pointed end.

Breeding sites: Exuviae were collected from ponds, kole wetlands, and irrigation canals associated with paddy fields in Thrissur and Palakkad. Exuviae were usually found on cling to vegetation.

16. *Lathrecista asiatica* (Fabricius, 1798) (Plate 16, Figs.a–f)

Materials examined: 28 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: AMD, ALP, KMG & CTR

Measurements: TBL:16; AL:10; AW:5; HL:4; HW:5; LL:5; LW:4; FFL:3; FTbL:3; FTaL:1.2; MFL:4; MTaL:3.5; MTbL:1.5; HFL:6; HTbL:5; HTaL:5; EPL:1; PPL:1.3; CRL:0.7.

Habitus: A small sized dark brown colored exuviae with short legs and hairs on the body.

Head: Broad; pentagonal in outline; compound eyes medium-sized, rounded, and protruding antero-laterally; filiform antennae with seven segments; first two segments are short and cylindrical; third antennomere is larger than other antennomeres; labium longer than width; reaching the upper half of the coxae of the first leg pair; labium typically spoon-shaped; the lateral margin smooth; premental setae 14+14; distal margin triangular; palpal setae 11+11; distal margin crenulated.

Thorax: Narrower than head; robust and well built; wing buds divergent; tip of hind wing reaching the posterior line of the S5; legs long and slender; hind leg extends beyond the abdomen; when pressed against abdomen, the hind leg femur reaching up to the posterior end of the S6; tarsal formula: 3-3-3.

Abdomen: Convex dorsally; flattened ventrally; abdominal terga with small spine along the posterior margin; S2–S8 nearly equal in size; widest at S5 and S6; mid-dorsal spines reduced; S10 very small and vestigial; postero-lateral spines on S8–S9; anal appendages short and pyramid like; cerci shorter than epiproct and paraproct; apex acuminate, epiproct acuminate, shorter than paraproct.

Breeding sites: The exuviae were found in ponds, kole wetlands and temporary ponds associated with paddy fields. Exuviae were usually found on vegetation near the water body.

17. *Neurothemis tullia* (Drury, 1773) (Plate 17, Figs. a–f)

Materials examined: 16 exuviae, *leg*. Shaun Paul Adambukulam

Collection sites:KUR, PLD, ELT, PLT, KTR, CRP, DMD, MMT, PKD, WYD, AMV, VYT, ALP, MRT, TMY, AMD, CKD, KNY, KLK, CTR, OLY, KLP & THT.

Measurements:TBL:17; AL:9; AW:4.5; HL:4; HW:3; LL:4; LW:3; FFL:2.5; FTaL:2.8; FTbL 0.7; MFL:4; MTbL:2.8; MTaL:1.2; HFL:5; HTbL:4.5; HTaL:1.5; EPL 0.5; PPL:0.6; CRL:0.3.

Habitus: A very small exuviae with dark brown colour; body without body hairs.

Head: Small; pentagonal in outline; compound eyes are large rounded, and protruding antero-laterally; covering more than half of the dorso-lateral margin of the head; filiform antennae with seven segments; first two segments are short and sturdy; labium longer than width; typically spoon shaped; prementum extends up to anterior region of second leg pair; distal margin of the prementum triangular; premental setae 13+13; palpal setae 8+8; distal margin of the palpus with small spines.

Thorax: Narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing sheaths divergent; tip of hind wing reaching the posterior half of S5; legs are long and slender; incomplete dark brown bands on the femurs of all three pairs of legs; hind leg extending beyond the abdomen; incomplete dark brown bands on the femurs of all three pairs of legs; tarsal formula: 3-3-3.

Abdomen: Dorso ventrally biconvex; more or less oval ; small spines along the lateral margin: widest at S6 and S7; all segments from S2 –S8 are equal; S10 very small and vestigial without lateral and dorsal spine; lateral spines on S8-S9; mid dorsal spines absent; anal appendages short; cerci shorter than epiproct and paraproct; apex acuminate; epiproct slightly shorter than paraproct.

Breeding sites: Exuviae were found in natural and man made ponds, cemented pools, natrual streams, irrigation canals, temporary ponds, paddy fields, kole wetland and rivers. Exuviae were seen on clinging to vegetation.

18. *Orthetrum sabina* (Drury, 1773) (Plate 18, Figs. a–f)

Materials examined: 85 exuviae; *leg.* Shaun Paul Adambukulam

Collection sites: KUR, PLD, ELT, KLK, SKP, PLT, MNK, MUK, MLM, KTR, CRP, DMD, MMT, PKD, TKV, PKM, WYD, PMR, AMV, VYT, ALP, MRT, TMY, AMD ,CKD, KNY, KLK, MLP, CTR, OLY, KLP, TNK, & THT.

Measurements: TBL:20; AL:15; AW:6; HL:4; HW:3; LL: 4; LW:3; FFL:4; FTbL:3; FTaL:1; MFL:5; MTaL:4; MTbL:2; HFL:6; HTbL:5; HTaL:3.5; EPL:2; PPL:2.5; CRL:0.3.

Habitus: Medium sized muddy brown colored exuviae with hairs throughout the body and covered with mud.

Head: Broad; pentagonal in outline; compound eyes medium sized; rounded, and protruding antero-laterally; covering more than half of the dorsolateral margin of the head; filiform antennae with seven segments; first two segments are short and sturdy; third antennomere larger than other antennomeres; labium longer than width; prementum reaching the base of fore leg pair; labium distally wide and spoon shaped; prementum distally triangular; premental setae 11+11; palpal setae 7+7; distal margin of palpus crenulated.

Thorax: Narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing buds are diverging; tip of the wing extends up to midpoint of S6; legs short and robust; femur and tibiae of fore and mid leg bears numerous hairs along their ventral margin; no hairs present along the hind leg; when pressed against abdomen the hind leg femur extends up to S6; tarsal formula: 3-3-3.

Abdomen: Dorso-ventrally biconvex; all segments from S2–S9 are equal; S10 very small and vestigial without lateral and dorsal spine; well-developed mid dorsal spines present from S3–S9; lateral spines present on S8–S9; tuft of hairs present on the ventro- lateral side of S9; caudal appendages elongated; cerci shorter than epiproct and paraproct; apex acuminate; paraproct acuminate slightly longer than epiproct; lateral surface with scattered long hair like setae.

Breeding sites: Exuviae were found in natural and man made ponds, cemented pools, natrual streams, irrigation canals, temporary ponds paddy fields, kole wetland and

rivers of all five districts. Mass emergence was observed after monsoon rains. Exuviae were seen on clinging to vegetation and usually covered with thick mud.

19 *Pantala flavescens* (Fabricius, 1798) (Plate 19, Figs.a–g)

Materials examined: 18 exuviae, *leg*. Shaun Paul Adamabukulam

Collection sites: AMD, PAL, KMG, ALP, KCY, THT, TNK, KLK & MBR.

Measurements: TBL:22; AL:13; AW:6.2; HL:4; HW:6; LL:6 5; LW:5; FFL:3.5; FTbL:4; FTaL:2.2; MFL:5; MTaL:4.5; MTbL:2; HFL:7; HTbL:6.5; HTaL:2.5; EPL:2.5; PPL:2.5; CRL:2.

Habitus: A medium to large sized exuvia with transparent colour; body has some irregular dark spots; legs are long and slender; the last segment is darkly pigmented.

Head: Broad; pentagonal in outline; compound eyes large rounded; protruding antero-laterally; covering more than half of the dorso-lateral margin of the head; filiform antennae with seven segments; first two segments are short and sturdy; third antennomere larger than other antennomeres; labium longer than width ; spoon shaped ; prementum reaching up to the base of coxae of the mid leg pair; premental setae 17+17; distal margin of prementum triangular; palpal setae 13+13; distal margin of palpus formed into large crescentric crenations.

Thorax: Narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing buds divergent; tip of the hind wing reaching the posterior half of the S4; legs long and slender; covered with minute spiniform setae along the ventral side; hind leg extends up to S5; tarsi of all three pairs darkly pigmented; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorsally; widest at S7 and S8; abdominal terga S1–S9 with markings; all segments from S2–S9 equal; mid dorsal spines absent; S10 very small; less than ¼ of anal appendages and vestigial without lateral and dorsal spines; well developed lateral spines on S8–S9; spine on S8 reaching up to the end of S9 and that on S9 up to the end of anal cerci which is distinctly shorter than paraprocts; anal appendages elongated and well developed; acuminate; broad at the base.

Breeding sites: Exuviae were observed in paddy fields of Thrissur and Palakkad districts. They emerge in large numbers after monsoon rain. Exuviae were seen on clinging to vegetation.

20. *Rhodothemis rufa* (Rambur, 1842) (Plate 20, Figs. a–e)

Materials examined: 14 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: AMD, PAL, KMG & ALP.

Measurements: TBL:16; AL:10; AW:6; HL:5; HW:3; LL:5; LW:4; FFL:3.5; FTbL:4; FTaL:1.5; MFL:4; MTbL:4.5; MTaL:2; HFL:5; HTbL:6; HTaL:2.8; EPL:1; PPL:1.2; CRL:0.8.

Habitus: Small to medium sized exuviae with semi circular abdomen and long legs.

Head: Broad; pentagonal in outline; compound eyes broad, rounded, and protruding anterolaterally; covering half of the dorsolateral margin of the head; filiform antennae with seven segments; first two segments are short and sturdy; third antennomere larger than other antennomeres; labium distally wide and spoon-shaped; longer than width; prementum reaching the upper half of the coxae of the first leg pair; premental setae 13+13; distal margin of prementum triangular; palpal setae 8+8; end hook small spine like.

Thorax: Narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing buds diverging; with the tip of the hind wing reaching the posterior half of S6; legs long and slender; hind leg extends beyond the abdomen; when pressed against abdomen hind femur extends up to the end of S7; tarsal formula:3-3-3.

Abdomen: Short and semi-circular; convex dorsally; widest at S6 and S7; all segments from S2 –S9 nearly equal; mid dorsal spines absent; S10 very small and vestigial; less than ¼ of anal appendages and without lateral and dorsal spine; lateral spine present on S9; ventrolaterally tuft of hairs present on S9; anal appendages short; epiproct triangular at the base; shorter than paraproct; paraproct acuminate.

Breeding sites: Exuviae were found in weedy ponds associated with paddy fields of Thrissur and exuviae were found to clinging on vegetation.

21. *Rhyothemis variegata* (Linnaeus, 1763) (Plate 21, Figs. a–f)

Materials examined: 12 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: TCR, PAL, KMG, ALP, AMD & TMY.

Measurements: TBL:14; AL:10; AW:5; HL:4; HW:3; LL:4; LW:3; FFL:4; FTbL:3; FTaL:1; MFL:4.5; MTbL:3.5; MTaL:1.5; HFL:6; HTbL:5.7; HTaL:3; EPL:0.3; PPL:0.2; CRL:0.1.

Habitus: A small sized exuviae with dorso-ventrally convex body covered with hairs: color varies from grey to brown.

Head: Medium sized; triangular in outline; compound eyes broad, rounded, and protruding antero-laterally; covering more than half of dorso-lateral margin of the head; filiform antennae with seven segments; first two segments short and sturdy; third antennomere larger than other antennomeres; labium spoon-shaped with distal end wide; labium longer than width; prementum reaching the upper half of the coxae of the first leg pair ; distal margin of prementum triangular; premental setae 1+1; palpal setae 5+5; end hook small spine like.

Thorax: Narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing buds are diverging ; tip of the hind wing reaching the posterior half of S5; legs long and slender; covered with minute spiniform setae; hind leg longest extends beyond the abdomen; tarsal formula: 3-3-3.

Abdomen: Short and semi-oval; convex dorsally; widest at S7and S8; all segments from S2–S9 nearly equal; mid dorsal spines present from S3–S9; S10 very small and vestigial, without lateral and dorsal spine; lateral spine present on S9; tuft of hairs present on ventrolateral position of S9; anal appendages short; epiproct and paraproct almost equal; cerci shorter than epiproct and paraproct, apex acuminate.

Breeding sites: Exuviae were collected from weedy ponds and temporary ponds associated with paddy fields of Thrissur district and exuviae were found to cling on vegetation.

22. *Tholymis tillarga* (Fabricius, 1798) (Plate 22, Figs. a–f)

Materials examined: 52 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: ERP, PLT, MMT, TKV, VYT, AMV, PAL, KMG, ALP, AMD, TMY, KCY, MBR, MLP, OLY & TNK.

Measurements: TBL:20; AL:13; AW:6.5; HL:4.2; HW:3.8; LL:4; LW:3.2: FFL:4; FTbL:4; FTaL:1.5; MFL:5.5; MTbL:4; MTaL:2; HFL:7.5; HTbL:5.5; HTaL:2.5; EPL:1.5; PPL:1.5; CRL:1.

Habitus: A medium sized exuviae with more or less oval abdomen and a dark marking on the abdomen.

Head: Large; triangular in outline; compound eyes broad, rounded, and protruding antero-laterally; covering more than half of the dorso-lateral margin of head; posterior margin of the occiput rounded at each side; filiform antennae with seven segments; first two segments are short, sturdy; third antennomere larger than other antennomeres; labium spoon-shaped with distal end wide; longer than width; prementum-postmentum articulation reaching the upper half of the coxae of the first leg pair; distal margin of the prementum triangular; premental setae 8+8; palpal setae 5+5; end hook small spine like.

Thorax; Narrower than head; more or less oval shaped; robust and well built; wing buds diverging; tip of the hind wing reaching the posterior half of the S6; legs long and slender; covered with minute spiniform setae; hind leg longest extends beyond the abdomen; when pressed against abdomen the hind femur extends up to end of S6; tarsal formula: 3-3-3.

Abdomen: Oval; biconvex dorsoventrally; widest at S6 and S7; all segments from S2–S9 are nearly equal; mid dorsal spines present from S4–S10; spines on S4–S5 small almost vertical; on S7–S9 strong, triangular and directed backwards; S10 smallest with a small median spine; lateral spines present on S8–S9; spine on S9 reaching up to the end of S10; anal appendages elongated with paraproct and epiproct equal in length; acuminate; cerci slightly shorter.

Breeding sites: Exuviae were found in natural and man made ponds, cemented pools, natural streams, irrigation canals, temporary ponds in paddy fields, kole wetland and rivers. Exuviae were found to cling on vegetation.

23 *Tramea basilaris* (Palisot de Beauvois, 1817) (Plate 23, Figs. a–f)

Materials examined: 16 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: TCR, CTR, THT, TNK, MLP, OLY & KLK.

Measurements: TBL:26; AL:16; AW:8.2; HL:6.5; HW:7.5; LL:8.8; LW:6.5; FFL:6; FTbL:5; FTaL:2.7; MFL:7; MTbL:6.5; MTaL:3; HFL:10; HTbL:9; HTaL:3.5; EPL:2; PPL:2; CRL:1.6.

Habitus: A fairly large transparent exuviae with well-built body with long legs and well developed lateral spines.

Head: Large; triangular in outline; compound eyes broad, rounded, and protruding anterolaterally; covering more than half of the dorsolateral margin of the head; filiform antennae with seven segments; first two segments short and sturdy; third antennomere larger than other antennomeres; labium enlarged spoon-shaped with distal end wide; longer than width; prementum reaching the upper half of the coxae of the third leg pair; distal margin of prementum triangular; premental setae 13+13; palpal setae 10+10; distal margin of the palpus crenulated; each crenation bears spiniform setae; movable hook small spine like.

Thorax: Narrower than the head; robust and well built; wing buds diverging; tip of the hind wing reaching the midpoint of the S6; legs very long and slender; covered with minute spiniform setae; hind leg longest and extends beyond the abdomen; when pressed against the abdomen, the hind femur extends up to the end of S7; tarsal formula:3-3-3.

Abdomen: Cylindrical; biconvex dorso ventrally; widest at S6 and S7; all segments from S2–S9 nearly equal; S10 small and vestigial; mid dorsal spine absent; well developed lateral spines beset with black setae present on S8–S9; spine on S8 reaching up to middle of S9; spine on S9 reaching up to end of anal appendage; anal appendages elongated; beset with setae; epiproct triangular at the base; paraproct and epiproct equal in length; acuminate; cerci slightly shorter than epiproct and paraproct.

Breeding sites: In the present study exuviae were found in weedy ponds of Palakkad district and from a man-made cement pool in a park from Thrissur and exuviae were found to clinging to vegetation or attached to the wall of the tank.

24. *Trithemis aurora* (Burmeister, 1839) (Plate 24, Figs.a–f)

Materials examined: 12 exuviae, *leg.* Shaun Paul Adambukualm

Collection sites: AMD, ALP, KMG, MRT, KCY, MBR, OLY, TKV, VYT, TKV, PKM, KUR, MMT, PKD, KGR, CRP, MUK, MLM, SKP & ERP

Measurements: TBL:14; AL:9; AW:6; HL:3; HW:4; LL:4; LW:3; FFL:3; FTbL:2.7; FTaL:1.2; MFL:3.5; MTbL:3.1; MTaL:2.; HFL:4; HTbL:4.5; HTaL:2.5; EPL:1; PPL:1.5; CRL:0.5.

Habitus: A small sized exuviae with light grey to brown with hook like mid dorsal spines.

Head: Medium sized; triangular in outline; compound eyes are broad, rounded, and protruding anterolaterally; covering more than half of the dorso-lateral margin of the head; filiform antennae with seven segments; the first two segments are short and sturdy; the third antennomere larger than other antennomeres; the labium longer than the width and spoon-shaped with the distal end wide; the prementum reaching the upper half of the coxae of the first leg pair; the distal margin of prementum triangular; premental setae 10+10; palpal setae 7+7; the distal margin of the palpus bear spiniform setae; end hook small spine like.

Thorax: Narrower than head; robust and well built; pronotum broadly rounded, not projecting laterally; wing buds are diverging, with the tip of the hind wing reaching the posterior half of the S6; legs long and slender; incomplete dark brown bands on the femurs of all three pairs of legs; covered with minute spiniform setae; hind leg longest and extends beyond the abdomen; when pressed against the abdomen the hind femur extends up to the end of S4; tarsal formula: 3-3-3.

Abdomen: Oval; convex dorsally; widest at S6 and S7; all segments from S2–S9 nearly equal; hook like mid dorsal spines present from S3–S9; on S3–S5 small and almost vertical; on S6–S8 strong, triangular and directed backwards; on S9 again small; S10 very small and vestigial, without lateral and dorsal spine; lateral spines present on S8–S9; tuft of hairs present on ventro lateral position of S9; anal appendages short; epiproct and paraproct almost equal; cerci shorter than epiproct and paraproct, apex acuminate, epiproct triangular at the base; paraproct acuminate.

Breeding sites: In the present study exuviae were found in weedy ponds, temporary pond associated with paddy field, natural streams and also from a man made cement pool in a park in Thrissur. Exuviae were found to cling on vegetation or attached to the wall of the tanks.

25. *Trithemis festiva* (Rambur, 1842) (Plate 25, Figs. a–f)

Materials examined: 16 exuviae, *leg.* Shaun Paul Adambukualm

Collection sites: AMD, ALP, KMG, MRT, KCY, MBR, OLY, TKV, VYT, TKV, PKM, KUR, MMT, PKD, KGR, CRP, MUK, MLM, SKP & ERP.

Measurements: TBL:15.5; AL:9; AW:6; HL:3; HW:4; LL:4; LW:3; FFL:3; FTbL:2.7; FTaL:1.2; MFL:3.5; MTbL:3.1; MTaL:2; HFL:4; HTbL:4.5; HTaL:2.5; EPL:1.5; PPL:1.5; CRL: 0.5.

Habitus: A small sized exuviae with light grey to brown color with mid dorsal spines

Head: Medium sized; triangular in outline; compound eyes broad, rounded, and protruding antero-laterally; covering more than half of the dorsolateral margin of the head; posterior margin of the occiput rounded at each side; filiform antennae with seven segments; the first two segments short and sturdy; the antennomere larger than other antennomeres; the labium longer than the width, spoon-shaped with the distal end wide; prementum reaching upper half of the coxae of the first leg pair; distal margin of prementum triangular; premental setae 11+11; palpal setae 6+6; the distal margin of the palpus bear spiniform setae; end hook small spine like.

Thorax: Narrower than the head; robust and well built; pronotum broadly rounded, not projecting laterally; the wing buds are diverging; tip of the hind wing reaching posterior half of the S6; the legs long and slender; incomplete dark brown bands on femurs of all three pairs of legs; minute spiniform setae present; hind leg extends beyond the abdomen; when pressed against the abdomen the hind femur extends up to the end of S4; tarsal formula: 3-3-3.

Abdomen: Oval; convex dorsally; widest at S6 and S7; all segments from S2–S9 nearly equal; mid dorsal spines present from S3–S9; on S3–S5 small almost vertical; on S6–S8 strong, triangular and directed backwards; on S9 again small; S10 very small and vestigial, without lateral and dorsal spine; lateral spine present on S8–S9;

tuft of hairs present on ventro laterally position of S9; anal appendages short; epiproct and paraproct almost equal; cerci shorter than epiproct and paraproct, apex acuminate.

Breeding sites: In the present study exuviae were found in weedy ponds, temporary pond associated with paddy field, natural streams and also from a man made cement pool in a park in Thrissur. Exuviae were found to cling on vegetation or attached to the wall of the tanks.

26. *Urothemis signata* (Rambur, 1842) (Plate 26, Figs. a–f)

Materials examined: 28 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: TCR, AMD, ALP, KMG & PAL.

Measurements: TBL:20; AL:11; AW:4.5; HL:4; HW:3; LL:4.5; LW:3; FFL:3; FTbL:2.8; FTaL:1.5; MFL:4; MTbL:3; MTaL:1.5; HFL:5; HTbL:4; HTaL:2; EPL:1.2; PPL:2.0; CRL:0.5.

Habitus: A medium sized exuviae with dark brown color; abdomen sub oval shaped without body hairs.

Head: Medium sized; pentagonal in outline; compound eyes medium sized, rounded and protruding antero-laterally; filiform antennae with seven segments; labium distally wide and spoon-shaped; longer than the width; prementum reaching up to the base of the third leg pair; premental setae 12+12; the distal margin of the prementum triangular; small crenations present along the margin; palpal setae 10+10; the distal margin of palpus crenated; movable hook sharp pointed.

Thorax: Prothorax narrower than the head; wing sheaths diverging and extends up to the anterior margin of S6; the legs long and slender; dark brown bands on the femurs of all three pairs of legs; the hind leg extends beyond the abdomen; tibiae of fore and mid leg bears hair like setae along the posterior margin; tarsal formula: 3-3-3.

Abdomen: Cylindrical; convex dorsoventrally; all segments with same size except S1 and S10; maximum width on S6; mid dorsal protuberances present on S4–S8; lateral spines absent from S1–S7; small lateral spines present on S8–S9; S10 smallest segment without mid dorsal and lateral spine; anal appendages short triangular at their base; epiproct and cerci have equal length; acuminate; paraproct slightly longer than epiproct; apex acuminate.

Breeding sites: The exuviae were found in a man-made garden cement pool in Thrissur. Exuviae were usually found on clinging on the wall of the tank.

27. *Zygonyx iris* (Selys, 1869) (Plate 27, Figs. a–f)

Materials examined: 12 exuviae, *leg.* Shaun Paul Adambukualm

Collection sites: PKM, KUR & TKV.

Measurements: TBL:24; AL:15; AW:7.8; HL:5; HW:6; LL:4; LW:3; FFL:5; FTbL:6; FTaL:3; MFL:6; MTbL:7; MTaL:3: HFL:7; HTbL:7; HTaL:3; EPL:1; PPL:1; CRL:0.5.

Habitus: A well-built large sized black colored exuviae with no hairs on the body and well developed lateral spines.

Head: Medium sized; triangular in outline; compound eyes broad, rounded, and protruding antero-laterally; covering more than half of the dorsolateral margin of the head; filiform antennae with seven segments; the first two segments short and sturdy; the third antenomere larger than other antennomeres; the labium longer than the width, spoon-shaped with distal end wide; prementum-postmentum articulation reaching the upper half of coxae of the first leg pair; the distal margin of the prementum triangular; premental setae 12+12; palpal setae 9+9; the distal margin of the palpus bears spiniform setae; end hook small spine like.

Thorax: Narrower than the head; robust and well built; pronotum broadly rounded, not projecting laterally; the wing buds diverging with tip of the hind wing reaching the posterior half of S6; legs long and robust; femurs of all legs flattened ;femur of hind leg extends to S7; tarsal formula: 3-3-3.

Abdomen: Convex dorso-ventrally; widest at S6 and S7; all segments from S2–S9 nearly equal; mid dorsal spines present from S1–S10; spine on S1 sharp and directed vertically upwards; spines on S2–S9 with blunt ends directing backwards; S10 very small and vestigial with small dorsal spine; outwardly directing lateral spines present on S8–S9; anal appendages short; epiproct and paraproct almost equal; cerci shorter than epiproct and paraproct, apex acuminate.

Breeding sites: Breeds in rivers near to forest areas. Exuviae were collected from the river Kabani at Kuruva Island and Pakkom in Wayanad district. Exuviae were found on exposed rocks.

28. *Zyxomma petiolatum* Rambur, 1842 (Plate 28, Figs. a–f)

Materials examined: 26 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: TCR, ATP, AMD, PAL, KMG, ALP, VYT, PKD & MLP.

Measurements: TBL:19; AL:12.5; AW:6.2; HL:4; HW:5; LL:4; LW:3; FFL:4; FTbL:3.5; FTaL:1.2; MFL:5; MTbL:4.5; MTaL:1.5; HFL:6; HTbL:5.5; HTaL:2; EPL1; PPL:1.2; CRL:0.5.

Habitus: A medium sized grey to black colored exuviae without hairs on the body surface; with well-developed lateral spines and no mid dorsal spines.

Head: Broad; pentagonal in outline; compound eyes medium sized, rounded, and protruding anterolaterally; filiform antennae with seven segments; first two segments short and cylindrical; the third antennomere larger than other antennomeres; the labium longer than the width, spoon-shaped reaching the upper half of the coxae of the first leg pair; the lateral margin smooth; premental setae 13+13; palpal setae 8+8; few spiniform setae present along the base; distal margin crenated; end hook small spine like.

Thorax: Narrower than the head; robust and well built; the wing buds divergent to abdomen; tip of the hind wing reaching the posterior line of S5; legs long and slender; hind leg longest; when pressed against the abdomen, the hind leg femur reaching up to the posterior end of S6; tarsal formula:3-3-3.

Abdomen: Cylindrical; convex dorsally; flattened ventrally; abdominal terga with small spine along the posterior margin; S2–S8 nearly equal in size; widest at S7 and S8; mid-dorsal spines present from S4–S10, spines on S4–S5small; and on S6–S9 prominent, sharp, and pointed; again on S10 very small; lateral spines on S8–S9; spine on S9 longest, reaching up to the length of epiproct; anal appendages short and pyramid like; cerci shorter than the epiproct and paraproct, epiproct shorter than the paraproct; apex acuminate.

Breeding sites: In the present study exuviae were found in weedy ponds, temporary pond associated with paddy field, natural streams man made cement pool in a park in Thrissur and also from man-made cement pool located near the Pookode Lake at Wayanad. Exuviae were found to cling on vegetation or attached to the wall of the tanks.

IV. Family Macromiidae

29. *Macromia flavocolorata* Fraser, 1922 (Plate 29, Figs. a–g)

Materials examined: 10 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: TKV, PKM & KUR.

Measurements: TBL:20; AL:12; AW:6; HL:5; HW:6; LL:5; LW:4; FFL:8; FTbL:7; FTaL:3; MFL:10; MTbL:9 ; MTaL:3.5; HFL:12; HTbL:11; HTaL:4; EPL:0.5; PPL:0.5; CRL:0.2.

Habitus: A fairly large exuviae with very long legs giving a spidery appearance; body covered with mud; labium is large cup shaped and covering the most part of the head. Abdomen oval shaped with curved mid dorsal spines.

Head: Wide; triangular in outline; compound eyes medium sized, triangular, and protruding dorsally; setaceous antennae with seven segments; the first two segments short and cylindrical; the third antennomere larger than other antennomeres; the post ocular lobes narrow with nipple shaped projections on the posterolateral sides; frons strongly up curved and finger like; labium exceptionally large and cover the major part of the head and typically spoon-shaped ; the lateral margin smooth; premental setae 7+7; distal margin slightly concave; palpal lobes with 6 U shaped indentations; palpal setae 5+5; end hook sharp and pointed.

Thorax: Prothorax as wide as head; robust and well built; wing buds divergent to the abdomen; the tip of the hind wing reaching posterior line of S6; legs very long and spidery; the hind leg when pressed against abdomen, the femur reaching up to the posterior end of S9; tarsal formula:3-3-3.

Abdomen: Roof like; S2–S8 nearly equal in size; widest at S7 and S8; mid-dorsal spines present from S3–S9, spines on S4–S5 small; and on S6–S9 prominent, sharp

and pointed; again on S10 very small; posterolateral spines on S8–S9, anal appendages short and pyramid like; cerci shorter than epiproct and paraproct, apex acuminate, epiproct acuminate, shorter than paraproct.

Breeding site: Exuviae were found in riverine habitat of Kabani (Wayanad).They were found to cling on vegetation and also from the surface of rocks.

30. *Macromia indica* Fraser, 1924 (Plate 30, Figs. a–g)

Materials examined: 12 exuviae, *leg.* Shaun Paul Adambukulam

Collection sites: TKV, PKM & KUR.

Measurements: TBL:18; AL:13; AW:8; HL:5; HW:6; LL:5; LW:5; FFL;7; FTbL:6; FTaL:2; MFL:9; MTbL:7; MTaL:3; HFL:11; HTbL:8; HTaL:4; EPL:0.3; PPL:0.3; CRL: 0.1.

Habitus: A medium sized exuviae with elongated leg giving spidery appearance; brown to muddy color. Abdomen oval shaped with sharply pointed mid dorsal spines.

Head: Triangular in outline; compound eyes small sized, rounded, and protruding dorsally; setaceous antennae with seven segments; first two segments short and cylindrical; the third antennomere larger than other antennomeres; postoccular lobes narrow with nipple shaped projections on posterolateral sides; the frons strongly up curved and finger like; the labium typically spoon-shaped; the lateral margin smooth; premental setae 8+8; distal margin triangular; palpal lobes with 6 U/V shaped indentations; paplal setae 6+6; few spiniform setae present along the base; the distal margin crenulated; end hook sharply pointed.

Thorax: Prothorax as wide as head; robust and well built; the wing buds divergent to the abdomen; with tip of the hind wing reaching posterior line of S6; legs very long and spidery; hind leg when pressed against abdomen, femur reaching up to the posterior end of S9; tarsal formula:3-3-3.

Abdomen: Roof like; S2–S8 nearly equal in size; widest at S7 and S8; mid-dorsal spines present from S3–S9, spines on S4–S5 small; and on S6–S9 prominent, sharp and pointed; again on S10 very small; postero-lateral spines on S8–S9, anal appendages short and pyramid like; cerci shorter than epiproct and paraproct, apex acuminate, epiproct shorter than paraproct.

Breeding site: Exuviae were found in riverine habitat of Kabani (Wayanad).They were found to cling on vegetation and also from the surface of rocks.

4.3 Taxonomic Key

Taxonomic keys are tools for the identification of organisms by using their distinct features and placing them in taxonomic hierarchy. The contrasting or contradictory statements or propositions aids the identifier to make the assessment and decisions based on statements in the key as related to the material to be identified (Narendran, 2006). Different types of keys are prevalent. The most commonly used keys are dichotomous keys. A dichotomous key is formed as a series of couplets, each couplets having two opposing features of an organisms (Miller & Levine, 2008). User can select the features that best fits the unidentified specimen and thus leads to another couplet.

A preliminary taxonomic key for the nymphs of thirty species of dragonflies, in this study was prepared by using their exuvia. The morphological features used for the family level identification of exuviae were summarised in the Table 7.

Table 7: Taxonomic features on exuviae for family level identification

SL.NO	Taxonomic features	Family			
		Aeshnidae	Gomphidae	Libellulidae	Macromiidae
1.	Habitus	Large sized; with or without body markings or stripes	Medium to large sized	Small to medium sized with body markings	Medium sized
2.	Color	Transparent to dark brown	Light brown to greyish black	Transparent to light brown to muddy brown	Muddy brown to greyish black
3.	Total body length in mm	30–60	18–48	12–26	22–28
4.	Head shape	Triangular	Pentagonal	Triangular/Pentagonal	Pentagonal;
5.	Compound eyes	Round, large and covers more than ½ of head	Round, medium sized and covers ½ of head	Round, medium to large sized ½ of head	Triangular; medium sized; covers ¼ of head
6.	Antenna	Filiform; 7 segmented; third segment larger than other	4 segmented; third segment broad at distal end; fourth segment reduced or vestigial	Filiform; 7 segmented; third segment larger than other	Setose; 7 segmented;
7.	Labium shape	Pear shaped; hinge joint extends to coxae of second or third leg pair.	Sub-quadrangular/sub-rectangular hinge joint extends to coxae of first or second leg pair.	Spoon-shaped; covers the ½ of head.	Large cup-shaped; covers the ¾ of head.
8.	Shape of distal margin of prementum	Convex with a median cleft	Convex shaped with palisade setae	Triangular shaped with small spiniform setae.	Flat with small setae.
9.	Premental setae	Completely absent	Completely absent	Present; number varies from 1–20	Present; number ranges between 8–12
10.	Shape of palp	Finger shaped with sharply pointed end hook	Finger shaped with sharply pointed end or blunt end	Flap like	Flap like
11.	Crenations at	Absent	Absent	Present in some species;	U /V shaped crenation

	the distal end of palp			triangular in shape	
12.	End hook	Large, sharply pointed; inner margin bears small spines	Small, sharply curved/ kukri shaped end hook	Sharply pointed spine like	Sharply pointed spine like
13.	Movable hook	Elongated;sharply pointed;inner margin with small spiniform setae	Elongated; curved at the distal end and sharply pointed	Sharply pointed spine like	Sharply pointed spine like
14.	Palpal setae	Present in some members of the genus *Gynacantha*	Completely absent	Present; number varies from 6–16	Present number ranges between 6–8
15.	Palpal teeth	Absent	Present; shape and number varies intra specifically	Absent	Absent
16.	Legs	Long and slender, Normal	Normal legs	Normal legs	Very long spider like
17.	Abdomen	Cylindrical	Dorso-ventrally flattened / round / oval shaped	Round /oval /sub oval shaped	Oval or round shaped
18.	Mid dorsal spines	Absent	Present; with sharply pointed or blunt end.	Present; with sharply pointed and curved.	Present ; sharply pointed and curved
19.	Lateral spines	Present from S6/S7-S9	Present;S3/S4/S6–S9	Present; S8–S9	Present ; S8–S9
20.	Anal appendage	Well developed; emarginated	Reduced or vestigial	Well-developed or Reduced	Reduced or vestigial

4.3.1 Keys to the exuviae of the suborders of Odonata

1. Slender exuviae; head wider than thorax and abdomen; abdomen terminating in three long caudal leaf or sac like gills……..**Zygoptera**

1'. Stout and well-built exuviae; head usually narrower than thorax and abdomen; abdomen terminating in five sharp pointed appendages……. ...**Anisoptera**

4.3.2 Keys to the exuviae of the families of Anisoptera

1. Antennae 4 segmented; 3rd antennomere broader than other three; 4th antennomere knob like or vestigial……**Gomphidae**

1'. Antennae 7 segmented; filiform; no structural difference in the 3rd and 4th antennomeres……**2**

2. Labium pear shaped with a median cleft in the distal margin**;** postmentum–prementum articulation extends up to the base of meso or meta coxae; no premental setae; cylindrical body; anal appendages elongated...……**Aeshnidae**

2'. Labium spoon or cup shaped without a median cleft in the distal margin; post mentum–prementum articulation extends up to the base of precoxae or mesocoxae; premental and palpal setae present; oval or sub oval body; anal appendages are short ……..……**3**

3. Legs very long giving a spidery appearance to exuviae; eyes protruding dorsally; frontal shelf with horn like tubercles present between the antennal bases; antennae setose…….**Macromiidae**

3'. Legs not very long; eyes protruding dorso-laterally; frontal shelf without horn like tubercles……...**Libellulidae**

4.3.3 Keys to the exuviae of the genera of family Gomphidae

1. Abdomen ends in siphon……**Macrogomphus**

1'. Abdomen without siphon…….....**2**

2. Well-built exuviae; kukri shaped palpus with 8 teeths…….....**Megalogomphus**

2'.Small exuvia; finger shaped palpus with 9–11teeths…….....**Microgomphus**

3. Abdomen cylindrical tapering towards the end……....**4**

3'. Round or lamellate roof like abdomen……..……**Ictinogomphus**

4. Fourth antennomere elongated; …..……..…….……..**Paragomphus**

4'. Fourth antennomere knob like……**Onychogomphus**

5. Lateral spines on S7–S9; tip of the palpus curved like a hook…..**Burmagomphus**

4.3.4 Keys to the exuviae of the species of family Gomphidae

1. Slender elongated exuviae; body length 46–49mm; labial palp with 5 incurved teeth; S9 with a prominent spine and elongated to a siphon ……....***Macrogomphus annulatus***

1'.Abdomen without a siphon……**2**

2. Well-built large exuviae; body length 40–42 mm; labial palp kukri shaped with eight incurved teeth; well-developed dorsal spines from S1-S9……..***Megalogomphus superbus***

2'.Small exuviae; body length 17-19mm; labial palp finger shaped with 9–11 teeth; dorsal spines are reduced or vestigial…….....***Microgomphus souteri***

3. Abdomen wider than head and thorax; roof like; round or lamellate; anal appendages reduced …….……***Ictinogomphus rapax***

3'.Abdomen narrower than head and thorax; dorso-ventrally flattened or cylindrical; anal appendages well developed……**4**

4. Dorso ventrally flattened abdomen; labial palp sharp pointed and end in curved hook……**5**

4'.Cylindrical abdomen; labial palp finger like and with blunt end……**6**

5. Well-developed sharply pointed mid dorsal spines on S7–S9……***Burmagomphus laidlawi***

5'.Dorsal spines on S2–S8 with blunt ends……***Burmagomphus pyramidalis***

6. Lateral spines on S6–S9; fourth antennomere is knob shaped; well -developed dorsal spines with blunt end present on S2–S9; palpus with 12 quadrate teeth.....***Onychogomphus malabarensis***

6'. Lateral spines on S2–S9; fourth antennomere elongated and bent outwards; sharply pointed dorsal spines on S2–S9; palpus without teeth……..***Paragomphus lineatus***

4.3.5 Keys to the exuviae of the genera of family Aeshnidae

1. Large transparent exuviae; labium without premental and palpal setae ……**Anax**

1'. Dark brown colored exuviae; labium with palpal setae…….....**Gynacantha**

4.3.6 Keys to the exuviae of the species of family Aeshnidae

1. Body length ranges 52–55mm; large transparent exuviae without any stripes on dorsal surface; labium without palpal setae; lateral spines on S7–S9 …***Anax indicus***

.**1'.** Body length ranges 30–33mm; brownish grey exuviae with a pair of median dorsal stripe on the dorsal surface; labium with palpal setae 3+3; lateral spines on S6–S9……***Gynacantha dravida***

4.3.7 Keys to the exuviae of the genera of family Macromiidae

1. Exuviae with very long legs; frontal shelf bear horns; large labium covers the entire head except eyes; labial palp with V or U shaped crenations; well-developed mid dorsal spines on S3–S8…….**Macromia**

4.3.8 Keys to the Exuviae of the species of Family Macromiidae

1. Eyes triangular protruding dorso-laterally; premental setae 7+7; palpal setae 5+5…….***Macromia flavocolorata***

1'. Eyes rounded protruding dorso-laterally; premental setae 8+8; palpal setae 6+6……***Macromia indica***

4.3.9 Keys to the exuviae of the genera of family Libellulidae

1. Abdomen oval or egg shaped; anal appendages reduced…….**2**

1'. Abdomen bi convex; anal appendages well developed …….**5**

2. Cerci 2/3 of paraproct…….……**Acisoma**

2'.Cerci ½ of paraproct…….....**Diplacodes**

3. Lateral spine on S9 inwardly curving towards S10…….....**Rhyothemis**

3' Lateral spine on S9 parallel to S10…… ……**Neurothemis**

4. Mid-dorsal spines as small ridges on S3–S8…….**Lathrecista**

4'. Mid-dorsal spines are absent…….**Rhodothemis**

5. Abdomen with well-developed mid-dorsal spines …….....**6**

5'. Abdomen without mid -dorsal spines……...**12**

6. Mid-dorsal spines on S1/S4–S10……**7**

6'. Mid-dorsal spines on S3–S9……..**9**

7. Lateral spines on S8–S9 outwardly projecting from abdomen……...**Zygonyx**

7'. Lateral spines on S8–S9 parallel to abdomen ……..**8**

8. Lateral spine on S9 short reaching up to the 1/2 of S10……**Tholymis**

8'. Lateral spine on S9 elongated reaching up to the 1/2 of epiproct……**Zyxomma**

9. Cerci 1/3 of epiproct……..**10**

9'. Cerci 1/2 of epiproct……..**Trithemis**

10. Lateral spine on S8 well developed; reaching beyond the mid of epiproct……**Hydrobasileus**

10'. Lateral spines on S8 not well developed; reaching 1/3 of S9…….**Brachythemis**

11. S9–S10 bears tuft of hairs ventrally.……**Orthetrum**

11'. No tuft of hairs ventrally……..**Urothemis**

12. Labial palp with well-developed crenations……..**Pantala**

12'. Labial palp without crenations…….....**Tramea**

13. Lateral spine on S9 extends up to the end of S10...…….....**Bradinopyga**

4.3.10 Keys to the exuviae of the species of family Libellulidae

1. Abdomen oval or egg shaped; anal appendages reduced……**2**

1'. Abdomen bi convex; anal appendages well developed …….**5**

2. Cerci 2/3 of paraproct; premental setae11+11; palpal setae 8+8; body length ranges between 10–12mm ……***Acisoma panorpoides***

2'. Cerci 1/2 of paraproct; premental setae 14+14; palpal setae 10+10……...***Diplacodes trivialis***

3. Lateral spine on S9 inwardly curving towards S10; mid dorsal spines present on S3–S9; premental setae 1+1; palpal setae 5+5; hind legs 1.5 times as long as abdomen ……..***Rhyothemis variegata***

3'. Lateral spine on S9 parallel to S10; premental setae 13+13; palpal setae 8+8; mid dorsal spines on S3–S8; hind legs as long as abdomen….....***Neurothemis tullia***

4. Mid-dorsal spines on S3–S8 present as small ridges; premental setae 14+14; palpal setae11+11; …….……***Lathrecista asiatica***

4'. Mid-dorsal spines are absent; premental setae 13+13; palpal setae 8+8……..***Rhodothemis rufa***

5. Abdomen with well-developed mid dorsal spines …….....**6**

5'. Abdomen without mid-dorsal spines……**13**

6. Mid-dorsal spines on S1/S4–S10……**7**

6'. Mid-dorsal spines on S3–S9……..**9**

7. Mid-dorsal spines on S1–S10 with blunt ends; lateral spines on S8–S9 outwardly projecting from abdomen; femora of all legs flattened; premental setae 12+12;palpal setae 9+9……...***Zygonyx iris***

7'. Mid-dorsal spines on S4–S10 with sharp pointed ends; lateral spines on S8–S9 parallel to abdomen ……..**8**

8. Lateral spine on S9 short reaching up to the 1/2of S10; premental setae 8+8;palpal setae 5+5……..***Tholymis tillarga***

8'. Lateral spine on S9 elongated reaching up to the 1/2 of epiproct; premental setae 13+13; palpal setae 8+8…….***Zyxomma petiolatum***

9. Cerci 1/3 of epiproct……**10**

9'. Cerci 1/2 of epiproct……**11**

10. Mid-dorsal spines on S7–S9 hook like; premental setae 10+10; palpal setae 7+7; body length ranges between 12–14mm…….…….....***Trithemis aurora***

10'. Mid-dorsal spines on S7–S9 spine like; premental setae 11+11; palpal setae 6+6; body length ranges between 13–15mm……..***Trithemis festiva***

11. Large exuvia; lateral spines on S8–S9 well developed; spine on S8 extends up to the midpoint of epiproct; spine on S9 extends up to the end of anal appendage; premental setae 12+12; palpal setae 9+9……..***Hydrobasileus croceus***

11'. Medium sized exuvia; lateral spines on S8–S9 not well developed; spine on S8 extends up to S9; spine on S9 extends up to the end of S10; premental setae 12+12; palpal setae 9+9…….***Brachythemis contaminata***

12. Lateral spines on S8–S9 very small and reduced; premental setae11+11; palpal setae 7+7; ventral side of the abdomen bears a tuft of hairs……***Orthetrum sabina***

12'. Brown colored exuviae**;** body length 20mm; premental setae 12+12; palpal setae 10+10;tuft of hairs absent ……..***Urothemis signata***

13. Premental setae 17+17; palpal setae 13+13; labial palps with well-developed crenations along distal margin; mid and hind tarsi with black markings; lateral spines

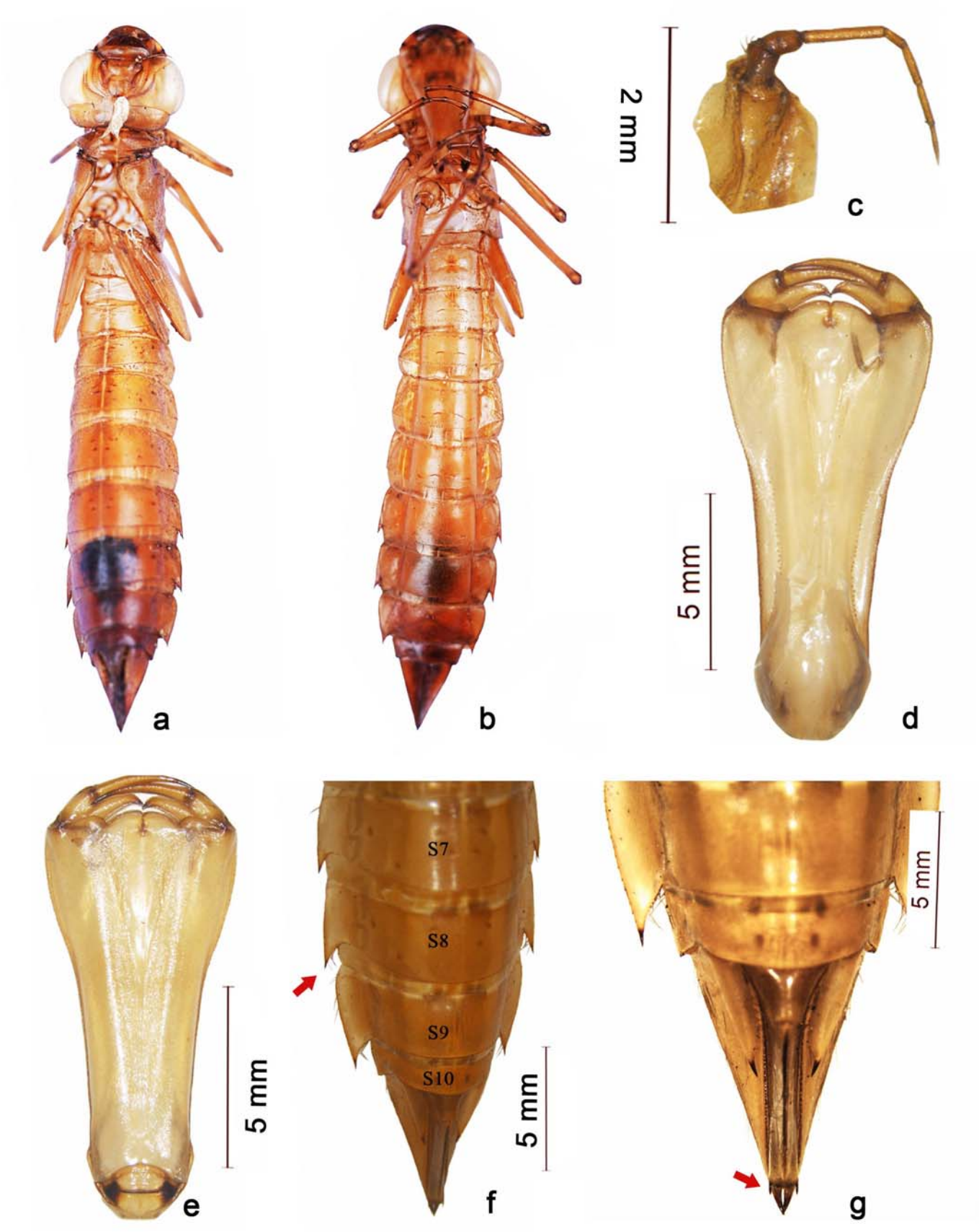
on S8–S9 well-developed without black colored setae laterally……***Pantala flavescens***

13'. Premental setae 13+13; palpal setae 10+10; labial palp without crenations; no black markings on mid and hind tarsi; lateral spines on S8–S9 well developed with black colored setae laterally……***Tramea basilaris***

14. Transparent exuviae; premental setae 19+19; palpal setae 16+16; lateral spines on S8–S9 with black tips; spine on S9 extends up to the end of S10….***Bradinopyga geminata***

PLATE 1

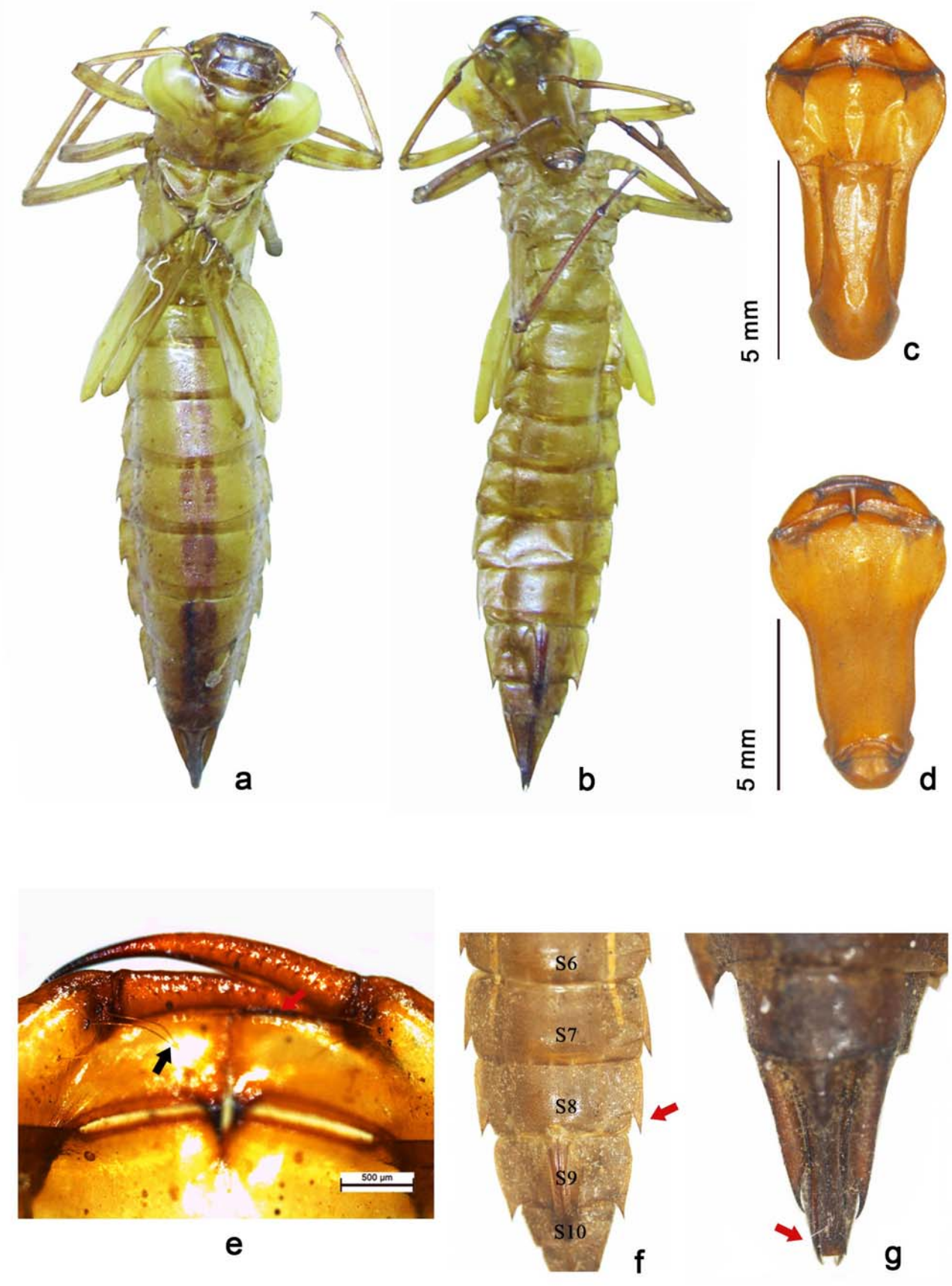
Anax indicus Lieftinck, 1942



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal lateral spines, g. Anal appendages.

PLATE 2

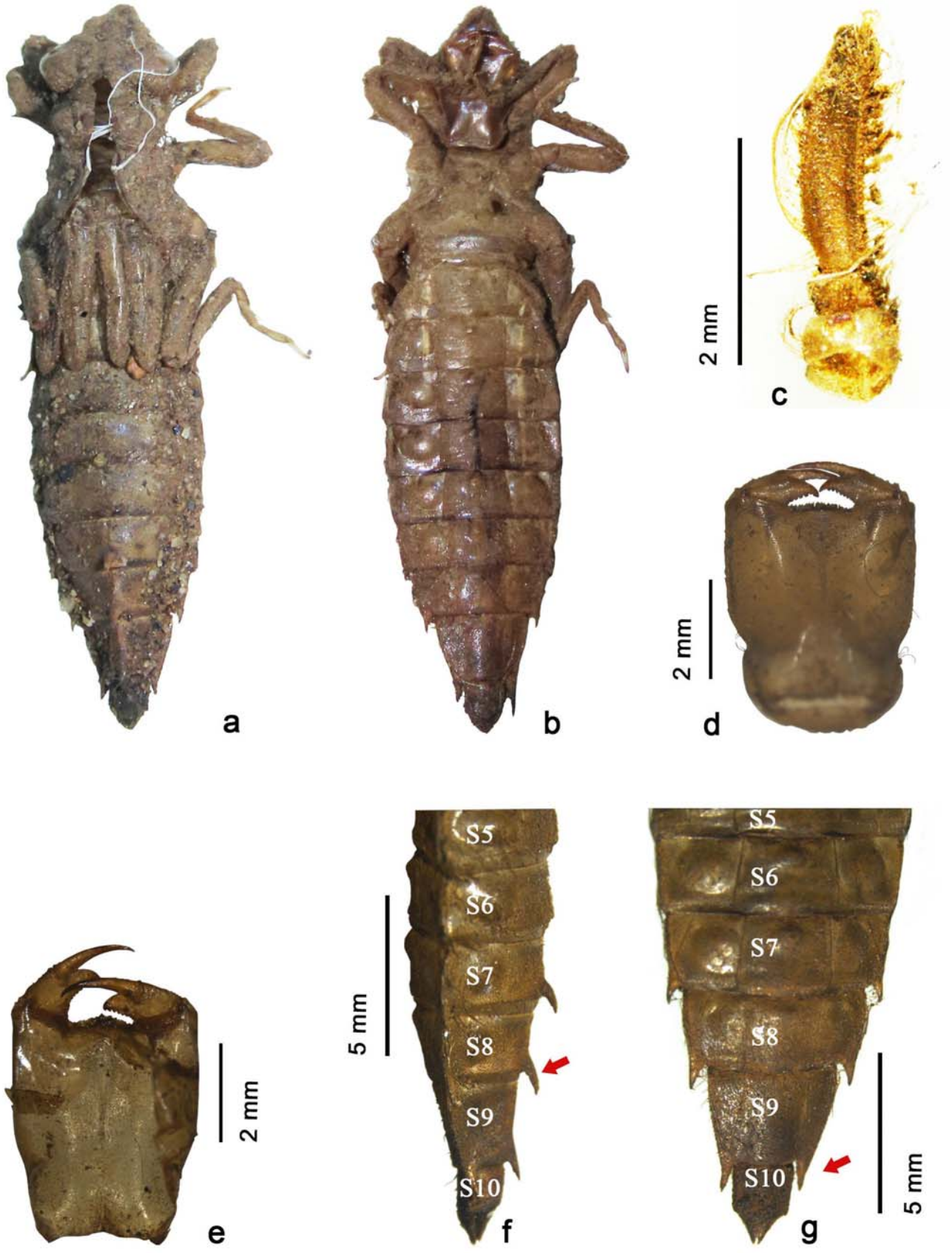
Gynacantha dravida (Lieftinck, 1960)



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Palpal setae, f. Abdominal lateral spines, g. Anal appendages.

PLATE 3

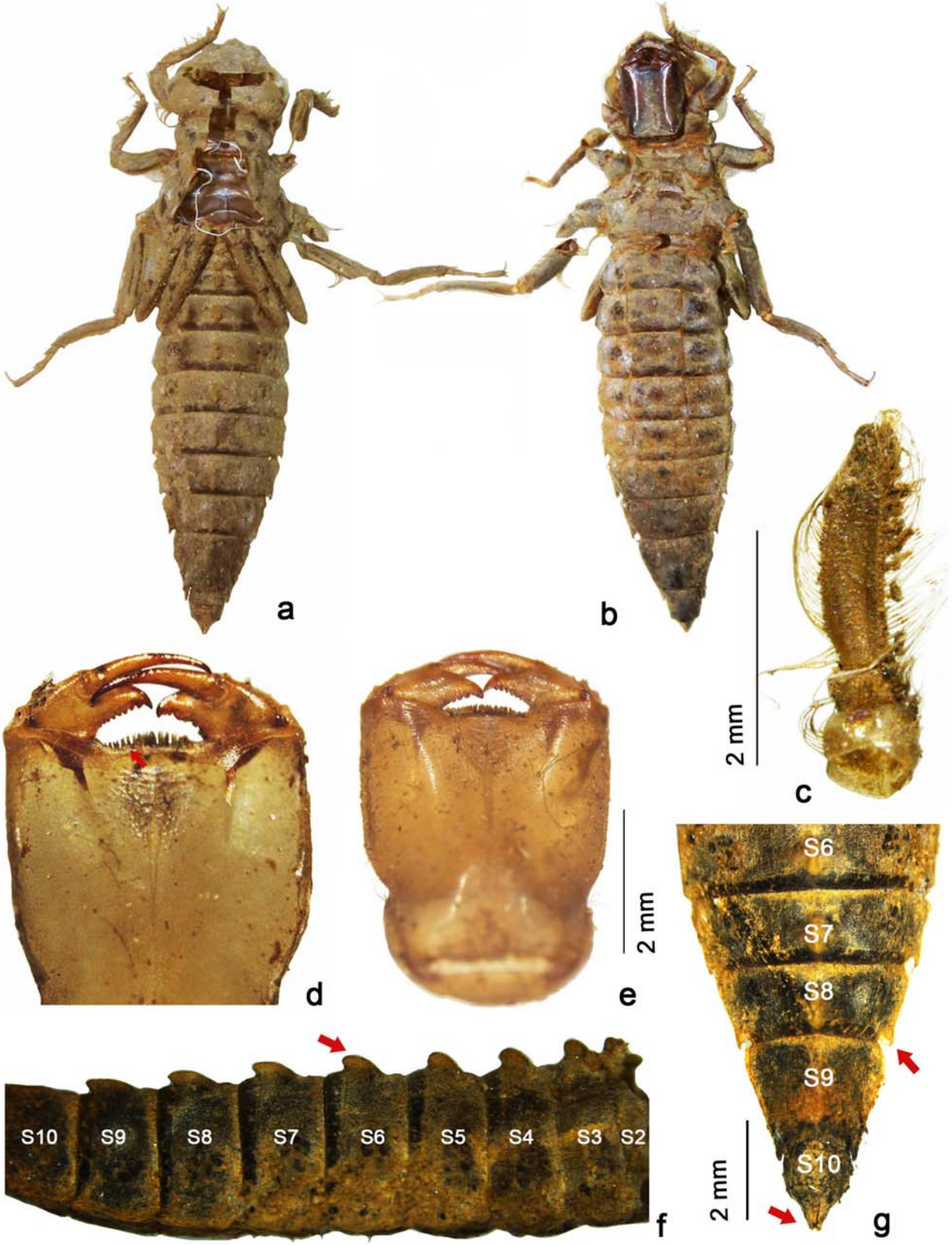
Burmagomphus laidlawi Fraser, 1924



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium ventral view, e. Labium dorsal view, f. Abdominal mid dorsal spines, g. Abdomen with lateral spines and anal appendages.

PLATE 4

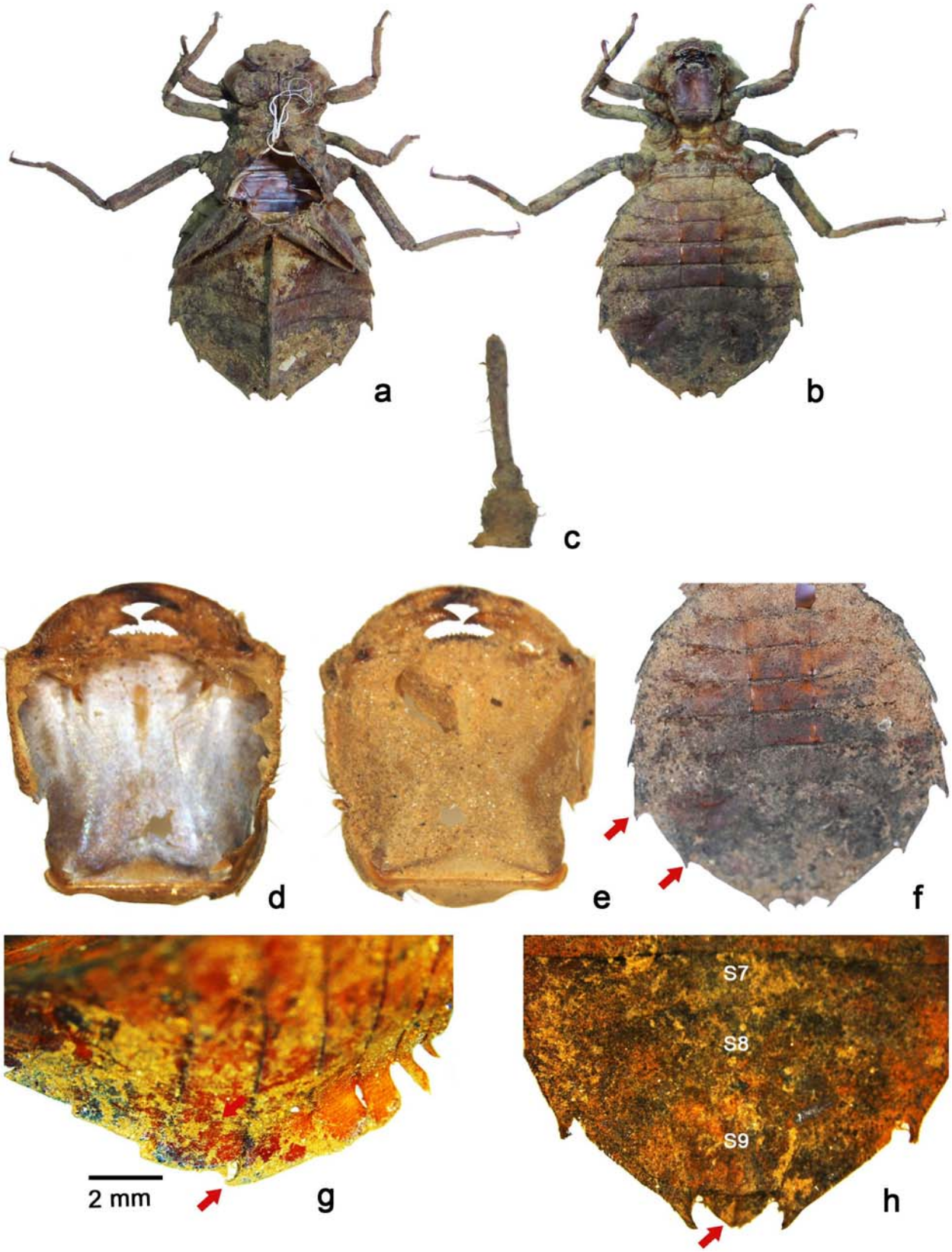
Burmagomphus pyramidalis Laidlaw, 1922



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdomen with mid dorsal spines, g. Abdomen with lateral spines and anal appendages.

PLATE 5

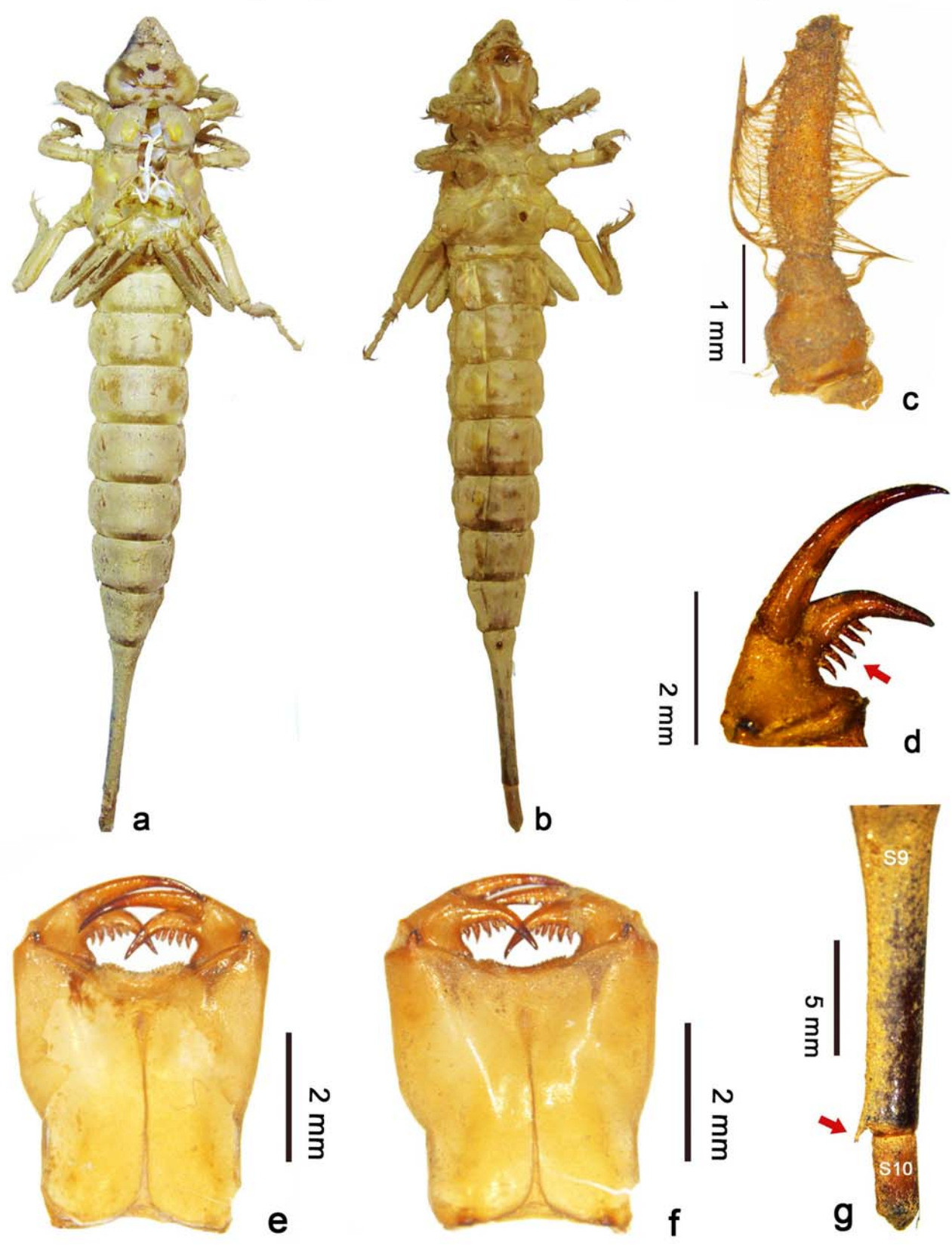
Ictinogomphus rapax (Rambur, 1842)



Figs. a–h: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdomen with lateral spines, g. Abdomen with mid dorsal spines, h. Anal appendage.

PLATE 6

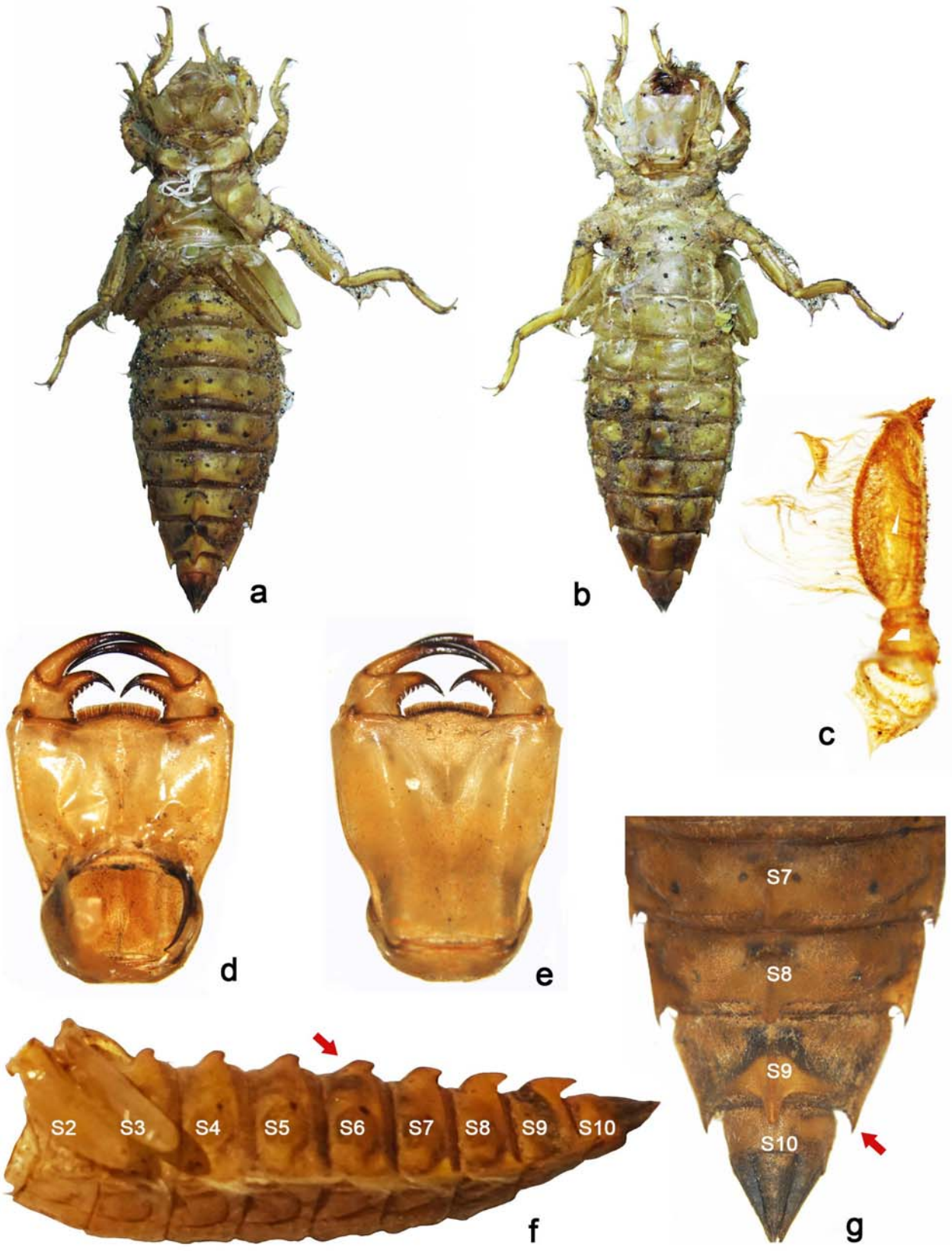
Macrogomphus annulatus (Selys, 1854)



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Palp with palpal teeth, e. Labium dorsal view, f. Labium ventral view, g. Spine on S9.

PLATE 7

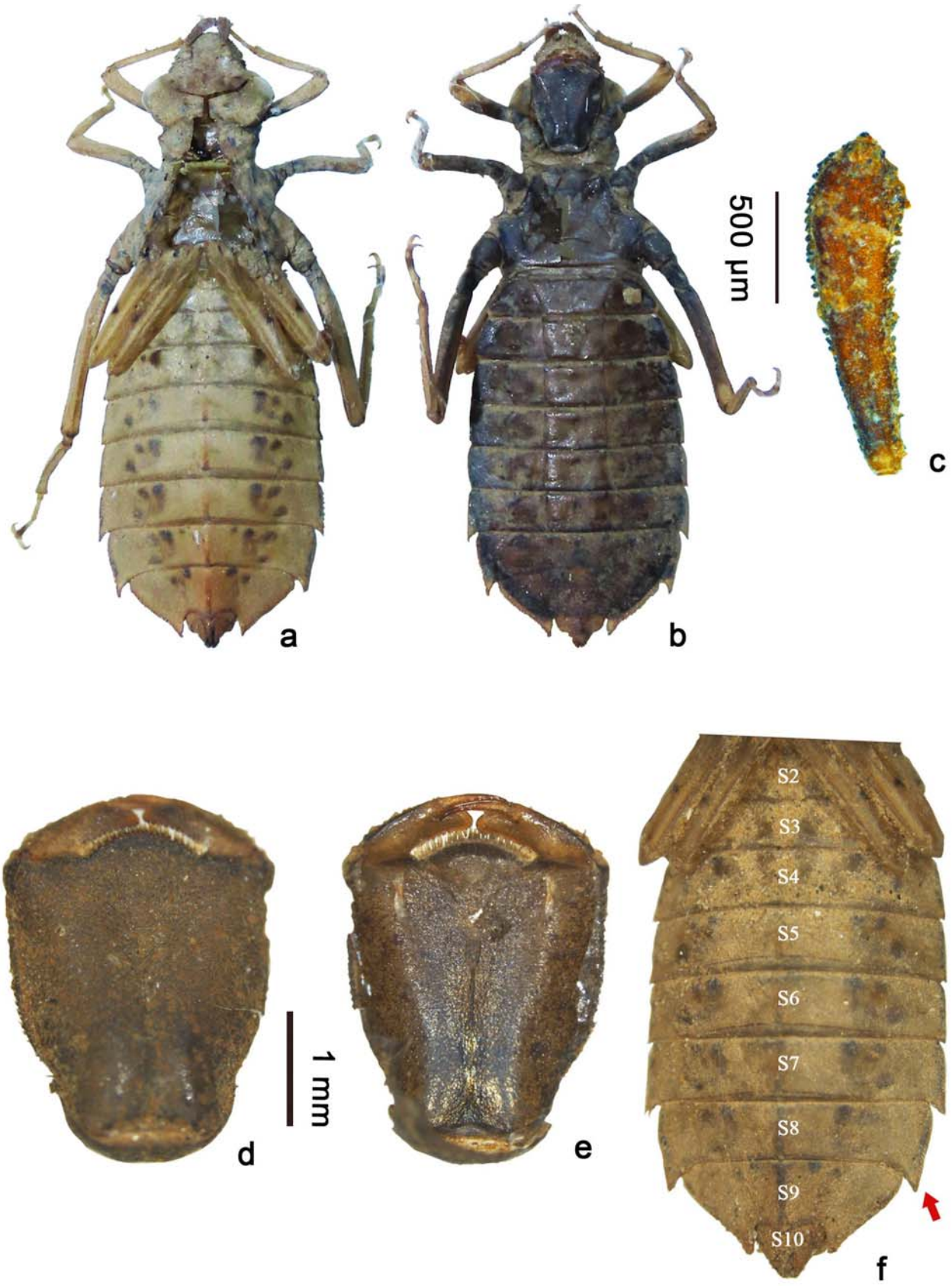
Megalogomphus superbus Fraser, 1931



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal dorsal spines, g. Abdominal lateral spines and anal appendages.

PLATE 8

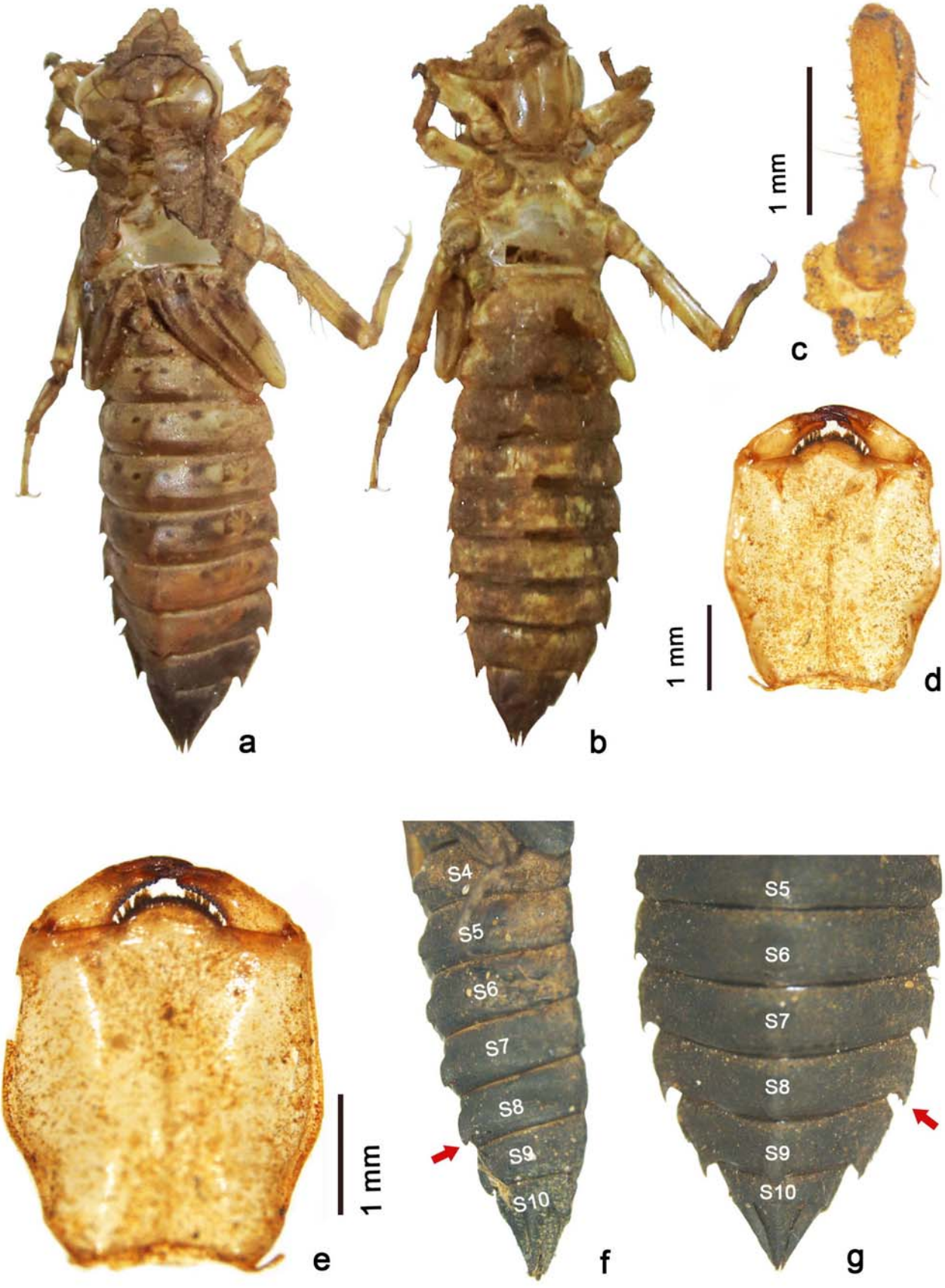
Microgomphus souteri Fraser, 1924



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal lateral spines with anal appendages.

PLATE 9

Onychogomphus malabarensis (Fraser, 1924)



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal mid dorsal spines, g. Abdominal lateral spines with anal appendages.

PLATE 10

Paragomphus lineatus (Selys, 1850)

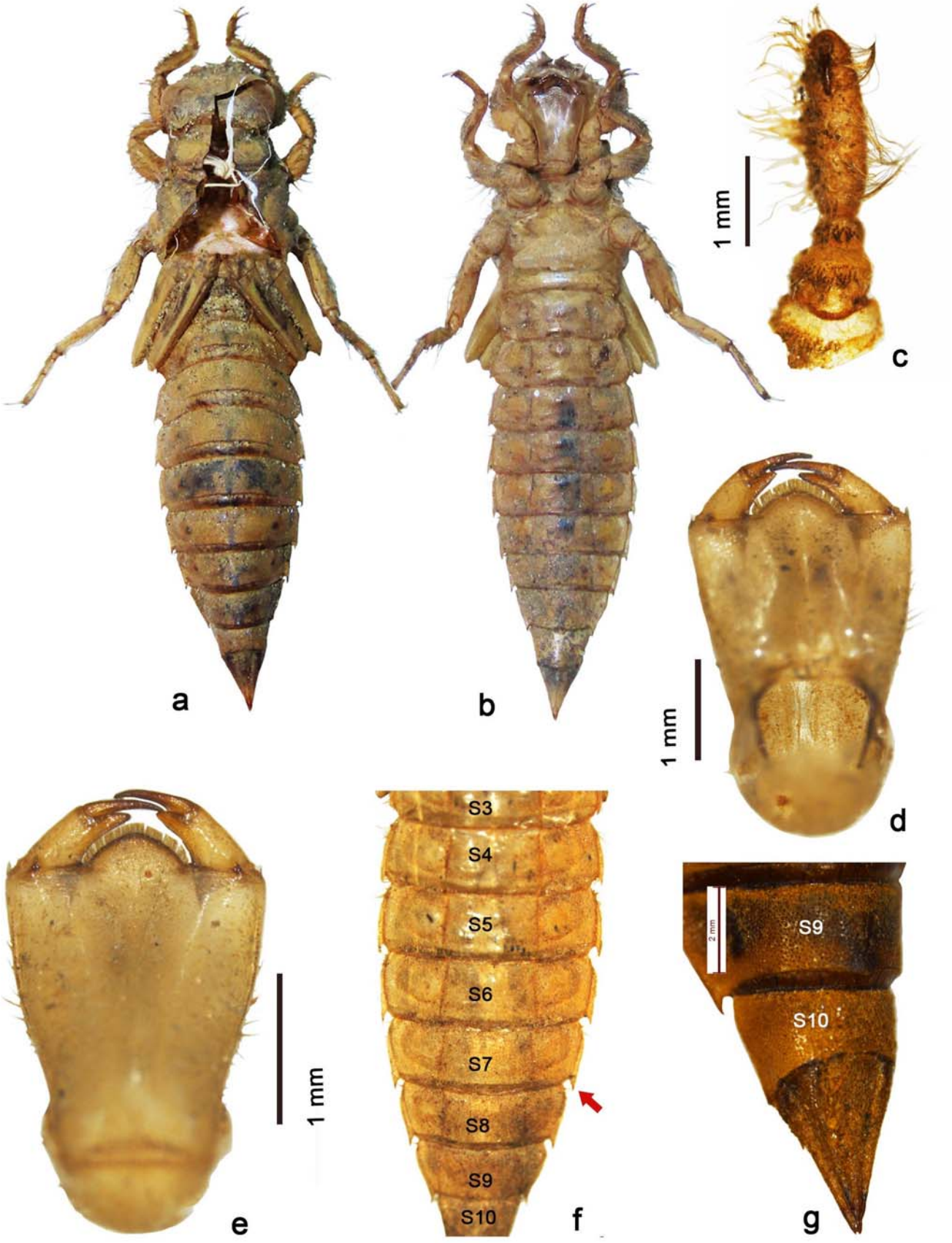
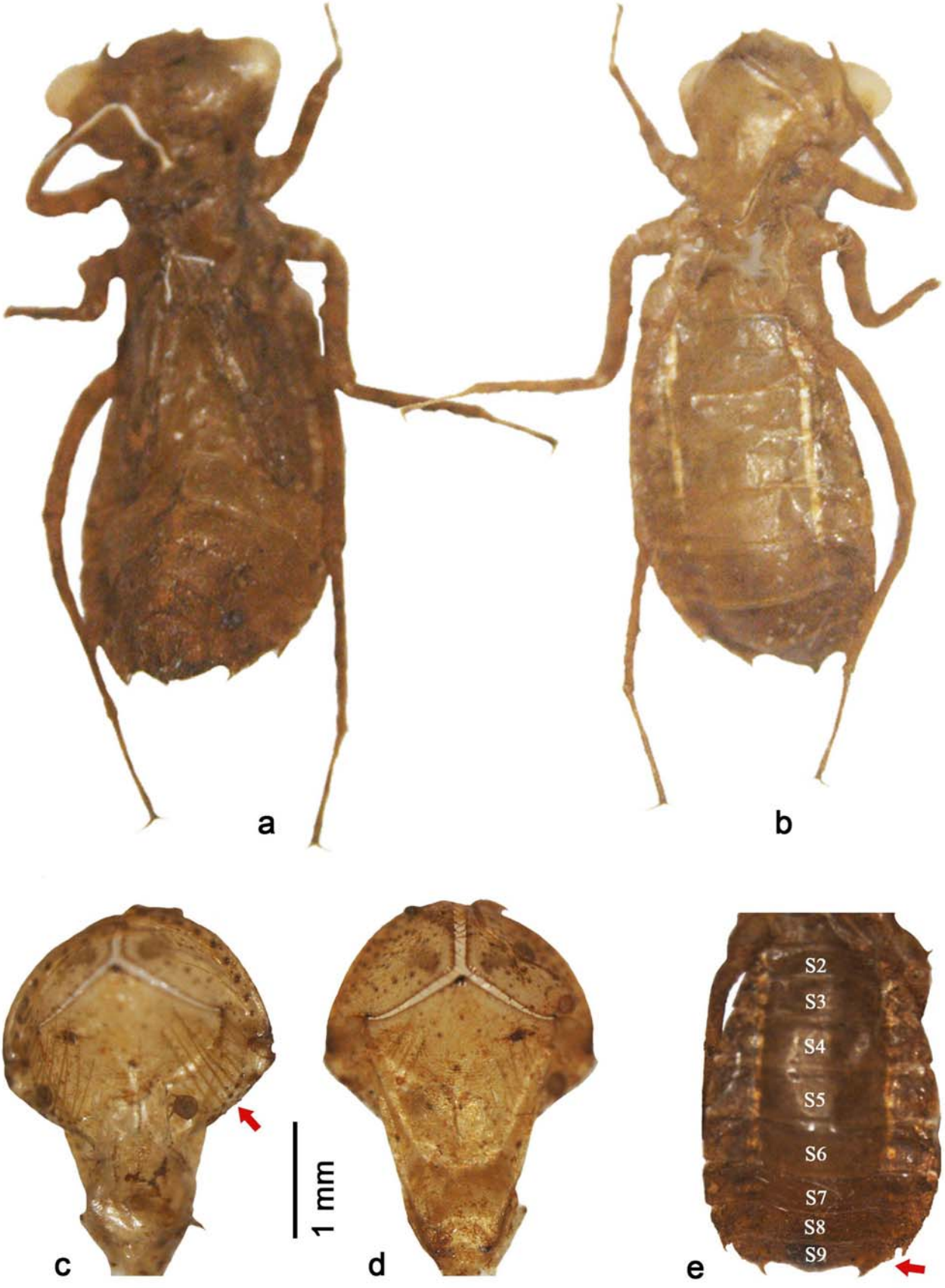


Fig. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdomen with lateral spines, g. Anal appendages.

PLATE 11

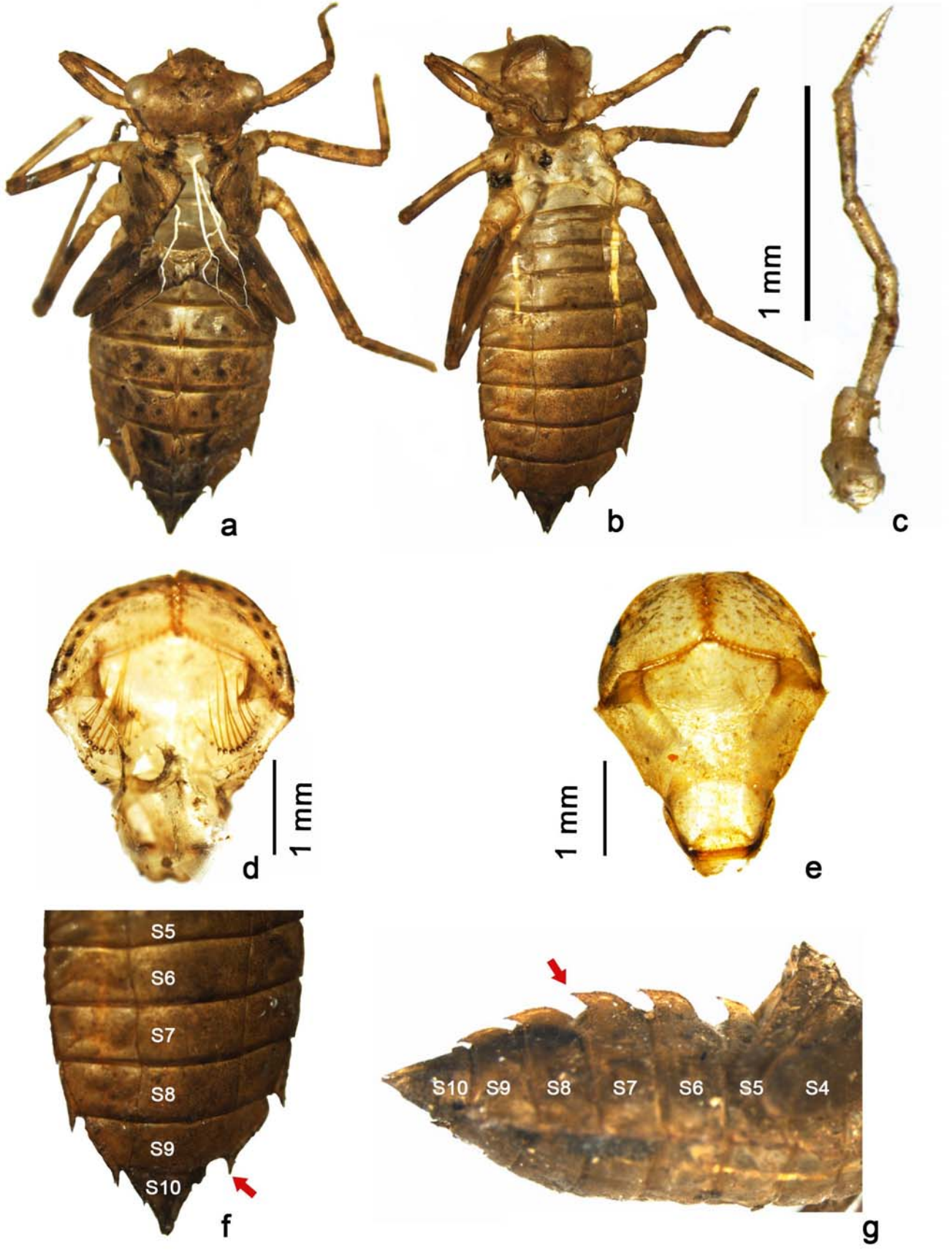
Acisoma panorpoides Rambur, 1842



Figs. a–e: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdominal lateral spines.

PLATE 12

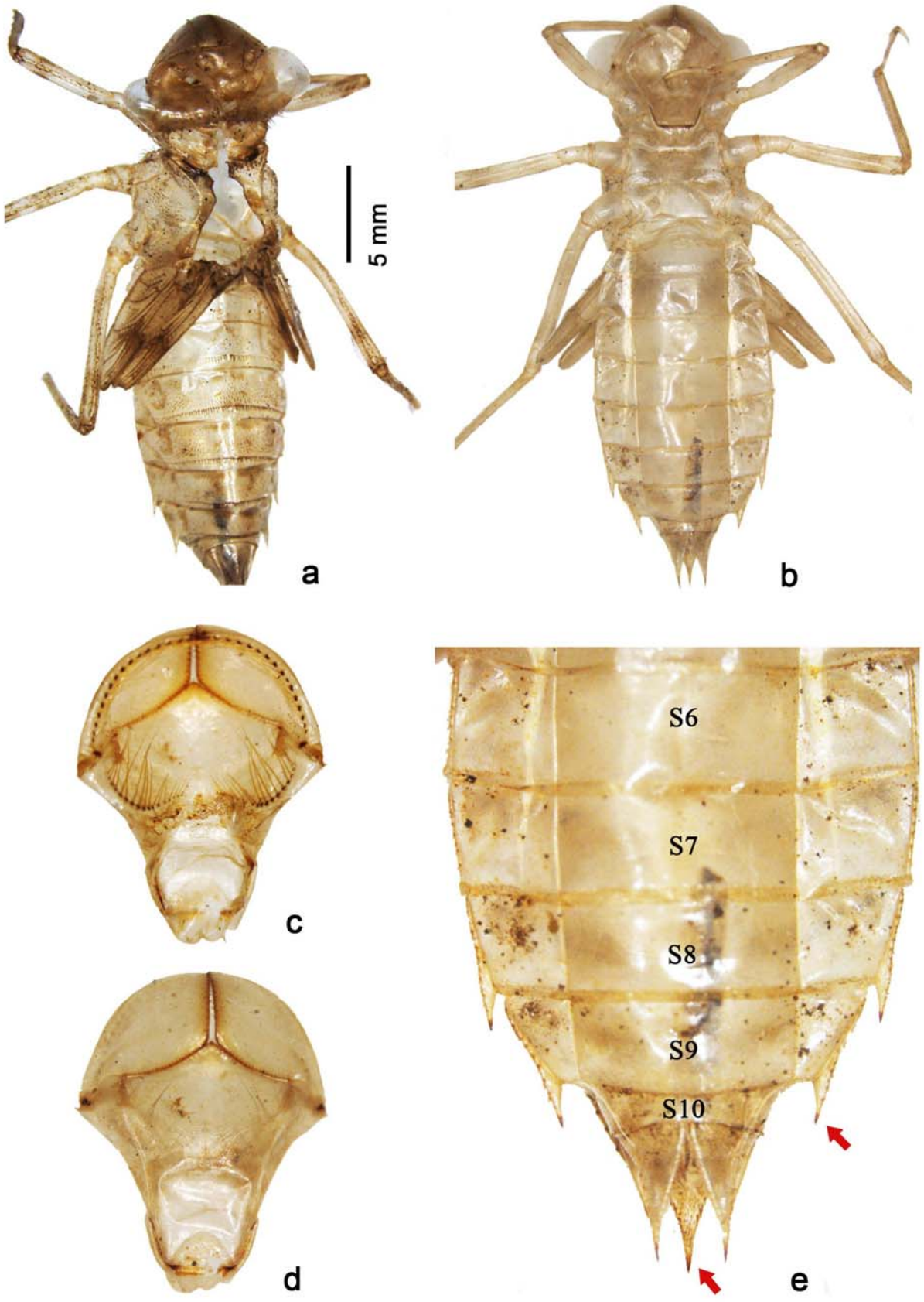
Brachythemis contaminata (Fabricius, 1793)



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal lateral spines, g. Abdominal mid dorsal spines.

PLATE 13

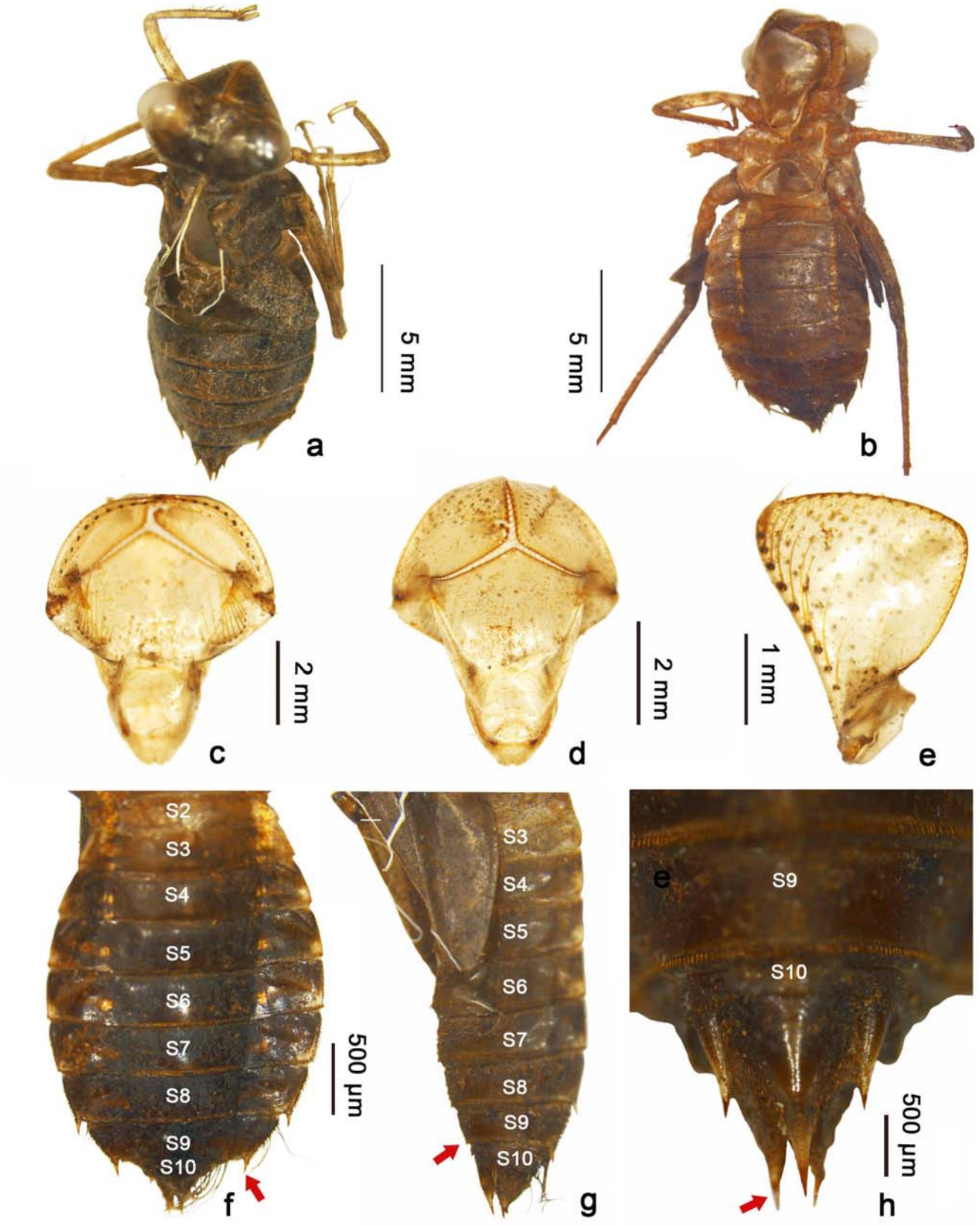
Bradinopyga geminata (Rambur,1842)



Figs. a–e: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdomen with lateral spines and anal appendages.

PLATE 14

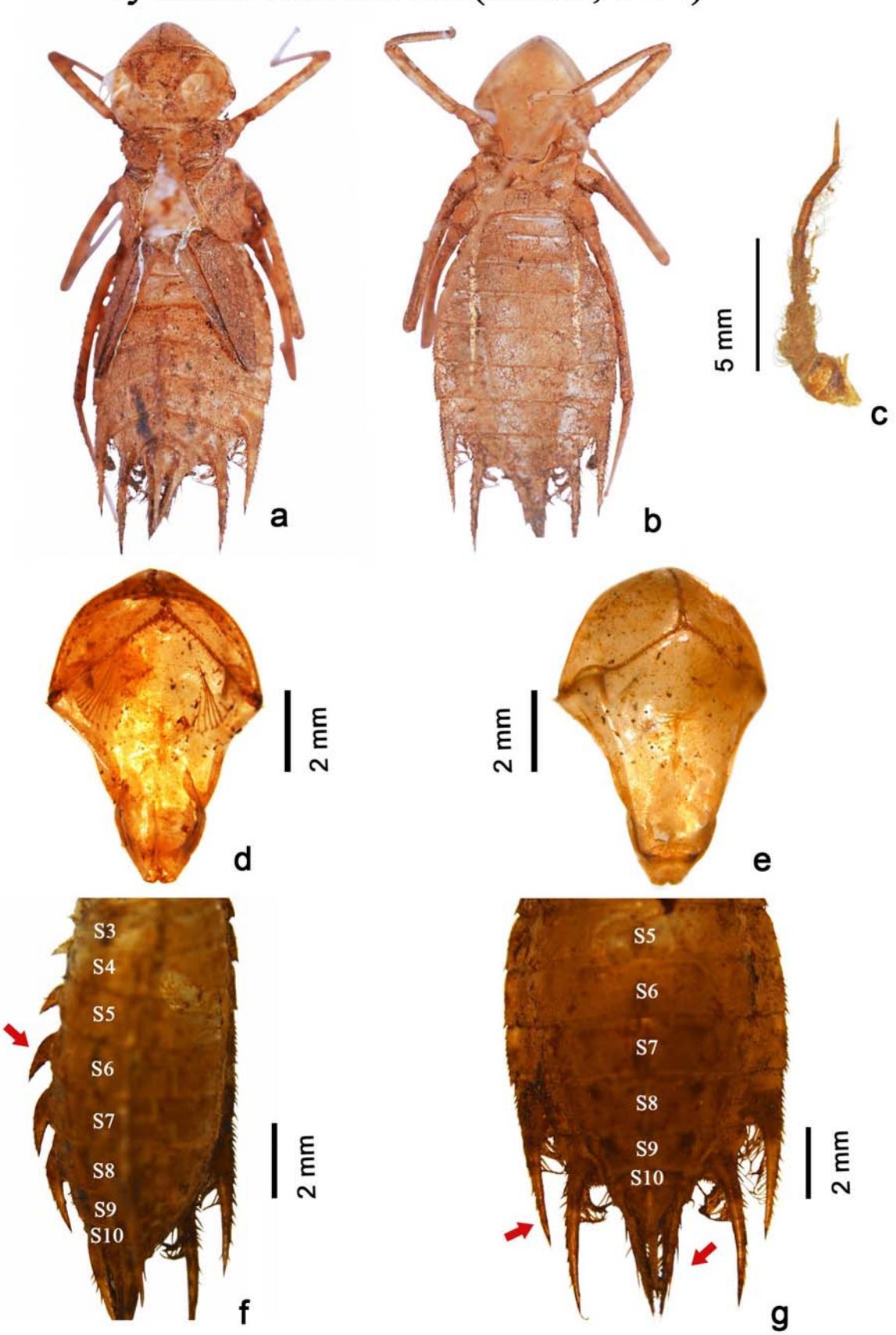
Diplacodes trivialis (Rambur, 1842)



Figs. a–h: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Palpus, f. Abdominal lateral spines, g. Abdominal mid dorsal spines, h. Anal appendages.

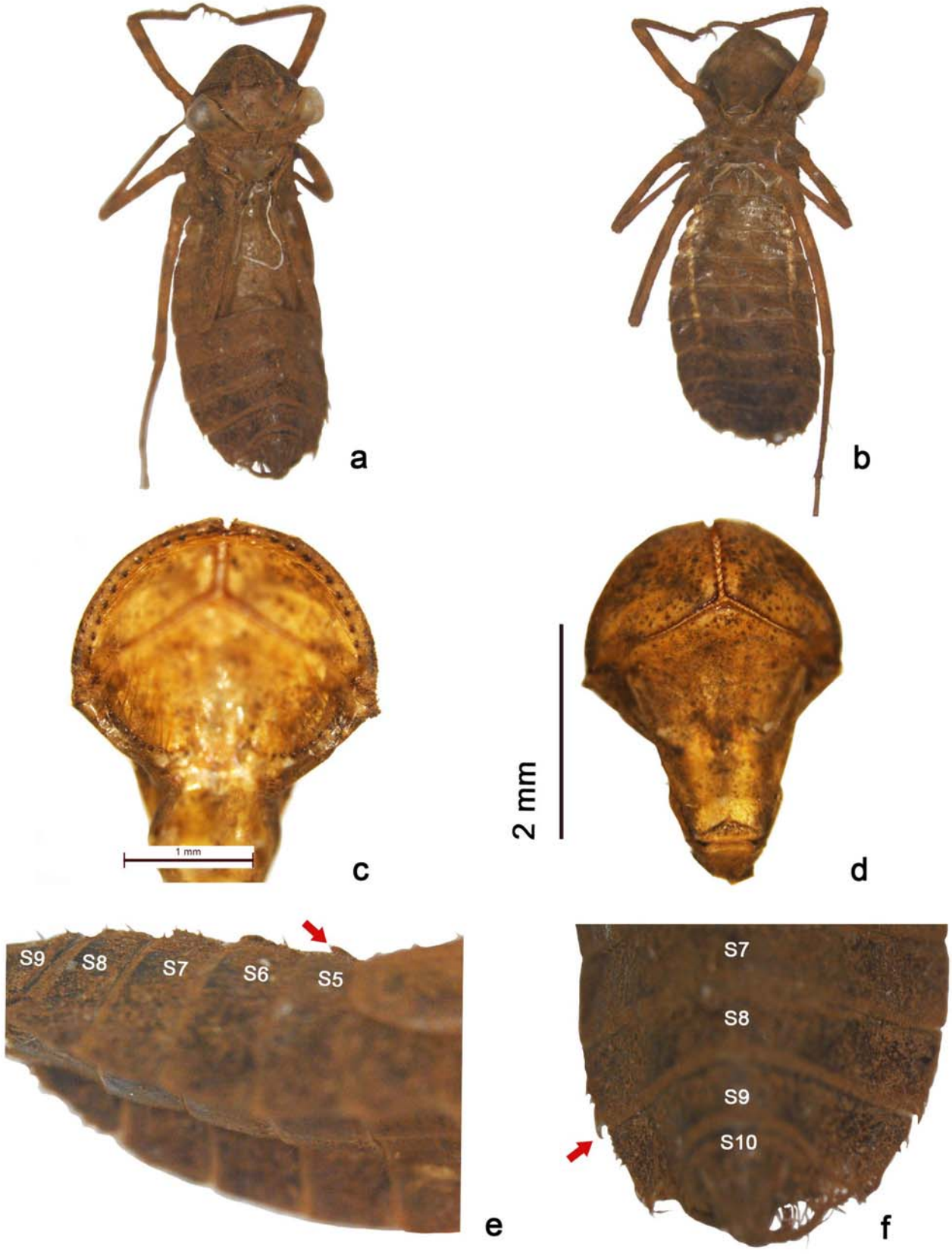
PLATE 15

Hydrobasileus croceus (Brauer, 1867)



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal mid dorsal spines, g. Abdominal lateral spines and anal appendages.

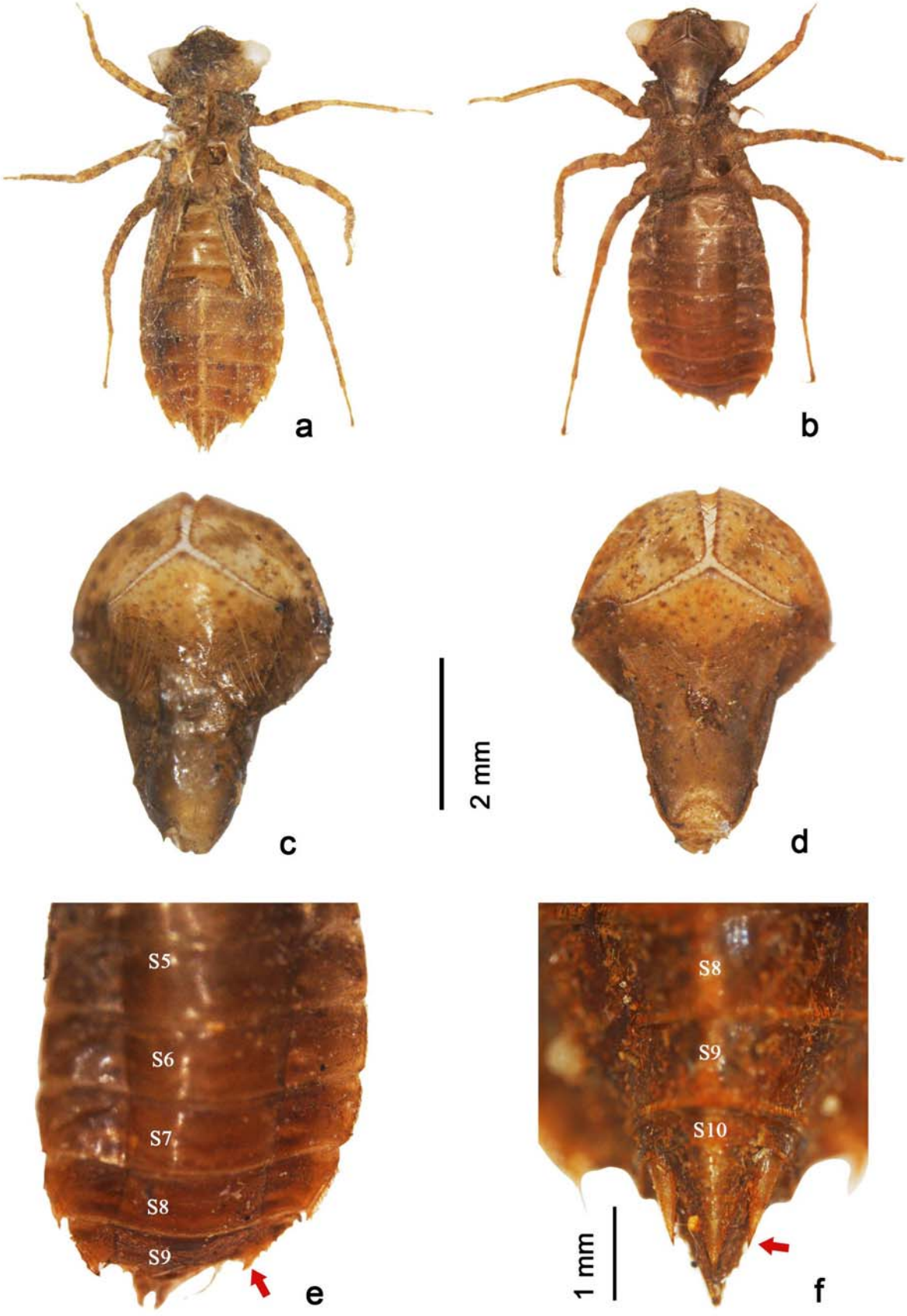
PLATE 16
Lathrecista asiatica (Fabricius, 1798)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdominal lateral spines and anal appendages.

PLATE 17

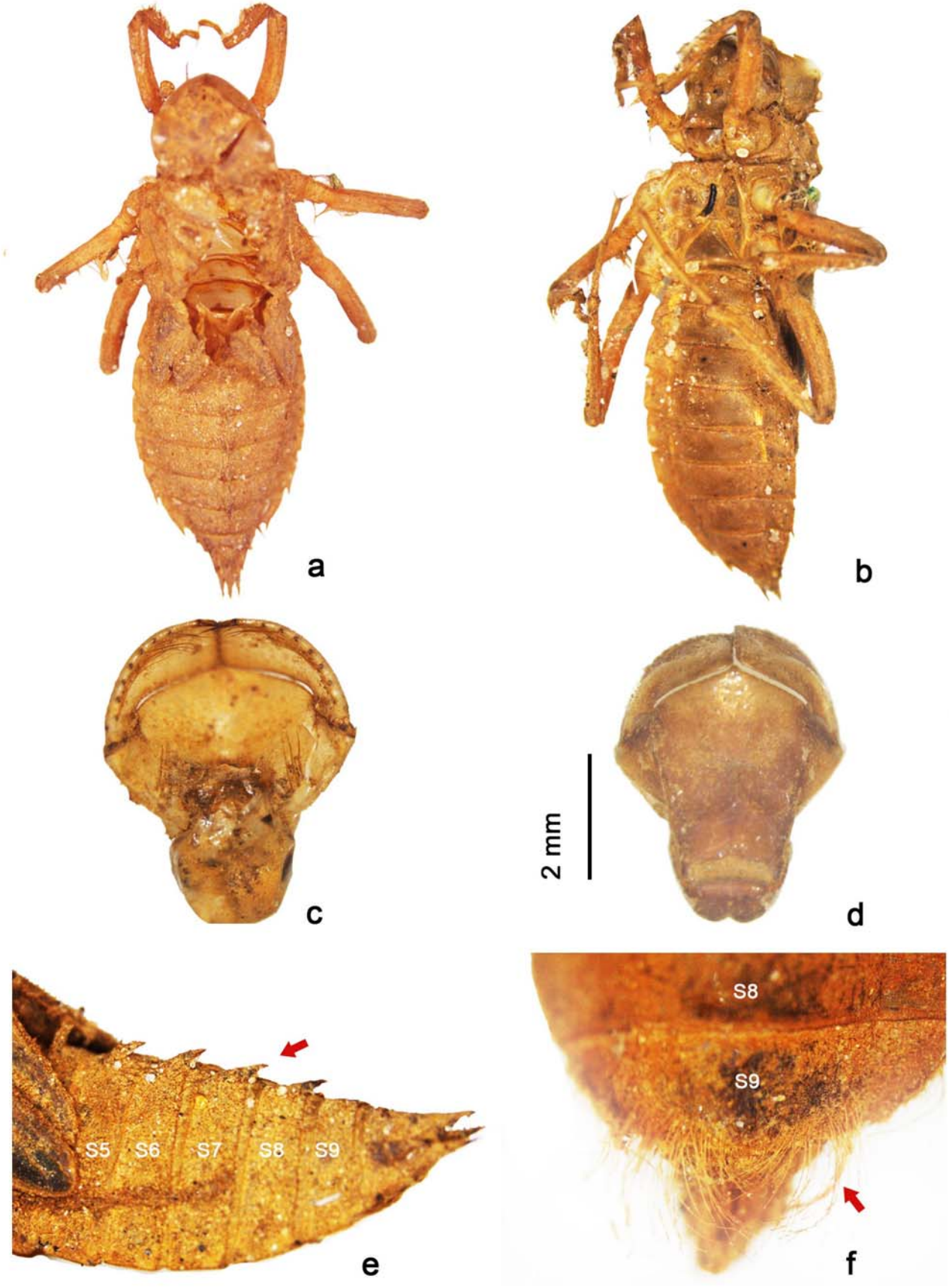
Neurothemis tullia (Drury, 1773)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdominal lateral spines, f. Anal appendages.

PLATE 18

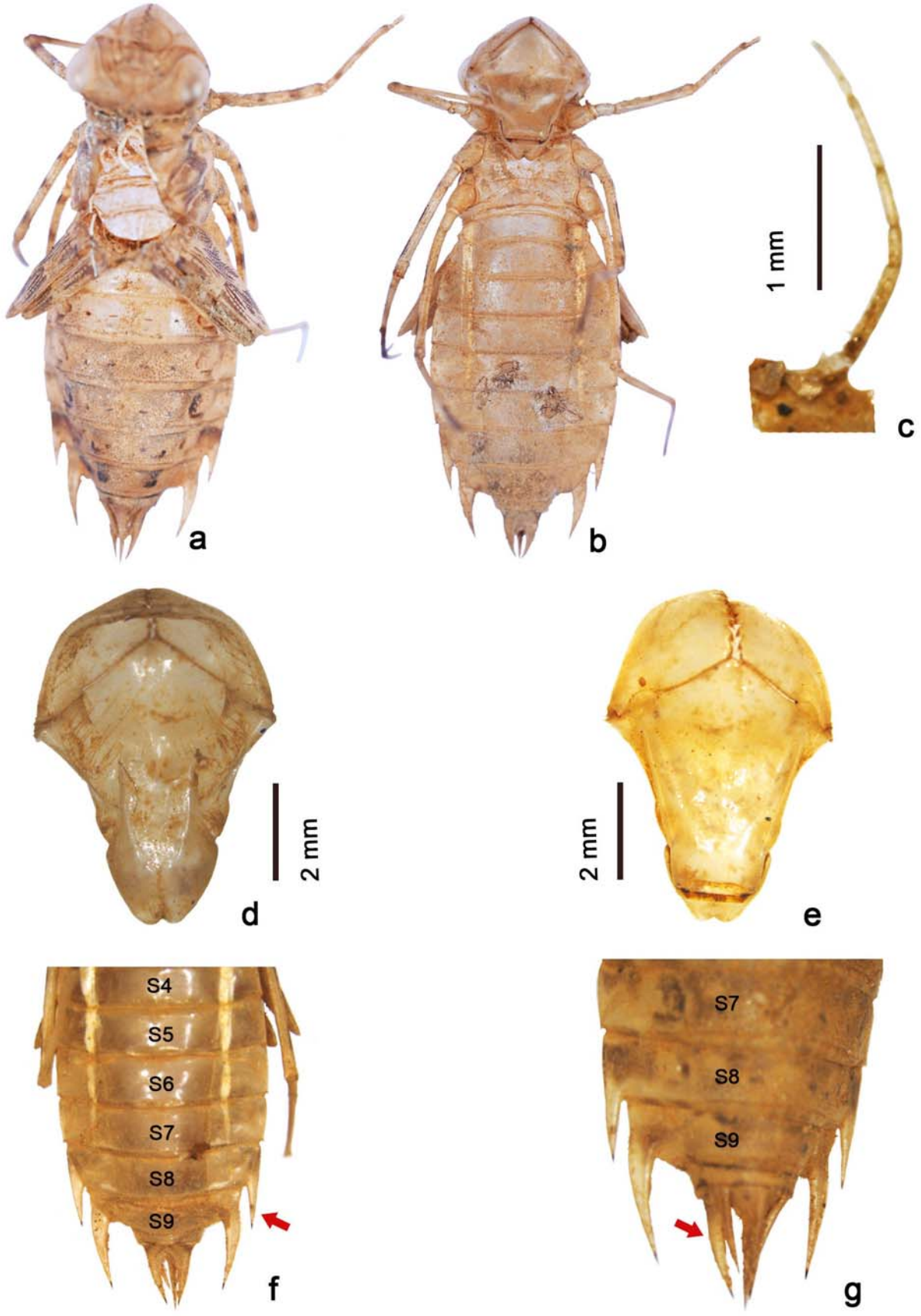
Orthetrum sabina (Drury, 1773)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view d. Labium ventral view, e. Abdominal mid dorsal spines, f. Hairs on S9.

PLATE 19

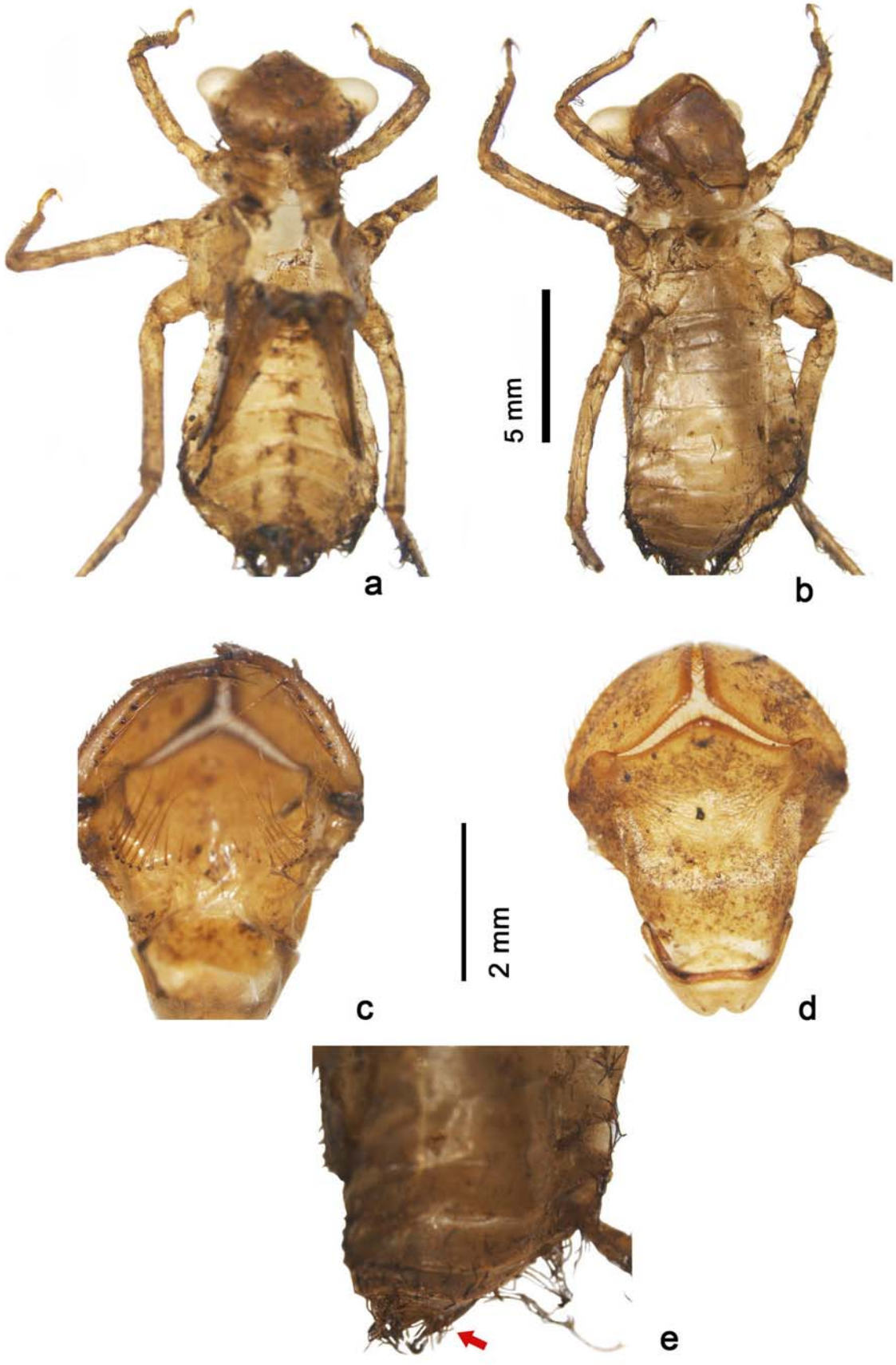
Pantala flavescens (Fabricius, 1798)



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal lateral spines, g. Anal appendages.

PLATE 20

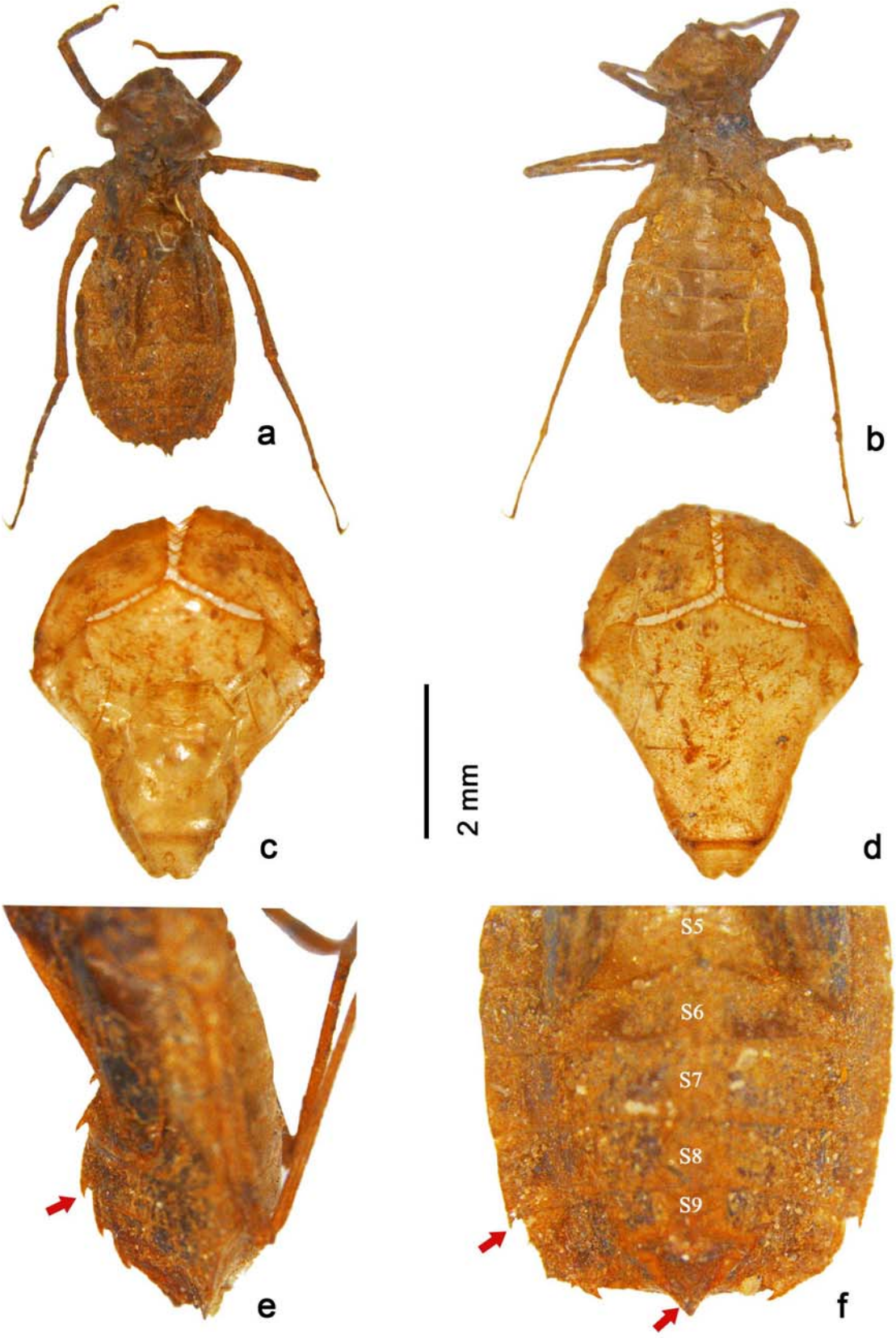
Rhodothemis rufa Rambur, 1842



Figs. a–e: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view d. Labium ventral view, e. Abdomen with anal appendages.

PLATE 21

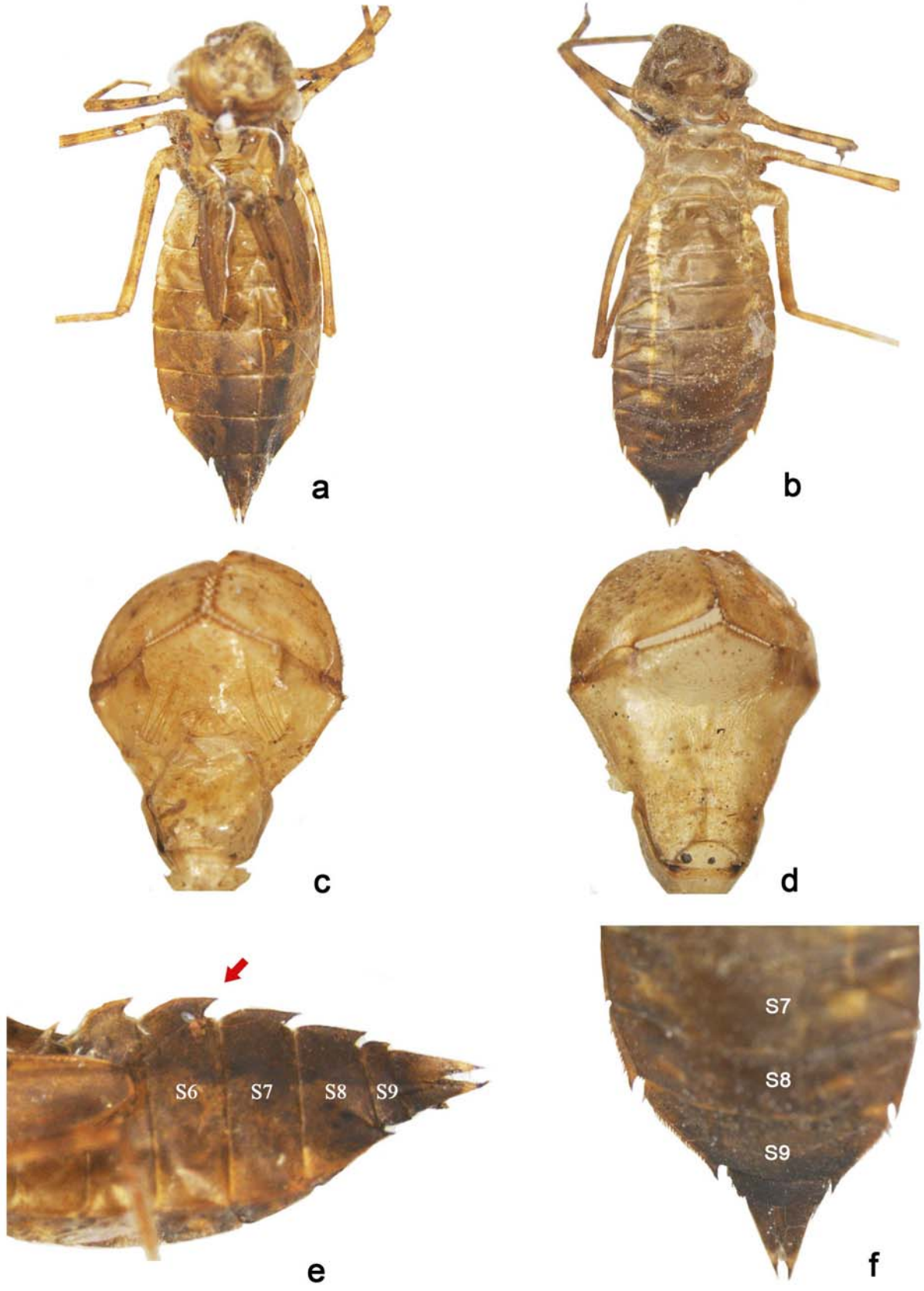
Rhyothemis variegata (Linnaeus, 1763)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdomen with lateral spines and anal appendages.

PLATE 22

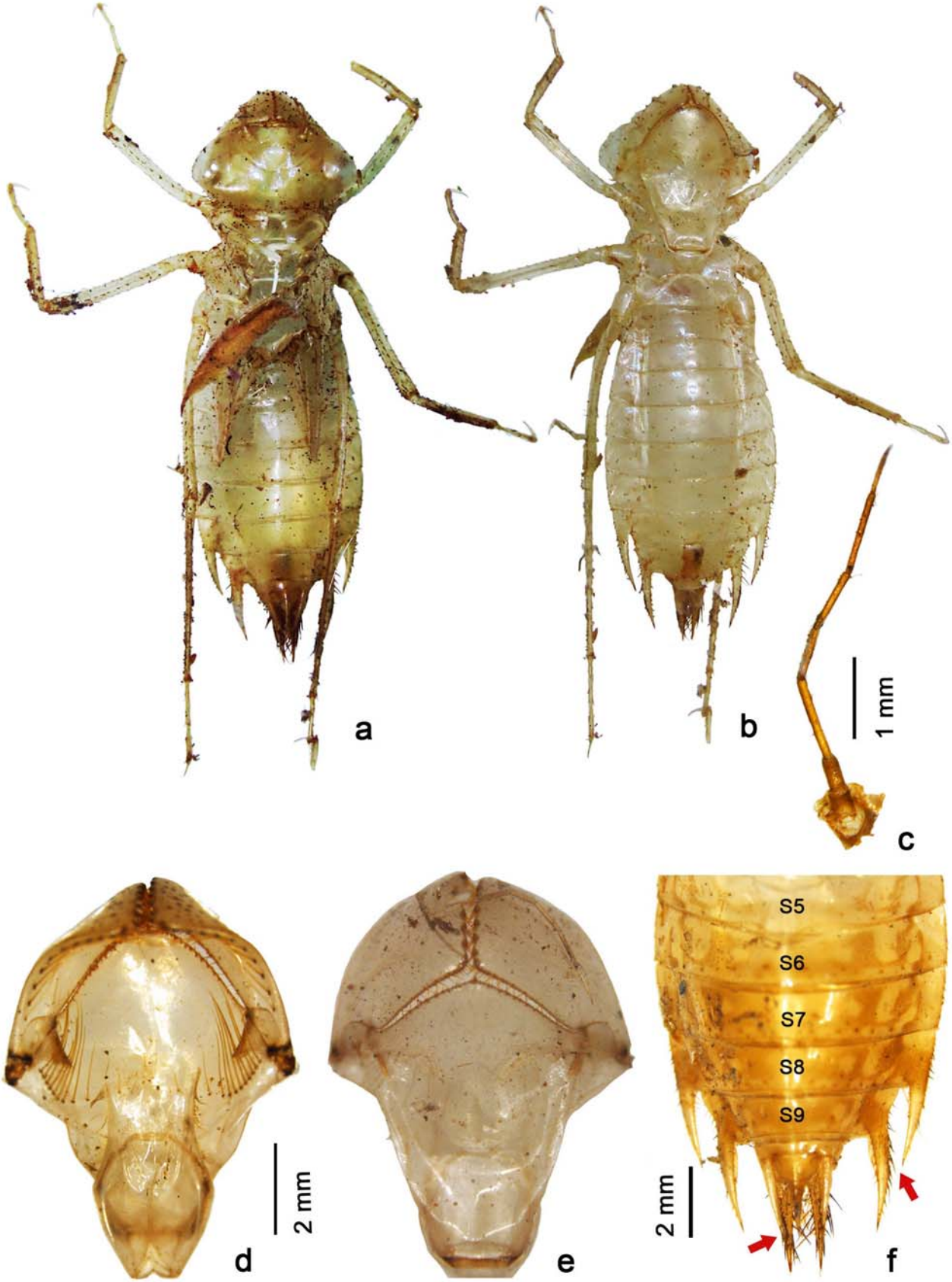
Tholymis tillarga (Fabricius, 1798)



Figs. a–e: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdomen with lateral spines and anal appendages.

PLATE 23

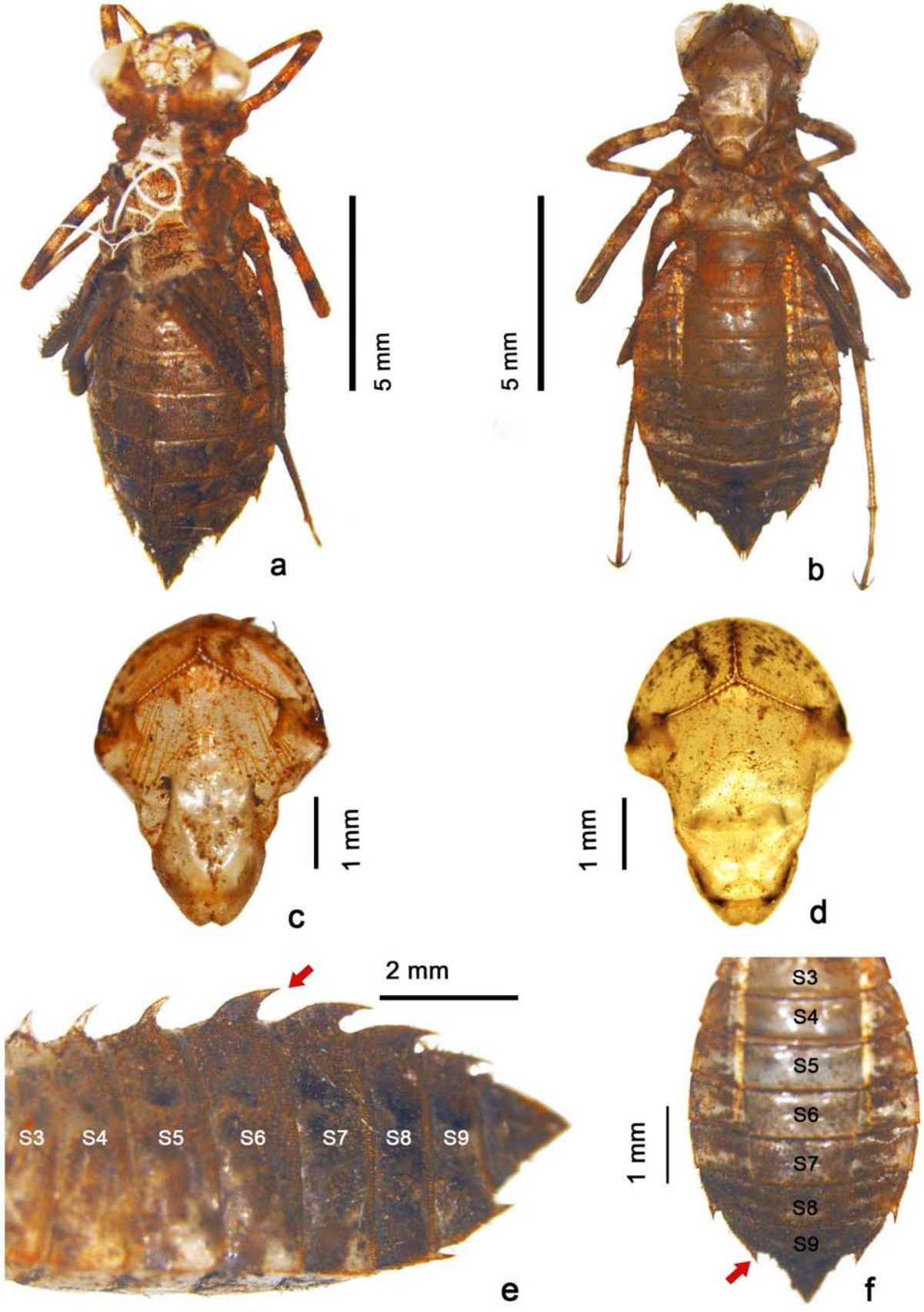
Tramea basilaris (Palisot de Beauvois, 1817)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdomen with lateral spines and anal appendages.

PLATE 24

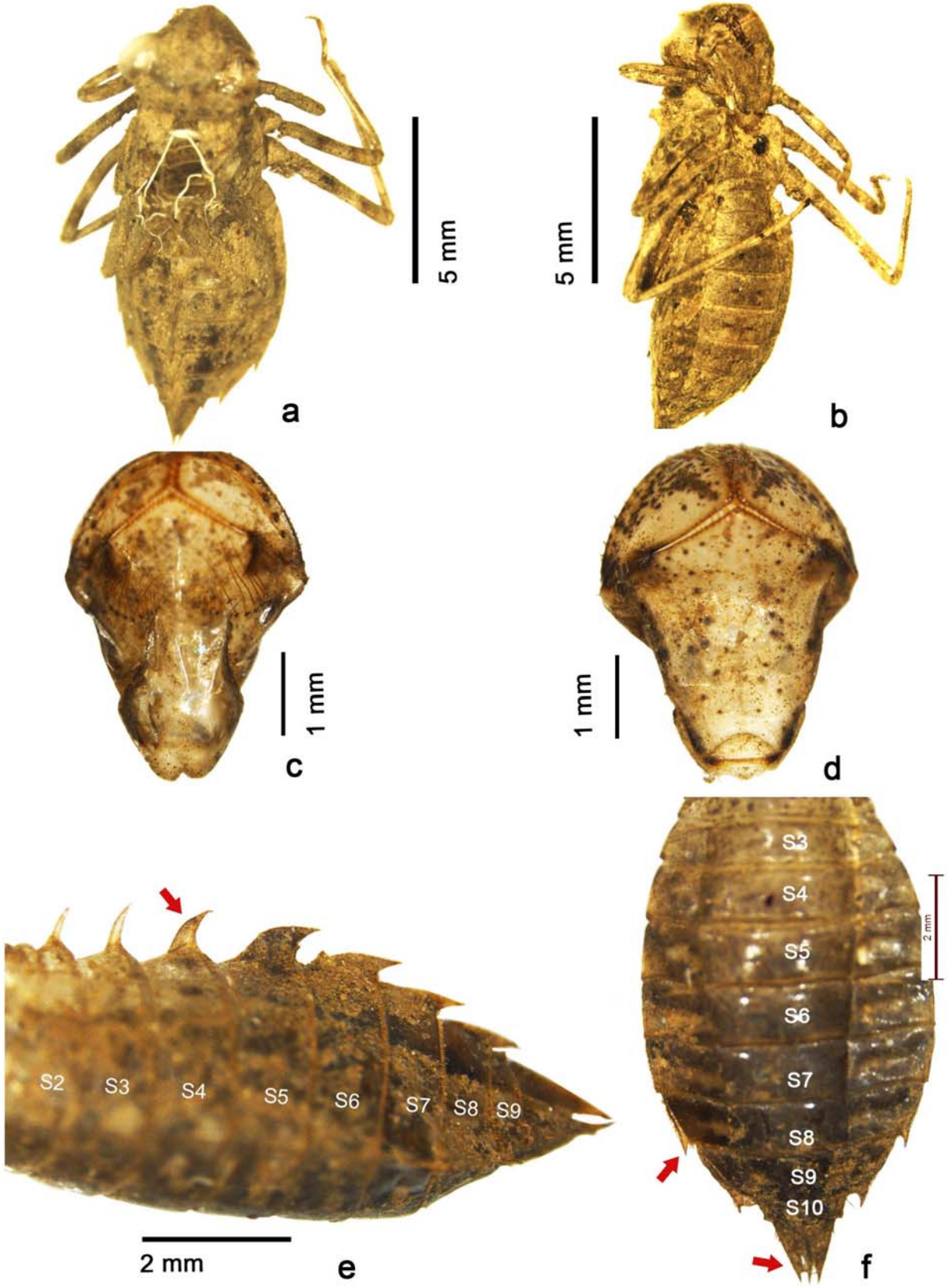
Trithemis aurora (Burmeister, 1839)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdomen with lateral spines and anal appendages.

PLATE 25

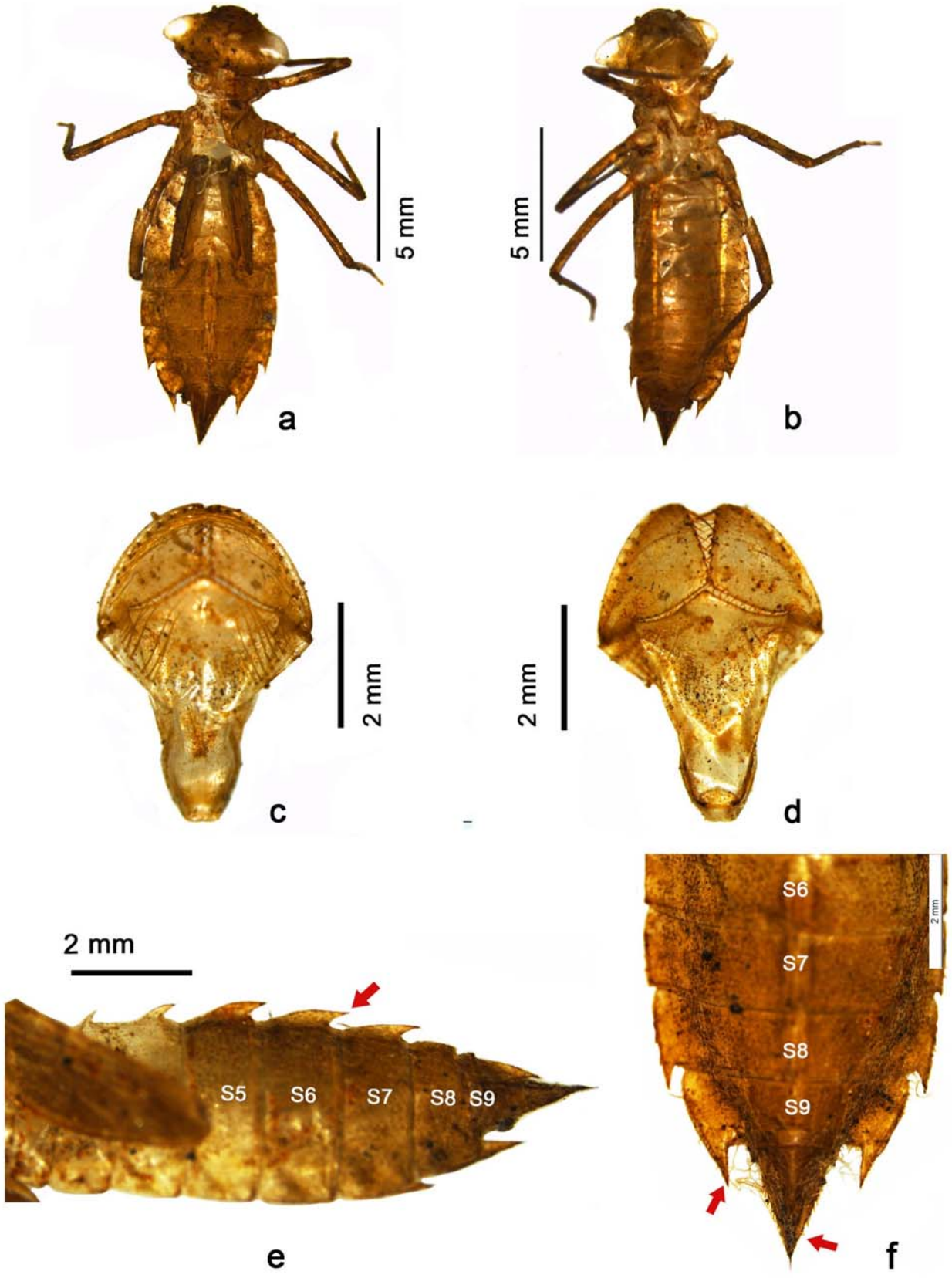
Trithemis festiva (Rambur, 1842)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdomen with lateral spines and anal appendages.

PLATE 26

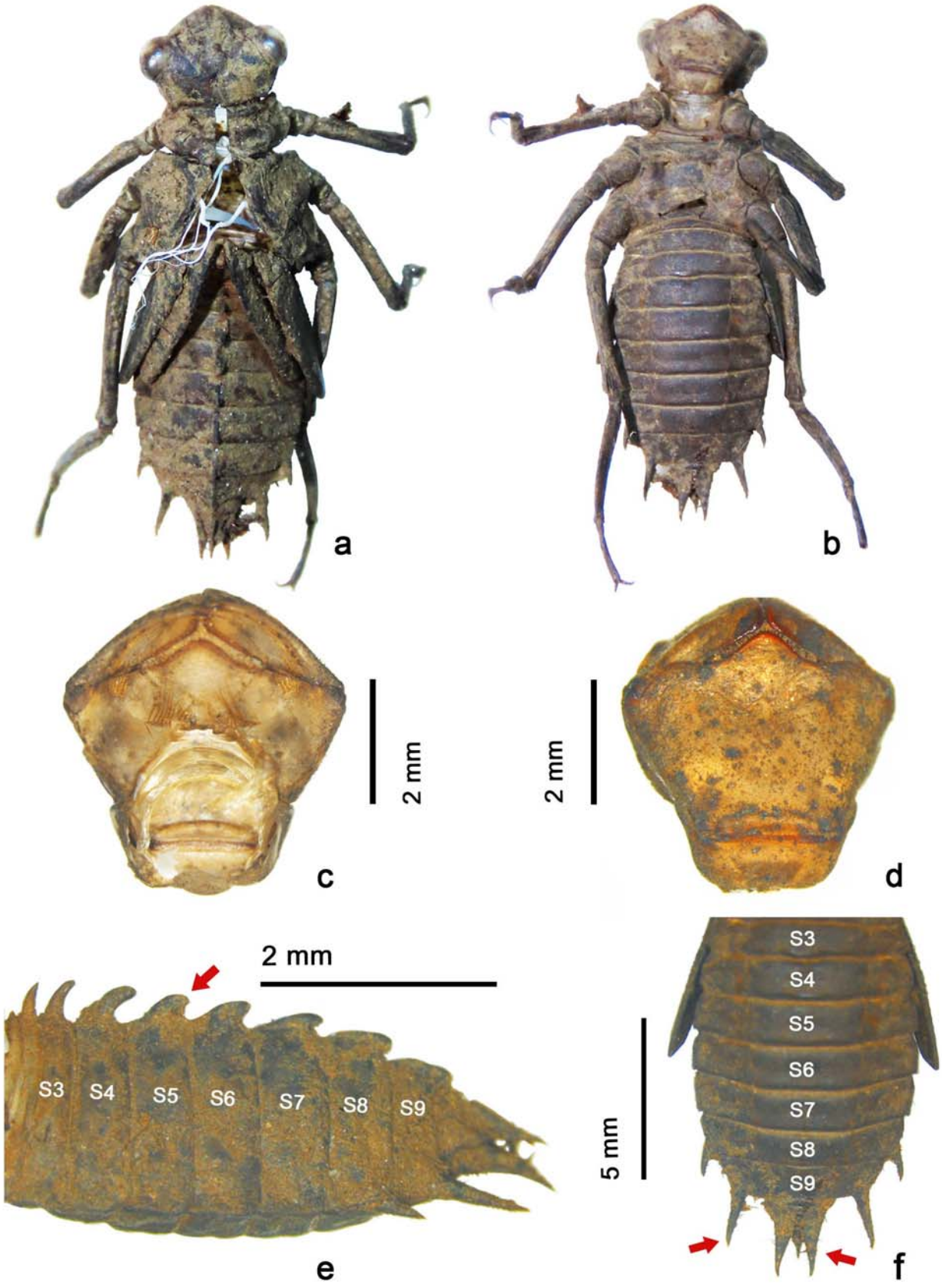
Urothemis signata (Rambur, 1842)



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdomen with lateral spines and anal appendages.

PLATE 27

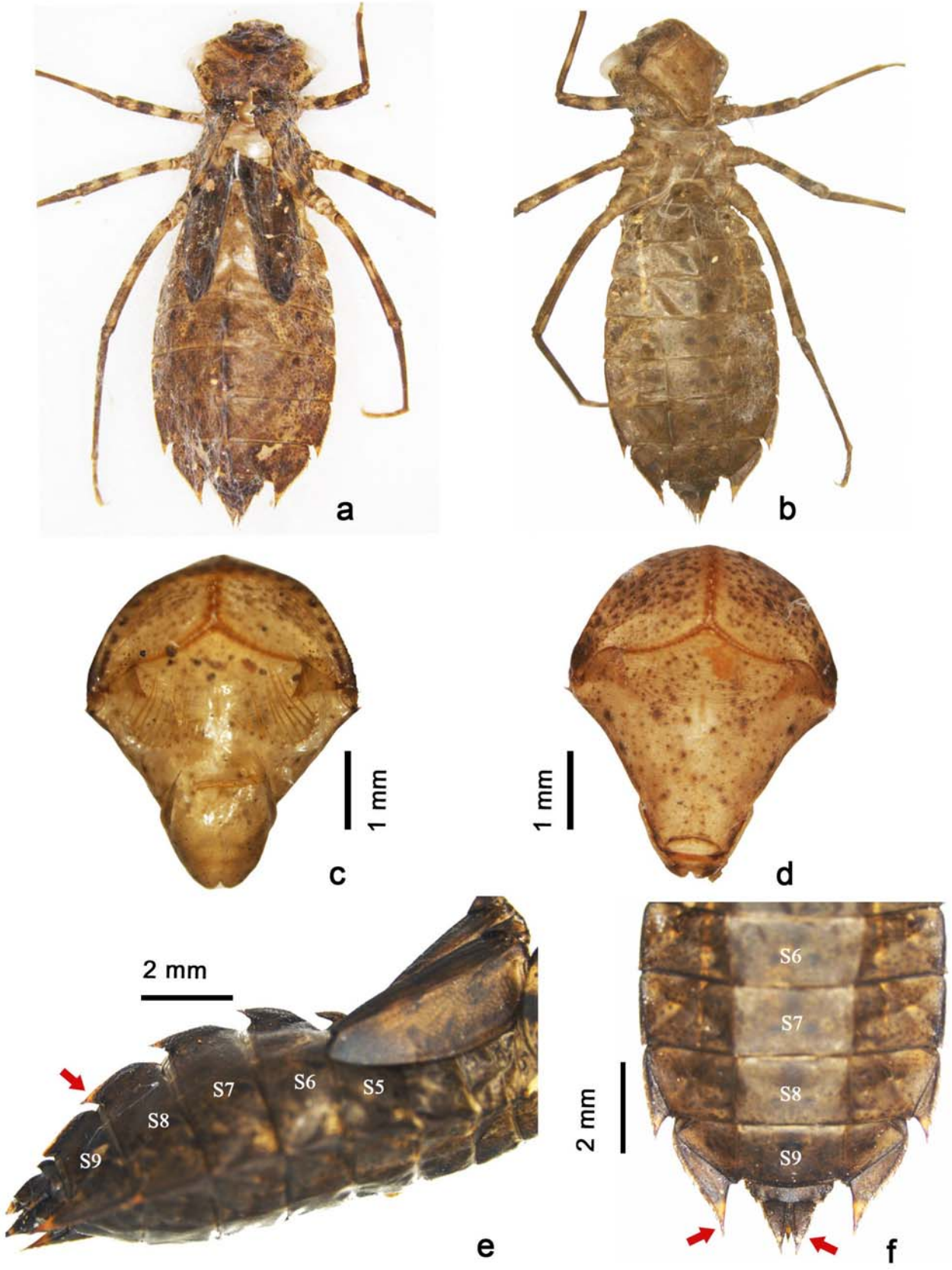
Zygonyx iris Selys, 1869



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdomen with lateral spines and anal appendages.

PLATE 28

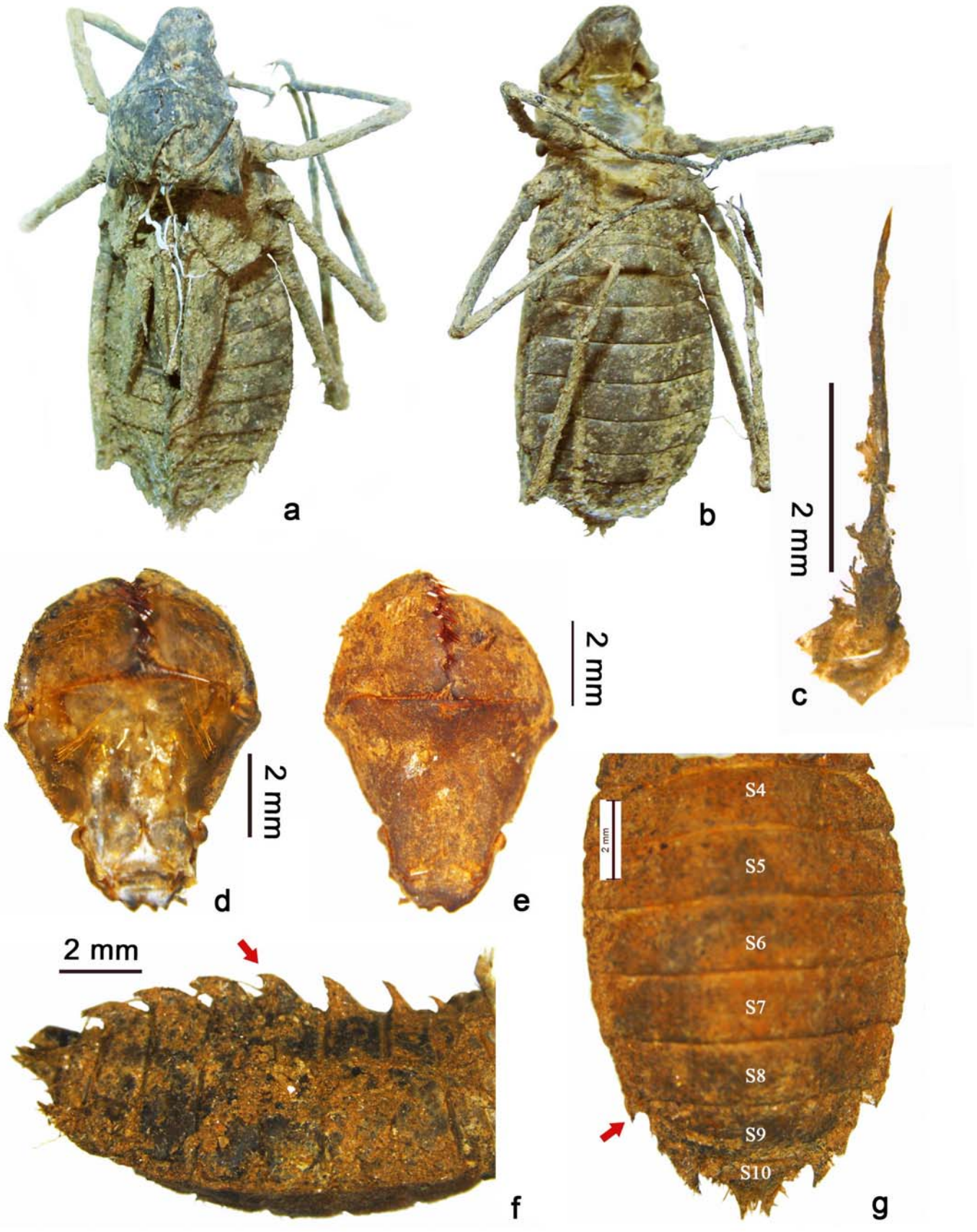
Zyxomma petiolatum Rambur, 1842



Figs. a–f: a. Habitus dorsal view, b. Habitus ventral view, c. Labium dorsal view, d. Labium ventral view, e. Abdominal mid dorsal spines, f. Abdomen with lateral spines and anal appendages.

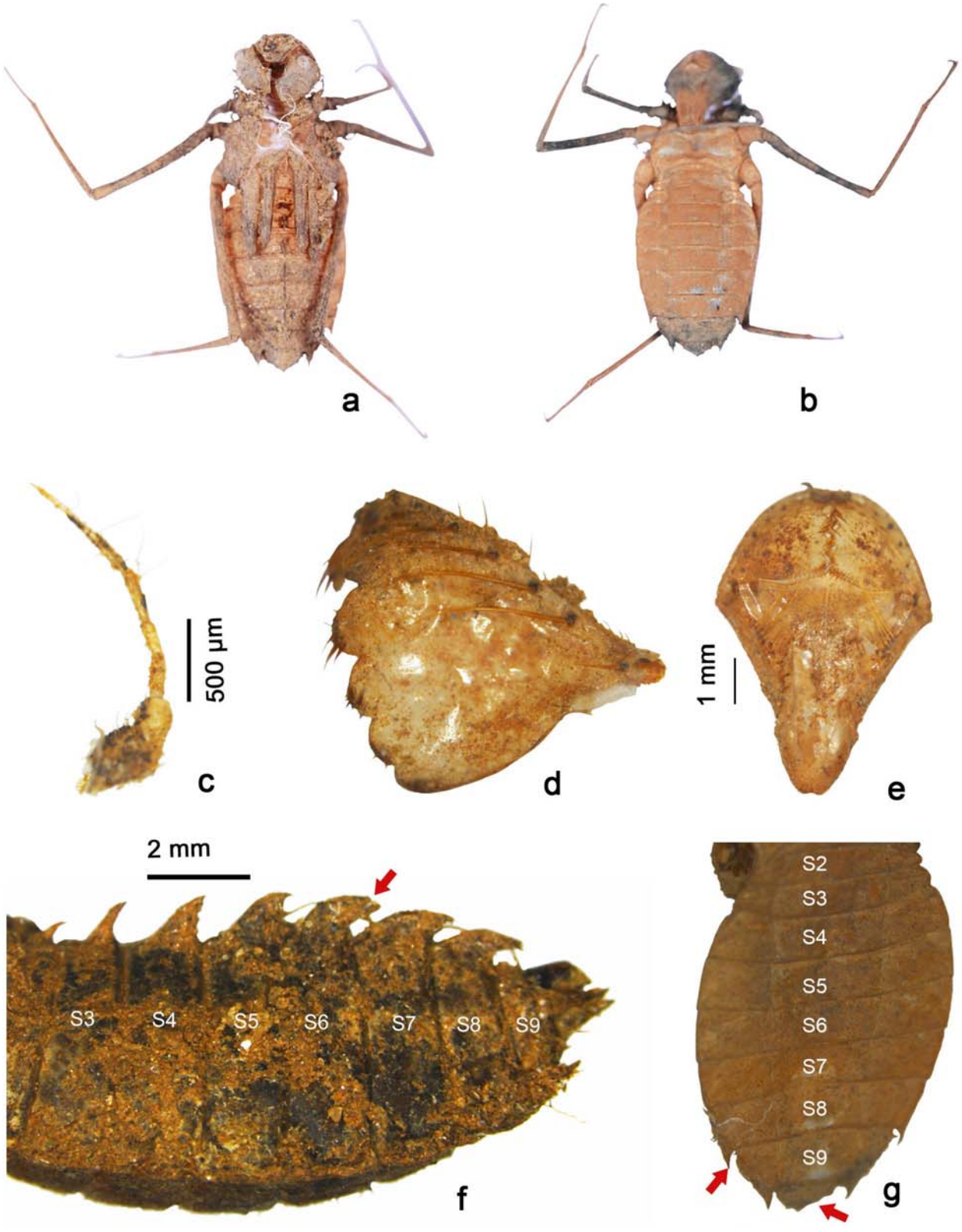
PLATE 29

Macromia flavocolorata Fraser, 1922



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Labium dorsal view, e. Labium ventral view, f. Abdominal mid dorsal spines, g. Abdomen with lateral spines and anal appendages.

PLATE 30
Macromia indica Fraser, 1924



Figs. a–g: a. Habitus dorsal view, b. Habitus ventral view, c. Antenna, d. Palp with setae, e. Labium dorsal view, f. Abdominal mid dorsal spines, g. Abdomen with lateral spines and anal appendages.

CHAPTER 5
DISCUSSION

CHAPTER 5

DISCUSSION

All the thirty species were described in detail and photographic plates of characteristic features were prepared. Family Libellulidae was dominant with eighteen species, followed by Gomphidae with eight species. Family Aeshnidae and Macromiidae were represented by two species each (see Table 4, Chapter 4). Of the thirty species, exuviae of eight have been described for the first time at global level and two have been described for the first time from India (see Table 5, Chapter 4). Of these five are endemics to the Western Ghats. The breeding sites of all the described species were summarised (see Table 6, Chapter 4). Exuviae of each family were characterised by unique features and Table 7 in Chapter 4 summarizes these taxonomic features. A taxonomic key for the described species was prepared upto species level using these features.

Family Aeshnidae is represented by nine species under three genera in Kerala *Anaciaeschna* (2), *Anax* (5) *and Gynacantha* (3) (Gopalan *et al.,* 2022). Nymphal features of four species of genus Anax and one species of Gynacantha are already done (Kumar & Sangal, 1970; Kumar, 1973; Kumar, 1984e; Sasamoto *et al.,* 2022; & Dawn & Chandra, 2016). In this study the final instar nymphs of *Anax indicus* and *Gynacantha dravida* were done for the first time. Comparing the nymphal features of other congeneric species (Refer Appendix Table I) *Anax indicus* shows close resemblance to *A. immaculifrons* (Kumar, 1984e) in their body size and appearance, but can be differentiated by the position of lateral spines on their abdominal segments. The former has lateral spines on S7–S9, and in the latter they are located on S6–S9. *G. dravida* shows greater resemblance to *G. millardi* (Dawn & Chandra, 2016), in their habitus and body color than the other described species in the genus (Refer Appendix Table II). Major differences between these species are in the number of palpal setae and in the presence of stripes on the body. In *G. millardi,* palpal setae are seven and the abdomen possess one mid dorsal and two lateral stripes (Dawn & Chandra, 2016), whereas in *G. dravida* palpal setae are 3–4 in number and the abdomen is characterized by the presence of two mid dorsal stripes and absence of lateral stripe. Exuviae of *A.indicus* and *G. dravida* shows marked differences in their features like

habitus, body size, palpal setae and lateral spines on abdomen (Refer Appendix Table III).

Members of the family Gomphidae represents 16 genera and 20 species in Kerala. Out of 20 species, 17 are endemic to the Western Ghats (Gopalan *et al.,* 2022). The present study described the nymphal features of eight species of Gomphids belonging to seven genera. The exuviae shows marked differences in their habitus, number of premental and palpal teeth, shape of abdomen, abdominal mid-dorsal spines and in the position of lateral spines (Refer Appendix Table.VIII). Out of these eight, four are endemic to the Western Ghats and are described for the first time. They are *Burmagomphus laidlawi* Fraser, 1924; *Microgomphus souteri* Fraser, 1924; *Onychogomphus malabarensis* (Fraser, 1924) and *Megalogomphus superbus* Fraser, 1931. Three species *Burmagomphus pyramidalis* Laidlaw, 1922, *Ictinogomphus rapax* (Rambur, 1842) and *Macrogomphus annulatus* (Selys, 1854) were described for the first time from Kerala and South India. *M. annulatus* is a new report from Kerala. *Paragomphus lineatus* is already described by Adambukulam & Kakkassery, (2013a) as a part of a pilot study conducted during 2012–2013.

The genus *Burmagomphus* is represented by seven species in India (Kalkman *et al.,* 2020; Joshi *et al.,* 2022) with four species occurring in the Western Ghats region of Kerala. They are *Burmagomphus pyramidalis* Laidlaw, 1922; *B. laidlawi* Fraser, 1924; *B. cauvericus* Fraser, 1926; and *B. chaukulensis* Joshi, Ogale & Sawant, 2022. The present study, described the nymphal features of two species *B. laidlawi* an endemic species of Wetsern Ghats (Gopalan *et al.,* 2022) and *B. pyramidalis.* The exuviae of both species are compared with all other congeneric species described (Refer Appendix Table IV). The major difference is observed in the presence and shape of mid-dorsal spines. In *B. laidlawi* well-developed mid-dorsal spines with sharp pointed end are present on S7–S9. In contrast, the exuvia of *B. pyrmidalis* is characterized by the presence of mid-dorsal protuberances with blunt ends from S2–S9. The nymphal features of the remaining two endemic species, *B. cauvericus and B. chaukulensis* are yet to be described.

Megalogomphus hannyngtoni (Fraser, 1923) and *Megalogomphus superbus* Fraser, 1931 are the two representative species of the genus Megalogomphus in Kerala. Both are endemics to the Western Ghats (Gopalan *et al.,* 2022). *M. hannyngtoni* is placed in

near threatened category of the IUCN Red List (Subramanian *et al.,* 2018). *M. superbus* is a very rare dragonfly of Kerala and was not recorded after Fraser 1934 (Nair *et al.,* 2021). Nymphal features of three species *M. hannyngtoni* (India), *M. ceylonicus* (Srilanka) and *M. icterops* (Malay Peninsula) are already described (Fraser, 1922, 1931 & Lieftinck, 1941). The features of the collected exuviae were compared with those of the described species. Differences were observed in the body size, the number of palpal teeth and also in the shape of mid dorsal spines (Refer Appendix Table V). *M. superbus* shows similarity to *M. hannyngtoni* only in body size, which ranges from 40–44mm. The sharply pointed, mid-dorsal spines are present from S1–S9 in *M. hannyngtoni* and in *M. superbus* the spines were blunt ended and located on S2–S9. The presence of exuviae indicated the successful breeding of this rare and endemic species at the study sites.

Microgomphus is represented by three species in India (Kalkman *et al.,* 2020). *Microgomphus souteri* Fraser, 1924, *Microgomphus torquatus* (Selys, 1951) and *Microgomphus verticalis* (Selys, 1973). All are endemic to Western Ghats. *M. souteri* is the only species of the genus Microgomphus in Kerala (Nair *et al.,* 2021). The nymphal description of *M. torquatus* was done by Fraser (1919). The features of the already described nymphs in the genus Microgomphus were tabulated (Refer Appendix Table VI). They show differences mainly in the number of premental and palpal teeth. The exuvia of *M. souteri* is different from that of *M. torquatus* in the body size and in absence of dorsal protuberance and show close resemblance to *M. camerunensis* and *M. svilheri* by the presence of lateral spines on S4–S9. *M. souteri* is different from all described species by the number of premental and palpal teeth (Refer Appendix Table VI).

Onychogomphus malabarensis (Fraser, 1924) is a very rare and endemic dragonfly species of the genus *Onychogomphus* reported from the state of Kerala by Fraser (1934). There were no records of adult sightings after Fraser (Nair *et al.,* 2021). The features of the exuviae were compared with other congeneric species of *Onychogomphus* (Appendix Table VII). Exuvia of *Onychogomphus malabarensis* shows close resemblance to South East Asian species *O.castor* by the presence of mid dorsal spines on S2–S9, lateral spines on S6–S9. The difference is observed in the

number of premental and palpal teeth. The presence of exuviae indicates the successful breeding of this rare and endemic species in the study site.

The genus Macrogomphus is represented by two species in Western Ghats *Macrogomphus annulatus* (Selys, 1854) and *Macrogomphus wynaadicus* Fraser, 1924. Both are endemic to Western Ghats but their distribution range is different. *M.annulatus* has been reported from Western Ghats region of Maharashtra so far (Fraser, 1934; Prasad, 1996) and *M.wynaadicus* from Kerala (Nair *et al.,* 2021).The exuviae of the genus Macrogomphus were found on the shores and also on rocks in the river Kabani at Thonikadavu in Perikkalur (Wayanad). Nymphal features on exuvia were compared with the description of *M.annulatus* by Fraser (1919) and identity confirmed. The exuviae is elongated, with cylindrical abdomen and is characterised by the presence of an elongated S9 with a spine which forms a siphon along with S10, projecting from the mud for respiration (Fraser, 1919). Thus *Macrogomphus annulatus*, an endemic species of India is reported for the first time from Kerala by the presence of its exuvia.

The genus Ictinogopmhus and Paragomphus were represented by single species in Kerala as *Ictinogopmhus rapax* and *Paragomphus lineatus*. Adambukulam and Kakkassery (2013a) described the nymphal features of *Paragomphus lineatus* as a part of a pilot study of this research work. Nymph of *Ictinogomphus rapax* was described by Begum *et al.,* (1980) and Kumar (1984i). Collected exuviae shows more resemblance to the description of Begum *et al.,* (1980) than Kumar's description as it has a more rounded abdomen, mid dorsal spines on S1–S9 and vestigial S10. The exuvia also possess lateral spines on S4–S9. *Paragomphus lineatus* (Selys, 1850)has been described by Kumar (1973) as *Mesogomphus lineatus*. The features on the collected exuviae such as four segmented antennae, strongly convex distal margin of prementum, presence of mid dorsal protuberances on S2–S9 and lateral spines on S3–S9 exactly matches with that of Kumar's description.

Family Libellulidae is the most dominant dragonfly family with 31 genera and 50 species in Kerala (Gopalan *et al.,* 2022). Of the fifty species reported in Kerala, nymphal features of eighteen species were described (Refer Appendix Table IX) in the present study from different study sites. Descriptions of *Zygonyx iris* (Selys, 1869) and *Hydrobasileus croceus* (Brauer, 1867) were done for the first time from India and

eleven species were described for the first time from Kerala and South India by using their exuviae.The remaining five species was described for the first time from Kerala by Adambukulam & Kakkassery (2013a & 2013b) which was a pilot study for this research (Refer Table 5, Chapter 4).

Acisoma panorpoides is the only representative of the genus in Kerala. The exuviae were found in all types of fresh water ecosystems. The nymph was described by Kumar (1984) and features on exuviae was compared with literature. No difference is observed from the previous description in published literature.

Brachythemis contaminata (Fabricius, 1793) is the single representative of the genus. The life history was studied by Kumar (1984) and Begum *et al.,* (1982). Brownish yellow exuviae were observed from all fresh water ecosystems of different locations. Features were compared with the previous description in the published literature and no difference was observed.

Genus *Bradinopyga* is represented by two species in Kerala, *Bradinopyga geminata* (Rambur, 1842) and *Bradinopyga konkanensis* Joshi & Sawant, 2020 (Gopalan *et al.,* 2022). The nymph of *B.geminata* was described by Sangal and Kumar (1970a). Exuviae of *Bradinopyga geminata* were found only in man made cement bottomed pools in gardens and parks in different localities of Thrissur district. Features on exuviae were compared with the described features and no difference is observed. The nymph of *B. konkanensis* are yet to be described.

The genus *Diplacodes* is represented by three species in Kerala namely *Diplacodes trivialis,* (Rambur, 1842), *Diplacodes nebulosa* (Fabricius, 1793) and *Diplacodes lefebvrii* (Rambur, 1842). The life history of *D.trivialis* was described (Kumar, 1984). Nymphal features on exuviae were compared with the description in the literature and found to be same.

Hydrobasileus croceus (Brauer, 1867) is a single species reported from the genus Hydrobasileus in Kerala (Gopalan *et al.,* 2022). The description was done for the first time from India. Exuviae were found in natural ponds and vegetations along the canal systems of different locations from Thrissur and Palakkad districts. Exuvia is characterized by the presence of large labium with twelve premental and nine palpal

setae, well developed backwardly directed hook like dorsal spines on S3–S8 and enlarged lateral spines on S8–S9.

Lathrecista asiatica (Fabricius, 1798), is the only species from the genus in Kerala (Gopalan *et al.,* 2022). The nymph was described for the first time by Adambukulam and Kakkassery in (2013b) during a pilot study for this research. Exuviae were observed from natural ponds and rivers. The exuvia is characterized by the presence of 14 premental and 11 palpal setae; absence of mid dorsal spines and poorly developed lateral spines and a tuft of hairs at the ventral position of S9 (Adambukulam & Kakkassery, 2013b).

The genus *Orthetrum* is represented by eight species in Kerala (Gopalan *et al.,* 2022). The exuvia of *Orthetrum sabina* (Drury, 1773) is described in the present study. The exuviae were observed in all types of fresh water ecosystems such as ponds, pools, paddy fields, rivers, kole wet lands and lakes. The life history was studied by Kumar (1989). The nymph was described by Chowdhury & Akhteruzzaman, (1981) in which the 11 premental and 9 palpal setae, mid dorsal spines on S3–S9, lateral spines on S8–S9 and the presence of tuft of hairs on ventral side of S9. Collected exuviae shows a difference in the number of palpal setae. The palpal setae is seven in the collected exuviae instead of nine. The reason for this difference needs to be investigated.

Three species from the genus *Neurothemis* has been reported from Kerala (Gopalan *et al.,* 2022). They are *Neurothemis tullia* (Drury, 1773), *Neurothemis intermedia* (Rambur, 1842) and *Neurothemis fulvia* (Drury, 1773). The nymphal features of *N. tullia* and *N. intermedia* were earlier described (Kumar, 1988; Begum *et al.,* 1990, & Suri Babu, 2000). In the present study the exuviae were found in natural ponds, streams, rivers and in irrigation canals associated with paddy fields. The features in the collected exuviae were compared with the descriptions in the published literature and no difference is observed. *N. tullia* is differentiated from *N. intermedia* in the number of premental and palpal setae and by the absence of mid dorsal spines. In the former 13 premental and 8 palpal setae and in the latter it is 14–16 and 11–13. Mid-dorsal spines are absent in *N. tullia* but it is presnt in *N. intermedia* on S3–S9 (Babu, 2000). The nymph of *N. fulvia* are yet to be described.

Pantala flavescens (Fabricius, 1798) is the single representative species present in the genus from Kerala. Exuvia were observed from paddy fields of Thrissur and Palakkad district and mass emergence was observed during post monsoon season. Adambukulam and Kakkassery described the nymphal features from exuviae (2013a) in a pilot study of this research. Exuviae characterized by the presence of dark spots on the body, enlarged labium with 17 premental and 13 palpal setae, crenulated palpus, absence of mid-dorsal spines and well-developed lateral spines on S8–S9. Features on exuviae were compared with the previously published literature of Kumar (1973). No differences were observed in the features.

Nymph of *Rhodothemis rufa* and *Urothemis signata* were described by Kumari and Nair (1981 & 1983) by rearing the nymphs in the laboratory. Exuviae of both species were found in natural ponds and temporary ponds associated with paddy fields and described in the present study. Features on the collected exuviae were compared with the available published literature and no difference was observed. Exuvia of *Rhodothemis rufa* is characterised by short body with long legs, 14 premental and 8 palpal setae and a small lateral spine on S9. Exuviae of *Urothemis signata* characterised by the presence of 12 premental and 8–10 palpal setae and mid dorsal spines on S4–S8.

Rhyothemis variegata (Linnaeus, 1763) and *Rhyothemis triangularis* (Kirby, 1889) are the two species reported in Kerala (Gopalan *et al.,* 2022). The nymph of *R.variegata* has been described by (Chowdhury & Akhteruzzaman, 1981). Exuviae were observed in temporary ponds associated with paddy fields in Thrissur and Palakkad districts. Nymphal features on the collected exuviae when compared with the available published literature showed difference in the number of premental setae. In the description, the number of premental setae is two, whereas in the collected exuviae, only one premental setae is observed. The reason for this difference is not known. The nymph of *R. triangularis* is still to be described.

Exuviae of *Tholymis tillarga* were observed in natural ponds, canals, rivers and also from man-made cement bottomed pools. The nymph was described by Fraser, (1919), Kumar, (1973) and Chowdhury & Akhteruzzaman, (1981). Features on the exuvaie were compared with the available published literature and no major difference was

observed. Exuviae were characterized by the presence of 8 premental and 5 palpal setae, hook like mid dorsal spines on S4–S10 and lateral spines on S8–S9.

Tramea basilaris (Palisot de Beauvois, 1817) and *Tramea limbata* (Desjardins, 1835) are the two species reported in Kerala from the genus *Tramea* (Nair *et al.,* 2021). The nymphal features of *T. basilaris* has been described by Kumar (1973c). Exuviae of *T. basilaris* were observed in weedy ponds and man made cement pool in a park in Thrissur. Features on the exuviae was compared with the nymphal description by Kumar, (1973c) and no difference is observed in the collected exuviae.

Genus *Trithemis* represented by four species in Kerala (Gopalan *et al.,* 2022) *Trithemis aurora* (Burmeister, 1839), *Trithemis festiva* (Rambur, 1842), *Trithemis kirby* Selys, 1891 and *Trithemis pallidinervis* (Kirby, 1889). The nymphal features of *T.aurora* and *T. festiva* was described by Kumar (1973c). Exuviae of these two species were collected from ponds and rivers of Thrissur, Palakkad and Wayanad. Features on the exuviae were compared with published literature. *T. aurora* and *T. festiva* can be differentiated by the number of premental and palpal setae. In *T. aurora* 10 premental setae and 7 palapl setae whereas in *T. festiva* it is 11 and 6 respectively. The shape of the mid-dorsal spines also helps to differentiate the two speices. In *T. aurora* the spines are more hook like whereas in *T. festiva* they are more spine like. The nymphal features of the remaining two species *T. kirby* and *T. pallidinervis* are yet to be described.

The nymph of *Zyxomma petiolatum* Rambur, 1842 was described by Kumar (1973c) and Chowdhury & Akteruzzaman (1981). Exuvia were found in temporary ponds associated with paddy fields and also from man-made cement bottomed pools in Thrissur, Palakkad and Wayanad districts. The exuviae is characterized by its dark black colour, 13 premental and 8 palpal setae and with well-developed mid dorsal spines on S4–S10.

Zygonyx iris (Selys, 1869) is the single species from the genus Zygonyx in Kerala (Gopalan *et al.,* 2022). Large well-built exuviae were found on the exposed rocks in the river Kabani near Kuruva island and also from Pakkaom. The exuvia resembles Corduliidae, but on close examination showed typical characteristics of Libellulidae. Few teneral adults were found associated with the nearby vegetation and rocks. They

were identified as *Z. iris*. The nymphal features on the exuviae were compared with the already described congeneric Srilankan species *Z. iris ceylonicus* (Refer Appendix Table X). The major difference between the two species were in the number of premental, palpal setae and in the number and shape of mid dorsal spines. In *Z. iris* 12 premental and 9 palpal setae whereas in Z. *iris ceylonicus* it is 10 and 9 respectively. Also the mid dorsal spines were located on S2–S10 in *Z. iris* and in *Z. iris ceylonicus* it is located on S3–S9.

The family Macromiidae was represented by ten species in Kerala and of these ten seven are endemic to Western Ghats (Gopalan *et al.,* 2022). Of these, larval descriptions of *Epopthalmia frontalis*, *E. vittata*, and *Macromia flavocolorata* has been published (Fraser, 1919 & 1922; Xu, 2010). Nymphs of family Macromiidae is characterized by the presence of very long legs, which gives a spidery appearance to the nymphs (Fraser, 1919). In the present study exuviae with very long legs were observed from the river Kabani at Thonikkadavu. The presence of teneral adults in the nearby vegetation confirmed the identification of the exuviae as *Macromia flavocolorata* (Fraser, 1922) and the endemic species *Macromia indica* (Fraser, 1924). *M. flavocolorata* is characterized by the presence of long legs, horns in the head region, seven premental and five palpal setae. These features were compared with Fraser (1922) and Xu (2010) and no major difference was observed. *M.indica* is different from other described species by its small size, presence of 8 premental and 6 palpal setae. All the features were compared with the already described species of the genus (Refer Appendix Table XI). *M.indica* shows a close resemblance to *M. calliope* (Xu, 2016) in the number of premental and palpal setae, but is smaller in size. The nymphal features on the exuviae of *M. flavocolorata* and *M. indica* were compared (Refer Appendix Table XII) and differences were observed in body size, shape of abdomen and in number of premental and palpal setae.

Odonate nymphs are highly specific in their habitat. The adults use both lotic and lentic fresh water habitats for their breeding. The present research work also documented and summarised the breeding sites and emergence period of all thirty described species (Refer Table 6, Chapter 4). Subramanian *et al.,* (2008) commented that most of the endemic species restricted to forested riverine habitats and habitats like ponds, lakes, irrigation canals and paddy fields have common and wide spread

species. In the present study the exuviae of rare and endemic species from families Gomphidae, Macromiidae and that of *Zygonyx iris* of family Libellulidae were observed in forested riverine habitats and are they emerged during premonsoon period (Refer Table 6 Chapter 4). The emergence of riverine species during premonsoon period is due to the fact that during monsoon and postmonsoon seasons, the water level in the rivers are usually high which will result in reduction of exposed emergence sites. *Zygonyx iris* is highly specific in their breeding habitat. They exclusively breeds in rivers closely associated to forest (Fraser, 1938). In the present study, the exuviae were found in riverine habitat of river Kabani near Kuruva Island.

Members of Aeshnidae prefers rivers and streams as their breeding sites (Kumar & Sangal, 1973, Fonseka, 2000). But in the present study exuviae of both *Anax indicus* and *Gynacantha dravida* were observed from weedy ponds and temporary or seasonal ponds associated with paddy fields in Thrissur and Palakkad districts.Their emergence is reported only during the monsoon season.

Family Libellulidae were diverse in their breeding sites (Fonseka, 2000). The present study observed that members of the family Libellulidae breeds in all types of freshwater ecosystems and their emergence were observed in all three seasons (Refer Table 6 Chapter 4). Species like *Orthetrum sabina, Brachythemis contaminata* and *Tholymis tillarga* become dominant in terms of their breeding sites and emergence period. Exuviae of these species were observed from all types of ecosystems and their emergence reported in all three seasons (pre monsoon, monsoon, & post monsoon). *Bradinopyga geminata* breeds only in man-made cement bottomed pools and no other species were found to breed in those pools where *B. geminata* breeds. Exuviae of *Trithemis aurora* and *Trithemis festiva* were found in natural ponds, streams and rivers. *Tramea basilaris, Urothemis signata, Neurothemis tullia,* and *Zyxomma petiolatum* were observed mainly from ecosystems such as ponds, rivers, irrigation canals and paddy fields. In addition to these natural habitats their exuviae were also found in man-made cement bottomed pools in gardens and parks which is not reported in previous studies. Species like *Acisoma panorpoides, Diplacodes trivialis, Hydrobasileus croceus, Lathrecista asiatica, Pantala flavescens, Rhodothemis rufa,* and *Rhyothemis variegata* primarily prefer ponds and canals associated with paddy fields, kole wetlands for their breeding.

Fraser (1919, 1925, 1933, 1934, & 1936) and Kumar (1971a,1971b, 1972a, 1972b, 1973a, 1973b, 1973c, 1973d, 1980, 1981, 1984a, 1984b, 1984d, 1984e, 1984i, 1988b, 1989b, & 1990b) in their nymphal studies, described the habitats of the nymphs. A summary of the breeding sites mentioned in published literature was compared with the breeding sites in the present study (Refer Appendix Table XIII) and many new sites could be associated with the breeding of the described species. This indicates that periodical and systematic survey can increase the existing knowledge of breeding sites of odonates.

The present study documented that the nymphal studies of dragonflies could be done by using their exuviae which possess all the nymphal features of the last instar and could be identified up to species level. This is a non-invasive method which will not disturb the existing diversity of nymphs and adults in an ecosystem. Thus this method could be adopted for the study of nymphal features of rare and endemic dragonfly species.The present study also throws light on the breeding sites of both common and endemic odonate species, which would help in future studies of nymphal ecology. Such ecological studies are crucial for the assessment of health of the aquatic ecosystems.

CHAPTER 6
RECOMMENDATIONS

CHAPTER 6

RECOMMENDATIONS

Based on the findings of this study recommendations are:-

1. Exuvia is the last instar larval skin which possess all the larval features, hence it could be used for the identification of the nymphs and adults up to species level.

2. Exuvia monitoring is a non-invasive method and will not affect the diversity of both adults and nymphs in particular ecosystem hence this method could be adopted for the diversity and population studies of both adult and nymphal studies.

3. Relevance of exuviae as an indication to actual adult dragonfly population needs to be explored. With proper identification of the exuviae, the presence and absence of the adult dragonflies could be determined to evaluate the ecosystem health.

4. Presence of exuvia could be used to monitor some rare and endemic dragonfly species whose adults are not commonly sighted in field. For example exuviae of *Onychogomphus malabarensis,* a rare and endemic dragonfly of Westerns Ghats whose adults were not reported after Fraser (1934) were observed from a study site which indicates the presence of their nymphs and inturn their adults in that area.

5. Rare and endemic species prefer riverine habitats as their breeding sites and emergence found to occur during premonsoon period. It is suggested to conduct surveys during these periods in such habitats for exploring the nymphs of rare and endemic species.

6. Out of 100 species of dragonflies reported in Kerala, nymphal studies of 30 species were conducted. Nymphal taxonomy of remaining species from Kerala and India must be studied. Nymphal taxonomy of damselflies also needs to be explored.

7. A detailed study of the ecology and life cycle of many species are still unknown and are to be studied.
8. Effect of climate change, habitat degradation, land use change and other anthropogenic drivers on the life cycle, emergence and population of this group needs to be investigated.
9. Effort to isolate DNA from exuviae collected during this study was not successful. Developing techniques to isolate DNA from exuviae is also suggested.

10. Studies revealing the role of dragonfly nymphs as predators and bio indicators are recommended.

Tips to overcome the challenges during exuvia collection.

Collection of exuviae can be challengeing due to many reasons.

1. The emergence sites such as steep banks, swamps, and water logged areas are often inaccessible. It is better to use small canoe for accessing these emergence sites.
2. The emergence of most of the species occurs during late night and early morning, so the teneral adults can be seen only if the observer is present during the emergence period. Future workers could keep this in mind while designing the study.
3. The exuviae can be washed out by rain or wind which could make the survey unsuccessful. So it is better not to conduct exuviae on rainy days.
4. Since the emergencne sites are mainly water associated habitats it is better not to conduct surveys all alone.

CHAPTER 7
SUMMARY

CHAPTER 7
SUMMARY

The order Odonata comprises Dragonflies and Damselflies. They are amphibiotic organisms with an aquatic nymphal life and terrestrial adult life. Both adults and nymphs act as bio indicators. Only very few studies have been conducted on the nymphal taxonomy of dragonflies of Kerala. At the end of the aquatic life, the nymphs climbs to suitable substratum like marginal vegetation, plant roots, exposed rocks or even to sand in the bank to split off their last instar skin before flying away. This last instar skin is called Exuvia. The exuviae bear the species specific features of the last instar and it could be used for the identification up to species level.

Exuviae were collected from different study sites where the possibility of finding exuviae was high such as natural and man-made ponds, lakes, rivers, canals, paddy fields, wetlands and cement bottomed pools in gardens and parks. A total of 45 such study sites were selected randomly from five districts of Kerala. Collection of the exuviae were done in the early morning hours and collected exuviae were transferred to small plastic containers. Teneral adults just emerged and found associated with the exuviae also helped to identify the species. Exuviae were dissected and nymphal features on the exuviae were photographed by using Leica S8AP0 and Nikkon D750 SLR. These features were compared with the available literature.

A total of 30 species of dragonfly nymphs belonging to four families such as Aeshnidae (2) Gomphidae (8) Macromiidae (2) and Libellulidae (18) were identified by using their exuviae. Of these thirty species, ten, including five endemics, were described for the first time in the world and two were described for the first time in India. They are *Anax indicus* Lieftinck, 1942; *Gynacantha dravida* Lieftnck, 1960; *Burmagomphus laidlawi* Fraser, 1924; *Burmagomphus pyramidalis* Laidlaw, 1922; *Microgomphus souteri* Fraser, 1924; *Onychogomphus malabarensis* (Fraser, 1924), *Megalogomphus superbus* Fraser, 1931, *Macromia indica* Fraser, 1924, *Hydrobasileus croceus* (Brauer, 1867), and *Zygonyx iris* (Selys,1869). Of the remaining 20 species, 15 species were described for the first time from Kerala and South India, and the remaining five were already described as a part of the pilot study for this research.

Taxonomic features present on the exuviae were photographed. Photographic plates of the exuviae displaying all visible identifying features which will aid future research were prepared. A preliminary taxonomic key, based on the morphological features on the exuviae was also prepared.

Breeding sites of all collected species were documented. From the study it was observed that the more common species prefer habitats such as natural ponds, streams, irrigation canals, temporary ponds as their breeding ground whereas the rare and endemic species prefer forested riverine habitats for their breeding. Those species breeding in rivers were found to emerge during premonsoon season where as emergence of more common species occur in all seasons. Presence of exuviae provide information regarding the successful breeding of the species in a particular habitat. Presence of exuviae confirms the presence of rare and endemic species which are scarcely observed as adults in the field.

Since exuviae are the last instar larval skin, collection of exuviae will not affect the existing diversity of both adults and nymphs.Thus, being a non-invasive method for diversity studies of dragonflies, it could be suggested for studies of dragonfly nymphs of endangered and protected species. Collection of the exuviae in a regular manner will facilitates the evaluation of the aquatic ecosystems over time.

REFERENCES

REFERENCES

Adambukulam, S. P., & Kakkassery, F. K. (2013a). Taxonomic and Diversity studies on Odonate nymphs by using their Exuviae. *Journal of Entomology and Zoology studies, 1* (4), 47–53.

Adambukulam, S. P., & Kakkassery, F. K. (2013b). Taxonomic studies of the last instar nymph of *Lathrecista asiatica asiatica* (Fabricius 1798) (Family: Libellulidae, Order: Odonata) by using its Exuvia. *Journal of Entomology and Zoology studies*, *1* (5), 103–109.

Adambukulam, S. P., & Kakkassery, F. K. (2023a). Description of final instar larva of *Burmagomphus laidlawi* Fraser, 1924, an endemic of the Western Ghats, India (Odonata: Gomphidae) *Odonatologica, 52* (3/4) 247–254.DOI:10.60024/odon. V.52i3-4.a7.

Adambukulam, S. P., & Kakkassery, F. K. (2023b). Taxonomical studies of dragonfly nymphs (Odonata, Libellulidae) using their exuviae. *Entomon, 48* (4): 497–510. https://doi.org/10.33307/entomon/v48i4/983.

Andrew, R. J., Subramanian, K. A., & Tiple, A. D. (2008). Common Odonates of Central India. *E-book for the 18th International Symposium of Odonatology*. Hislop College, Nagpur, India. Available from: http://www. intecol.net //down.php.

Andrews, R. J., & Patankar, N. (2010). The process of moulting during final emergence of the dragonfly *Pantala flavescens* (Fabricius, 1798) (Anisoptera: Libellulidae), *Odonatologica, 39* (2) 141–148.

Arguel, L., Denis, A. S., Danflous, S., Gouix, N., Santoul, F., Buisson, L. & Pelozuelo, L. (2022). Detection and Monitoring of Riverine Dragonfly of Community Interest (Insecta: Odonata): Proposal for a Standardised Protocol Based on Exuviae Collection. *Diversity*, *14*, 728. https://doi.org/10.3390/.

Asahina, S. (1982b). The larval stage of the Himalayan *Neallogaster hermionae* (Fraser, 1927) (Anisoptera; Cordulegasteridae) *Odonatologica, 11* (4), 309–315.

Bedjanic, M. (2000). Description of the last larval instar of *Epophthalmia vittata cyanocephala* (Hagen, 1867) (Anisoptera: Corduliidae). *Odonatologica, 29* (1), 57–61.

Begum, A., Bashar, M. A., & Biswas, B.R. (1980). Life history of *Ictinogomphus rapax* (Rambur, 1842) (Anisoptera: Gomphidae), *Bangladesh Journal of Zoology, 8* (1), 53–60.

Begum, A., Bashar, M. A., & Biswas, V. (1991). Description of larval instars and some aspects on biology of *Urothemis signata signata* (Rambur, 1842) (Odonata: Libellulidae). *Dhaka University Studies, (E) 6* (2), 125–132.

Begum, A., Bashar, M. A., & Nasiruddin, M. (1985). Studies on the life history of *Crocothemis servilia servilia* (Drury, 1770) (Anisoptera: Libellulidae). *Dhaka University Studies, (B) 33* (1), 137–143.

Begum, A., Bashar, M. A., Ahmed M. U., & Biswas, V. (1993). Studies on the life history of *Potamarcha congener* (Rambur, 1842) (Odonata: Libellulidae) *Annals of .Entomological Society of America, 11* (1), 26–33.

Begum, A., Bashar, M.A., & Biswas, B.R. (1982a). Life history and external egg and larval morphology of *Brachythemis contaminata* (Fabricius, 1793) (Anisoptera: Libellulidae). *Odonatologica, 11* (2), 89–97.

Begum, A., Bashar, M.A., & Biswas, B.R. (1982b). Studies on the life history of *Zyxomma petiolatum* (Odonata: Libellulidae) *Odonatologica*, *11* (2), 98–102.

Belle, J. (1972). An Unknown Gomphid larva from Surinam, possibly *Progomphus geijskesi* Needham, 1944 (Odonata) *Odonatologica, 1* (2), 113–116.

Belle, J. (1991). The Ultimate instar larvae of Central American species of *Progomphus* (Selys) with a description of *Progomphus belyshevi* spec. nov. from Mexico (Anisoptera: Gomphidae) *Odonatologica, 20* (1), 9–27.

Belle, J. (1992). Studies on Ultimate instar larvae of Neotropical Gomphidae with a description of *Tibiagomphus* nov. (Anisoptera) *Odonatologica, 21* (1), 1–24.

Bick, G. H. (1941). Life history of the dragonfly *Erythemis simplicicollis* (Say, 1839), *Annals of Entomological Society of America, 34* (1), 215–230.

Bick, G. H. (1951a). The nymph of *Libellula semifaciata* (Burmeister, 1839) (Odonata: Libellulidae) *Proceedings of the Entomological Society of Washington, 53* (5), 247–250

Bick, G. H. (1951b). The early nymphal stages of *Tramea lacerata* (Hagen, 1861) (Odonata: Libellulidae) *Entomological News*, *62* (10), 293–303.

Bick, G. H. (1953). The nymph of *Miathyria marcella* (Selys, 1857) (Odonata: Libellulidae) *Proceedings of the Entomological Society of Washington*, *55* (1), 30–36.

Bick, G. H. (1955). The nymph of *Macrodiplax balteata* (Hagen, 1861) *Proceedings of the Entomological Society of Washington, 57* (4), 191–196.

Bird, R. D. (1934). The emergence and nymph of *Gomphus militaris* (Hagen, 1858) (Odonata: Gomphidae) *Entomological news, .45*, 44-46

Boonsoong, B., & Chainthong, D. (2014a). Description of the final instar larva of *Heliogomphus selysi* (Fraser, 1925) (Odonata: Gomphidae) *Zootaxa, 3764* (4), 482–488. https://doi.org/10.1 1646/ zootaxa. 3764.48

Boonsoong, B., & Chainthong, D. (2014b). Description of the last stadium larva and female of *Microgomphus thailandica* Asahina, 1981 (Odonata: Gomphidae) *Zootaxa, 3811* (2), 271–279. https://doi.org/10.11646/zootaxa.3811.2.8.

Borisov, S.N. (2008). The Larvae of *Anormogomphus kiritshenkoi* Bertenef, 1913 (Odonata, Gomphidae). *Euroasian Entomological Journal, 7* (4), 307–310.

Brochard, C., Ploeg, E., Seidenbusch, R., & Chelmick, D. (2013). The identification of the exuviae of the genus *Trithemis* (Family: Libellulidae) found in Europe. *Boletin Rola n^{o} 2 mayo,* 5–25.

Broughton, E. (1928). Some new Odonata nymphs. *Canadian Entomologist*, *60* (2), 32–34.

Butler, S. G (2007a). The larva of *Gomphidia t-nigrum* Selys, 1854 from Nepal (Anisoptera: Gomphidae). *Odonatologica, 36* (4), 399–403.

Butler, S. G. (1992). The larvae of *Orthetrum nitidinerve* Selys, 1841 (Anisoptera: Gomphidae). *Odonatologica, 21* (1), 73–78.

Butler, S. G. (1993a). Key to the larvae of European *Orthetrum* Newman (Anisoptera: Libellulidae). *Odonatologica, 22* (2), 191–196.

Butler, S. G. (1998). The larvae of European *Aeshnidae* (Anisoptera). *Odonatologica, 27*(1), 1–23.

Butler, S. G. (2002). The larvae of *Macromia euterpe* Laidlaw, 1915 (Anisoptera: Macromiidae). *Odonatologica, 31* (4), 383–388.

Butler, S. G. (2003a). The larvae of *Isomma hieroglyphicum* Selys 1892 (Anisoptera: Gomphidae). *Odonatologica, 32* (1), 79–84.

Butler, S. G. (2003b). The larvae of *Phyllomacromia trifasciata* Rambur 1842 (Anisoptera: Macromiidae). *Odonatologica*, *32* (2), 159–163

Butler, S. G. (2004). Description of the last instar larva of *Onychogomphus aequistylus* Selys 1892 (Anisoptera: Gomphidae). *Odonatologica, 33* (2), 189–194.

Butler, S. G. (2007b). The larva of *Idionyx stevensi* Fraser, 1924 from Nepal (Anisoptera: Corduiidae). *Odonatologica*, *36* (3), 285–290.

Butler, S. G. (2012). Description of the last instar larva of *Brachydiplax farinosa* Kruger*,* 1902 from Borneo (Anisoptera: Libellulidae). *Odonatologica, 41* (3), 277–282.

Butler, S. G. (2013). Description of the last instar larva of *Orchithemis pulcherrima* Brauer, 1878 from Sarawak, Malaysia. *Odonatologica, 42* (3), 247–251.

Butler, S. G., Chelmick, D. G., & Vick, G. S. (2006). Description of the last instar larvae of *Neodythemis hildebrandti* Karsh, 1889 and *N. afra* (Ris, 1909) with comments on the status of the genus and subfamily (Anisoptera: Libellulidae, Tetrathemistinae). *Odonatologica, 35* (3), 233–241

Butler, S. G., Steinhoff, P. O. & Dow, R. A. (2016). Description of the final instar larva of *Acrogomphus jubilaris* Lieftinck, 1964 (Odonata, Gomphidae), with information on the distribution of Acrogomphus in Borneo, *Zootaxa, 4184*(2), 367–375. https://doi.org/10.11646/zootaxa.4184.2.8.

Bybee, S. M., Kalkman, V. J., Erickson, R. J., Frandsen, P. B., Breinholt, J. W., Suvorov. A., Dijkstra, K. B., Cordero-Rivera, A., Skevington, J. H., Abbott, J. C., Sanchez Herrera, M., Lemmon, A. R.., Moriarty Lemmon, E. & Ware, J. L. (2021). Phylogeny and classification of Odonata using targeted genomics. *Molecular Phylogenetics and Evolution,* 160, 107115 .doi: 10.1016/j.ympev. 2021.107115. Epub 2021 Feb 18. PMID: 33609713.

Bybee, S. M., Ogden, T. H., Branham, M. A., & Whiting. M. F. (2008). Molecules, morphology and fossils: a comprehensive approach to odonate phylogeny and the evolution of the odonate wing. *Cladistics, 24*, 477–514.

Bybee, S., C´ordoba-Aguilar, A., Duryea, M. C., Futahashi, R., Hansson, B., Lorenzo-Carballa, M.O., Schilder, R., Stoks, R., Suvorov, A., Svensson, E.I., Swaegers, J., Takahashi, Y., Watts, P.C., & Wellenreuther, M. (2016). Odonata (dragonflies and damselflies) as a bridge between ecology and evolutionary genomics. *Frontiers in Zoology,* 13, 46.

Byers, C. F. (1927a). The nymph of *Libellula incesta* Hagen, 1861 and key for the separation of the known nymphs of the genus Libellula (Odonata). *Entomological News, 38*, 113–115.

Byers, C. F. (1927b). Notes on some American dragonfly nymphs (Odonata: Anisoptera). *Journal of New York Entomological Society, 35*, 65–74.

Byers, C. F. (1936). The immature form of *Brachymesia gravida* Calvert, 1890 with notes on the taxonomy of the group. *Entomological News, 47*. 35–48.

Byers, C. F. (1941). Notes on the emergence and life history of the dragonfly *Pantala flavescens* (Fabricius, 1798). *Proceedings of the Florida Academy of Sciences, 6* 14–25.

Cabot, L. (1872). The immature state of the Odonata Part I Subfamily-Gomphina, *Memoirs of the museum of Comparative Zoology, 2* (3). 1–17.

Cabot, L. (1881). The immature state of the Odonata Part II Subfamily-Aeshnina, *Memoirs of the museum of Comparative Zoology*, *8*, (1). 1–39.

Cabot, L. (1890). The immature state of the Odonata Part III Subfamily Cordulina, *Memoirs of the museum of Comparative Zoology, 17* (1), 1–52

Calvert, P. P. (1904). On a Nymph of *Micrathyria berenice* Drury 1773 *Entomological news, 15*, 174–175.

Carchini, G., & Domenico, DI. M. (1996). Description of the last instar larvae of *Orthetrum hintzi* Schmidt, 1951 and comparison with other African Orthetrum species (Anisoptera: Libellulidae). *Odonatologica*, *25(1)*, 73–77.

Carchini, G., & Domenico, DI. M. (2008). The last instar larva of *Gynacantha villosa* Gruenberg, 1902 and *G.manderica* Gruenberg, 1902 Anisoptera: Aeshnidae). *Odonatologica, 37* (3), 257–264.

Carchini, G., Samways M. J., & Caldwell P. M. (1992). Descriptions of the ultimate instar larvae of five higher altitude *Trithemis* species in Southern Africa (Anisoptera: Libellulidae). *Odonatologica, 21*(1), 25–38.

Carchini, G., Samways M. J., & Domenico, DI. M (1995). Description of the last instar larva of *Agriocnemis pinheyi* Balinsky 1963 (Zygoptera: Coenogrionidae), *Odonatologica, 24(1),* 109–114.

Carrico, C., Costa, J. M., Santos, C.T., & Anjos-Santos, D. (2011). Description of the last instar larva of *Phyllocycla gladiata* (Hagen in Selys, 1854) (Anisoptera: Gomphidae). *Entomo Brasilis, 4* (1), 26–29.

Carvalho, A. L (1989). Description of the larva of *Neuraeschna costalis* Burmeister, 1839 with notes on its biology, and a key to the genera of Brazillian Aeshnidae larvae (Anisoptera). *Odonatologica, 18*(4), 325–332.

Carvalho, A. L. (1987). Description of the larva of *Gynacantha bifida* Rambur, 1842 (Anisoptera: Aeshnidae). *Odonatologica, 16* (3), 281–284.

Carvalho, A. L., & Ferreira, N. Jr. (1989). Descrição da larva de *Gynacantha mexicana* Selys, 1869, e notas sobre a sua biologia (Odonata, Aeshnidae). *Revista brasileira de Entomologia, 33* (3/4), 413–419.

Carvalho, A. L., Calil, E. R., & De-Carvalho Werneck, P. C. (2002). Description of the larvae of two species of Dasythemis Karsch 1889 with a key to the genera of Libellulidae occurring in the states of Rio De Janerio and Sauo Paulo,Brazil (Anisoptera).*Odonatologica, 31* (1), 23–33.

Chainthong, D., & Boonsoong, B. (2016). Description of two final stadium *Onychogomphus* larvae from Thailand (Odonata: Gomphidae). *Zootaxa, 4066*(5), 561-570. https://doi.org/10.11646/zootaxa.4066.5.4

Chapman, R. F. (2013). *The insects Structure and Function*, 5th Edition; Cambridge University Press, USA, 962.

Chelmick, D. G. (2001). Larvae of the genus Aeshna Fabricius in Africa South of the Sahara (Anisoptera: Aeshnidae). Odonatologica*, 30* (1), 39–47.

Chesalmah, M. R., Hassan, S. T. S., Ali, A., Hassan, & Abu, A. (1999). Life history of *Neurothemis tullia* in a tropical rainfed rice field (Anisoptera: Libellulidae). *Odonatologica, 28* (1), 1–11.

Chowdhury, S. H., & Akhteruzzaman, M. D. (1981). Dragonfly (Odonata: Anisoptera) larvae from Chittagong. *Bangladesh Journal of Zoology, 9* (2), 131–144.

Clark, T. E., & Samways, M. J. (1996). Dragonflies (Odonata) as indicators of biotope quality in the Kruger National Park, South African. *Journal of Applied Ecology*, *33* (5), 1001–1012.

Corbet, P. S., (1962). *A Biology of Dragonflies*. London: Witherby, 247.

Corbet, P.S. (1999). Dragonflies: Behaviour and Ecology of Odonata, *Aquatic Insects, 23* (1), 83

Corbet, P.S., & Hoess, R. (1998). Sex ratio of Odonata at emergence. *International Journal of Odonatology. 1*(2), 99–118

Corbet, P.S., & Mc Crae A.W.R. (1981). Larvae of *Hadrothemis scabrifrons* Ris, 1910 in a tree cavity in East Africa (Anisoptera: Libellulidae). *Odonatologica, 10* (4), 311–317.

Costa, J. M., & DE Assiss, C. V. (1994). Description of the larva of *Tauriphila argo* Hagen, 1869, from Sao Paulo, Brazil (Anisoptera: Libellulidae). *Odonatologica, 23* (1), 51–54.

Costa, J. M., & Regis L. P. R. B. (2005). Description of the last instar larva of *Perithemis lais* (Perty) and comparison with other species of the genus (Anisoptera: Libellulidae), *Odonatologica, 34* (1), 51–57.

Costa, J. M., Ravanello, C. T., & Franco, S. G. M. (2008). The larvae of *Argia croceipennis* Selys, 1865, (Zygoptera: Coenogrionidae).*Odonatologica 37* (3), 265–271.

Costa, J. M., Santos, T. C., & Telles, A. M. (1999). *Phyllogomphoides annectens* Selys, 1869, description of the last instar with a key to the South American species (Anisoptera: Gomphidae). *Odonatologica, 28* (1), 79–82.

Costa, J. M., Santos, T. C., Oldrini, B. B., Triplehorn C. A., & Johnson N. F. (2011). Odonata *Estudos dos insetos* 7th edition Cengage Learning Translator, 816.

Couteyen, S., & Papazian, M. (2000). Description of the larva of *Gynacantha bispina* Rambur, 1842, (Odonata, Aeshnidae). *Entomologiste*, *56* (5), 215–219.

Dawn, P., & Chandra, K. (2016). Description of the larva of *Gynacantha millardi* Fraser, 1920 (Odonata: Aeshnidae) from Chhattisgarh, India. *Zootaxa, 4132* (2), 290–294. https://doi.org/10.11646/zootaxa.4132.2.12.

Dawn, P., (2016). Odonata Larval studies in India that remained under water, Parthenos

Dawn, P., (2019). Description of the last instar larva of *Calicnemia eximia* (Selys, 1863) (Odonata: Platyonemididae) from West Bengal India. *Zootaxa, 4657*(1), 183–187. https://doi.org/10.11646/zootaxa.4657.1.10.

Din, A., Zia, A., Bhatti, A. R., & Khan, M. N. (2013). Odonata naiads of Potohar plateau, Punjab. *Pakistan Journal of Zoology 45*(3), 695–700.

Domenico, DI. M., Carchini, G., & Samways, M. J. (1994). Description of the last instar larvae of *Phyllogomphus brunneus* Pinhey 1976 (Anisoptera: Gomphidae). *Odonatologica 23* (4) 413–419.

Domenico, DI. M., Carchini, G., Samways, J. M. & Whiteley, G. (2001). Descriptions of the last instar larvae of *Chalcostephia flavifrons* Kirby 1889 and comparison with other Brachydiplactinae (Anisoptera: Libellulidae). *Odonatologica, 30* (1), 97–101.

Domenico, DI. M., Clausnitzer, C., & Carchini, G. (2006). Larval morphology of three species of the genus *Hadrothemis* Karsch (Anisoptera: Libellulidae). *Odonatologica, 35* (2) 117–125.

Domenico, DI. M., Dijkstra, B., & Carchini, G. (2016). Redescription of the larva of *Gynacantha cylindrata* Karsch, 1891 (Insecta: Odonata: Aeshnidae). *Zootaxa, 4078* (1), 78–83. http://dx.doi.org/ 10.11646/zootaxa.4078.1.8

Domenico, DI. M., Samways, M. J., & Carchini, G. (1996). Description of the last instar larvae of *Agriocnemis F. falcifera* Pinheyi, 1959 (Zygoptera: Coenogrionidae), *Odonatologica, 25* (3), 297–301.

Dumont H. J., Haritonov A. Y., & Borisov S. N. (1992). Larval morphology and range of three West Asiatic species of the genus Onychogomphus Selys, 1854. (Insecta: Odonata). *Hydrobiologia 245*, 169–177.

Ellenrieder, V. N. (2007b). Some Libellulidae larvae from the Yungas forest, Argentina: *Macrothemis hahneli* Ris, 1913 *Brechmorhoga nubecula* Rambur, 1842 and *Dasythemis mincki clara* Ris, 1908 (Anisoptera).*Odonatologica, 36* (3), 263–273.

Etscher, V., Miller, M. A., & Burmiester, E. G. (2006). The larva of *Polythore spaeteri* Burmiester & Borzsony, 2003, with comparison to other polythorid larvae and molecular species assignment (Zygoptera: Polythoridae).*Odonatologica, 35* (2), 127–142.

Ferreira, S., Antón, G.V., Brochard, C., Vieira, C., Alves, P. C., Thompson, D. J., Watts, P. C., & Brito, J. C. (2014). A Critically Endangered new dragonfly species from Morocco: *Onychogomphus boudoti* sp. nov. (Odonata: Gomphidae). *Zootaxa 3856,* (3), 349–365

Ferro, L. M., & Sites, W. R. (2006). Description of the larva of *Gomphidictinus perakensis* Laidlaw, 1902 (Odonata: Gomphidae) with distributional notes. *Proceedings of the Entomological Society of Washington, 108* (1), 76–81.

Folsom, T. C. & Manuel, K. L. (1983). The life cycle of the Dragonfly *Lanthus vernalis* Carle, 1980 from a mountain stream in South Carolina, United states (Anisoptera: Gomphidae).*Odonatologica, 12* (3), 279–283.

Foster, S. E., & Soluk, D. A. (2004). Evaluating exuvia collection as a management tool for the federally endangered Hines's emerald dragonfly, *Somatochlora hineana* Williamson, 1931 (Odonata: Cordulidae). *Biological Conservation, 118*, (1), 15–20.

Frank Suhling., Ole Muller & Andreas Martens (2014). The dragonfly larvae of Namibia, *Libellula Suppliment 13*, (5), 1–103.

Frantsevich, L. & Frantsevich, L (2018). Leg deformation during imaginal ecdysis in the downy emerald, *Cordulia aenea* (Odonata, Corduliidae). *Zoology*, *127*, 106–113. https://doi.org/10.1016/j.zool.2018.01.001.

Fraser, F. C. (1919a). The larva of *Micromerus lineatus* Burm. *Records of the Indian Museum, 16* (2) 197–198.

Fraser, F. C. (1919b). Description of new Indian Odonate larvae and Exuviae. *Records of the Indian Museum, (B), 16* (7), 459–467.

Fraser, F. C. (1920). Description of *Rhinocypha* larva from Shillong *Memoirs of Department Agriculture India (Entomology), 7*(2), 13–14

Fraser, F. C. (1921). Further notes on *Rhinocypha* larvae, *Memoirs of department of Agriculture in India, Entomological Series*, 7, 79–81.

Fraser, F. C. (1922). Notes on new and rare Indian Dragonflies. *Jouranl of Bombay Natural History Society* 29(1–2).

Fraser, F. C. (1925). The true position of the genera Orogomphus and Chlorogomphus as demonstrated by a study of the larvae of *O. atkinsoni* and *O. campioni* and by a comparison of the latter with the larva of *Anotogaster nipalensis* (Odonata).

Records of the Zoological Survey of India, *27* (5), 423–429. https:// doi.org/10.26515/rzsi/v27/i5/1925/163442.

Fraser, F. C. (1931). Additions to the Survey of the Odonate (Dragonfly) Fauna of Western India, with descriptions of nine new species. *Records of the Zoological Survey of India*, *33*(4), 443–474. https:// doi.org/ 10.26515/ rzsi/v33 /i4/ 1931/ 162484.

Fraser, F. C. (1933). *Fauna of British India Odonata Vol I.* Taylor and Francis Ltd, London, 423

Fraser, F. C. (1934). *Fauna of British India Odonata Vol.II*. Taylor and Francis Ltd, London, 398.

Fraser, F. C. (1936). *Fauna of British India Odonata Vol.III.* Taylor and Francis Ltd, London, 461

Fraser, F. C. (1943). New Oriental odonate larvae. *Proceedings of the Royal Entomological Society, London, (B). 12* (5/6), 81–93. https://doi.org/ 10.1111/ j.1365-3113.1943.tb00749.x.

Garrison, M. C., & Tennessen, K. J. (2020). Collection guide lines for exuvia.Nymph Cove, *ARGIA, 32* (3), 18–19.

Gopalan, S.V., M. Sherif & Chandran A. V. (2022). A checklist of dragonflies & damselflies (Insecta: Odonata) of Kerala, India. Journal of Threatened Taxa 14(2): 20654–20665. https://doi.org/10.11609/jott.7504.14.2.20654-20665.

Gutierrez, N. R. (1989). The larvae of *Agriogomphus tumens* Calvert, 1905 (Anisoptera: Gomphidae). *Odonatologica, 18* (2), 203–207.

Gutierrez, N. R. (1993). Four new larvae of *Phyllogomphoides* Belle from Mexico (Anisoptera: Gomphidae). *Odonatologica 22* (1), 17–26.

Gutierrez, N. R. (2002). Larvae of *Ophiobolus* species group of *Erpetogomphus* Hagen in Selys from Mexico and Central America (Anisoptera: Gomphidae). *Odonatologica, 31* (1), 35–46.

Gutierrez, N. R. (2005). Five new *Erpetogomphus* Hagen in Selys larvae from Mexico with a key to the known species (Anisoptera: Gomphidae). *Odonatologica, 34* (3), 243–257.

Gutierrez, N. R. (2009). Description of the last instar larva of *Agria barreti* Calvert, 1902 (Zygotera: Coenagrionidae). *Odoanatologica, 37* (4), 367–373.

Gutierrez, N. R., & Chesalmah M. R. (2006). The larva of *Macromia cincta* Rambur, 1842 with a key to the known Macromia larvae of the Malaysian Peninsula (Anisoptera: Macromiidae). *Odonatologica*, *35* (1), 61–66.

Gutierrez, N. R., & Chesalmah, M. R. (2013).Two interesting larvae of Onychogomphus from Malaysia (Anisoptera: Gomphidae) *Odonatologica 42(1)*, 31–38.

Gutierrez, N. R., & Sites, R.W. (2019a). The probable larva of *Anotogaster gregoryi* Fraser, 1923, with new distributional records of the genus from northern Thailand (Odonata: Cordulegastridae). *Zootaxa, 4565* (1), 138–144. https:// doi.org/10.11646/zootaxa.4565.1.12.

Gutierrez, N. R., & Sites, R.W. (2019b). The larvae of *Phaenandrogomphus* Lieftinck, 1964 in Thailand, including the description of *P. tonkinicus* (Fraser, 1926) with a larval diagnosis and new province records of *P. asthenes* Lieftinck, 1964 (Odonata: Gomphidae). *Zootaxa, 4700* (3), 377–384. https: //doi.org/ 10.11646/zootaxa.4700.3.6

Gutierrez, P. L. A. (2007). The larvae of *Teinopodagrion caquetanum* De Marmels, 2001 and *T.vallenatum* De Marmels, 2001 (Zygoptera: Megapodagrionidae). *Odonatologica, 36* (3), 307–313.

Hagen, H. A. (1885). Monograph of the earlier stages of Odonata. Sub families Gomphina and Cordulogastrina, *Transactions of American Entomological Society,* 12, 249–291.

Hartung, M. (2022). Description of the larva of *Micrathyria venezuelae* Demarmels (Odonata: Libellulidae), *Odonatologica, 51* (1/2), 147–156.

Hassan, T. A. (1977a). The larval stages of *Urothemis assignata* Selys, 1872 (Anisoptera: Libellulidae). *Odonatologica, 6* (3) 151–161.

Hassan, T. A. (1977b). Studies on the life history of *Palpopleura lucia lucia* Drury, 1773 (Anisoptera: Libellulidae). *Nigerian Journal of Entomology, 2* (1), 57–67.

Hawking, J. H., & Theischinger, G. (2002). The larvae of *Orthetrum balteatum* Lifetinck, 1933 (Odonata: Libellulidae). *Linzer Biology, 34* (2), 1511–1514.

Heckman, C.W. (2006). *Encyclopedia of South American Aquatic insects: Odonata-Anisoptera*, Springer Publication, VII, 725

Hoekstra, J. D. & Smith, L. R. (1999). Description of the final instar larvae of *Argia sabino* Garrison, 1994 and *Argia pima* Garrison, 1994 (Odonata: Coenagrionidae). *Proceedings of Entomological Society Washington, 101*(4) 887–896 https://doi.org/10.33307/entomon.v48i2.894

Hussain, R. & Ahmed, K. B. (2004). The description of naiads of *Orthetrum, Trithemis and Sympetrum* (Odonata: Libellulidae) from Sindh Province. *Pakistan Journal of Biological Sciences, 7* (3), 419–422. https: //doi.org /10.3923/ pjos. 2004.419. 422.

Hussain, R., & Riaz, M. (1999a). Description of last instar naiads of *Rhyothemis variegata variegata* (Linnaeus, 1763) and *Pantala flavescens* (Fabricius, 1798) (Libellulidae: Odonata), *International Journal of Agricultural and Biological Engineering, 1*, 145–146.

Hussain, R., & Riaz, M. (1999b). The naiads of *Acisoma panorpoides panorpoides* Rambur, 1842 and *Brachythemis contaminata* (Fabricius, 1793) (Libellulidae: Odonata). *International Journal of Agricultural and Biological Engineering, 1*, 147–148.

Hussain, R., & Riaz, M. (2000). Description of the naiads of *Gomphidia t-nigrum* Selys and *Anax parthenope* Selys (Anisoptera: Odonata). *International Journal of Agricultural and Biological Engineering, 1,* 167–168.

Jacob, S., Thomas, A. P., & Manju, E. K. (2017). Odonata (Dragonflies and Damselflies) as Bio indicators of Water Quality. *International Journal of Innovative Research in Science, Engineering and Technology, 6*, (9).19464–19474. doi: 10.15680/ IJIRSET.2017.0609144

Jiang, Y. H., & Wang, T. (2007). Description of the larva of *Cordulegaster pekinensis* Selys, 1886 from China (Anisoptera: Cordulegastridae). *Odonatologica, 36* (2), 197–200

Jiang, Y. H., & Zhang, H. M. (2008). Descriptions of the full grown *Cephalaeshna partrorum* Needham, 1930 and *Planaeschna shanxiniensis* Zhu & Zhang, 2001 larvae from China (Anisoptera:Aeshnidae).*Odonatologica, 37* (3) 273–275.

Joshi, S., Sawanth, D., Kunte, K., & Ogale, H. (2022). *Burmagomphus chaukulensis,* a new species of Dragonfly (Odonata: Anisoptera: Gomphidae) from Western Ghats, Maharashtra. *Zootaxa, 5133* (3), 413–430. https://doi.org/10.11646/zootaxa.5133.3.6

Jung, K. S. (2011) *Odonata Larvae of Korea*. Nature & Ecology Academic series 3 pp. 399. [In Korean with English summary].

Kalish, J. A. (2014). *Introduction to Entomology,* University of Nebraska, 1–28.

Kalkman, V. J., Babu, R., Bedjanic, M., Conniff, K., Gyeltshen, Khan, M. K., Subrmanian, K. A., Zia, A., & Orr, A. (2020). Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Srilanka. *Zootaxa, 4849* (1), 1–75. http://doi.org/10.11646/zootaxa.4849.1.1.

Kalkman, V. J., Clausinitzer, V., Dijkstra, K. D. B., Orr, A. G., Paulson, D. R., & Van Tol, J. (2008). Global Diversity of Dragonflies (Odonata) in Freshwater. *Hydrobiologica,* 595, 315–363.

Kennedy, C. H. (1917). Notes on the life history and ecology of the dragonflies of Central California and Nevada. *Proceedings of. United. States National Museum, 52*, (2192) 483–635.

Kennedy, C. H. (1919). The naiad of the Odonata genus *Coryphaeschna*. *Entomological News,* 30,105–108.

Kennedy, C. H. (1923). The naiad of *Pantala hymenaea* (Say, 1839).*Canadian Entomologist, 54,* 36–38.

Kennedy, C. H. (1924). Notes and descriptions of naiads belonging to the Dragonfly genus *Helocordulia. Proceedings of United States National Museum, 64* (12)1–4

Khaliq, A., & Murtaza, G. M., (1994). Description of the last instar larva of *Anax nigrolineatus* Fraser, 1935. *Fraseria, 1* (2), 3–5.

Khaliq, A., Aslam, S., & Anjum, S. A. (l994b). The naiads of *Orthetrum pruinosum neglectum* (Rambur, 1842) and *Trithemis pallidinervis* (Kirby, 1889) (Libellulidae. Odonata). *Pakistan Entomologist, 16*, 51–53.

Khaliq, A., Aslam. S., & Anjum, S. A. (1994a). Description of the last instar naiad of *Anax immaculifrons* Rambur, 1842 (Aeshnidae: Odonata). *Pakistan Entomologist, 16*, 75–76.

Khaliq, A., Murtaza, H. G.; Khan, M. R. (1995b). Description of the naiads of three species of genus *Orthetrum* (Libellulidae: Odonata). *Pakistan Journal Zoology, 27* (3), 245–247.

Khaliq, A.; Aslam, S.; Anjum, S.A. (1995a). Description of the naiads of six species of Odonata from Poonch Valley of Azad Kashmir. *Pakistan Journal of Zoology*, 27 (1), 71–76.

Khelifa, R., Zebsa, R., Khalerras, A., Labour, A., Mahdjoub, H., & Houhamdi, M. (2013). Description of the final instar exuvia of *Urothemis edwardsii* Selys, 1849 with reference to its emergence site selection (Odonata: Libellulidae), *Entomologia Generalis, 34* (4), 303–312.

Kim, D. G., Yum J. W., Yoon, T. J., & Bae, Y.J. (2010). Life history of an endangered dragonfly *Nannophya pygmaea* Rambur, 1842 in Korea (Anisoptera: Libellulidae), *Odonatologica, 39* (1), 39–46.

Kumar, A. (1971a). Taxonomic studies of last instar larvae of Odonata from the Dehra Dun Valley (India) *Ph.D. Thesis*, University of Meerut, India

Kumar, A. (1971b). The larval stages of *Orthetrum brunneum brunneum* (Fonscolombe, 1837) with description of the last instar larva of *Orthetrum*

taeniolatum (Schneider, 1845) (Odonata: Libellulidae). *Journal of Natural History, 5.* 121–132. https://doi.org/ 10.1080/00222933.1971.10309717

Kumar, A. (1972a). The life History of *Lestes praemorsa praemorsa* Selys, 1862 (Odonata: Lestidae). *Treubia. 28* (1), 3–20.

Kumar, A. (1973a). Description of the last instar larvae of Odonata from Dehra Dun Valley India with notes on biology, I (Suborder: Zygoptera). *Oriental Insects, 7* (1), 83–118.

Kumar, A. (1973b). Description of the last instar larvae of Odonata from Dehra Dun Valley India with notes on biology, II (Suborder: Anisoptera). *Oriental Insects*, *7* (2), 291–331.

Kumar, A. (1973c). Description of larvae of *Anax nigrofasciatus nigrolineatus* Fraser, 1935 and *A. parthenope parthenope* (Selys, 1839) from India, with a key to the known larvae of the Indian representatives of the genus Anax Leach. 1815 (Anisoptera: Aeshnidae). *Odonatologica, 2* (2), 83–90.

Kumar, A. (1980). Studies on the Life history of Indian dragonflies, *Pseudagrion rubriceps* Selys, 1876 (Coenagrionidae; Odonata). *Records of Zoological. Survey of India, 75*, 371–381.

Kumar, A. (1981). Studies on the life history of dragonflies, *Ceriagrion coromandelianum* (Fabricius, 1798) (Coenagrionidae: Odonata). *Records of Zoological. Survey of India, 76*, 249–258.

Kumar, A. (1984a). Studies on the life history of Indian dragonflies, *Acisoma panorpoides panorpoides* Rambur, 1842 (Libellulidae: Odonata). *Records of Zoological. Survey of India, 81* (3&4), 203–213

Kumar, A. (1984b). Studies on the life history of Indian dragonflies *Diplacodes trivialis* Rambur, 1842 (Libellulidae: Odonata) *Records of Zoological. Survey of India, 81*(3& 4), 13–22.

Kumar, A. (1984d). Studies on the life history of Indian dragonflies *Pantala flavescens* (Fabricius, 1798) (Libellulidae: Odonata). *Annals of Entomology*, *2* (1), 43–50.

Kumar, A. (1984e). Studies on the life history of Indian dragonflies, *Anax immaculifrons* Rambur, 1842 (Aeshnidae: Odonata). *Entomon, 9* (2), 127–133.

Kumar, A. (1984i). Studies on the life history of Indian dragonflies *lctinogomphus rapax* Rambur, 1842 (Gomphidae: Odonata). *Annals of Entomology, 3* (2), 29–38.

Kumar, A. (I988b). Studies on the life history of Indian dragonflies *Neurothemis tullia tullia* Drury, 1773 from Dehra Dun, India (Odonata: Libellulidae). *Indian Odonatology, 1,* 35-44.

Kumar, A. (I989a). Studies on the life history of Indian dragonflies *Tramea virginia* (Rambur 1842) (Odonata: Libellulidae). *Indian Odonatology, 2*, 5–14.

Kumar, A. (I990a). Studies on the life history of Indian dragonflies *Orthetrum sabina sabina* Drury, 1770 (Odonata: Libellulidae) *Records of Zoological. Survey of India, 88* (4), 1–6.

Kumar, A. (l972b). Studies on the life history of *Trithemis festiva* (Rambur 1842) (Odonata: Libellulidae). *Odonatologica*. *1* (2), 103–112.

Kumar, A. (l973d). Studies on the life history of *Bradinopyga geminata* (Odonata: Libellulidae). *Gurukula Kangri Viswavidyalaya Journal of .Scientific Research*, *5* (1&2), 50–57.

Kumar, A., & Khanna, V. (1983). A review of the taxonomy and Ecology of Odonata larvae from India, *Oriental Insects*, *17*,127–157.

Kumar, A., & Prasad M. (1977d). On the larva of genus *Rhinocypha* Rambur, 1842, from Garhwall hills (Western Himaaya, U.P) (Chlorocyphidae: Odonata) *Oriental Insects, 11* (4), 547–554.

Kumar, A., & Prasad M. (1977f). On two peculiar Odonate Larvae from Western Himalaya, *Entomon*, *2* (2), 225–230.

Kumar, A., & Prasad M. (1978). On a new species of *Agriocnemis* Selys (Coenogrionidae; Odonata) with description of its larva from Dehra Dun Valley, *Journal of the Bombay Natural History Society, 75* (1),174–179.

Kumar, A., & Prasad M. (l977b). On the larva of *Tramea virginia* Rambur, 1842 from India, with notes on the larva of Indian representatives of genus *Tramea* Hagen 1861(Libellulidae: Odonata). *Journal of the Bombay Natural History Society, 74,* 199–202.

Kumari, N. K. R., & Balakrishnan Nair, N. (1981). On the predacious naiad of *Rhodothemis rufa* (Rambur, 1842). *Entomon*, *6* (1), 57–60.

Kumari, N. K. R., & Balakrishnan Nair, N. (1983). Final instar nymph of *Urothemis signata signata* (Rambur, 1842) from South West Coast of India. *Entmon, 8* (2), 193–197.

Laidlaw, F. F. (1920). XXI, Notes on some interesting larvae of dragonflies (Odonata) in the collection of the Indian museum. *Records of the Indian Museum, 19*, 185–187.

Lamb, L. (1929). The later larval stages of *Pantala* (Odonata: Libellulidae) *Transactions of American Entomological Society, 55* (4), 331–333.

Lieftinck, M. A. (1932). Notes on the larvae of two interesting Gomphidae (Odon.) from the Malay Peninsula, *Bulletin of the Raffles Museum. Straits Settlements, 7*, 102–115.

Lieftinck, M. A. (1940). On some Odonata collected in Ceylon, with the description of new species and larvae. *Spolia Zeylanica*, *22*, 115–116.

Lieftinck, M. A. (1941). Studies on oriental Gomphidae (Odon.), with descriptions of new interesting larvae. *Treubia, 18* (2), 233–253.

Lieftinck, M. A. (1953). The larval characters to the Protoneuridae (Odon.), with special reference to the genus *Selysioneura* Forster, and with notes on other Indo-Australian genera. *Treubia, 21* (3), 641–684.

Lieftinck, M. A. (1964). Some Gomphidae and their larvae, chiefly from the Malay Peninsula. *Zoologische Verhandelingen, 69*, 1–38.

Linzer biologische Beitrage, 39 (2), 1233-1237, http://doi.org/10.5281/zenodo.10114280

Lopez, K. E., Fernández, J. B., Cardo-Maeso, N., Montejano, S.T., & Martínez, C. D. (2020). *Onychogomphus cazuma* sp. nov. from Spain: Molecular and morphological evidence supports the discovery of a new European dragonfly species (Odonata: Gomphidae). *Odonatologica 49* (1/2), 125–154.

Louton, J. A. (1983). The larva of *Gomphurus ventricosus* (Walsh, 1863) and comments on relationships within the genus (Anisoptera: Gomphidae), *Odonatologica 12* (1), 83–86.

Loxdale, H. D. (2016). Insect science a vulnerable discipline? *Entomologia Experimentalis et Applicata* The Netherlands Entomological Society, 1–14.

Macklin, M. J. (1963). Notes on the life history of *Anax junius* (Drury, 1773) (Odonata: Aeshnidae).Indiana Academy of Sciences 73, 154–163.

Makbun, N., & Fleck (2018). Description of *Microgomphus farrelli* sp.nov. (Odonata: Anisoptera: Gomphidae) based on adults of both sexes and larvae from Northern Thailand. *Zootaxa 4422,* (3), 442–450

Makbun, N., Wongkamhaeng, K., & Keetapithchayakul, T. S. (2022). *Anax aurantiacus* sp. nov., a new dragonfly from mainland Southeast Asia (Odonata: Aeshnidae), *Odonatologica 51* (3/4), 301–306.

Marmels, De. J. (1981). The larva of *Progomphus abbreviates* Belle 1973 from the Venezuela (Anisoptera: Gomphidae), *Odonatologica 10* (2), 147–149.

Marmels, De. J., & Neiss, G. U. (2011). Description of the larva of *Gynacantha auricularis* Martin, 1909 (Odonata: Aeshnidae), *Zootaxa*, *3137,* 64–68.

Martens, K., & Dumont, H. J. (1983). Description of the larval stages of the Desert Dragonfly *Paragomphus sinaiticus* Morton,1929 with notes on the larval habitat, and a comparison with three related species (Anisoptera: Gomphidae). *Odonatologica 12*, 285–296.

Matsuki, K. (1978).Taxonomic studies of larval stages of Gomphidae (Odonata). *Annual Report Taiwan Provincial Museum*, 21, 133–180. [In Japanese with English summary]

Matsuki, K., & Lien, J. C. (1984a). Description of the larva of *Periaeschna magdalena* Martin, 1909 from Taiwan (Anisoptera: Aeshnidae). *Odonatologica, 13* (2), 245–248.

May, L. M. (2019). Odonata: who they are and what they have done for us lately: classification and ecosystem services of dragonflies. *Insects 10* (62). doi: 10.3390/insects 10030062 www//mdpi.com/journal/insects.

Meurgey, F. (2009). Description of the larva of *Macrothemis meurgeyi* Daigle, 2007 from the lesser Antilles (Anisoptera: Libellulidae). *Odonatologica 38* (4), 365–368.

Meurgey, F. (2010). Description of the larva of *Protoneura romanae* Meurgey, 2006 from the West Indies (Zygoptera: Protoneuridae), *Odonatologica, 39* (2) 153–157.

Mike, W., & Alvah, P. (1944). A key to the genera of Anisopteraous Dragonfly Nymphs of the United States and Canada (Odonata, Anisoptera) *The Ohio Journal of Science*, *44* (4), 151–166.

Miller, K. R., & Levine, J. (2008), *Biology*.Boston, Pearson/Prentice Hall.

Miller, P. L., (1995). *Dragonflies*. Richmond Publ. Co., Slough/UK.

Moore, N. W., & Corbet, P. S. (1990). Guidelines for monitoring dragonfly populations. *Journal of the British Dragonfly Society. 6* (2), 21–23.

Muller, O. & Schiel J. F. (2012). Description of the final instar larva of *Rhinoaeschna elsia* Calvert 1952 (Odonata: Aeshnidae), *Libellula supplement 12*, 133–142.

Muller, O., & Suhling, F. (2001). Description of the final instar larva of *Phyllogomphoides litoralis* Belle, 1984 (Anisoptera: Gomphidae). *Odonatologica, 30* (4), 451–456.

Muller, O., Taron, U., Jansen, A., & Schneider, T. (2012). Description of the larva of *Boyeria cretensis* Peters, 1991 and comparison with *B.irene* Fonscolombe, 1838 (Anisoptera: Aeshnidae), *Odonatologica 41* (1), 47–54.

Muzon, J. (1993). *Lestes spatula* Fraser, 1946 description of the final larval instar and redescription of male and female adults (Zygoptera: Lestidae). *Odonatologica 22* (4), 443–454.

Muzon, J., & Pessacq, P. (2005). Description of the last larval instar of *Ischnura ultima* Ris, 1908 (Zygoptera: Coenagrionidae).*Odonatologica*, *34* (3), 303–306.

Naeem, M., Sathar, S., Zia, A., Rehman, A., Iqbal, T., Mehmood, S. A., Ahmed S., & Shahjeer. K. (2022). Diversity of Odonata naiads of sub Himalayan hill tracks of Pakistan. *Journal of Animal and Plant Sciences, 32* (6), 1616–1627.

Narendran, T. C. (2006). *An introduction to Taxonomy,* Director, Zoological Survey of India, Kolkata 1–80.

Needham, J. G. (1911). Notes on a few nymphs of *Agrioninae* (Order Odonata) of the Hagen Collection. *Entomological News*, 22 (4) 342–344.

Needham J. G. (1937). The nymph of *Pseudagrion superbum* (Hagen, 1861).Reprint from December 1937 issue *Pomona College Journal of .Entomology and Zoology*.*35* (2), 28–31.

Needham, J. G., & Fisher, E. (1936). The nymphs of North American Dragonflies. *Transactions of American Journal of Entomological Society, 62*, 107–116

Nevin, R. (1929). Larval Development of *Sympetrum vicinum* (Hagen, 1861)(Odonata: *Libellulidae*) *Transactions of American Journal of Entomological Society*,*55* 79–102.

Ngiam, R.W.J., Sun, S.W. & Sek, J.Y. (2011). An update on *Heliogomphus cf. retroflexus* Ris, 1912, with notes on *Microgomphus chelifer* Selys, 1858 in Singapore (Odonata: Anisoptera: Gomphidae). *Nature in Singapore*, 4, 95–99.

Novelo-Gutierrez, R. (1993). Four new larvae of *Phyllogomphoides* Belle from Mexico (Anisoptera: Gomphidae). *Odonatologica 22* (1), 17–26.

Novelo-Gutierrez, R., & Sites, R.W. (2019a). The probable larva of *Anotogaster gregoryi* Fraser, 1923, with new distributional records of the genus from northern Thailand (Odonata: Cordulegastridae). *Zootaxa, 4565* (1), 138–144. https:// doi.org/10.11646/zootaxa.4565.1.12.

Novelo-Gutierrez, R., & Sites, R.W. (2019b). The larvae of *Phaenandrogomphus* Lieftinck, 1964 in Thailand, including the description of *P. tonkinicus* (Fraser, 1926) with a larval diagnosis and new province records of *P. asthenes* Lieftinck, 1964 (Odonata: Gomphidae). *Zootaxa, 4700* (3), 377–384. https: //doi.org/ 10.11646/zootaxa.4700.3.6

Olivera–Junior, J. M. B.; Rocha, T. S., Vinaragre, S. F., Miranda-Filhio, J.C., Mendoza-Penagos, C. C., Dias-Silva, K., Juen, L., & Calvao, L. B. A. (2022). A

bibliometric analysis of the global research in Odonata trends and gaps. *Diversity 14*, 1074 1–16 http://doi.org/10.3390/d1412074.

Paulson D., Schorr M., & Deliry C. (2024). World Odonata List. Last revision: 10 April 2024, URL (Accessed on 29.4.2024): https://www.pugetsound.edu/puget-sound-museum-natural-history/biodiversity-resources/insects/dragonflies/world-odonata-list.

Pimento P. C., & Pellie, A. (2019). The life of Dragonflies: Order Odonata. *Capa, Ciencia e Natura, 41*, e 43 doi: 10.5902/2179460X32305.

Prasad, M. (1996). An account of odonata of Maharashtra state, India. *Records of the Zoological Survey of India, 95* (3–4), 305–327.

Price, P.W., Denno, R. F. Eubanks, M. D., Finke, D. L., & Kalpan, I. (2011). *Insect Ecology: Behaviour, Populations and Communities*. Cambridge University Press.

Quentin, & Douglas, (1973). Results of the Austrian-Ceylonese hydrobiological mission of 1970of the Ist Zoological Institute of the University of Vienna (Austria) and the Department of Zoology of the Vidyalankara University of Ceylon, Kelaniya, Part 12: Contributions to the ecology of the larvae of some Odonata from Ceylon. *Bulletin of Fisheries Research Station Sri- Lanka (Ceylon) 24,* (1/2) 113–124.

Quintana, T. D. A., & Tur, B. R. (2008). Description of the last instar larva of *Erythrodiplax fervida* Erichson 1848 (Anisoptera: Libellulidae), with notes on the biology of the species. *Zootaxa, 1688*, 66–68.

Raebel, E. M., Merckx, T., Riordan, P., Macdonald W.D., & Thompson D. J. (2010). The dragonfly delution: why it is essential to sample exuviae to avoid biased surveys. *Journal of insect conservation*. *14*, (5) 523–533.

Rahman, Z., Rahman, A., Sharif, J., Mia, S., Kamal, M., Razzak M. A., & Bashar, K. (2022). Predatory efficiency of dragonfly nymphs, *Crocothemis servilia* Drury, 1770 and *Rhyothemis variegata* Linaeus, 1763 against the mosquito, *Culex quinquefasciatus* Say, 1823 *Asian-Australasian Journal of Bioscience and Biotechnology, 7* (3), 82–89. https:// doi.org/10.3329/aajbb.v7i3.62338.

Ramirez, A. (1996). Six new Dragonfly larvae of the family Gomphidae in Costa Rica with a key to the Central American genera (Anisoptera). *Odonatologica 25* (2) 143–156.

Reels G. (2009). Dragonfly emergence at a small newly- created pond in Hong Kong. *Hong Kong Entomological Bulletin. 1* (2), 32–37.

Rodrigues, C. A., Muzon, J., & Capitulo, R. A. (1990). The larval instars of *Orthemis nodiplaga* Karsh, 1891 from Argentina (Anisoptera: Libellulidae). *Odonatologica 19* (3), 283–291

Sadasivan, K., Nair, V. P., & Samuel, A. (2023). A review of Macromia Rambur, 1842 (Odonata, Macromiidae) of Western Ghats, with taxonomic notes on *Macromia miniata* Fraser, 1924 and *M. irata* Fraser, 1924*, Entomon*, *48* (2), 253–286.

Samway M. J., Domenico, DI. M., & Carchini, G. (1993). Last instar larvae of *Trithemis werneri* Ris, 1912, and comparison with other *Trithemis* species (Anisoptera: Libellulidae). *Odonatologica 22* (2) 223–228.

Samway M. J., Whiteley, M., Domenico, DI. M., & Carchini, G. (1997). Description of the last instar larva of *Notiothemis jonesi* Ris 1919 (Anisoptera: Libellulidae). *Odonatologica, 26* (2), 221–226

Sangal, S. K. & Kumar, A. (1970b). Studies on the taxonomy of larvae of Deon Valley, Odonata-II, *Anax guttatus* (Burnmiester, 1839) and *Anax immaculifrons* Rambur 1842(Aeshnidae). *Journal of Natural History, 4*, 305–313. https://doi.org/10.. 1080/00222937000770291.

Sangal, S. K., & Kumar, A. (1970a). Studies on the taxonomy of larvae of Doon Valley, Odonata-I. *Crocothemis servilia* (Drury, 1770) and *Bradinopyga geminata* (Rambur, 1842) (Family: Libellulidae). *Journal of Natural History, 4*. 33–38. https:// doi.org/ 10.1080/00222937000770041

Santos, N. D., Costa, J. M., & Luz, J. R .P. (1987). Descricao da ninfa de *Gynacantha membranalis* Karch, 1891 (Odonata: Gynacanthini) e notas sobre o imago (Brazilan) *Anais da Sociedade Entomologica do Brasil 162*, 437–443.

Sasamoto, A., & Kawashima, I. (2009). Description of the last instar larva of *Hylaeothemis clementia* Ris, 1909 from Lass (Anisoptera: Libellulidae). *Odonatologica, 38* (4), 369–374.

Sasamoto, A., & Kawashima, I. (2022). Description of larva of *Anax ephippiger* (Burmeister, 1839) from Japan, including changes and developments in external morphology (Odonata: Aeshnidae). *Tombo*, *65*, 28–37

Schutte, C., Schridde, P., & Suhling, F. (1998). Life history patterns of *Onychogomphus uncatus* Charpentier, 1840 (Anisoptera: Gomphidae), *Odonatologica, 27*, (1), 71–86.

Sonia Jacob., Thomas, A. P., & Manju E. K. (2017). Odonata (Dragonflies and Damselflies) as Bio indicators of Water Quality. *International Journal of Innovative Research in Science, Engineering and Technology, 6* (9), 19464–19474.

Srivastava, B. K., Suri Babu, B., & Srivastava, V. K. (1992). Description of the larva of *lschnura aurora* (Brauer) (Zygoptera: Coenagrionidae) from Sagar (M.P.). *Abstract of Fourth South Asian Symposium of Odonatologv*, Allahabad,

Stainer, H. (2012). Collecting Dragonfly Exuviae, Monitoring and Research Group, Ecology Group, Topic Sheet, Wild Life Trust, BCN.http//www.wildlifebcn.org.

Steffens, W. P., & Smith W. A. (2006). Description of the larva of *Somatochlora incurvata* Walker, 1918 (Anisoptera: Corduliidae). *Odonatologica 35*(4) 379–383.

Subramanian, K. A. (2009). *Dragonflies of India-A field guide.* Vigyan Prasar, Department of Science and Technology, Govt. of India. 168.

Subramanian, K. A., & Babu R. (2018). Insecta: Odonata *Faunal Diversity of Indian Himalaya*: Zoological Survey of India, Kolkata. 227–240.

Subramanian, K. A., Ali, S., & Ramachandra T. V. (2008). Odonata as indicators of riparian ecosystem health a case study from South Western Karnataka, India. *Fraseria, 7*, 83–95.

Suhling, F., Muller Ole., & Martens Andreas (2014).The dragonfly larvae of Namibia, *Libellula Supplement 13*, 5–106.

Suhling, F., Sahlén, G., Gorb, S., Kalkman, V. J., Dijkstra, K.-D. B., & van Tol, J. (2015). Order odonata: In Thorp and covich's freshwater invertebrates Fourth edition, Elsevier, 893–932.

Suri Babu, B. (1998). Description of the larva of *Pseudagrion decorum* Rambur, 1842 from Central India (Zygoptera: Coenagrionidae). *Odonatologica*, *27* (4), 473–477.

Suri Babu, B. (2000). Description of the larva of *Neurothemis intermedia* (Rambur, 1842), with notes on biology (Anisoptera: Libellulidae). *Odonatologica, 29* (4), 341–346.

Tennessen K. J. (2019). *Dragonfly nymphs of North America*, An identification Guide Springer Nature Switzerland.

Tennessen, K. J. (1993). The larvae of *Progomphus bellei* (Knopf & Tennessen, 1980) (Anisoptera: Gomphidae). *Odonatologica, 22* (3), 191–196.

Terrence de Fonseka. (2000). *The Dragonflies of Srilanka*. WHT Publications Pvt. Ltd, Colombo, Srilanka.

Theischinger, G (1975). Two undescribed *Acanthaeschna* larvae from New South Wales, Australia (Anisoptera: Aeshnidae). *Odonatologica, 4* (3) 185–190.

Theischinger, G (1998). The larvae of the Australian Gomphidae (Anisoptera), *Odonatologica, 27* (4), 433–465.

Theischinger, G. (2001). The larva of *Gynacantha mocsaryi* Forster, 1898 (Odonata: Aeshnidae). *Linzer Biologische Beiträge, 33* (1), 603–606.

Theischinger, G. (2007). Preliminary Keys for the Identification of larvae of Australian Odonata: Cordulephyidae, Oxygastridae, Corduliidae. Hemicorduliidae (all Corduliidae), Libellulidae and Urothemistidae. Department of Environment and Conservation NSW, Sydney, 124.

Theischinger, G. (2007). The final instar larvae of *Gynacantha rosenbergi* KAUP and *Antipodogomphus proselythus* (MARTIN) (Odonata, Aeshnidae & Gomphidae),

Theischinger, G. (2009). *Identification guide to the Australian Odonata.*Department of Environment, Climate change and Water, NSW, 278.

Tillyard, R. J (1917). *The Biology of Dragonflies: (Odonata or Paraneuroptera*). Cambridge University Press, Cambridge.

Tillyard, R. J. (1921). On an Anisozygopterous larvae from Himalayas (Order Odonata), *Records of the Indian Museum, 22*, 93–107.URL: http// www.stateofkerala.in.(Accessed on 29/05/2024)

Uyizeye, E., Clausnitzer, V., Kipping, J., Dijkstra K. D. B., Willey, L., & Kaplin B. A. (2021). Developing an Odonate-based index for prioritizing conservation sites and monitoring restoration of freshwater ecosystems in Rwanda. *Ecological Indicators* 125. 107586 https://doi.org/10.1016/j.ecolind.2021.107586.

Venkatesh A., & Tyagi, B. K. (2013). Predatory potential of *Bradinopyga geminata* and *Ceriagrion coromandelianum* larvae on dengue vector *Aedes aegypti* under controlled conditions (Anisoptera: Libellulidae; Zygoptera: Coenagrionidae; Diptera: Culicidae). *Odonatologica, 42* (2), 139–149.

Verschuren, D., Demirsoy, A., & Dumont H. J. (1987). Description of the Larva of *Cordulegaster mzymtae* Bartenef, 1929 with a discussion of its taxonomic position (Anisoptera: Cordulegastridae). *Odonatologica, 16* (4), 401–406.

Walker, E. M. (1913). New nymphs of Canadian Odonata, *Canadian Entomologist, 45* 161–177.

Walker, E. M. (1914). New and little known nymphs of Canadian Odonata, *Canadian Entomologist, 46*, 349–369.

Walker, E. M. (1916). Nymphs of North American species of *Leucorrhinia*, *Canadian. Entomologist, 48*, 414–417.

Walker, E. M. (1917). The known nymph of North American species of *Sympetrum*, *Canadian Entomologist 49*, 409–414.

Walker, E. M. (1921). The nymph and breeding place of *Aeshna stichensis* Hagen. *Canadian Entomologist* 53, 221–224.

Walker, E. M. (1928). The nymph of Stylurus group of the genus Gomphus with notes on its distribution in Canada, *Canadian Entomologist* 60, 78–81.

Walker, E. M. (1933). The nymph of Canadian species of *Ophigomphus*, *Canadian Entomologist, 65*, 217–220.

Walker, E. M. (1934). The nymphs of *Aeshna junea* L. and *Aeshna subarctica Canadian Entomologist, 66*: 267–269.

Walker, E. M. (1941). The nymph of *Aeshna verticalis* Hagen. *Canadian Entomologist.* 73, 229–231.

Wan F. X., Jiang Y. H., & Wan. J. (2011). Descriptions of *Anax immaculifrons* Rambur *Tetracanthagyna waterhousie* McLachlan Exuviae from China (Anisoptera: Aeshnidae), *Odonatologica, 40* (4), 339–345.

Watson M. C. (1956). The utilisation of Mandibular armature in taxonomic studies of Anisopterous nymphs. *Transactions of the American Entomological Society*, 81, 3/4, 155–202.

Watson, J. A. L., & Theishinger, G. (1980). The larvae of *Antipodophelbia asthenes* Tillyard, 1916 A terrestrial Dragonfly? (Anisoptera: Aeshnidae). *Odonatologica*, *9* (3), 253–258.

Westfall, J. M. (1989). The Larvae of *Desmogomphus pausinervis* Selys, 1873 and *Perigomphus pallideistylus* Belle, 1972 (Anisoptera; Gomphidae), *Odonatologica, 18* (1), 99–106.

Wheldon, A. D. (1918). Comparative morphology and possible adaptations of the abdomen in the Odonata. *Transactions of the American Entomological Society 44*, 373–437.

Whiteley, M., Samway M. J., Domenico, DI. M., & Carchini, G. (1999). Description of the last instar larva of *Hemistigma albipuncta* Rambur 1842 and comparison with other Brachydiplactinae (Anisoptera: Libellulidae). *Odonatologica, 28* (4), 433–437.

Wigglesworth (1964). *Entomology Dictionary*, Reference book, Course of general Entomology.

Wilson, K. D. P., & Theischinger, G. (1996). Further notes on Macromia Rambur from Hong Kong, with the descriptions of the larvae (Anisoptera: Corduliidae). *Odonatologica, 25* (3), 275–282.

Winstanley, W. J. (1981). Emergence behaviour of *Uropetala carovei carovei* (Odonata: Petaluridae), in New Zealand. *New Zealand Journal of Zoology, 8* 409–411.

Winstanley, W. J. (1984). The larvae of the new Caledonian endemic Dragonfly *Synthemis ariadne* Lifetinck, 1975 (Anisoptera: Synthesmidae), *Odonatologica*, *13* (1) 159–164.

Wong, K. C., Yeh, W. C., & Chan, T. W. (2012). Description of the final stadium larvae of *Polycanthagyna omithocephala* (Mc Lachian, 1896) from Taiwan, with a key to the known larvae of the genus (Odonata: Anisoptra), *Zootaxa, 2177* (1), 1–62.

Wooton, R. J. (1981). Palaeozoic insects. *Annual Review of Entmology*.26, 319-344.

Wright, M. & Peterson, A. (1944). A key to the genera of Anisopterous Dragonfly Nymphs of the United States and Canada (Odonata, Suborder: Anisoptera.*The Ohio Journal of Science*, *44* (4), 151–166.

Xu, Q. H. (2010).The larvae of *Macromia flavocolorata* and *M. septima* from Fujian, China (Odonata: Macromiidae).*International Journal of Odonatology, 13* (1), 145–152.

Xu, Q. H. (2012). Description of the last instar larva of *Amphigomphus hansoni* Chao, 1954 with notes on the systematic status of the genus *Amphigohus* Chao (Anisoptera: Gomphidae). *Odonatologica*, *41* (1), 55–59.

Xu, Q. H. (2016a). Description of the final stadium larva of *Macromia calliope*, Ris, 1916 (Odonata: Anisoptera: Macromiidae) *Zootaxa, 4067 (5),* 594–598.

Xu, Q. H., & Zhang, H. (2014). Description of the final stadium larva of *Periaeschna zhangzhouensis* Xu, 2007 with discussion of taxonomic characters of the larvae of the genus *Periaeschna* Martin (Odonata: Aeshnidae). *International Journal of Odonatology*, *17* (1), 53–58

Zhang, H. M., & Tong, X. L. (2009). First Descritpion of the larva and adult male *Paragomphus wuzhishanensis* Liu, 1988 (Anisoptera: Gomphidae). *Odoantologica*, *38* (2), 173–178.

Zhang, H. M., & Tong, X. L. (2011). Description of *Boyeria karubei* Yokoi, 2002 and *Periaeschna f. flinti* Asahina, 1978 larvae from China (Anisoptera: Aeshnidae). *Odonatologica, 40* (1), 57–65.

Zhao, X. (1990). *The Gomphid dragonflies of China (Odonata Gomphidae).*Fujian Science and Technology Publishing House pp. 486. [In Chinese with English summary]

APPENDICES

Table I: Comparison of nymphal features of Genus Anax with the exuvia of *Anax indicus*

SL.NO	Morphological Characters	*Anax guttatus* Kumar & Sangal, 1970	*Anax parthenope* Kumar, 1973c	*Anax nigrofasciatus* Kumar, 1973c	*Anax immaculifrons* Kumar, 1984e	*Anax ephippigger* Sasamoto *et al.,* 2022	*Anax aurantiacus* Makbun *et al.,* 2022	***Anax indicus***
1.	Total body length in mm	41–44	48–49	52–54	52–55	39–42	59–62	**52–55**
2.	Colour	Light brown	Dark brown	Dark brown	Dark brown	Light brown	Transparent	**Transparent**
3.	Labium	Long, Pear-shaped	Long, Pear-shaped	Long, Pear-shaped	Long, Pear-shaped	Long, Pear-shaped	Long, Pear-shaped	Long, Pear-shaped
4.	Depth of median cleft in mm	0.5	0.4	0.4	0.2	0.1	0.1	**0.2**
5.	Wing pads	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4
6.	Abdomen	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical	**Cylindrical**
7.	Lateral spines	S7–S9	S7–S9	S7–S9	S6–S9	S7–S9	S7–S9	**S7–S9**
8.	Legs	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender	**Long and slender**
9.	Anal appendages	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	**Well-developed and emarginated**

Table II: Comparison of nymphal features of Genus *Gynacantha* with the exuvia of *Gynacantha dravida*

SL.NO	Morphological Characters	*Gynacantha bifida* Carvalho, 1987	*Gynacantha membranalis* Santos *et al.,* 1987	*Gynacantha mexicana* Carvalho & Ferreira, 1989.	*Gynacantha nervosa* Heckman, 2006	*Gynacantha bispina* Couteyen & Papaz1an, 2000	*Gynacantha manderica* Carcini & Domenico, 2008	*Gynacantha mocsayri* Theischinger, 2001
1.	Total body length in mm	44	42	44	46	42	36–40	32–40
2.	Colour	Dark brown	Pale brown with a dark median stripe	Pale brown with a prominent dark median and less prominent lateral stripes	Pale brown with a prominent dark median and lateral stripes	Pale brown with a prominent dark median and lateral stripes	Pale brown with dorsal darker double stripes	Greyish yellow to brown with darker markings on abdomen
3.	Labium	Long, Pear shaped	Long, pear shaped	Long, Pear shaped	Long, pear shaped	Long, Pear shaped	Long, pear shaped	Long, Pear shaped
4.	Palpal Setae	>10	Moderately developed	< 10	>10	5+	7+	5
5.	Teeth at the median cleft	Very small and inconspicuous	Small and inconspicuous	Strong pointed	Very small and inconspicuous	Small and inconspicuous	Small and inconspicuous	Small inconspicuous
6.	Wing pads	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4	Extends up to S4
7.	Abdomen	cylindrical	cylindrical	cylindrical	cylindrical	cylindrical	cylindrical	cylindrical
8.	Lateral spines	S6–S9	S6–S9	S6–S9	S6–S9	S6–S9	S6–S9	S6–S9
9.	Legs	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender
10.	Anal appendages	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated	Well-developed and emarginated

Table II: Comparison of nymphal features of Genus *Gynacantha* with the exuvia of *Gynacantha dravida*

SL.NO	Morphological Characters	*Gynacantha gracilis* Heckman, 2006	*Gynacantha rosenbergi* Theischinger, 2007	*Gynacantha villosa* Carcini & Domenico 2008	*Gynacantha auricularis* Marmels & Neiss, 2011	*Gynacantha cylindrata* Domenico *et al.,* 2016	*Gynacantha millardi* Dawn & Chandra 2016	***Gynacantha dravida***
1.	Total body length in mm	44	42	42	36–39.5	44	25.6	**32.5**
2.	Colour	Pale brown without any stripes	Light brown	Light brown	Pale brown	Pale brown without stripes	Brownish with a median and two lateral stripes	**Light to Dark brown with a pair of median stripes**
3.	Labium	Long, Pear shaped	Long, Pear shaped	Long, Pear shaped	Long, Pear shaped	Long, Pear shaped	Long, Pear shaped	**Long, Pear shaped**
4.	Palpal Setae	Poorly developed	6–7	7+	7+	5–7	7	**3-4**
5.	Teeth at the median Cleft	Strong pointed teeth present	Teeth absent	Teeth absent	Teeth vestigial	Small teeth present	Teeth absent	**Small pointed teeth present**
6.	Wing pads	Extends up to S4	Extends up to S4	Extends up to S3	Extends up to S4	Extends up to S4	Extends up to S4	**Extends up to S4**
7.	Abdomen	cylindrical	cylindrical	cylindrical	cylindrical	cylindrical	cylindrical	**cylindrical**
8.	Lateral spines	S5–S9	S5–S9	S7–S9	S5–S9	S6–S9	S6–S9	**S6–S9**
9.	Legs	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender	**Long and slender**
10.	Anal appendages	well-developed and emarginated	well-developed and emarginated	well-developed and emarginated	well-developed and emarginated	well-developed and emarginated	well-developed and emarginated	**well-developed and emarginated**

Table III: Comparison of nymphal features on the exuviae of *Anax indicus* and *Gynacantha dravida*

SL NO	Morphological characters	***Anax indicus***	***Gynacantha dravida***
1.	Total body length in mm	52–55	32.5
2.	Colour	Transparent	Light to Dark brown
3.	Labium	Pear shaped, extends up to the base of third leg pair	Pear shaped, extends up to the base of second leg pair
4.	Prementum	Hood shaped with a median cleft	Hood shaped with a median cleft
5.	Depth of median cleft in mm	0.6	0.2
6.	Palp	Finger like, inner margin with small teeth and end in a sharp pointed end tooth	Finger like, inner margin with small teeth and end in a sharp pointed end tooth
7.	Palpal setae	Absent	3–4
8.	Wing pads	Extends up to S4	Extends up to S4
9.	Abdomen	Cylindrical without any stripes	Cylindrical with two mid dorsal stripes
10.	Lateral spines	S7–S9	S6–S9
11.	Legs	Long and slender	Long and slender
12.	Anal appendages	Emarginated, cerci ½ of the epiproct	Emarginated, cerci ¾ of the epiproct

Table IV: Comparison of nymphal features of Genus Burmagomphus with the exuviae of *Burmagomhus laidlawi* and *Burmagomphus pyramidalis*

SL.NO	Morphological features	*Burmagomphus pyramidalis sinautus* Lieftinck, 1940	*Burmagomphus williamsoni javicus* Lieftinck, 1964	*Burmagomphus divaricatus* Lieftinck, 1964	*Burmagomphus sivalikensis* Kumar, 1973	*Burmagomphus vermicularis* Matzuki, 1978
1.	Total body length in mm	28.5	20–21.5	21.3	17.5	22–23
2.	Colour	Yellowish brown	Sandy yellowish grey	Yellowish brown	Grey	Pale brown
3.	Head	Triangular	Broad and flat	Small, sloping downward	Triangular	Triangular
4.	Antenna	4 segmented	4segmented	4segmented	4 segmented	4 segmented
5.	Labium	Rectangular	Rectangular	Rectangular	Rectangular	Rectangular
6.	Distal margin of Prementum	Slightly convex beset with setae	Slightly triangle with setae	Convex at anterior end with setae	Convex beset with setae	Convex beset with setae
7.	Palpal lobe	Finger shaped with blunt end	Finger shaped with blunt end	Finger shaped with blunt end	Finger shaped with blunt end	Finger shaped with incurved end
8.	Palpal teeth	7–8	Crenulated	7	Serrated	10
9.	Abdomen	Fusiform	Broad, lanceolate tapering	Flattened, tapering with pale grey triangular spots on S5-S9	Fusiform	Flattened
10.	Dorsal hooks on abdomen	S8–S9	S8–S9	S8–S9	S2 –S9	S8–S9
11.	Lateral spines	S7–S9	S7–S9	S7–S9	S8–S9	S7–S9

Table IV: Comparison of nymphal features of Genus Burmagomphus with the exuviae of *Burmagomhus laidlawi* and *Burmagomphus pyramidalis*

SL.NO	Features	*Burmagomphus intinctus* Zhao,1990	*Burmagomphus sowerbyi* Zhao,1990	*Burmagomphus collaris* Jung, 2011	***Burmagomphus pyramidalis***	***Burmagomphus laidlawi*** Adambukulam & Kakkassery, 2023a
1.	Total body length in mm	27–28	22	21.3	**22**	**21**
2.	Colour	Yellowish brown	Sandy yellowish grey	Yellowish brown	**Muddy brown**	**Muddy brown**
3.	Head	Triangular	Broad and flat	Small, sloping downward	**Triangular**	**Triangular**
4.	Antennae	4 segmented	4segmented	4segmented	**4 segmented**	**4 segmented**
5.	Labium	Rectangular	Rectangular	Rectangular	**Rectangular**	**Rectangular**
6.	Distal margin of Prementum	Slightly convex beset with setae	Slightly triangle with setae	Convex at anterior end with setae	**Convex beset with setae**	**Convex beset with setae**
7.	Palpal lobe	Finger shaped with blunt end	Finger shaped with blunt end	Finger shaped with blunt end	**Finger shaped with blunt end**	**Finger shaped with blunt end**
8.	Palpal teeth	7–8	Denticulate	7	**7–8**	**7–8**
9.	Abdomen	Fusiform	Broad, lanceolate tapering	Flattened, tapering With pale grey triangular spots on S5-S9	**Flattened, tapering With pale grey triangular spots on S5-S9**	**Flattened tapering**
10.	Dorsal spines on abdomen	S8–S9	S8–S9	S8–S9	**S2–S9 with blunt end**	**S7–S9 sharp pointed**
11.	Lateral spines	S7–S9	S7–S9	S7–S9	**S7–S9**	**S7–S9**

Table V: Comparison of nymphal features of Genus Megalogomphus with the exuviae of *Megalogomphus superbus*

SL.NO	**Features**	*Megalogomphus hannyngtoni* Fraser, 1922	*Megalogomphus ceylonicus* Fraser, 1933	*Megalogomphus icteorps* Lieftinck, 1941	***Megalogomphus superbus***
1.	Total body length in mm	44	38	40	**42**
2.	Colour	Pale brown	Pale brown	Pale brown	**Muddy brown**
3.	Head	Pentagonal	Pentagonal	Pentagonal	**Pentagonal**
4.	Antennae	4 segmented, third segment oval shaped; fringed with hairs, fourth segment vestigial and knob	4segmented, third segment oval shaped; fringed with hairs, fourth segment vestigial and knob like	4 segmented, third segment oval shaped; fringed with hairs, fourth segment vestigial and knob like	**4 segmented, third segment oval shaped; fringed with hairs, fourth segment with sharp pointed tip**
5.	Labium	Trapezoid	Trapezoid	Trapezoid	**Trapezoid**
6.	Distal margin of Prementum	Convex shaped; without median depression	Convex with median depression	Flat without median depression	**slightly convex without median depression**
7.	Palpal lobe	Kukri shaped	Kukri shaped	Kukri shaped	**Kukri shaped**
8.	Palpal teeth	4	4	8	**8**
9.	Abdomen	Broad and arched dorsally; ventrally flattened	Broad and arched dorsally; ventrally flattened	Broad and arched dorsally; ventrally flattened	**Broad and arched dorsally; ventrally flattened**
10.	Dorsal hooks on abdomen	S1–S9	S1–S9	S1–S9	**S2–S9**
11.	Lateral spines	S7–S9	S7–S9	S7–S9	**S7–S9**

Table VI: Comparison of nymphal features of Genus Microgomphus with the exuvia of *Microgomphus souteri*

SL No.	Morphological Characters	*Microgomphus torquatus* Fraser, 1919	*Microgomphus wijaya* Lieftinck, 1940	*Microgomphus. cameruensis* Corbet, 1977	*Microgomphus chelifer* Ngiam *et al.,* 2011	*Microgomphus svihleri* Boonsoong & Chainthong, 2014	*Microgomphus farrelli* Makbun & Fleck, 2018	***Microgomphus souteri***
1.	Total body length in mm	15	17.8	16.4	16	19.1	18.0	**18.8**
2.	Colour	Dark brown	Yellowish brown	Brown with yellowish pattern	Greyish black	Dark brown	Brown with yellowish pattern	**Brown with yellowish pattern**
3.	Antenna	4 segmented ; fourth segment, with a small pointed tip	4 segmented ; fourth segment, with a small	4 segmented ; fourth segment, with a small	4 segmented ; fourth segment small , with rounded tip	4 segmented ; fourth segment, with a small pointed tip	4 segmented ; fourth segment small , with nipple like outgrowth	**4 segmented; fourth segment small ,with nipple like outgrowth**
4.	Number of teeth on Distal margin of Prementum	Fine crenulations	14–16	Fine crenulations	24–28	20–24	18–22	**20–22**
5.	Palp	Short with round apex	Short with round apex	Short with round apex	Short with round apex	Short with round apex	Short with round apex	**Short with round apex**
6.	Number of Teeth on inner margin of Palpus	Fine crenulations	11–12	Fine crenulations	8–10	12–16	12–13	**9–12**
7.	Abdomen	Strongly flattened	Strongly flattened	Strongly flattened	Strongly flattened	Strongly flattened	Strongly flattened	**Strongly flattened**
8.	Mid dorsal protuberance	S1–S9	S1–S9	Reduced	S4–S9	Absent on S2–S8 but a small hook on S9	Absent on S2–S8 but a small hook on S9	**Absent**
9.	Lateral spines	S7–S9	S7–S9	S7–S9	S3–S9	S4–S9	S4–S9	**S4–S9**

Table VII: Comparison of nymphal features of Genus Onychogomphus with the exuvia of *Onychogomphus malabarensis*

SL No.	Morphological Characters	*Onychogomphus assimilis* Dumont *et al.,*1992	*Onychogomphus lefebvrei* Dumont *et al.,*1992	*Onychogomphus flexuosus* Dumont *et al.,*1992	*Onychogomphus aequistylus* Butler, 2004	*Onychogomphus thienemanni* Gutiérrez & Che salmah, 2013
1.	Total body length in mm	26	21–24	18–21	20.5	19.2
2.	Colour	Dark brown	Light grey – brown	Light brown	Dark brown	Yellowish brown
3.	Antenna	4 segmented ; fourth segment, with a small tubercle	4 segmented ; fourth segment, with a small tubercle	4 segmented ; fourth segment, with a small conical tip	4 segmented ; fourth segment, with a small pointed tip	4 segmented ; fourth segment, with a small
4.	Number of teeth on Distal margin of Prementum	32	26–28	28–30	Fine crenulations	14–16
5.	Palp	Finger like with blunt end	Finger like with blunt end	Finger like with blunt end	Short with round apex	Short with round apex
6.	Teeth on palpus	14	16	14–16	10–11	17–18
7.	Abdomen	Flat, narrow	Flat, narrow	Elongated and swollen	Strongly flattened	Strongly flattened
8.	Mid dorsal protuberance	Blunt end spine on S2–S9	Spine like on S3-S5; blunt end on S6–S9	Spine like on S2–S10	Blunt end spine on S2–S9	No spines; small humbs on S2–S9
9.	Lateral spines	S7–S9	S7–S9	S7–S9	S5–S9	Rudimentary spines on S8–S9

Table VII: Comparison of nymphal features of Genus Onychogomphus with the exuvia of *Onychogomphus malabarensis*

SL No.	Morphological Characters	*Onychogomphus boudoti* Ferreira *et al.,* 2014	*Onychogomphus duaricus* Chaithong & Boonsong 2016	*Onychogomphus castor* Chaithong & Boonsong 2016	*Onychogomphus cazuma* Lopez *et al.,* 2020	***Onychogomphus malabarensis***
1.	Total body length in mm	23-25	24	28	21	22
2.	Colour	Dark grey	Brown with yellowish pattern	Greyish black	Dark brown	**Brown to greyish black**
3.	Antenna	4 segmented ; fourth segment, with a small	4 segmented ; fourth segment, with a small	4 segmented ; fourth segment small , with rounded tip	4 segmented ; fourth segment, with a small pointed tip	**4 segmented; fourth segment small ,with nipple like outgrowth**
4.	Number of teeth on Distal margin of Prementum	Few crenations	Fine crenulations	24–28	20–24	**20–22**
5.	Palp	Short with round apex	Short with round apex	Short with round apex	Short with round apex	**Short with round apex**
6.	Teeth on palpus	12–14	15–16	15–18	10–11	**11–12**
7.	Abdomen	Strongly flattened	Strongly flattened	Strongly flattened	Strongly flattened	**Strongly flattened**
8.	Mid dorsal protuberance	Protuberances present on S1–S9	Blunt end spines on S2–S9	Sharp pointed spines on S2-S9	Sharp pointed spines S2-S9	**Blunt end spines on S2–S9**
9.	Lateral spines	S8–S9	S7–S9	S6–S9	S7–S9	**S6–S9**

Table VIII: Comparison of taxonomic features on the exuviae of different species of Family Gomphidae

SL.NO	Morphological features	***Burmagomphus pyramidalis***	***Burmagomphus laidlawi*** Adambukulam & Kakkassery, 2023a	***Megalogomphus superbus***	***Microgomphus souteri***
1.	Total body length in mm	22	21	42	18.8
2.	Colour	Muddy brown	Muddy brown	Muddy brown	Brown with yellowish pattern
3.	Head	Triangular	Triangular	Pentagonal	Pentagonal
4.	Antenna	4 segmented; fourth segment small knob like	4 segmented; fourth segment small knob like	**4 segmented;** fourth segment with sharp pointed tip	4 segmented; fourth segment small ,with nipple like outgrowth
5.	Labium	Rectangular	Rectangular	Trapezoid	Trapezoid
6.	Distal margin of Prementum	Convex beset with setae	Convex beset with setae	Slightly convex without median depression	Convex beset with setae
7.	Palp	Finger shaped with blunt end	Finger shaped with blunt end	Kukri shaped with sharp pointed end	Finger shaped with blunt end
8.	Palpal teeth	7–8	7–8	8	9–12
9.	Abdomen	Flattened, tapering	Flattened tapering	Broad and arched	Dorso-ventrally flattened
10.	Mid-dorsal spines	S2–S9 blunt end	S7–S9 with sharp pointed end	S2–S9 with blunt end	Absent
11.	Lateral spines	S7–S9	S7–S9	S7–S9	S4–S9
12.	Anal appendage	Short; triangular pyramid like	Short; triangular pyramid like	Short; triangular pyramid like	Short; triangular pyramid like

Table VIII: Comparison of taxonomic features on the Exuviae of different species of Family Gomphidae

SL NO	Morphological features	***Onychogomphus malabarensis***	***Macrogomphus annulatus***	***Ictinogomphus rapax***	***Paragomphus lineatus***
1.	Total body length in mm	22	48	25	26
2.	Colour	Brown to greyish black	Muddy brown	Muddy brown to greyish balck	Light brown to dark brown
3.	Head	Triangular	Triangular	Pentagonal	Pentagonal
4.	Antenna	4 segmented; fourth segment small ,with nipple like outgrowth	4 segmented; fourth segment small ,with nipple like outgrowth	4 segmented; fourth segment small ,with nipple like outgrowth	4 segmented; fourth segment elongated and sharply bent downwards
5.	Labium	Trapezoid	Trapezoid	Slightly trapezoid	Slightly trapezoid
6.	Distal margin of Prementum	Strongly convex with setae	Strongly convex with setae	Slightly convex with setae	Strongly convex with setae
7.	Palp	Finger shaped with blunt end	Kukri shaped with sharp pointed end	Finger shaped with sharp pointed end	Finger shaped with sharp pointed end
8.	Teeth on palpus	11–12	5	8–10	No teeth
9.	Abdomen	Slightly roof like flattened ventrally	Elongated, cylindrical ; S9 long tube like	Limbet like rounded	Elongated, cylindrical, tapering towards end
10.	Mid dorsal spines	S2–S9 with blunt end	Only on S9 sharp pointed	S3–S9	Reduced spines on S2–S9
11.	Lateral spines	S6–S9	Absent	S3–S9	S2–S9
12.	Anal appendages	Short pyramid like	Short pyramid like	Short pyramid like	Short pyramid like

Table IX: Comparison of Nymphal features on the exuviae of Familiy Libellulidae

SL No.	Morphological Characters	*Acisoma panorpoides*	*Brachythemis contaminata*	*Bradinopyga geminata*	*Diplacodes trivialis*	***Hydrobasileus croceus***	*Lathrecista asiatica*
1.	Total body length in mm	10	15	20	17	**24.2**	16
2.	Colour	Dark brown	Light to dark brown	Transparent	Dark brown	**Muddy brown**	Muddy brown
3.	Head	Pentagonal	Triangular	Pentagonal	Pentagonal	**Pentagonal**	Pentagonal
4.	Antenna	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented	**Filiform ;7 segmented**	Filiform ;7 segmented
5.	Labium	Spoon shaped	Spoon shaped	Spoon shaped	Spoon shaped	**Spoon shaped**	Spoon shaped
6.	Prementum Distal margin	Triangular	Triangular	Triangular	Triangular	**Triangular**	Triangular
7.	Premental setae	11	12	19	14	**12**	14
8.	Palp	Flap like	Flap like	Flap like	Flap like	**Flap like**	Flap like
9.	Palpal setae	8	7	12	10	**9**	11
10.	Abdomen	Oval shaped	Oval shaped	Slightly oval	Oval shaped	**Slightly oval**	Oval shaped
11.	Legs	Long and slender	Long and slender	Long and slender legs with dark bands on femurs	Long and slender	**Long and slender**	Long and slender
12.	Mid dorsal spines	Absent	S2–S8	Absent	Absent	**S3–S8**	Reduced S3–S8
13.	Lateral spines	S8–S9	S8–S9	S8–S9	S8–S9	**Well-developed S8–S9**	S8–S9

Table IX: Comparison of nymphal features on the exuviae of Familiy Libellulidae

SL No.	Morphological Characters	*Neurothemis tullia*	*Orthetrum sabina*	*Pantala flavescens*	*Rhodothemis rufa*	*Ryothemis variegata*	*Tholymis tillarga*
1.	Total body length in mm	17	20	22	16	14	20
2.	Colour	Dark brown	Muddy brown	Transparent	Muddy brown	Muddy brown	Muddy brown
3.	Head	Pentagonal	Pentagonal	Pentagonal	Pentagonal	Pentagonal	Pentagonal
4.	Antenna	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented
5.	Labium	Spoon shaped	Spoon shaped	Spoon shaped	Spoon shaped	Spoon shaped	Spoon shaped
6.	Prementum Distal margin	Triangular	Triangular	Triangular	Triangular	Triangular	Triangular
7.	Premental setae	13	11	17	13	1	8
8.	Palp	Flap like	Flap like	Flap like	Flap like	Flap like	Flap like
9.	Palpal setae	11	7	13	8	5	5
10.	Abdomen	Oval shaped	Cylindrical	Cylindrical	Oval shaped	Oval shaped	Oval shaped
11.	Legs	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender	Long and slender
12.	Mid dorsal spines	Absent	S3–S9	Absent	Absent	Absent	S4–S10
13.	Lateral spines	S8–S9	S8–S9	S8–S9	S8–S9	S8–S9	S8–S9

Table IX: Comparison of nymphal features on the exuviae of Family Libellulidae

SL No.	Morphological Characters	*Tramea basilaris*	*Trithemis aurora*	*Trithemis festiva*	*Urothemis signata*	***Zygonyx iris***	*Zyxomma petiolatum*
1.	Total body length in mm	26	14	15.5	20	**24**	19
2.	Colour	Transparent	Greyish black	Grey to brown	Light brown	**Black**	Greyish black
3.	Head	Triangular	Pentagonal	Pentagonal	Pentagonal	**Triangular**	Pentagonal
4.	Antenna	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented	Filiform ;7 segmented	**Filiform ;7 segmented**	Filiform ;7 segmented
5.	Labium	Spoon shaped	Spoon shaped	Spoon shaped	Spoon shaped	**Spoon shaped**	Spoon shaped
6.	Distal margin of Prementum	Triangular	Triangular	Triangular	Triangular	**Triangular**	Triangular
7.	Premental setae	13	10	11	12	**12**	13
8.	Palp	Flap like	Flap like	Flap like	Flap like	**Flap like**	Flap like
9.	Palpal setae	10	7	6	10	**9**	8
10.	Abdomen	Cylindrical	Biconvex	Biconvex	Slightly oval	**Cylindrical**	Cylindrical
11.	Legs	Long and slender	Long and slender	Long and slender	Long and slender	**Long and slender**	Long and slender
12.	Mid-dorsal spines	Absent	S3–S9 spine like	S3–S9 hook like	S4–S8	**S1–S10 with blunt end**	S4–S10
13.	Lateral spines	Well-developed with lateral setae S8–S9	S8–S9	S8–S9	S8–S9	**Outwardly directing S8–S9**	S8–S9

Table X: Comparison of Nymphal features of *Zygonyx iris ceylonicus* with the Exuvia of *Zygonyx iris*

SL No.	Morphological Characters	*Zygonyx iris ceylonicus* (St.Quentin,1973)	***Zygonyx iris***
1.	Length in mm	24	**24**
2.	Colour	Black	**Black**
3.	Antenna	7 segmented	**7 segmented**
4.	Labium	Spoon shaped	**Spoon shaped**
5.	Prementum	Trapezoidal with distal margin triangular	**Trapezoidal with distal margin triangular**
6.	Premental setae	8–10	**12**
7.	Palp	Flap like ; distal margin without crenations	**Flap like ; distal margin without crenations**
8.	Palpal setae	8–9	**9**
9.	Abdomen	Biconvex	**Biconvex**
10.	Mid-dorsal protuberance	Hook like spines with sharp pointed ends S3–S9	**Blunt end spines on S1–S10**
11.	Lateral spines	S8-S9	**S8-S9**

Table XI: Comparison of nymphal features of Genus Macromia with the exuvia of *Macromia indica*

SL No.	Morphological Characters	*Macromia zeylanica* Lieftnick, 1940	*Macromia moorei* Kumar, 1973	*Macromia beralndi* Wilson & Theishinger 1996	*Macromia katae* Wilson &Theishinger 1996	*Macromia urania* Wilson &Theishinger *1996*
1.	Length in mm	20.5	25.5–28.5	26–29	21–23.5	21.5–23.5
2.	Colour	Yellowish brown	Pale yellowish to dark brown	Pale brown to dark brown	Pale brown to dark brown	Pale brown to dark brown
3.	Head	Pentagonal with projecting horns in the frons	Pentagonal with projecting horns in the frons	Pentagonal with projecting horns in the frons	Pentagonal with projecting horns in the frons	Pentagonal with projecting horns in the frons
4.	Antenna	Setaceous, 7 segmented	Filiform, 7segmented	Setaceous , 7 segmented	Setaceous , 7 segmented	Filiform , 7 segmented
5.	Labium	Large cup shaped	Large cup shaped	Very large ,cup shaped	Very large ,cup shaped	Very large ,cup shaped
6.	Prementum Distal margin	Triangular	Triangular	Triangular	Triangular	Slightly triangular
7.	Premental setae	7	16–17	12	16	14
8.	Palp	Flap with 7 U shaped creantions	Flap like with 7 cenations	Flap like with crnations	Flap like with 6–7 crenations	Flap like with 7 crenations
9.	Palpal setae	6	6–7	7	5 –6	6
10.	Abdomen	Strongly flattened and oval or round	Strongly flattened egg shaped	Strongly flattened Oval or round shaped	Oval or round shaped	Oval or round shaped
11.	Lateral spines	S8–S9	S8–S9	S8-S9	S8–S9	S8–S9
12.	Legs	Very long and slender	Very long and slender	Very long and slender	Very long and slender	Very long and slender
13.	Mid dorsal protuberance	S3–S9	S1–S9	S3–S9	S4–S9	S3–S9

Table XI: Comparison of nymphal features of Genus Macromia with the exuvia of *Macromia indica*

SL No.	Morphological Characters	*Macromia euterpe* Butler, 2002	*Maxcromia cincta* Gutiérrez & Salmah ,2006	*Macromia septima* Xu, 2009	*Macromia flavocolorata* Xu, 2009	*Macromia calliope* Xu, 2016	*Macromia flavocolorata*	***Macromia indica***
1.	Total body length in mm	26.5	24.5	21–22	20.5–22.8	20.5	**20**	**18**
2.	Colour	Light brown	Reddish brown	Brown to yellowish brown	Greyish black	Pale brown	**Greyish black**	**Muddy brown**
3.	Head	Pentagonal	Triangular	Pentagonal	Triangular with projecting horns in the frons	Pentagonal with projecting horns	**Triangular with projecting horns in the frons**	**Triangular with projecting horns in the frons**
4.	Antenna	Setaceous, 7 segmented	Setaceous, 7 segmented	Setaceous, 7 segmented	Setaceous, 7 segmented	Setaceous, 7 segmented	**Setaceous, 7 segmented**	**Setaceous, 7 segmented**
5.	Labium	Large, cup shaped	Large, cup shaped	Large, cup shaped	Large, cup shaped	Large, cup shaped	**Large, cup shaped**	**Large,cup shaped**
6.	Distal margin of Prementum	Triangular	Slightly Triangular	Slightly Triangular	Slightly concave	Slightly convex	**Triangular**	**Triangular**
7.	Premental setae	11	6–7	7	8	7	**7**	**8**
8.	Palp	Flap like with 7 U shaped crenations	Flap like with 7 rounded crenations	Flap like with 4 V shaped crenations	Flap like with 7V shaped crenations	Flap like with 5–6 V shaped crenations	**Flap like with 6 U shaped crenations**	**Flap like with 6 U shaped crenations**
9.	Palpal setae	6	4	5	5	6	**5**	**6**
10.	Abdomen	Oval or round	Oval or round	Oblong, roof shaped	Oval or round shaped	Oval or round	**Oval or round shaped**	**Oval or round shaped**
11.	Legs	Very long and slender	Very long and slender	Very long and slender	Very long and slender	Very long and slender	**Very long and slender**	**Very long and slender**
12.	Mid dorsal protuberance	S2–S10	S3–S10	S3–S9	S3–S9	S3–S9	**S3–S9**	**S3–S9**
13.	Lateral spines	S8–S9	S8–S9	S8–S9	S8–S9	S8–S9	**S8–S9**	**S8–S9**

Table XII: Comparison of Nymphal features on the exuviae of *Macromia flavocolorata* and *Macromia indica*

SL No.	Morphological Characters	*Macromia flavocolorata*	*Macromia indica*
1.	Total body length in mm	20	**18**
2.	Colour	Muddy brown to greyish black	**Muddy brown**
3.	Head	Triangular with projecting horns in the frons	**Triangular with projecting horns in the frons**
4.	Antenna	Setaceous, 7 segmented	**Setaceous, 7 segmented**
5.	Labium	Large, cup shaped	**Large, cup shaped**
6.	Prementum	Flattened at the distal margin	**Triangular**
7.	Premental setae	7	**8**
8.	Palp	Flap like with 6 U shaped crenations	**Flap like with 6 U shaped crenations**
9.	Palpal setae	5	**6**
10.	Legs	Very long and slender	**Very long and slender**
11.	Abdomen	Cylindrical or slightly oval shaped	**Oval or round shaped**
12.	Mid-dorsal protuberance	S3–S9	**S3–S9**
13.	Lateral spines	S8–S9	**S8–S9**

Table XIII: Comparison of breeding sites of nymphs based on the exuviae collected from the study sites

Family	Species	IUCN status & endemicity	Breeding sites mentioned in literature	Breeding sites in the present study
Aeshnidae	*Anax indicus* Lieftinck, 1942	LC	No descriptions	Temporary pond in paddy field
	Gynacantha dravida Lieftinck,1960	DD	No descriptions	Temporary pond in paddy field
Gomphidae	*Burmagomphus laidlawi* Fraser,1924	DD,E	No descriptions	Forested riverine habitat
	Burmagomphus pyramidalis Lieftinck,1960	LC	No descriptions	Forested riverine habitat
	Ictinogomphus rapax (Rambur, 1842)	LC	Streams and rivers	Forested riverine habitat
	Macrogomphus annulatus (Selys, 1854)	DD	Running and still water	Forested riverine habitat
	Megalogomphus superbus Fraser 1931	DD, E	No descriptions	Forested riverine habitat
	Microgomphus souteri Fraser, 1924	LC,E	No descriptions	Forested riverine habitat
	Onychogomphus malabarensis (Fraser, 1924)	DD, E	No descriptions	Forested riverine habitat
	Paragomphus lineatus (Selys, 1850)	LC	Streams and rivers	Forested riverine habitat
Libellulidae	*Acisoma panorpoides* Rambur 1842	LC	Weeded tanks	Temporary ponds in paddy field
	Brachythemis contaminata (Fabricius,1793)	LC	Sluggish streams and weedy tanks	Temporary ponds in paddy fields, streams, rivers, irrigation canals Ponds, man-made cement pool
	Bradinopyga geminata (Rambur 1842)	LC	Man- made cemented tanks	Man- made cement pool
	Diplacodes trivialis (Rambur, 1842)	LC	Ponds	Ponds, Temporary ponds in paddy field
	Hydrobasileus croceus (Brauer, 1867)	LC	No descriptions	Ponds, rivers, streams, irrigation canals in paddy fields
	Lathrecista asiatica (Fabricius, 1798)	LC	No descriptions	Temporary pond in paddy field
	Neurothemis tullia (Drury, 1773)	LC	Marshes and drainage channels in paddy fields	Temporary ponds in paddy fields, streams, Rivers, irrigation canals
	Orthetrum sabina (Drury, 1773)	LC	Perennial and seasonal	Temporary ponds in paddy fields,

			ponds	streams, rivers, irrigation canals Ponds, man-made cement pool
	Pantala flavescens (Fabricius, 1798)	LC	Weedy marshy ,shallow ponds paddy fields	Temporary ponds in paddy fields,
	Rhodothemis rufa (Rambur, 1842)	LC	Weedy ponds and tanks	Temporary ponds in paddy fields
	Rhyothemis variegata (Linnaeus, 1763)	LC	Ponds, paddy fields	Temporary ponds in paddy fields
	Tholymis tillarga (Fabricius, 1798)	LC	Weedy marshes and ponds	Temporary ponds in paddy fields, streams, rivers, irrigation canals Ponds, man-made cement pool
	Tramea basilaris (Palisot de Beauvois,1817)	LC	Weedy tanks and ponds	Ponds, man-made cement pool
	Trithemis aurora (Burmeister, 1839)	LC	Sluggish streams and irrigation canals	Ponds, streams, rivers,
	Trithemis festiva (Rambur, 1842)	LC	Sluggish streams and irrigation canals	Ponds, streams, rivers,
	Urothemis signata (Rambur,1842)	LC	Weedy tanks and sluggish streams	Man-made cement pool
	Zyxomma petiolatum Rambur, 1842	LC	Stagnant pools ,domestic wells	Temporary ponds in paddy fields, , ponds, man-made cement pool
	Zygonyx iris Selys,1869	LC	No descriptions	Forested riverine habitat
Macromiidae	*Macromia indica* Fraser 1924	LC, E	No descriptions	Forested riverine habitat
	Macromia flavocolorata Fraser, 1922	LC	Fast flowing running water	Forested riverine habitat

Table XV: Legends used for locations

SL.NO	Districts	Study sites	Legends
1.	Kasaragod	Kudumboor	KUR
2.		Palamthadi	PLD
3.		Eranjipuzha	ERP
4.		Pulliyamthuruth	PLT
5.		Kollikund	KLK
6.		Sankarampadi	SKP
7.		Churithode	CHT
8.		Mannadukkam	MNK
9.		Mudiyakkal	MUK
10.		Kunnukai	KUK
11.		Malom	MLM
12.	Kannur	Madayippara	MPR
13.		Kottiyoor	KTR
14.		Mambaram	MBR
15.		Cherupuzha	CRP
16.		Dharmadam	DMD
17.	Wayanad	Meenmutty	MMT
18.		Pookode	PKD
19.		Thonikkadavu	TKV
20.		Wayanad	WYD
21.		Krishnagiri	KGR
22.		Kuruva	KUR
23.		Panamaram	PMR
24.		Pakkam	PKM
25.		Ambalavayal	AMV
26.		Vythiri	VYT
27.	Thrissur	Thrissur	TCR
28.		Poomala	PML
29.		Palakkal	PAL
30.		Kanimanglam	KMG
31.		Allapad	ALP
32.		Marottichal	MRT
33.		Athirappilly	ATP
34.		Thumoormuzhy	TMY
35.		Ammadam	AMD
36.		Chalakkudy	CKD
37.	Palakkad	Kinassery	KCY
38.		Kollengode	KLK
39.		Chittur	CTR
40.		Malampuzha	MLP
41.		Olassery	OLY
42.		Kalpathy	KLP
43.		Thathamanglam	THT
44.		Thenkurissi	TNK
45.		Elamanam	ELM

LIST OF PUBLISHED PAPERS

LIST OF RESEARCH PAPERS PUBLISHED

1. **Shaun Paul Adambukulam** & Francy K. Kakkassery (2023). Taxonomical studies of dragonfly nymphs (Odonata: Libellulidae) using their exuvia. ***Entomon, 48(4)*** pp. 497-510. ISSN: 0377-9335

2. **Shaun Paul Adambukulam** & Francy K Kakkassery (2023). Description of the final instar larva of *Burmagomphus laidlawi* Fraser, 1924, an endemic of the Western Ghats, India (Odonata: Gomphidae). ***Odonatologica 52(3/4)*** pp. 247-254. ISSN: 0375-0183

PRESENTATIONS

Research Centre & Post Graduate Department of Zoology
SREE NEELAKANTA GOVT. SANSKRIT COLLEGE, PATTAMBI
PALAKKAD KERALA, INDIA 679306
Affiliated to University of Calicut, Accredited by NAAC with A+ grade (CGPA 3.46)

Biodiversity for sustainable future
14-16 NOV 2023

Directorate of Collegiate Education Sponsored 3 Day National Seminar

BIODIVERSITY FOR SUSTAINABLE FUTURE

CERTIFICATE

This is to certify that ~~Prof./ Dr./~~ Mr./~~Ms.~~ Shaun Paul Adambukulam., Part-time Research Scholar., St. Thomas College., Thrissur presented a paper in the Directorate of Collegiate Education, Kerala sponsored 3 day National Seminar entitled "Biodiversity for Sustainable Future" organized by the Department of Zoology, Sree Neelakanta Govt. Sanskrit College, Pattambi from 14th to 16th of November 2023.

Dr. Abdul Rasheed V. T.
Co-ordinator

Dr. Zeena K. V.
Head, Dept. of Zoology

Prof. Dileep C. D.
Principal

INTERNATIONAL CONFERENCE
ON RECENT ADVANCES IN

ANIMAL BIOLOGY AND CONSERVATION

(ICRABC)

Organized by
Department of Zoology,
University College,
Thiruvananthapuram, Kerala, India
December 19th -21st, 2023

CERTIFICATE

This is to certify that

Shaun Paul Adambukulam

Research Scholar, Department of Zoology, St.Thomas College, Thrissur

attended the Conference and **Presented a Paper**.

Title: "Nymphal taxonomy studies of dragonflies (Order: Odonata) of Kerala by using their exuvia"

Dr. T. Subhash	**Dr. Aruna Devi C.**	**Dr. Mano Mohan Antony**
Principal & Patron	HOD & General Convener	Organizing Secretary
ICRABC 2023	ICRABC 2023	ICRABC 2023